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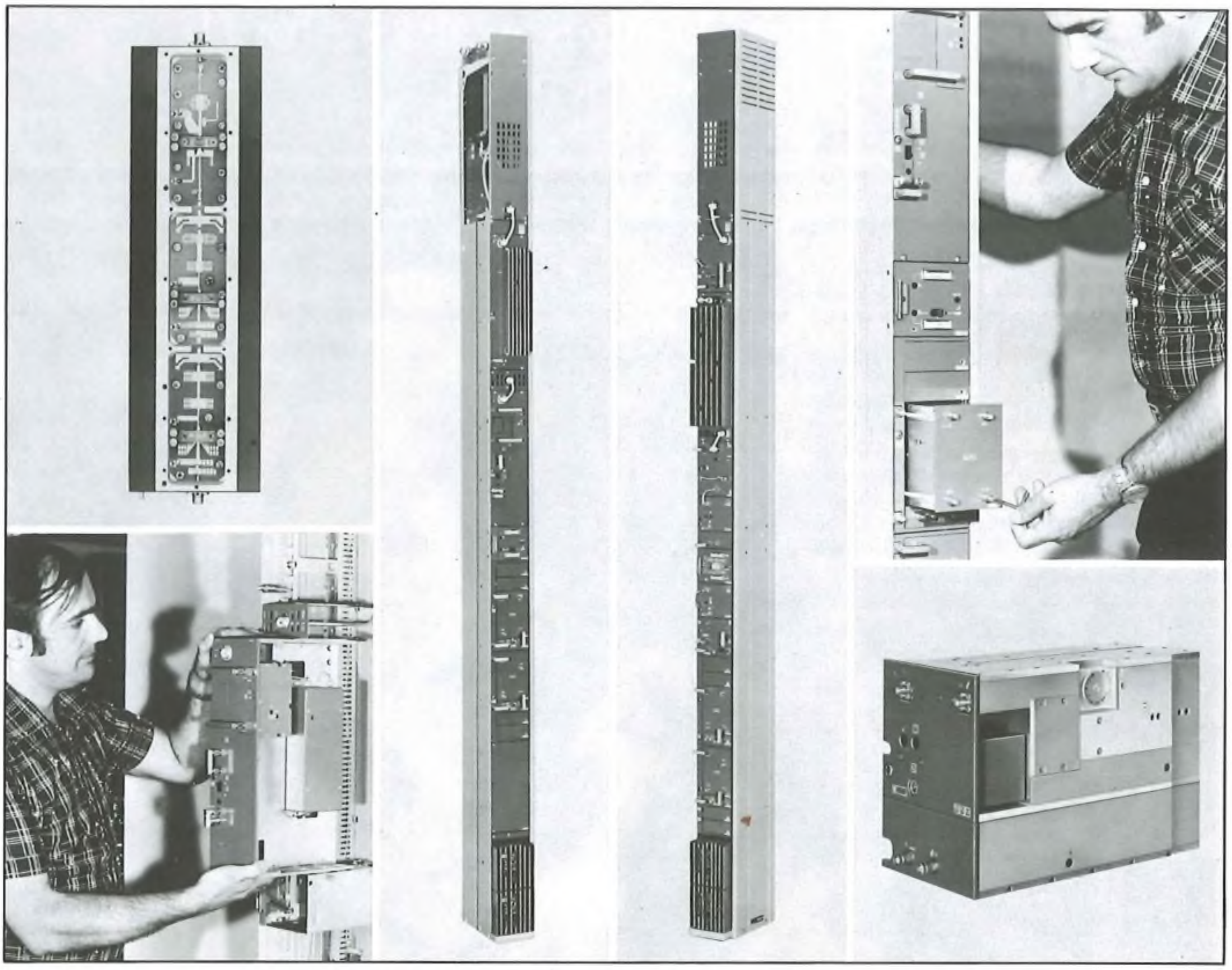

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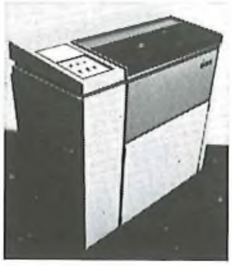

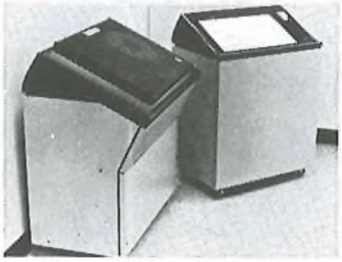

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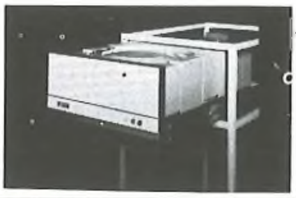

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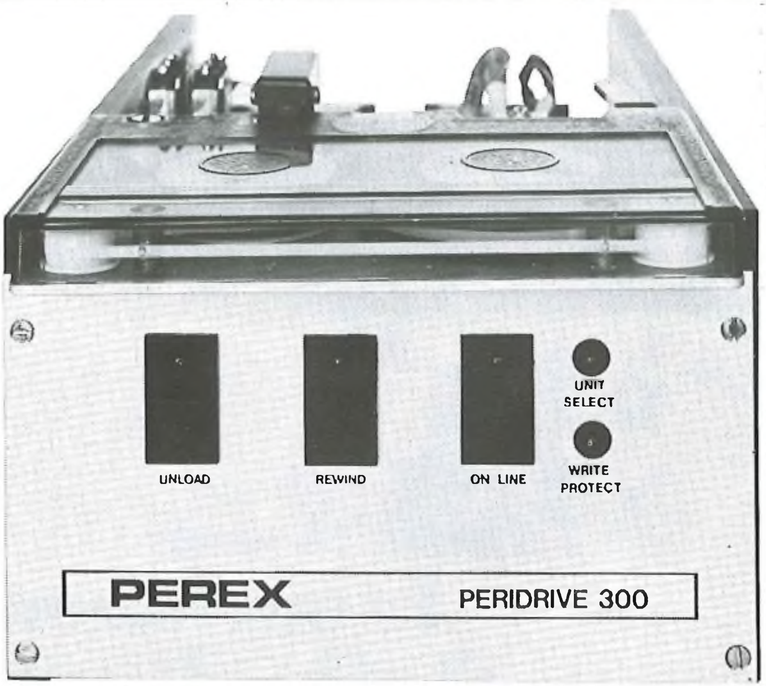

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The Post Office Electrical Engineers' Journal

EDITORIAL

The British Post Office (BPO) has adopted a 30-channel pulse-code modulation (PCM) standard to supersede that of the existing BPO 24-channel PCM system. The first 24-channel systems were installed in the UK in 1968, and by the end of 1978 there will be some 7000 of these systems in service. An article in this issue of the *Journal* records the end of the 24-channel PCM era and gives a summary of the main factors that influenced the BPO in its adoption of the new standard. Also included in this issue is the first part of a 3-part article that describes the 30-channel PCM system. Part 1 describes the multiplex equipment, and subsequent articles will describe the digital line system and the signalling equipments.

The BPO has recently announced its decision to install a measurement and analysis centre (MAC) in each of the 61 Telephone Areas in the UK. The MAC scheme will provide facilities to measure automatically the quality of service given by the BPO public switched telephone network. The benefits to be derived from the proposed scheme encompass an improved service to customers, more efficient use of telephone exchange maintenance staff effort (faults at distant exchanges will be diagnosed quicker, thus leaving more time to locate and clear faults in home exchanges), and an improved service to management at all levels (by providing precise statistical information on the performance of individual switching units and more information on the overall performance of the telephony network).

In this issue is the concluding part of an article describing the MAC concept and the programming and operation of the processors that control the pattern of test calls and the information output. Subsequent articles related to MAC will give fuller technical description of the equipment and details of operational experience of the system.

Viewdata is an interactive information medium developed by the BPO. The system provides a visual display on modified domestic television receivers of information obtained from computer banks. Access to computer centres is achieved by use of the public switched telephone network. The Viewdata system arrangement is described in this issue.

The End of the First Pulse-Code Modulation Era in the UK

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

UDC 621.376.56

This article reviews the use of 24-channel pulse-code modulation (PCM) systems, which have been in service in the British Post Office telephone network since 1968. The BPO has now adopted a 30-channel format as a new national PCM standard. This article includes a summary of the main factors that influenced the BPO to adopt the new standard.

INTRODUCTION

As a result of the availability of suitable transistors, the first practical pulse-code modulation (PCM) transmission systems began to emerge in a number of countries in the early 1960s. Several experimental designs were produced by UK industry, and the British Post Office (BPO) Research Department carried out a great deal of basic research on PCM technology, particularly in the area of speech encoding. From all this work, emerged what has become one of the 2 internationally-recognized encoding laws used in PCM designs. This encoding law is known as the *A law*.

By the second half of the 1960s the BPO had established a standard specification for a 24-channel PCM system[1], and production orders had been placed for these systems to come into service in 1968 onwards.

24-CHANNEL PCM NETWORK

24-channel PCM systems were designed primarily for short-distance (less than 32 km) transmission routes, particularly those within large urban conurbations. In several large cities, the BPO was faced with a situation where both audio pair-type cables and cable ducts were reaching exhaustion. Telephone-traffic growth was increasing rapidly and there was a need to augment quickly the existing circuit capacity, with a minimum of disturbance to congested roads and in the most cost-effective manner. PCM transmission systems provided an ideal solution to this problem. At the end of 1978, there will be some 7000 systems in the BPO 24-channel PCM network. The location of these systems is shown in Fig. 1, from which it can be seen that the preponderance of the PCM systems are clustered around large cities and in the heavy-industrial parts of the country such as the Midlands, South Wales and the Clyde/Forth valley; this indicates clearly the role of 24-channel PCM systems.

Some 40% of the systems are allocated specifically to the main network, and approximately 50% of the systems to the junction network. The remaining 10% carry a mixture of both main-network and junction-network circuits. The average length of a main-network PCM system is approximately 30 km and the average length of a junction-network PCM system is approximately 25 km. While PCM systems are estimated to use approximately 1·5% of the available pair-length of junction cable, their contribution to the total traffic-carrying capacity of the junction network is equivalent to 10%. Fig. 2 shows the distribution of length of all the planned 24-channel PCM systems.

† Network Planning Department, Telecommunications Headquarters

FIG. 1—British Post Office 24-channel PCM network at 1978 (7000 systems)

SERVICEABILITY OF 24-CHANNEL PCM SYSTEMS

Digital circuitry is characterized by the need to use a large number of active components to carry out many of the circuit functions. While the reliability of components such as diodes and transistors had largely been proven by the time time-division multiplexing equipment was introduced into the field, the combined reliability of the large number of components used in a PCM system of an average length of say

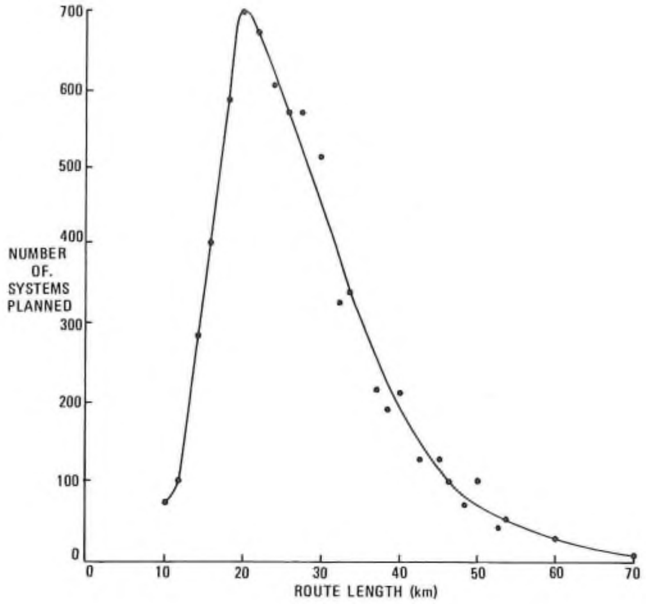

FIG. 2—Distribution of length of 24-channel PCM systems

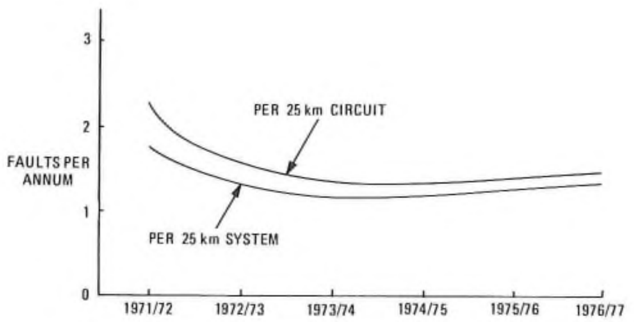

FIG. 3—24-channel PCM equipment faults

25 km, was largely unknown. Apart from the usual problems found at the beginning of any new design, the reliability of 24-channel PCM equipment has, in fact, been found to be reasonably satisfactory. The fault-rate per annum of an average 25 km PCM system and a 25 km circuit (that is, including PCM signalling units) is shown in Fig. 3. The mean-time-between-failures of a typical PCM multiplex unit is of the order of 2 years, while that of a both-way regenerator is typically 100 years. A study of these fault statistics clearly indicates areas of design and component weaknesses which largely control the fault-rate of systems. Although it is not always possible or economically practicable to take corrective action to eliminate weaknesses to existing designs, the knowledge and experience gained from operating systems can be applied to future designs.

THE CHOICE OF PCM STANDARDS

It has already been indicated that PCM systems were introduced primarily to increase the efficiency of use of existing pair-type cables on short-distance routes. Thoughts of a world-wide integrated network of digital transmission and switching systems were far from the minds of engineers who designed and planned the first systems of this new technology. However, no sooner had the first PCM systems been successfully introduced into the field, than thoughts of extending the technology to higher-capacity transmission systems and to switching systems started taking root on both sides of the Atlantic. In the UK, the BPO experimented with coaxial-cable systems and adopted a 120 Mbit/s digital system[2] (1680 circuits) which, from a cable standpoint, was designed to be compatible with a 12 MHz frequency-division multiplex system. This factor permitted the rapid introduction of digital systems into the coaxial-cable network, and production models of 120 Mbit/s digital line systems will, in fact, be coming into service in 1978 at much the same time as the 30-channel PCM systems. On the switching front, the BPO, in association with UK industry, is developing a family of digital-switching exchanges, known as *System X*, that will provide the switching element of an integrated network of digital transmission and switching systems. System X exchanges should be in service at the beginning of the 1980s. Similar development patterns can be seen in other countries.

There was, however, an intermediate stage of development between the first PCM systems and the integrated digital era now being planned by many telephone administrations. In the USA, 24-channel systems were introduced prior to those in the UK, but with a number of different features. One important difference was the encoding law. As already explained, UK PCM designs use the A-law, while the first North American designs used what is known as the *mu = 100* law. However, both the UK and North American first-production designs are considered unsatisfactory for universal application and for the basic building block of an evolving hierarchical digital structure. The needs of new digital switching systems had also to be taken into account when establishing PCM standards. Despite these new considerations, it was still considered important to exploit symmetrical pair-type cables (paper-core quad trunk cable in the BPO network) to the maximum extent possible, and this factor played an important part in determining future PCM standards. Consideration of these matters by European and North American administrations, resulted in the emergence of 2 solutions which have now been standardized as CCITT* recommendations. One recommendation is based on a USA 24-channel design, and the second recommendation is based on a 30-channel design evolved by a number of European telephone administrations. Though both designs are capable of meeting the requirements of a world-wide integrated digital transmission and switching network, they differ in some major respects and will not interwork directly with one another. It has, however, been agreed that countries adopting the 24-channel design must bear the cost of providing the appropriate code-conversion facilities to allow the interworking of channels derived from the 2 different systems.

The major differences, apart from package size, between the 2 CCITT recommendations are

(*a*) the encoding law,
(*b*) the frame-alignment strategy, and
(*c*) the signalling strategy.

Encoding Laws

The 30-channel system uses the A-law encoder developed by the BPO but, instead of using 7 binary digits per sample as used at present in the BPO 24-channel system, 8 binary digits per sample are recommended. On the other hand, the CCITT 24-channel design uses the North American mu-law encoder but up-rated for more accurate encoding at low levels (by changing from mu = 100 to mu = 255), using substantially 8 binary digits ($7\frac{5}{6}$ digits). However, for international calls, the full 8 binary digits are used.

A comparison of the 2 encoding laws shows a balance of favour towards the A-law in that

(*a*) a small, but nevertheless significant, advantage is gained in respect of quantizing distortion, in particular within the most significant part of the dynamic range,

* CCITT—International Telegraph and Telephone Consultative Committee

(*b*) digital manipulation of signals (for example, for transmission-loss control, conference working and operator intervention) is more easily applied to A-law encoded signals, and

(*c*) there are economic advantages in terms of circuit realization under production conditions and ease in subsequent maintenance of the equipment.

Frame-Alignment Strategy

The 2 CCITT designs use quite different frame-alignment strategies. The 24-channel design uses a frame-alignment signal that is distributed amongst several frames, whereas the 30-channel design bunches the frame-alignment word into a separate 8 bit time-slot (TS0). The bunched strategy has the following advantages:

(*a*) the total information for alignment is greater and results in a significantly faster recovery of frame alignment following a loss of alignment,

(*b*) the extraction of the alignment word is easier (an important factor in digital switching applications),

(*c*) extracting time-slots is simpler, as is the combining of time-slots to carry wideband services (digital paths derived in this way are, in fact, inherently bit-sequence independent, thus giving great flexibility in the use of digital paths), and

(*d*) spare capacity exists within the framing time-slot, which may be used for conveying network-management information and low-speed data; for example, alarm signals.

Signalling Strategy

The third basic difference between the 2 CCITT designs is in the signalling strategies. In the 24-channel design, the signalling information is conveyed within each speech time-slot (a technique called *bit stealing*), this results in a slight reduction in speech-coding performance. In the 30-channel design, the signalling information for all the channels is encoded and conveyed in a separate 8 bit time-slot (TS16). The signalling time-slot is sub-multiplexed and provides a signalling capacity of 2 kbit/s for each speech channel. The signalling capacity is arranged to provide 4 independent 500 bit/s signalling channels in a manner which is described in an article[3] in this *Journal*. The advantage of this arrangement is that it will permit a large number of network and customer facilities to be applied as the integrated digital network evolves. The signalling arrangements and the inherent fast frame-alignment recovery time associated with the chosen frame-alignment strategy makes it possible to meet the requirements of common-channel signalling systems which are now under development.

ADOPTION BY THE BPO OF THE 30-CHANNEL SYSTEM

Neither of the 2 CCITT approved designs will interwork with the present BPO 24-channel system. It has been indicated that the existing BPO 24-channel design is not suitable as a national or international standard, therefore the BPO had to choose for its national standard one of the 2 designs recommended by the CCITT. In discussions between telephone administrations throughout Europe, it was agreed that it would be sensible for countries with a large measure of inter-working (such as is found in Europe) to adopt the same standard and, for the reasons which have been explained, the European administrations chose to adopt the 30-channel design. Today, most countries, with the exception of North America and Japan, have adopted the 30-channel format. The wide acceptance of the 30-channel format must clearly influence the development of digital transmission and switching systems in the future, not only for telephony, but for other services such as data.

Ten years have passed since the first generation of PCM equipment first carried public traffic. During this period of time, PCM systems have ceased to be solely a useful solution to a particular problem but have become the generally accepted method for building the telecommunication systems of the 1980s and the 1990s. The 30-channel PCM assembly has been adopted by the BPO as the basic digital building-block for both digital transmission and switching systems. In order to achieve a high degree of equipment flexibility, well-defined interfaces have been established between the 30-channel multiplex equipment and the 2·048 Mbit/s line transmission system, and between the multiplex equipment and the signalling units. Thus, the 30-channel PCM multiplex equipment, the line transmission system and the associated signalling units can all be treated as independent units for planning and procurement purposes, and it is probable that each of these separate units will follow independent development paths in the future. A series of articles[3] to be published in this *Journal* will describe in detail the first BPO version of the CCITT recommended 30-channel format.

THE FUTURE

And what will the future bring? While it is always difficult to forecast exactly what the future has in store, already a few pointers to the way ahead can be discerned. Equipment design lives are likely to be much shorter in order to capitilize on the rapid strides in component technology. Thus the design life of the first generation of 30-channel multiplex equipment could last only 5 years compared with the 10 years of 24-channel PCM equipment. Secondly, the 30-channel group is a comparatively large circuit block for the network as we know it today, and for some considerable time ahead. Two of the possible solutions to this problem are: dividing the 30-channel group into 2×15 channel blocks, or adopting single channel encoding/decoding techniques so that only the minimum amount of equipment need be supplied to meet the demand. The preferred solution is still a matter for considerable study. A further development is to access one or more channels at a digital interface, so that a 30-channel group can carry a mixture of different types of traffic, irrespective of an analogue or digital source. No doubt, other requirements will emerge and it is of interest to note that the basic 30-channel design permits all the design possibilities so far considered. This indicates that the choice of the 30-channel format as the new BPO national PCM standard was unquestionably the right decision.

Acknowledgement

Acknowledgement is given to the work of many BPO Telecommunications Headquarters personnel who contributed to the formation of the CCITT recommendations relating to the 30-channel PCM format; in particular, those of the Line and Radio Systems Division, Telecommunications Development Department.

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30-Channel Pulse-Code Modulation System

Part 1—Multiplex Equipment

E. C. VOGEL and R. W. McLINTOCK, B.SC.†

UDC 621.376.56

This first part of a 3-part article describes the historical background to the adoption by the British Post Office of the 30-channel pulse-code modulation standard and includes a technical description of the multiplex equipment. Parts 2 and 3 will describe the digital line and signalling equipments respectively.

INTRODUCTION

As a direct result of the progress made over the last 10 years or so in the advancement of semiconductor devices and, in particular, those of integrated circuits, it has become economic to provide telecommunication networks using entirely digital techniques.

Relevant technical and economic studies made by many telecommunication administrations throughout the world have clearly shown that an integrated digital-transmission and digital-switched network is likely to be the most viable means of satisfying the future needs of telecommunication networks.

The British Post Office (BPO), with the full collaboration of UK industry, has taken firm steps to realize an integrated transmission and switched network, and several elements of such a network are in advanced stages of development. The most advanced development is that of the primary telephony digital-transmission system, known as the *30-channel pulse-code modulation (PCM) system.* During 1978, several hundred 30-channel PCM systems will be installed in the BPO telephone network and, as a result, this year will be a milestone in the history of UK digital-transmission developments. Although a few years are to elapse before the first digital-switched exchanges (incorporating 30-channel PCM systems) become operational, more importantly perhaps, 1978 will mark the stage when the first practical steps were taken to realize an integrated transmission and switched network in the UK.

Digital transmission, and in particular the technique of PCM has been established for many years. In the BPO network, PCM has been in use for just a decade, and some 7000 24-channel PCM systems[1] are now in service. With such a significant penetration of 24-channel systems already in the network, the question is posed: why change to a 30-channel standard?

Before answering this question and discussing the main features of the 30-channel PCM system, it is appropriate to review briefly the background of PCM developments with reference to the dominant considerations which gave rise to the UK changing its standards.

HISTORY OF PCM SYSTEM DEVELOPMENT

In the early 1960s, the USA was the first nation to exploit the technique of PCM as a means of providing speech circuits as an alternative to the then traditional analogue methods.

The USA system, known as the *T1 system*, provides for 24 channels, and operates at an overall digit-rate of 1544 kbit/s. At present, over 40 000 systems are operating in urban areas throughout the USA. The USA understandably pressed through the CCITT* that their T1 system should be adopted as a single world standard.

Likewise the BPO, whose development was only a little later than USA, urged that the BPO 24-channel system should also be a standard, at least for Europe. The USA T1 system and the BPO 24-channel system are significantly different in their respective characteristics such that the 2 systems cannot interwork directly. In the event, the BPO 24-channel system was not accepted as the European standard. Several reasons can be attributed to this outcome which embrace technical, political and commercial aspects.

It is a fact that at the time of the CEPT‡ and CCITT international debates on the drafting of recommendations for PCM, the USA and the UK had a substantial lead over the rest of Europe, in terms of fully engineered and available systems and the number of PCM systems installed.

Taking into account some valid technical disadvantages of both the T1 and BPO 24-channel systems, the CEPT evolved a new PCM format (with full cooperation of the UK). This format, the 30-channel one, is now established in the CCITT as one of 2 recommendations; the other being substantially the USA T1 format.

Thus, throughout the world, Postal and Telecommunication Administrations are faced with a decision regarding the choice of format. As far as the UK is concerned, a choice from 3 formats arose and, when all aspects were taken into account, the 30-channel format emerged as the best from the BPO viewpoint. This choice was dictated by geographical considerations (with the need to interwork operationally with close European neighbours), the status of the UK as part of the European Economic Community, the desirability of UK designed and manufactured equipment being suitable for export and, not least, the technical advantages of the 30-channel format over the original BPO 24-channel and the USA T1 formats.

An article in this issue[2] expands upon the technical differences between the 2 CCITT recommended standard formats.

TECHNICAL DESCRIPTION

A 30-channel PCM multiplex system provides a transmission capability by digital means of 30 telephony circuits between 2 locations. Each system consists of terminal multiplex equipment and an associated digital-line system.

† Telecommunications Development Department, Telecommunications Headquarters

* CCITT—International Telegraph and Telephone Consultative Committee

‡ CEPT—Conference of European Posts and Telecommunications Administrations

A complete terminal equipment consists of a multiplex equipment and 30 signalling units which are selected on a circuit basis from a range of units offering a variety of signalling facilities. This article describes the 30-channel PCM multiplex equipment; subsequent articles will describe the digital-line equipment and the signalling units.

Frame Structure

Each audio channel (0–4 kHz) is sampled at a rate of 8 kHz; that is, every 125 μs. In each period of 125 μs is contained an amplitude sample from each of the 30-channels and this period is known as a *frame*. Each frame is divided into 32 *time slots* (TSs), and these are designated *TS0–TS31*; the 2 extra TSs are used to convey frame-alignment and signalling information. Each TS contains 8 binary digits; these binary digits constitute the line signal and occur at a gross digit rate of 2048 kbit/s.

The frame format on which 30-channel PCM is based is shown in Fig. 1; the format accords with CCITT recommendations.[3]

The gross digit rate equals the frame repetition rate (8000 Hz) multiplied by the number of TSs in a frame (32) multiplied by the number of binary digits per TS (8), therefore,

$$\text{gross digit rate} = 8000 \times 32 \times 8,$$
$$= 2048 \text{ kbit/s}.$$

The signalling information for all 30 channels is conveyed in TS 16; clearly, 8 binary digits is insufficient capacity to do this directly. The capacity of TS16 is therefore sub-multiplexed over a period of 16 frames (the frames are numbered 0–15), this latter period is known as a *multiframe*. During frame 0, a multiframe-alignment signal is transmitted in TS16 to identify the start of the multiframe structure. In each of the succeeding frames, the 8 binary digits available are shared by 2 channels for signalling purposes. After one multiframe (2 ms), each channel will have been allocated a 4 bit word for signalling. This corresponds to a signalling information rate of 2 kbit/s per channel.

TS0 contains a frame-alignment signal which enables the distant terminal to recover the identity of TSs. The frame-alignment signal (0011011) is transmitted in binary digits 2–8 in alternate frames. In the intermediate frames, a signal known as the *not word* is transmitted; only binary digit 2 of this word is fixed as being a *one*. The fact that this binary digit is the complement of the corresponding binary digit in the frame-alignment signal, significantly reduces the possibility of the demultiplex misaligning to imitative frame-alignment signals. Whilst it is possible that a sequence of binary digits, other than TS0, might continuously mimic the frame-alignment signal, it is much less likely that any imitation would include the alternation in the state of binary digit 2.

A number of binary digits in TS0 and TS16 are not allocated for any specific purpose and are referred to as *spare* binary digits (see Fig. 1). Two other binary digits are used to convey the state of the local alarms to the distant terminal:

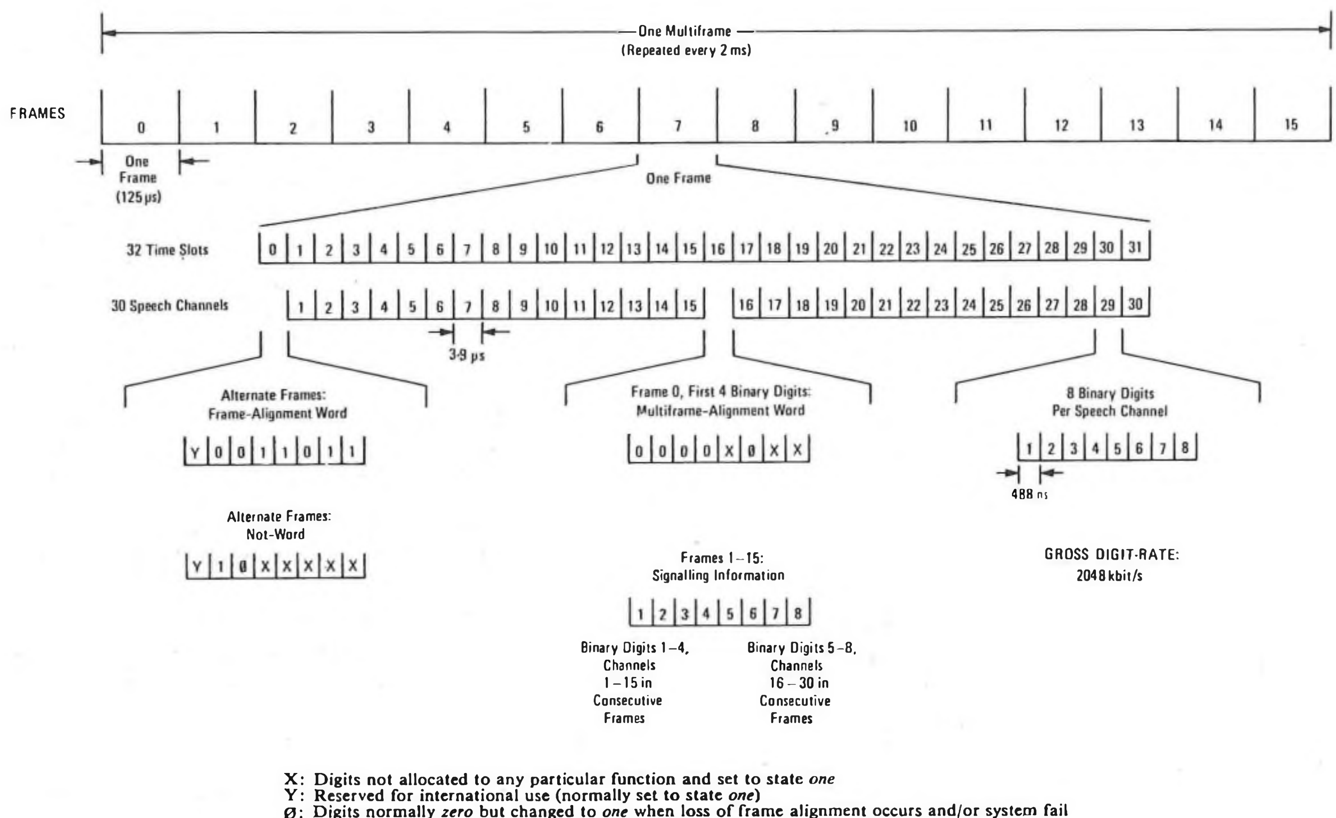
(*a*) Binary digit 3 of TS0 in frames not containing the frame-alignment signal indicates the state of the multiplex alarms.

(*b*) Binary digit 6 of TS16 in frame 0 conveys the state of alarms associated with multiplexing of the signalling information.

Signalling Unit Interface

The interface with the signalling units consists of a 4-wire speech path, based on a characteristic impedance of 600 Ω, and 2 highways along which signalling information is transmitted/received; this information is in the form of 4 bit words every multiframe. Basic clocks and power are supplied to the signalling units from the multiplex. The signalling unit to multiplex interface is shown in Figs. 2 and 3 for transmit and receive directions of transmission respectively.

The entire interface (performance parameters and operating conditions) is tightly controlled by specification; this is



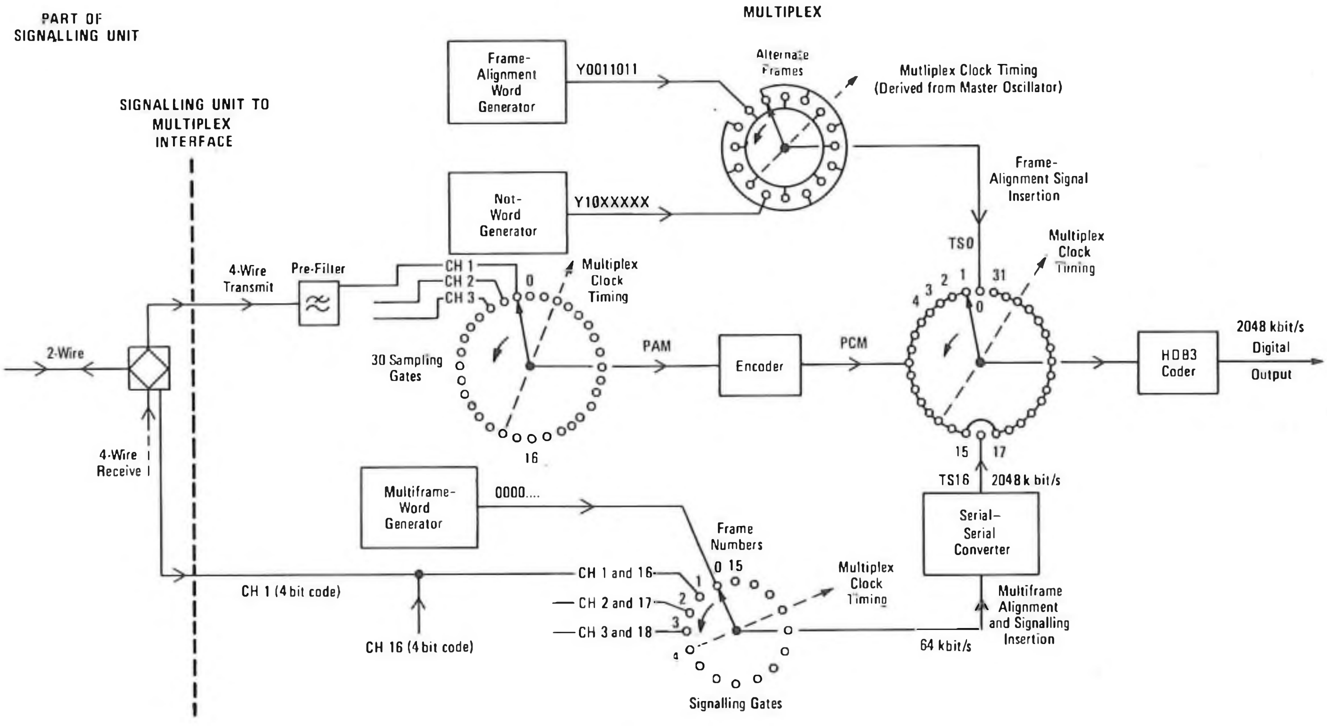
X: Digits not allocated to any particular function and set to state *one*
Y: Reserved for international use (normally set to state *one*)
Ø: Digits normally *zero* but changed to *one* when loss of frame alignment occurs and/or system fail alarm occurs (TS0 only) or when loss of multiframe alignment occurs (TS16 only)

FIG. 1—Frame format for 30-channel PCM system

essential because it is required that signalling units from any manufacturer should operate satisfactorily in any design of multiplex.

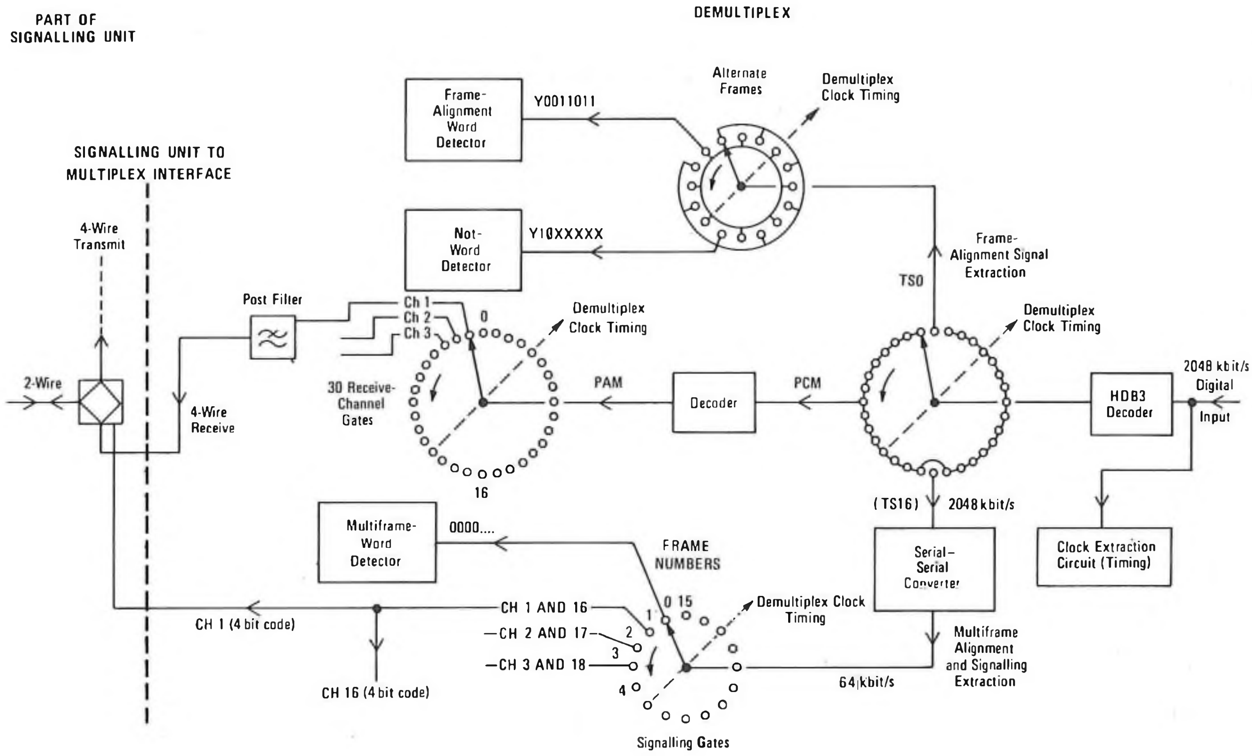
Pre-filtering

In the multiplex, the input signal is first connected to a low-pass filter to reduce the level of any components above 4 kHz. Frequency components above 4 kHz can arise from preceding frequency-division multiplex equipment, preceding PCM systems, crosstalk from other high-frequency services, and a number of other sources. Any such components can, as a result of the subsequent sampling process, reappear in the



CH: Channel

FIG. 2—Transmit speech and signalling information



CH: Channel

FIG. 3—Receive speech and signalling information

wanted signal band (300–3400 Hz) and it is necessary to ensure that they are of sufficiently low level not to impair the wanted signal. Practical realization of pre-filtering is based upon the use of traditional inductive-capacitive (LC) filters; active filters are not used on the grounds of cost and power consumption.

Sampling and Multiplexing

For a period slightly less than the time allocated to a TS, each filtered channel is gated in turn onto a common highway known as the pulse-amplitude-modulated (PAM) highway. In this single operation, the channels are sampled and time-division multiplexed. A great deal of care is taken in the realization of this part of the multiplex since it is here that interchannel crosstalk can be introduced. Because of the large bandwidths involved and also its physical length, the highway is also prone to other forms of noise interference if adequate precautions are not taken.

Encoding

The encoder operates in turn on the samples appearing on the PAM highway and, for each one, generates an 8 bit code word, the first binary digit of which denotes the polarity and the remaining 7 bit the amplitude of the sample. This facilitates the representation of 256 (2^8) discrete signal values. The difference between the closest approximation and the input signal is the error which gives rise to quantizing distortion. The 256 possible values are not equally spaced between the negative and positive overload points (linear coding) but instead, more values are ascribed to the lower signal values and fewer to the larger signal values (see Fig. 4). This has the same effect as compressing the input signal before linear encoding. The overall result is that the signal-to-quantizing-distortion-ratio performance is almost constant over a considerable range of input signal levels. This factor is of vital importance since, when account is taken of the possible positions in the network where PCM might be used, the distributions of mean talker levels, syllabic powers and preceding circuit losses, the required dynamic range is considerable. To achieve this same range with a linear encoder would require 12 bit representation.

The compression characteristic, based on an approximation to a logarithmic law, is known as the CCITT *A-law*.

The encoder operates according to a successive approximation approach, achieving the compression characteristic by manipulation of current sources and attenuators.

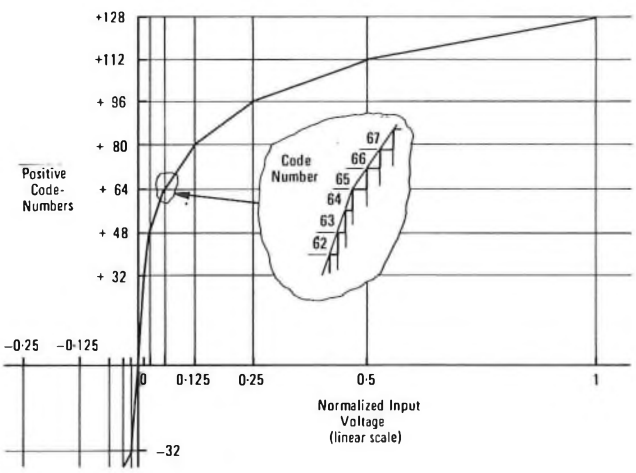


FIG. 4—A-law companding characteristic

Signalling Multiplexer

The 4 bit words from the signalling units are time-interleaved in the TS16 common equipment, and the multiframe-alignment signal is added at the appropriate time. The resulting 64 kbit/s digital stream is added to the output from the encoder after first converting it into 8 bit bursts at the 2048 kbit/s rate. The frame-alignment signal (TS0) is added in a similar fashion.

Line Coding

The binary-digit stream at 2048 kbit/s is not suitable for transmission directly to line (as will be explained in Part 2 of this article). Therefore, it is converted to a ternary line code known as *high-density bipolar 3* (HDB3). The rules for this code are that a binary *one* is transmitted alternately as a positive or negative pulse (nominally rectangular in shape, 2·37 V, 50% duty cycle); this pulse is known as a *mark*. A binary *zero* is transmitted as zero voltage. The coding arrangement described so far is the same as that known as *alternate mark inversion* (AMI), which is used on the BPO 24-channel PCM systems.

The following modifications are applied to the AMI code to ensure that an adequate mark density is transmitted to line under the condition of a long succession of consecutive *zeros* appearing in the binary signal:

(*a*) In any sequence of 4 consecutive binary *zeros*, the ultimate *zero* is substituted by a mark of the same polarity as the previous mark (that is, a bipolar violation).

(*b*) In cases where successive violations would otherwise be of the same polarity (that is, even number of marks between violations), the first of the 4 consecutive *zeros* is replaced by a mark of the opposite polarity to the previous mark. The insertion of this mark ensures that consecutive violations are of opposite polarity, thereby maintaining zero disparity in the output signal.

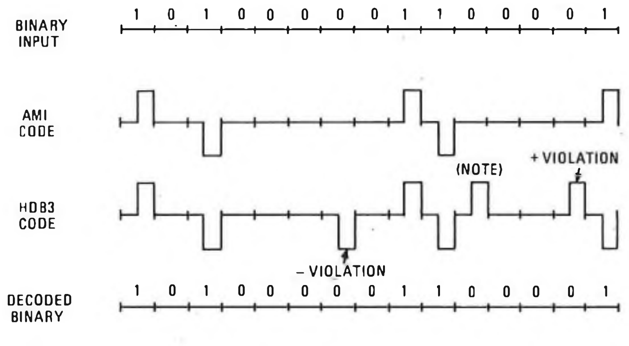
In the HDB3 line code, the "3" denotes the maximum number of consecutive *zeros* that can exist in the signal.

To subsequently remove the HDB3 coding at the distant terminal, the following rule is applied. On recognition of a bipolar violation preceded by 2 *zeros*, the violation and 3 preceding digits are replaced by 4 *zeros*. Fig. 5 illustrates the coding strategy.

The coded digital line signal is presented at a 75 Ω coaxial interface and is in a form suitable for cabling over distances of up to 330 m to line equipment, to higher-order digital-multiplex equipment, or to any other 2048 kbit/s bearer plant.

Demultiplexing

In the demultiplexing equipment, the 2048 kbit/s digital signal is HDB3 decoded after first having had a 2048 kHz clock extracted from the line signal (see Fig. 3). Clock extraction is achieved by full-wave rectifying and slicing the line signal,



Note: Added mark in first *zero* position to ensure that consecutive violations are of opposite polarity

FIG. 5—Example of HDB3 coding

followed by selective filtering of the 2048 kHz component by means of an LC tuned circuit. The Q-factor of this tuned circuit is sufficiently low that it tracks satisfactorily any jitter introduced by the line system. After squaring, this clock is used to derive all the other required timing signals.

Frame Alignment

The binary stream is examined for the presence of the frame-alignment signal, which marks the position of TS0 and from which all the other TSs can be found. A strategy is specified for searching for the frame-alignment signal, and is a compromise between the time taken to confirm the presence of the frame-alignment signal and the risk of incorrectly aligning to imitations of it. To establish alignment, a frame-alignment signal, a *not word* and a frame-alignment signal must be correctly received in TS0 in 3 consecutive frames.

A different strategy is specified for detecting loss of alignment. This is a compromise between starting a search unnecessarily, as a result of a number of errors in the line signal, and delaying the start of the search too long in the case of a real loss of alignment. In fact, 3 consecutive frame-alignment signals must be received erroneously before a search is started.

Signalling Demultiplexer

The signalling information contained in TS16 is removed and passed to the signalling demultiplex equipment as a 64 kbit/s signal. The signal is scrutinized for the presence of the multi-frame-alignment signal according to a strategy similar to that for frame alignment. Once identified, the timing signals are aligned, so enabling each signalling unit to identify its relevant 4 bit word in the stream every multiframe.

Decoding

In the decoder, the 8 bit codes control a number of current sources and attenuators and, in this way, reconstruct the samples which approximate to the original. The samples each last for slightly less than a TS and are arranged in time sequence on the receive PAM highway. Precautions against noise and interchannel crosstalk are taken in this area; these precautions are similar to those taken on the transmit PAM highway.

Post Filtering

Under the control of appropriate timing signals, each channel sample is gated in turn from the common highway. This may or may not be accompanied by a pulse-stretching stage (based on a sample-and-hold circuit). The stretching process increases the power level of the wanted signal but it also introduces an in-band amplitude-frequency distortion which must be corrected in the subsequent filter. This effect is known as *aperture distortion.*

The signal is passed through a low-pass filter which attenuates the level of the unwanted sideband and sampling frequency components. In practice, these filters have a performance very similar to that of the pre-filters. The output of the filter is buffered and presented to the signalling unit.

System Gain

The nominal gain of the multiplex path from the audio 4-wire transmit input to the 4-wire receive output is 4·6 dB. The nominal loss of the 2-wire-to-4-wire convertor in each of the signalling units is 3·8 dB. Thus, the circuit loss between 2-wire points is 3 dB.

Alarm Facilities

Monitoring facilities are provided to detect certain fault conditions. When a fault condition is detected, station alarms are raised and traffic is taken from the system and circuits are backward-busied automatically.

Manual facilities are also provided to enable traffic to be removed from the system for maintenance purposes. In this mode, circuits are not force-released but are only busied when existing calls have been completed. An indication is given when all 30 circuits have been busied.

The fault conditions that can be detected are,

(*a*) power failure,
(*b*) loss of digital input signal,
(*c*) loss of frame alignment,
(*d*) encoder/decoder (CODEC) failure,
(*e*) error rates of 1 in 10^3, 1 in 10^4, 1 in 10^5, and
(*f*) loss of multiframe alignment.

Three additional conditions are monitored that are associated with alarms being detected at the distant terminal or in the digital path. These are,

(*a*) distant multiplex alarm,
(*b*) distant signalling multiplex alarm, and
(*c*) receipt of an alarm-indication signal.

The function of the majority of the fault condition alarms is self explanatory, however, some are described here in more detail.

CODEC Monitor

An automatic check is made upon the performance of the local encoder and decoder (CODEC) combination during TS0 when it is not required for processing any of the 30 speech signals. An 8 bit test code is applied to the decoder; the sample produced is applied to the encoder, and the output code produced is compared with the original test code. Provided that the difference is within certain limits, then the CODEC is deemed to be operating satisfactorily. A number of test codes are used sequentially to confirm satisfactory operation over different parts of the dynamic range. While this simple and relatively cheap supervision will not detect every possible CODEC fault, it is believed that it will detect a very high proportion.

Error-Rate Monitors

Three levels (all related to telephony performance) of error-rate monitor are provided at 1 in 10^3, 1 in 10^4 and 1 in 10^5. Since an assessment of the complete end-to-end digital path performance is required, the use of error detectors based on detection of HDB3 code errors is inadequate. A digital path, routed partly over higher-order digital plant, involves recoding of the HDB3 line signal. Any recoding process removes irregularities in the HDB3 code that have been introduced by errors in preceding sections. Of course, the binary signal still contains the errors but the HDB3 signal would appear error-free.

In the method adopted, the detectors monitor the frame-alignment signal. By counting the number of times that the frame-alignment signal is incorrectly received in a given time, and assuming that during this time any errors are evenly distributed throughout the whole signal structure, then the error rate of the digital signal can be estimated. Clearly the system is a sampling one, based upon a sample size of less than 1·5%. To achieve satisfactory confidence limits for any conclusions drawn, the signal must be monitored over fairly lengthy periods, particularly in the case of the 1 in 10^5 error-rate monitor.

The 1 in 10^5 error-rate alarm gives a visual indication only that performance is marginal. An option exists for removing traffic at either the 1 in 10^3 or the 1 in 10^4 error-rate levels. Traffic is normally removed at the 1 in 10^4 error-rate level. However, if the loss of a system would cause serious congestion on a traffic route, then traffic is removed at the 1 in 10^3 error-rate level.

Distant Alarms

Three conditions are monitored which indicate that alarms have already been detected at the distant terminal or at some intermediate point.

Binary digit 3 of TS0 and binary digit 6 of TS16 indicate multiplex or signalling multiplex alarms respectively at the distant terminal. In both cases, automatic busying is initiated but, normally, alarms are not extended to the station alarm unless the distant exchange is unattended.

The third alarm condition, an alarm-indication signal (AIS), is receipt of an HDB3 signal equivalent to binary all-*ones*. This signal indicates that a fault has been detected elsewhere; for example, at a higher-order digital multiplex equipment. Busying action is taken but no alarms are extended. The AIS is useful in preventing the promulgation of a multiplicity of alarms when a single fault affects a higher-order digital multiplex or line equipment.

Power

The multiplex operates from the nominal 50 V station supply, using a DC–DC convertor to generate appropriate supplies. The maximum permissible input to the convertor is limited to 150 W. The signalling units derive their power from the convertor and represent a maximum load of 75 W.

Based on advice from appropriate medical authorities, the level of acoustic radiation emitted by the convertors is tightly controlled. This includes control of the levels of radiation above the audible range. Subjectively, the convertors appear silent, even to more youthful colleagues! The emission of electrical interference of various forms is also controlled to ensure compatibility with adjacent equipments.

Equipment Practice

The multiplex is constructed in 62-type equipment practice on 5 adjoining shelves. The top shelf is normally used to house power convertors and alarm units, and the second shelf for the multiplex common-equipment cards and the channel units. Apart from a small part of the fourth shelf used for the signalling multiplex, the remaining 3 shelves accommodate the 30 signalling units. The front and rear views of a 5-shelf multiplex terminal are shown in Figs. 6 and 7 respectively. Generally it has been found preferable to route the wiring at the rear of a multiplex terminal on a point-to-point basis rather than in cable forms. This results in greater immunity from electromagnetic interference generated by signalling/switching equipment.

Three complete multiplex equipments, and an alarm shelf which concentrates the alarms from the 3 systems, can be mounted on a 3200 mm high rack.

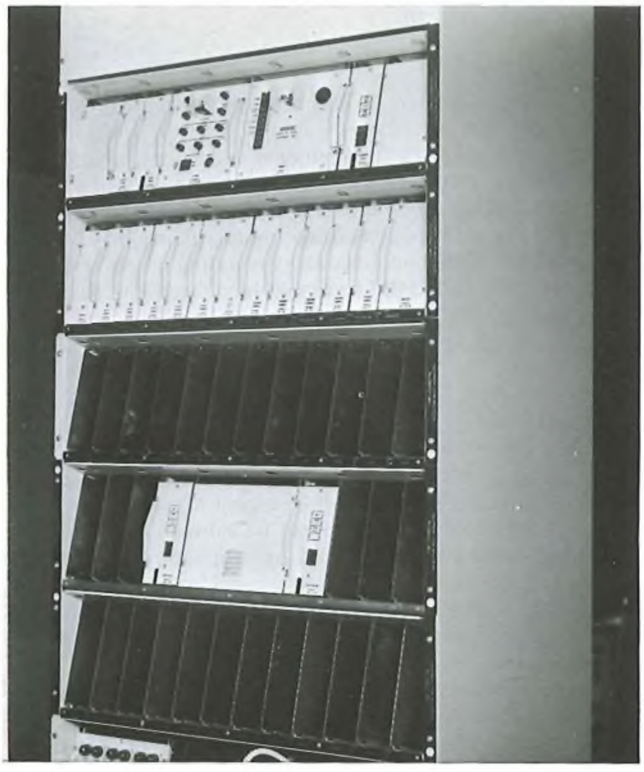
Components

Extensive use is made of standard power transistor-transistor-logic integrated circuits for the digital parts of the equipment. (These components must comply with the standards of BPO specification D3000 and the British Standards Institution specification BS9400.) Examples of the component packing densities achieved are shown in Figs. 8, 9 and 10.

FUTURE DEVELOPMENTS

A possible future next generation multiplex may include the following developments:

(*a*) The use of large-scale integrated circuits could bring about space and power savings. However, quantities play an



Note: Each of the vacant shelf positions will accommodate a signalling unit

FIG. 6—A 5-shelf multiplex terminal

(Photograph by courtesy of Marconi Communication Systems Limited)

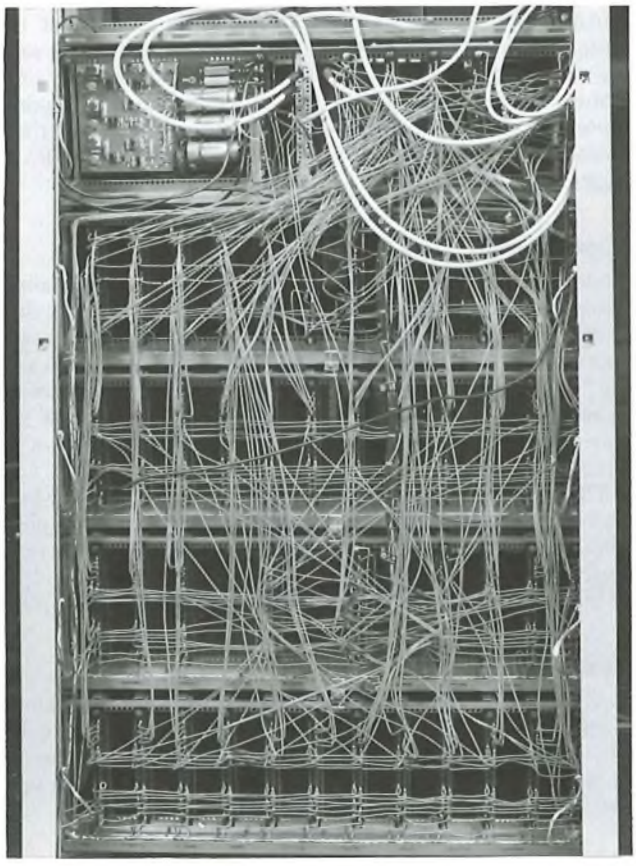
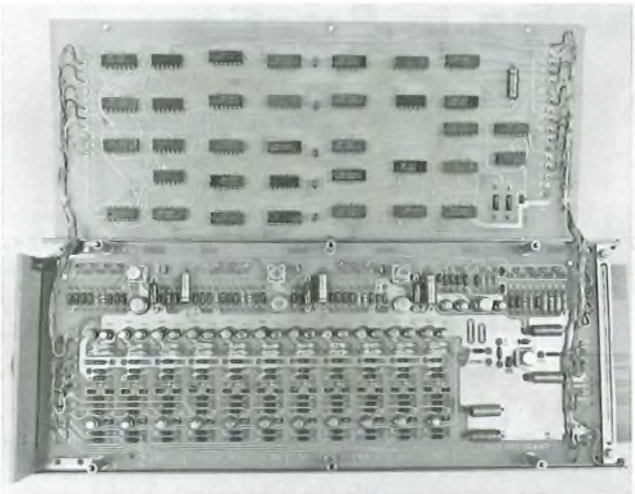


FIG. 7—Rear view of a 5-shelf multiplex terminal

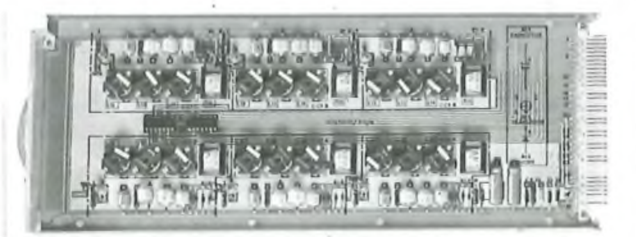
(Photograph by courtesy of Plessey Telecommunications Limited)



Note: The encoder unit contains 2 printed-wiring boards. The digital board (top) controls the sequence of successive approximations which are generated by the precision components on the analogue board (lower)

FIG. 8—Encoder unit

(Photograph by courtesy of Pye-TMC Limited)



Note: Contains the pre-filters for 6 channels

FIG. 9—Transmit channel-card

(Photograph by courtesy of GEC Telecommunications Limited)

Note: This unit interfaces with the incoming digital line signal. Clock extraction, HDB3 decoding and timing-signal generation occur here

FIG. 10—Receive timing-card

(Photograph by courtesy of Standard Telephone and Cables Limited)

important part in the economics of equipment provision, especially in the case of custom-built integrated circuits.

(*b*) Replacement of the single shared-CODEC with CODECs on a per-channel basis is being considered. Many development establishments are striving to achieve this end, not only for application in PCM multiplex equipment but also for digital switching applications. At present, no compelling technical reasons indicate that single-channel CODECs should be adopted in a multiplex; cost is likely to be the ultimate deciding factor.

(*c*) In association with single-channel CODECs, the use of digital filtering techniques is being pursued to replace, in part, the existing channel filters.

(*d*) A facility to provide access to the 64 kbit/s capacity of TSs for use by non-speech services such as digital data, is also being considered.

(*e*) With the introduction of digital switching into the network, it will be important to specify separately the transmission performance of PCM multiplex equipment from analogue-to-digital mode and from digital-to-analogue mode. In those cases where a 30-channel multiplex interfaces directly with the switch, its encoder will have to be capable of interworking with a variety of other decoders to which it may be connected via the switch; that is, an encoder and a decoder would not be associated permanently. These considerations also require that appropriate test equipment is evolved.

These are just a few of the aspects being considered and provide an apt reminder of the long time-scales involved in the development of this type of equipment from first thoughts to the ready-for-service date.

SUMMARY

This article has described the historical background to the adoption of the 30-channel PCM system for the BPO telephony network, and given a technical description of the multiplex equipment. Parts 2 and 3 of the article will describe the digital line equipment and signalling equipments respectively.

Over the last 2 years, multiplex equipment from 5 UK manufacturers has been tested extensively in the field under live-traffic conditions. Apart from a few minor difficulties, which have now been resolved, all designs have been found entirely satisfactory. As a result, all manufacturers have gained the necessary type approval, and the equipment is in production.

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2 BOAG, J. F. The End of the First PCM Era in the UK. *POEEJ*, Vol. 71, p. 2, Apr. 1978.

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Telecommunications Forecasting in Practice

W. M. TURNER, B.SOC.SCI.(M.E.S.), and J. PHILLIPS†

UDC 621.395: 313

This article describes the methods of producing the range of forecasts required in the British Post Office at national, Regional and Area levels. The uses of these forecasts are discussed, weaknesses are identified and possible remedial improvements are described.*

INTRODUCTION

Before describing some of the methods currently in use to forecast future telecommunications demands, it is worthwhile considering some of the uses of forecasts. Forecasts are used to determine the probable number of exchange connexions customers will require in the future, the calls they will wish to make and when they wish to make them, the average conversation time of the calls and their destination. From such information, planners can estimate the financial prospects of telecommunications, manpower requirements and capital investment. Some of the decisions such as those concerning prices, must be made at the highest level in the British Post Office (BPO), but many local decisions, on such diverse matters as recruitment, stores ordering, building, site acquisition and contract exchange extensions, must also be based on forecasts.

The forecast must help answer 2 important questions: the first is when are present resources likely to exhaust; the second is how much should be ordered on replenishment. It takes about 6 months to recruit and train local engineering and operating staff, whereas several years are required to find a new site; thus, different requirements exist for exhaustion forecasts. Similarly, replenishment periods vary widely depending on the economics of provision.

Consequently, requirements of forecasts vary enormously, and it is a very important part of the forecasting function to ensure that the many different forecasts made throughout the Telecommunications Business are compatible. This has been traditionally accomplished by operating a *top-down, bottom-up* forecasting system for exchange connexions, which is described more fully below. With the advent of new exchange systems, busy-hour traffic is becoming a more critical factor in the exchange-equipment programme, and the first steps in the production of an equivalent *top-down, bottom-up* process for traffic forecasts are now in preparation.

This article also describes the production of a national traffic forecast and previews some developments in traffic forecast procedures; these have been designed to be complementary to the recently-introduced BPO group-switching-centre planning-line procedures, and will be incorporated directly into the forthcoming local-exchange planning-line instructions.

TOP-DOWN, BOTTOM-UP

These procedures refer to the breaking down of the national figures into Regional, Area and exchange shares (*top-down*), and the aggregation of the individual exchange forecasts to give a national figure (*bottom-up*). They have been operating for over 10 years on exchange-connexion forecasting, as described below, and have proved their worth. The *up* and *down* processes are complementary to each other, and each tends to overcome the weaknesses in the other. At present, it is practicable to take into account only the economic forecasts, the relationship of telecommunications prices with movements of the retail price index (RPI), and the effects of the proposed tariff changes on the national forecasts. A *bottom-up* procedure on its own could not evaluate these and would therefore be misleading. On the other hand, a breakdown of national figures by analysis of past shares would not take into account changes in local characteristics. North Sea oil activity is an excellent example of this, and Scotland now requires a larger share of the national total than past statistics indicate.

There is no doubt that other sectors of the forecasting task would benefit from the discipline of *top-down, bottom-up* and it is intended to extend it to cover more fully stations, traffic and calls forecasting.

EXCHANGE-CONNEXION FORECASTING AT THE NATIONAL LEVEL

Forecasts of exchange connexions‡ are made at all levels in the Business, from the UK national forecast at one end of the scale to the forecasting of terminations on a primary connexion point (PCP) at the other.

In the UK, the forecasting of the future telephone connexion requirements is primarily a matter for the commercial side of the Business, and the forecasters employed at Telecommunications Headquarters (THQ), Regions and Areas are part of the marketing organization. Apart from the need to be in close touch with such things as market stimulation campaigns and tariff policy, it is an advantage to separate the forecasting function from the planning function; this counters any tendency for forecasts to be adjusted to suit the planners' convenience.

The problems of forecasting vary with the size of territory under examination, and the methods of tackling the job change somewhat at different levels. One factor is common, however, the business and residential sectors of the market are treated separately. Both in theory and in practice, demand patterns for business and residential connexions are different.

Residential growth is more price sensitive, less sensitive to variations in the economy, and is tied to household formation, not working population, size and composition; the residential growth rate is more than double that of business. Fig. 1 shows, on a moving-monthly basis, the annual growth rate in the residential market since 1955. Every downturn is associated with an increase in price, particularly the connexion charge or, as in 1966, with an increase in rental-in-advance. Over this period, whenever the trend has moved upwards

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* Editors Note: This article was first submitted in 1977 and had to be held over for publication because of limitation of *Journal* space (hence the emphasis on 1976/77).

‡ For brevity, connexion forecasts in this article are in terms of the potential size of system; that is, working connexions plus orders-in-hand. The difference from year to year of this series is numerically equal to annual figures of net demand less cessations

(generally, as measured in this way, 12 months after the price increase), only another price change has reversed it. Growth has averaged 7% per annum over the period 31 March 1955 to 31 March 1976.

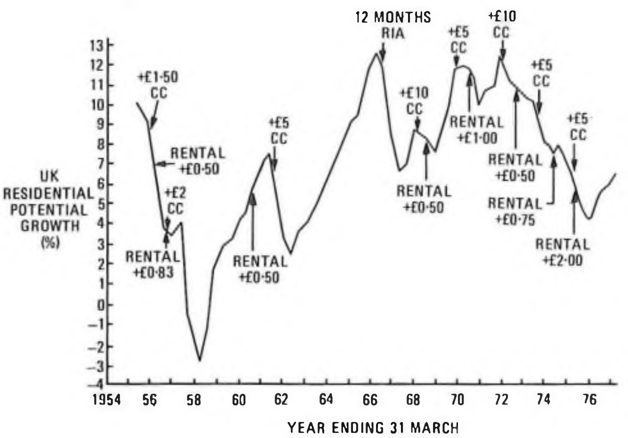
In contrast, Fig. 2 shows that the business market can turn down in the absence of a price change (see 1965 for one example), and can also grow despite price increases as illustrated by apparent absence of impact of the £10 increase in maximum connexion charge in May 1972. Growth over the period 31 March 1955 to 31 March 1976 averaged 2·6%.

Economic Factors

Figs. 1 and 2 illustrate that it is an important first step in producing the national forecast to make a prediction of the future course of the UK economy, with special emphasis on economic growth and inflation. Forecasts of total final expenditure (TFE), that is, gross domestic product plus imports, and the RPI are prepared by a small team of economists in the BPO Central Headquarters; after approval by the Post Office Board, these are used throughout the BPO for forecasting and planning purposes.

Fig. 3 shows the history of growth in TFE since 1955. It has been typical UK experience that, whenever the Government has attempted to accelerate growth in the economy, it has run into balance-of-payment difficulties, which have been solved by slowing down the rate of growth. This, together with the world trade cycle, has led to the familiar *stop-go* pattern of growth in the UK economy. The depression in world trade, starting with the interruption of oil supplies in late-1973, followed by the quadrupling of oil prices, exacerbated in the UK by the 3-day week brought on by the miners' strike of early 1974, the consequential boost in UK inflation and the slide of the pound, combined to make the depression of 1975/76 the worst in the last 20 years. TFE has started to improve in 1976/77, although it is still running behind the levels achieved in 1973. The forecast shown in the graph, while not the current official forecast, is typical of the pattern of growth expected over the next decade.

The acceleration in the rate of inflation has been halted and the RPI, which was growing at an annual rate of 26·9% in August 1975, was down to 17·1% in May 1977. The future course of inflation will have a major impact on BPO costs and, hence, prices. Fig. 4 shows how BPO prices have fared compared with the RPI since 1960/61. In determining future policy for BPO prices, calculations are made using an initial forecast that assumes that prices will be raised in line with



CC—Connexion charge
RIA—Rental in advance

FIG. 1—Annual growth rate of residential connexions

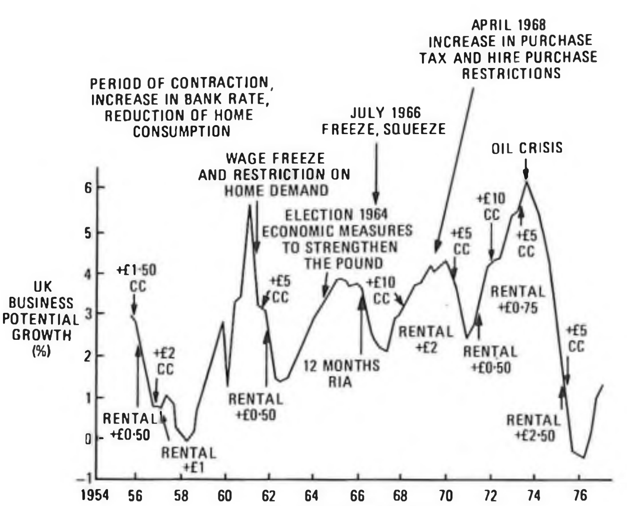


FIG. 2—Annual growth rate of business connexions

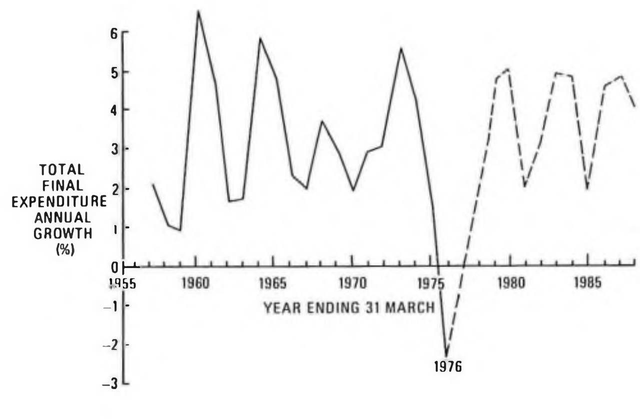


FIG. 3—Annual growth of total final expenditure

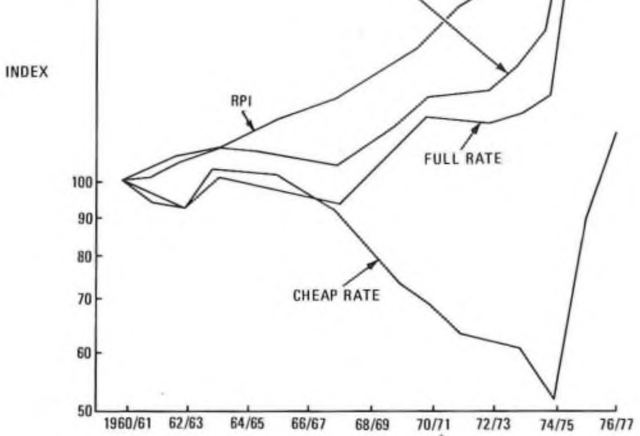


FIG. 4—Comparison of variation in BPO tariffs and RPI

the RPI. Forecasts are subsequently adjusted as necessary, in an iterative manner, in conjunction with the BPO Planning and Tariff Divisions, until a stable solution has been reached. BPO forecasts assume that Government policy to counter inflation will continue to be successful and that the UK will return to single-figure inflation in the next year or so.

Conversion of Economic Factors into Forecasts

The next stage in the forecasting process is to turn the economic growth and pricing assumptions into a forecast and, to do this, a number of equations have been developed that relate residential and business growth to the following factors.

(*a*) Residential growth is related to

(*i*) growth in personal disposable income at constant prices, and

(*ii*) BPO price increases—particularly the connexion charge or down-payment increases.

(*b*) Business growth† is related to

(*i*) investment at constant prices,

(*ii*) the financial position of the company sector, and

(*iii*) BPO price increases—particularly the connexion charge.

The equations developed do not explain growth exactly; that is, there is always a forecast error. They are, therefore, better described as statistical models. Their validity decreases with the timespan of the forecast and, in the longer term, it is necessary to consider models that have saturation parameters. The most common of these in use in the telecommunications field is the logistic curve, and a typical example is shown in Fig. 5. This is not the only saturating curve available for model building but, in many tests, it has outperformed its rivals. The equation of the curve is given by

$$Y_t = S + \frac{A}{1 + B\exp(-kt)^{e_t}},$$

where Y_t is penetration at time t,

S, A, B, and k are constants, and

e_t is error term at time t.

The curve has the following interesting properties:

(*a*) the minimum value of Y is S,

(*b*) the maximum value of Y is $S + A$,

(*c*) the point of maximum incremental growth occurs at a point halfway between the minimum and maximum values (T_i on Fig. 5), and

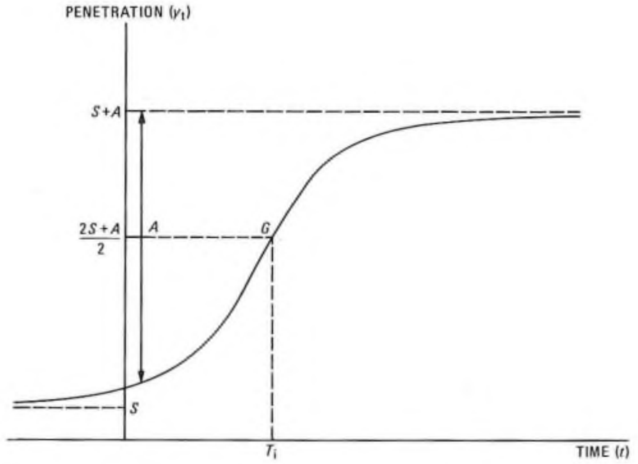
(*d*) provided S does not equal zero, percentage growth reaches a maximum point prior to the incremental growth maximum at a point shown below:

$$\text{maximum incremental growth} = \frac{1}{2k}\log\frac{S + A}{2B^2}.$$
$(T_p$ on Fig. 6)

These values are illustrated in Figs. 5 and 6.

One of the more interesting tests performed is to fit data from other countries to the curve. Fig. 7 shows that the logistic curve has managed to fit a variety of growth patterns which, when extended, produce plausible forecasts. A number of other tests, which truncate the data series and use the earlier years to produce forecasts of the later years, have shown the logistic curve to be a reasonable, but not infallible, tool. Any trend forecast implies that the experience underlying achievement to date will be reproduced in the projection period. As tariffs and income are the dominant long-term factors influencing residential growth, a straightforward acceptance of the trend forecast implies that income growth and BPO tariffs, compared with other prices, will be similar over the forecast period to the period when the trend was estimated. The current BPO forecasts are compatible with this requirement, but account must be taken of the very low achievement in the last 2 years. Current views are that a step change has been introduced into the trend and the forecast adopted at present is permanently about a year behind the logistic

† Bleaney, F. A further examination of the Demand for Business Telephone Connexions. BPO SBRD Report No. 65.



Note: Not to scale

Fig. 5—Shape of logistic curve

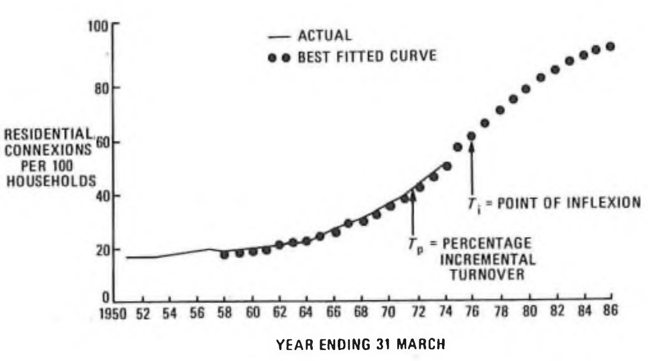


Fig. 6—Use of logistic curve to forecast UK household penetration

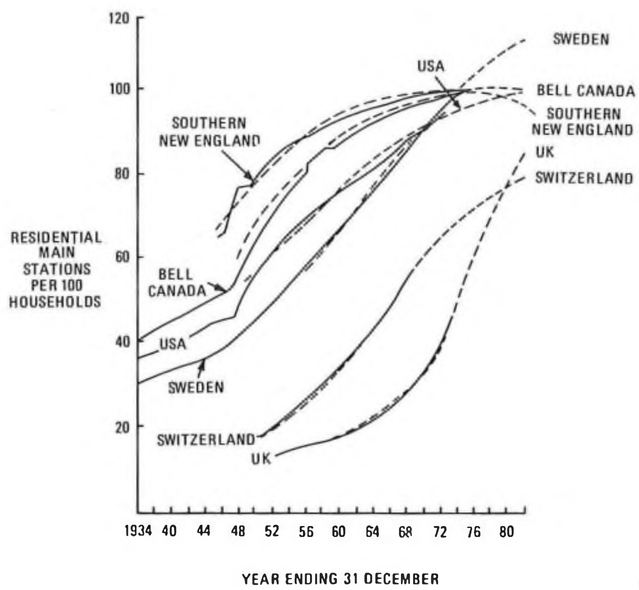


Fig. 7—Fit of logistic curve to household penetration in various countries

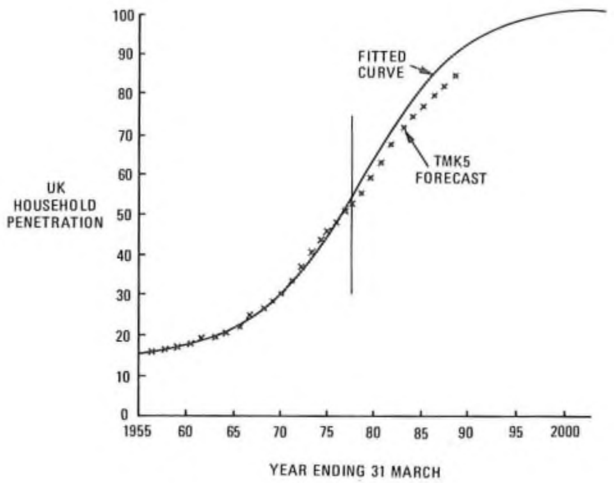


FIG. 8—Comparison of logistic curve and current BPO forecast of UK household penetration

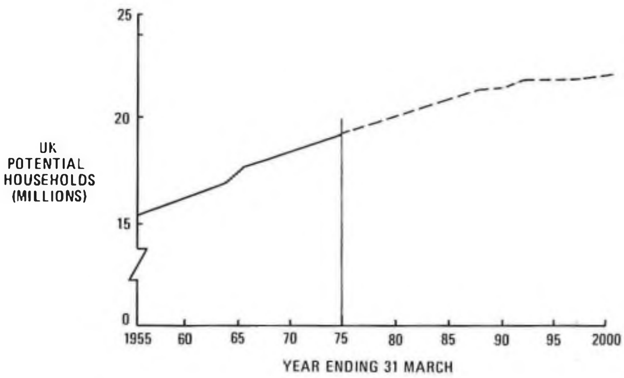


FIG. 9—Variation of UK households, historical and forecast

trend, as illustrated in Fig. 8 showing UK household penetrations.

There are various other projections made using logistic curves of

(*a*) individual Regional household penetration,
(*b*) individual Regional residential connexions per capita,
(*c*) UK residential connexions per capita, and
(*d*) individual productions of UK social class household penetration.

All give different answers and give the forecaster some idea of the range of variation likely about the chosen forecast, as shown in Table 1.

TABLE 1

Differences in Penetration Forecasts for UK

Type of Forecast	31 March 1981	31 March 1986
Summated Regional household penetration	14 940	18 467
Summated Regional exchange connexions per capita	14 962	18 389
UK household penetration	14 855	18 358
UK exchange connexions per capita	14 868	18 231
UK social class household penetration	15 068	18 771

So far, discussion has centred on penetration, but it is also necessary to have forecasts of households and population. Population forecasts are supplied to the BPO on an annual basis, for the UK and for BPO Regions, by the Office of Population Census and Statistics (OPCS). Forecasts of households are provided periodically by the Department of the Environment, based on OPCS forecasts broken down in government standard regions. The standard region figures are allocated to BPO Regions in Telecommunications Headquarters (THQ), using data on boundaries supplied by Areas and Regions. Both population and household data are subject to check at Regional level, and discrepancies are ironed out with THQ. The current forecast for UK households is compared with growth from 1955 in Fig. 9.

For business connexions, the idea of saturation is less obvious, but it is clear that, once every member of the working population has a telephone available for his exclusive use, growth prospects would be extremely low. Once exclusion of the bulk of certain occupations, such as transport drivers, refuse-disposal operatives and agricultural labourers, is made, it is evident that the ceiling will be below one telephone per worker. Unfortunately, the information on penetration by type of industry and type of worker, together with the historic trends of both penetration and changes in industrial mix, is not available for the UK. Studies have been undertaken in West Germany, which is similar in many respects to the UK, and a ceiling of 70 business stations per 100 workers is indicated. In Sweden, which is the most highly penetrated country in terms of business stations per 100 workers, a ceiling of around 70 was obtained by statistical means; thus, in the absence of anything better, 70 business stations per 100 workers has been chosen for the time being as the ceiling for UK forecasts. Fortunately, forecasts for the next 5 years are not very sensitive to the ceiling chosen as shown in Table 2.

TABLE 2

Sensitivity of Forecasts to Ceiling Chosen

Ceiling Chosen (stations per 100 workers)	Resulting Business Station Forecast (millions)	
	31 March 1981	31 March 1986
60	11·76	13·97
65	12·05	14·59
70	12·21	15·01

Although the forecast becomes more sensitive to the ceiling chosen by the end of the decade, this is not the only forecasting tool available; information supplied by Regions on the long-term business prospects, built up from local knowledge, supplements the meagre information available nationally and greatly assists in the selection of the appropriate ceiling. Fig. 10 shows the current UK penetration forecast based on a ceiling of 70 stations per 100 workers.

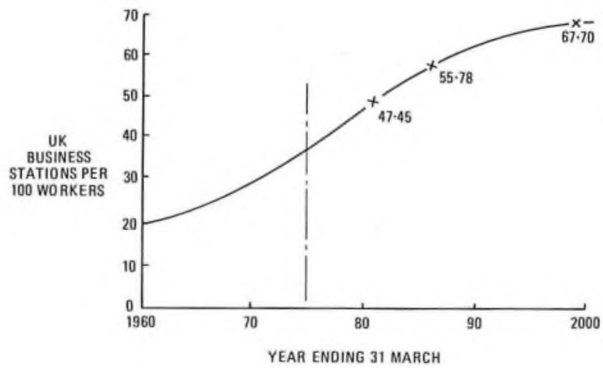


FIG. 10—Current forecast of UK business penetration

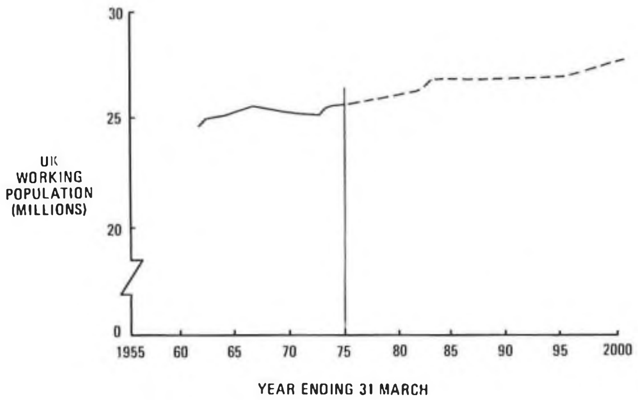


FIG. 11—Current forecast of UK working population

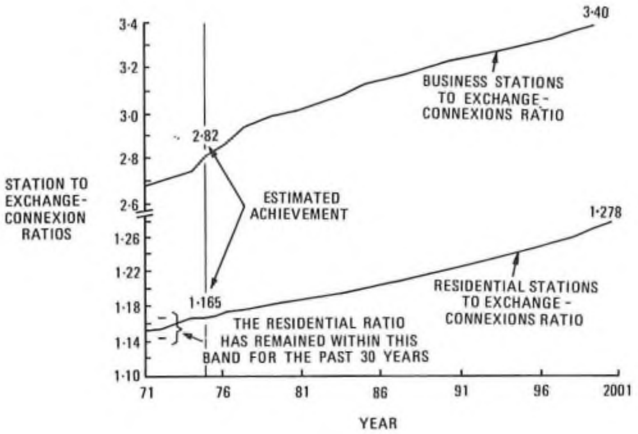


FIG. 12—Current forecasts of UK stations to exchange-connexion ratios

As with the residential forecasts, the forecast of business penetration must be used in conjunction with a forecast of working population. The same small group of economists, who produce the BPO economic forecasts, have also devised national forecasts of working population, which have recently been extended to most BPO Regions. Fig. 11 shows the current forecast of UK working population. Forecasts of future birth rates, which are the most unpredictable part of demographic projections, do not affect either the household or the working population forecast until at least 1993; that is, until children born in 1977 and beyond become available for work and household formation from age 16 onwards. In consequence, the base forecasts of households and working population are likely to be accurate to within 1–2%.

To convert business station forecasts to connexions, it is necessary to divide by the forecast ratio of stations per connexion. To assist in this forecast, the plans for future selling of PBXs, key and lamp units and other products are evaluated to determine whether the long-term upward movement in the ratio of stations per connexion is likely to continue. The result is shown in Fig. 12.

The forecast of business connexion growth, obtained from station considerations, is compared with forecasts from the econometric model and with separate extrapolation of connexion growth; any inconsistencies are investigated and eliminated.

CONNEXION FORECASTING AT REGIONAL AND AREA LEVEL

The UK forecast is divided up between Regions according to individual Regional logistic type trends and their historic shares in the UK system. Meanwhile, Regions will have produced their own predictions using similar methods to those used for the national forecast. Differences are debated in detail, with both parties constrained by forecast of key data: households, working population, economic growth and BPO tariffs. When agreement is reached, the Regional figures are aggregated and the final UK forecast is produced.

Regional forecasts are, in turn, divided into Area shares. The Area forecasting function is rather more complex. Total Area forecasts have to be produced that align, within certain percentages, to their share allocated by Region. These form the basis for the Areas' financial estimates, both capital and current account. The Area forecast has to be split amongst their exchanges, for equipment planning purposes and, finally, line-plant forecasts are produced down to PCP level.

Two methods are adopted by Areas on receipt of their share of the Regional forecast to

(*a*) produce an Area forecast and

(*b*) divide the allocation amongst exchanges.

Some prepare an Area forecast first, using general trends, such as population movement, economic changes, industrial and commercial developments, discuss with Region any differences between their prediction and the allocation and, when agreement has been reached, divide the forecast among their exchanges. This is the recommended method, but many Areas prefer first to prepare their exchange forecasts, then adjust and readjust until they arrive at a total that is reasonably close to the allocation. Only if they find it impossible to fit the total within the envelope do they open discussions with their Region. This is not the best forecasting practice—it is accepted that forecasting for the corporate whole is always more accurate than adding together forecasts of the parts.

Whichever of the 2 methods is adopted, Area forecasters have to break down their Area forecast into exchange forecasts. This is not too difficult a task because updating and monitoring of the growth of exchanges against their forecasts is a continuing exercise. All relevant information about such items as development, planning, housing, population trends, and industrial and commercial structure within an exchange boundary, is obtained from the local authority and other sources. It is sifted, assessed and recorded, so that reviews of forecasts can be made quite readily. The main review of all exchanges and alignment with the allocation from Region takes place annually; thereafter, 2 supplementary reviews are made at 4-monthly intervals. (A reduction to one supplementary review is being considered.) However, for these, no *top-down* figures are produced; Areas are allowed to amend their forecasts to within certain defined percentages of the agreed July figures.

When exchanges are nearing exhaustion and the planners start design work on the extension of equipment, a more detailed forecast is demanded, broken down into categories such as residential direct and shared service, business single lines, PBX, coinboxes and Datel. Trend forecasting is used for these categories, based on historical growth lines, together with local knowledge acquired by visiting, but the result must be contained within the envelope of the standing exchange forecasts as last reviewed.

Line-plant forecasts, based on PCPs, are prepared as and when required. Planners and forecasters between them decide on a yearly programme of revisions. Nowadays, no attempt is made to keep an up-dated standing forecast of line plant for the whole exchange. This philosophy was abandoned when it was found that standing forecasts soon became out of date and it was necessary to carry out fresh field revisions for practically every request for forecasts. Revisions are currently carried out for only those specific PCP areas affected by a scheme. This piecemeal approach immediately raises the question about how a check can be kept on the exchange total. In practice, no attempt is made to keep the sum of the PCP forecasts closely balanced with the standing exchange-equipment forecast, although Areas are advised that the figures should be within 15% of each other.

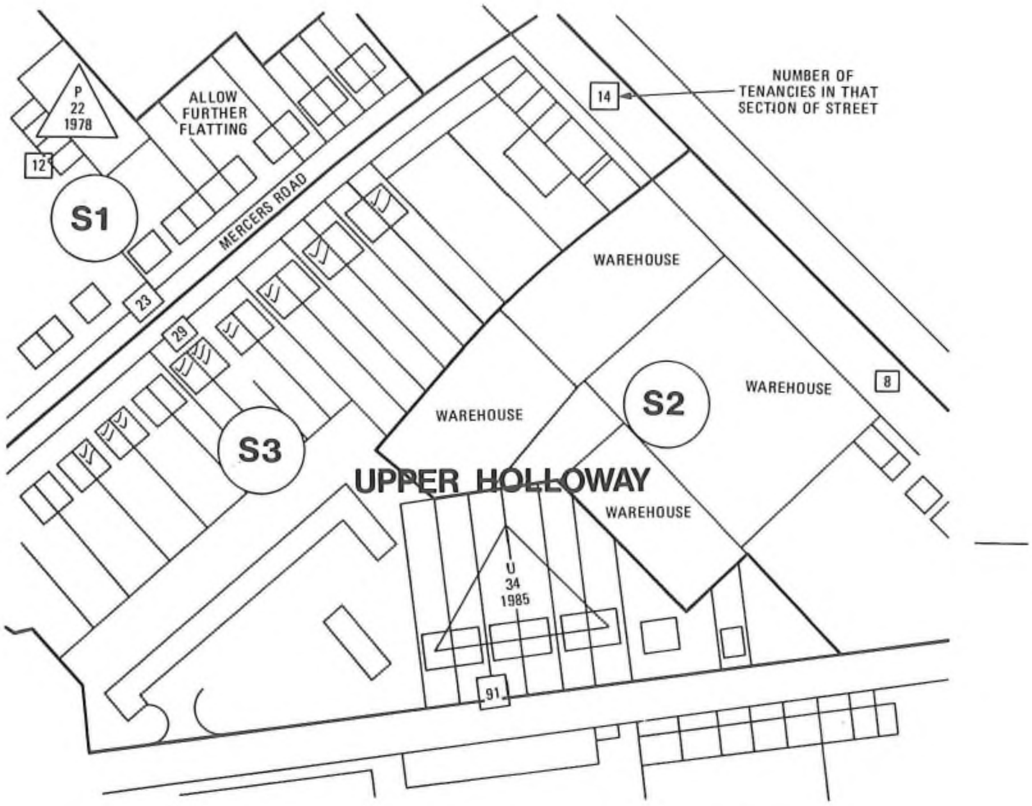


FIG. 13—Typical section of a line-plant map used for forecasting

On receipt of a request from the line-plant planners for a forecast, the first thing that is checked is the achievement, which is compared with achievement at the time of the last survey. If growth is proceeding in line with forecast, and there are no reports from the local authority or other sources of any changes or developments occurring, the previous forecast can be confirmed. If the forecast looks suspect or if, according to local authority information, the area is subject to change, a survey will be conducted.

A vital forecasting tool is the map; Fig. 13 shows a typical section of the line-plant map, showing the marks and symbols used by the forecaster. PCP areas are divided into *sections*, which are the lowest forecasting units. Those shown in Fig. 13 are numbered S1, S2 and S3. Sections will have been determined during earlier forecasting and remain static as far as possible. All dwellings within a section are considered to have uniform telephone potential and, consequently they can be forecast to have a uniform rate of telephone growth. Nevertheless, the forecaster touring the area shown in Fig. 13, which has large good-quality houses, would be able to foresee many changes; these won't necessarily change the telephone value of the dwellings, but will add considerably to their number. Several conversions to good-quality flats have happened already; the small ticks indicate when this has happened. If the conversion of a house has been well done and looks permanent, the forecaster will be happy that there will be no further change throughout the 20-year forecast period. If the house is badly converted, or flatted without proper conversion, or just generally rundown, some kind of change will be forecast, probably demolition and replacement. The triangles indicate these localities: the U means *unplanned;* P means *planned*, where planning consent has been applied for; the year indicates when it is estimated that a change will occur. It can be seen that in other streets, and for individual properties, the forecaster has speculated that further flatting will occur.

The figures of dwellings within a section are totalled, and the next task is to forecast the rate of telephone penetration. In this particular locality of good-class residential property, penetration is likely to be high—it is probably already over 80%. In such a locality, it would not be unreasonable to forecast that an ultimate saturation point is over one connexion per dwelling.

For business customers with 4 lines or more, direct forecasts are made by a study of past growth and, if necessary, a visit to the customer. Smaller businesses are lumped together and a joint forecast made within the section; for example, a line of shops would be assessed as having an ultimate penetration of one connexion per shop, with an extra allowance for the possible arrival of a travel agency, bookmaker or bank, requiring more than one line.

When all the field data has been gathered in, forecasts are prepared for the first 5 years, plus the 10, 15 and 20 year census dates. The section totals are added up into cabinet totals, and the completed job is presented to the line-plant planners, summarized on special forms, and accompanied by the maps.

STATIONS FORECASTING AT THE LOCAL LEVEL

There has, in recent years, been a greater emphasis on stations forecasting. Currently, the UK is going through a period of maximum growth of exchange connexions because of the high level of demand from the residential sector. However, by the mid-1980s, this source of new business will begin to fade because, by then, over three-quarters of households will have telephones, and selling to the hard core of the reluctant remainder will become increasingly difficult. To compensate for the slackening of supply work, and to avoid laying-off engineering staff, it will be necessary to stimulate the sales of extensions to both business and residential customers. Exchange connexions will gradually lose their claim to be the prime forecasting statistic.

Another important use of the station forecast is for long-term manpower predictions in the planning of operational buildings such as telephone engineering centres (TECs). Recently, it was discovered that, compared with other administrations, long-term station forecasting was over-optimistic and it looks as if some over-provision of TEC facilities has been made as a result. Until last year, the forecasting has been entirely on a *bottom-up* basis; this is an excellent example of how a compensating *top-down* exercise would have helped to control the situation.

Recently, another and no less important, item has been added to the uses to which stations forecasts are put: traffic forecasting. It has been found that nationally, there is a more reliable relationship between erlang calling rates and stations than there is with exchange connexions. THQ is already using stations to produce national traffic forecasts, and it is hoped that ways can be found to extend the method into Regions and Areas.

BUSY-HOUR ERLANGS: THE NATIONAL FORECAST

The state of the art is not as well developed for traffic as it is for connexions and stations. Until quite recently, THQ was unable to provide national forecasts of busy-hour erlangs, and much of the advice given to Regions and Areas had to be based on call information.

It has long been realized that the use of national call growth rates, broken down into Regional shares and further distributed to set parameters around Area traffic forecasts, is far from ideal. Steps were therefore, taken to collect busy-hour traffic information and, since 1970, Areas have been required to submit data from the exchange traffic records (the A854 records). After validating its accuracy, the data has been collated to form a data base from which to project erlang forecasts. As explained earlier, straightforward projection of historical data, carries with it the assumption that, whatever caused growth in the past, would continue to affect the future in the same way. An analysis of past connexion growth, compared with its forecast, shows that such an assumption would be misleading.

Considering the make-up of the size of system in terms of exchange connexions, it can be broadly divided into 2 categories: business (more accurately designated as non-residential) and residential. Residential customers have a much smaller and different calling pattern from business customers, and the mix of the two is a very important element in forecasting levels of calls and traffic. In the past 20 years, the residential component has grown approximately 2½ times as rapidly as the business section and, at present, there are about 3 times as many residential customers as there are business. Although future growth will continue to come mainly from the residential market and the business component will continue to become a smaller proportion, residential growth is forecast to be only 1½ times that of the business section in the next decade. Because even the trend in the change in mix is non-linear, it is essential to evaluate the usage characteristics of each class and apply them to their respective growth rates.

Unfortunately, class calling rates are not directly measured, so attempts were made to identify them using regression techniques to historical data. The attempt proved unsuccessful and class calling rate, expressed in terms of exchange connexions, proved to be highly unsatisfactory. As Table 3 highlights, it was recognized that the business calling-rate was itself an amalgam of contributions from single and multi-line businesses, the proportions of which were changing.

Since the calling characteristics of each of these individual categories is markedly different, any assumption that depends on a static business calling-rate will not succeed. Therefore, it became necessary to divide the business connexions down into smaller components, and that was achieved by using stations. Application of business and residential stations into the regression models proved highly successful (see Appendix 1), and station calling rates were thus identified.

TABLE 3

Average Quarterly Call Bill for March Quarter 1976 per Exchange Connexion

Type of Installation	Average Quarterly Bill (£)
Single line business	42·36
2–10 lines business	123·68
11 or more lines business	236·00
Average business	63·45
Average residential	10·91

Source MRIS

By applying the station calling rates to the forecast stations, traffic levels compatible with the size of system were obtained.

There are other factors, besides the make-up and increase in the size of system, that affect traffic and call growth rates; among these factors, the principal ones are economic growth rates and call tariffs. The effect of these factors is reflected in the traffic forecasts at national levels by relating the traffic growth rates with the econometrically produced call forecasts. Thus, the national traffic forecasts reflect the changing pattern of the economy as well as the size of system growth.

As far as Regions and Areas are concerned, procedures for producing traffic forecasts, which can be compared with the national figures, are still at an early stage. This is being rapidly changed, because there are considerable variations between Regions and Areas and the general use of national figures, without tailoring to meet the local picture, is misleading.

To ensure that realistic forecasts are established, it is essential to have a full *top-down*, *bottom-up* procedure, in which Areas submit growth rates to Regions and Regions to THQ. It is only in this way that Regions and Areas can have a say in the production of national figures and policy and, in turn, THQ can be sure that the effects of economic growth and tariffs, which can be clearly seen in the national figures, are reflected in local forecasts. Ideally, such exchanges of information and the ensuing dialogue should take place before forecasts are finalized and passed to the Planning Department for their use.

BUSY-HOUR ERLANGS: FORECASTS AT THE LOCAL LEVEL

Recently, attention has been focused on the methods that Area design teams currently use for producing forecasts from historical data. Past techniques have depended upon trend extrapolation of the past data which, in some circumstances, can be misleading. Apart from missing records, the historical data may be distorted by the opening of exchange extensions, which permit the clearance of large waiting lists; these would give large increases in the size of system, thereby introducing jumps into the historic series. In addition, variations with the season of the year and unusual peaks and depressions, brought about by tariff and economic activity, have caused large deviations from trend lines. Unless these are taken into account, straightforward extrapolation, including computer curve-fitting techniques, could give seriously-distorted forecasts.

Recognizing these weaknesses, a new technique has been developed, which will identify and make allowances for unusual variations including those due to season. Fig. 14 shows how marked the difference can be between trend lines obtained from least-squares regressions of unmodified exponential curves (straight lines on log-linear graph paper) and curves modified for seasonal variations and jumps.

Trials of the procedure, using the new methods on past data, have been made; the forecasts have been compared with

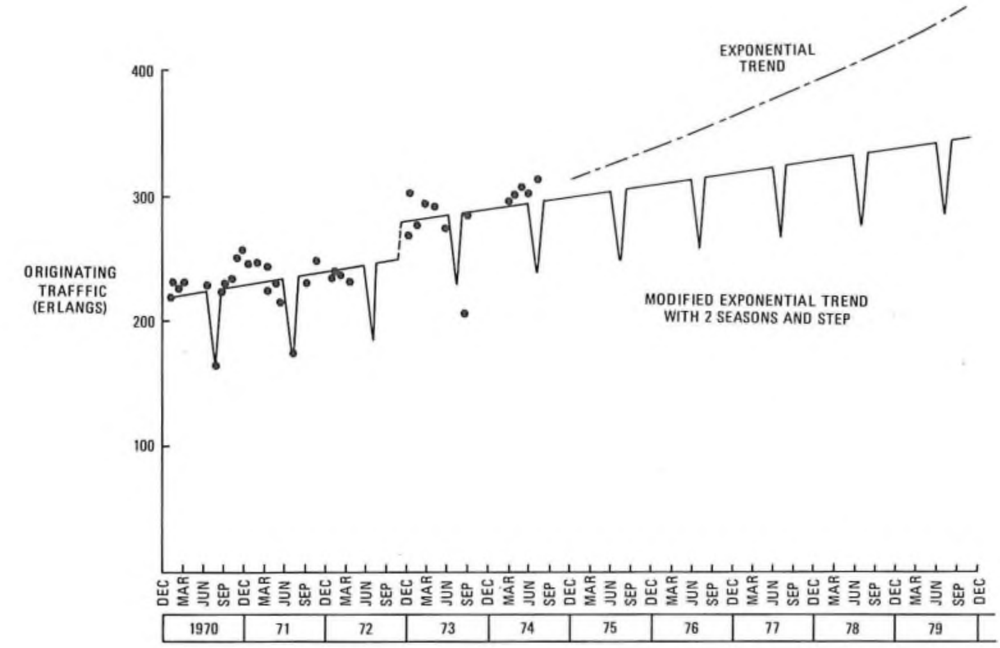


FIG. 14—Forecasts of originating traffic using exponential trend, unmodified and modified for seasonal variations and jumps

achieved traffic and the results have been highly satisfactory. The system, which has been designated *calling rate and traffic extrapolation routine* (*CRATER*), is now being prepared for national implementation, and arrangements are in hand to train Area staff in its use.

COMPATABILITY

It is fundamental that forecasts of connexions, stations, calls, or traffic, are fully compatible with each other and, equally, that Area, Regional and national forecasts are congruent. The whole must form a balanced picture. This article has shown that BPO procedures largely achieve this aim and, where deficiencies occur, these are being rapidly rectified.

APPENDIX 1

Derivation of Station Calling Rates

Because of the unsatisfactory results obtained using connexions growth to explain originating time-consistent busy-hour erlang growth, a model of the following form was tried:

$$T_t = Ax_t + By_t + E_t,$$

where T_t = morning busy-hour originating traffic in year t,

A = non-residential (business + service lines + coin boxes) erlang calling rate per station,

B = residential erlang calling rate per station,

x_t = number of non-residential stations in year t,

y_t = number of residential stations in year t, and

E_t = error in year t.

The result was

$$T_t = 0{\cdot}0309x_t + 0{\cdot}0131y_t,$$
$$[29{\cdot}7] \quad [14{\cdot}2],$$

Durbin-Watson statistic = 2·66,

$R^2 = 0{\cdot}99$,

degrees of freedom = 3.

The figures in brackets are t statistics.

Although there were a very small number of degrees of freedom, the coefficients were highly significant and the pattern of errors showed no trend. This latter point is important because the model assumes that station calling rates are constant and this would be untenable if errors from the model showed a trend. To test further what appears to be a plausible, but unsubstantiated, hypothesis (that is, station calling rates are constant), the ratio of business morning busy-hour erlangs per connexion to residential morning busy-hour erlangs per connexion was calculated using the constant station calling rates. For 1974, the ratio was 5·7:1 and, for 1956, 4·5:1. This information tallied with the few direct measurements made in recent years of class calling rates and with pre-STD information.

Thus, the hypothesis, although not proved, fits in with the sparse knowledge available.

The Eighth International Symposium on Human Factors in Telecommunication, Cambridge, 1977

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UDC 658.3.05:061.3

This article gives a brief review of the Eighth International Symposium on Human Factors and its activities.

The Eighth International Symposium on Human Factors in Telecommunication was held at Cambridge during September 1977 under the sponsorship of the International Telephone and Telegraph Corporation. Ninety delegates from 10 countries met to discuss a wide range of human factors issues which telecommunications administrations are currently investigating. Coincidentally, Cambridge was the venue for the first Symposium, which was held in 1961. The event has grown since those early days both in the number of delegates that attend and in the scope of the topics covered.

Forty-four papers, 11 of which had been written by members of the British Post Office (BPO), were presented in 15 sessions. Each session was chaired by one of the senior delegates. The authors summarized their papers and described any additional work that may have been carried out; the Chairman then reviewed the content of the papers and compared and contrasted them. This brief presentation was followed by the main business of the Symposium, a discussion of the questions stimulated by the contributions. A great variety of subjects was considered, reflecting the expanding role of human factors as new technology is applied in telecommunications systems, and as new customer services and equipment are developed.

Until recently, workers in the human factors field of telecommunications have concentrated mainly on the problems encountered by customers when using the telephone service. However, it is becoming increasingly recognized that the skills and methods that have proved useful for optimizing the interface between the customer and the telecommunications system can also make a valuable contribution to the solution of man-machine problems within the organization itself. Eleven of the papers presented at the Symposium dealt with projects which concerned employees. The effects were considered of changes in the working environment brought about by reorganization, new methods of payment and the introduction of modern telephone exchanges on such variables as working methods, attitudes and skill requirements. The development of the human aspects of an automated telephone-repair office was described. The need for appropriate documentation for training, installation and maintenance was discussed; in particular, the use of procedural maintenance aids in place of the traditional equipment-oriented textual format. Finally, a method of describing the operation of telephone systems from the users' viewpoint by means of symbols was presented. This method was said to be useful to development, planning and maintenance engineers.

The majority of papers dealt with issues which principally affect the customers who use telecommunications services. Advances in technology are leading to a situation where the capabilities and limitations of the user, rather than cost or technical constraints, determine what can be achieved. The human implications of new systems, such as teleconferencing, electronic mail and videophone were explored, and the need was stressed for the component parts of such systems to be designed with the user in mind. Thus, the design of symbols and recorded announcements, and the use of light-emitting diodes and flashing-light codes were discussed.

Investigations into the effect of delays between dialling (or keying) a telephone number and receipt of a tone (for example, ringing tone or busy tone) were reported in several papers. The distribution of these delays is likely to change as new switching techniques are adopted, and telephone administrations are concerned with the impact that this may have on their customers.

Another area of interest to human factors researchers is the interface between employees and customers. An example which was discussed at the Symposium is the directory-enquiry function. The expansion of telephone systems has put considerable strain on the directory-enquiry service, and several administrations have considered alternatives to the use of traditional paper directories. Papers describing both microfilm and computerized systems were presented.

Delegates were given an opportunity to visit Standard Telecommunications Laboratories Limited at Harlow, the Applied Psychology Unit of the Medical Research Council at Cambridge or the BPO Research Centre at Martlesham Heath. All the visits were judged to be of great interest. About 45 delegates visited the BPO Research Centre, where they saw exhibits and demonstrations of current work. Examples of projects in the fields of postal mechanization, visual telecommunications, telephony transmission performance and electro-acoustics were on display. Demonstrations of the Viewdata system and the new acoustic test and measurement facility were given. The Research Centre's human factors section presented an exhibition of a wide range of projects, including telephone aids for the handicapped, design of symbols and the choice of acoustic feedback to improve performance with no-travel push-buttons. One item which provoked a good deal of interest was the computer-based method for selecting participants for human factors experiments from the panel of about 1600 volunteers that has been established at Ipswich.

Human factors is still a relatively new discipline, and there is still much to be learnt about the best way of practising it within a telecommunications organization. One paper dealt solely with this topic and several others touched upon it. Ideas of appropriate working methods and organization were freely exchanged, both within the sessions and in the informal discussions that continued throughout the Symposium. It is a credit to the atmosphere of mutual trust prevalent at the Symposium that delegates were prepared to discuss how best to carry out and apply human factors work as well as reporting their own achievements.

Copies of the proceedings of the Eighth Symposium are lodged in some technical libraries including the BPO Research Department Library at Martlesham Heath.

† Research Department, Telecommunications Headquarters

VIEWDATA: An Interactive Information Medium for the General Public

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UDC 681.321: 681.3.05: 621.397

Viewdata is the most recent development in the art and technology of electronic communication by means of the written word, intended for members of the general public. This article first appeared in Electronics and Power (June 1977) and is reproduced by kind permission of the Institution of Electrical Engineers.

INTRODUCTION

It was well over 200 years after Caxton that the germ of the idea for communicating at a distance, which did not involve the physical transportation of written material, was proposed by Robert Hooke in an address to the Royal Society in 1684. But it was over 100 years after that that the first realization of a practical visual semaphore was engineered by Claude Chappe in France in 1790. A further 50 years were to elapse before the first commercial electric telegraph was installed by Cooke and Wheatstone for the Great Western Railway in 1839.

In the pre-electronic age, the means of communicating at a distance to and by the mass of the population developed from voice (the wandering minstrels) to the pictorial (the mystery plays) and thence to the written word, the latter when printing was invented. Electronic communication at a distance followed a roughly similar pattern several hundred years later, starting with the telephone and progressing through radio broadcasting, television and now culminating with the electronic written word in teletext* and Viewdata. The telegraph, which was first introduced in 1839, well before the telephone, remained a tool for the professional and the business man.

TELETEXT AND VIEWDATA SERVICES

Both teletext (Ceefax and Oracle systems) and Viewdata are electronic information services intended for the general public, and both make use of developments in digital television and display technology. In these respects, they are similar to each other and, although apparently competitive over a narrow range of information services, it will be shown that they are broadly complementary, each meeting essentially different requirements. The apparent similarity of these 2 media is indeed only superficial. By exploiting advances in computer technology and the technology of data transmission over the telephone network, Viewdata gains immeasurably in acquiring a scope extending far beyond that of a simple information service, as will become clear later in this article.

Viewdata was developed at the British Post Office (BPO) Research Centre, when the latter was located at Dollis Hill, and development is now continuing at Martlesham Heath. From its earliest days, Viewdata was conceived not only as a visual information service, with an encyclopaedic range of data and information, and indeed literary matter if required, but also as a very powerful communicating system for conveying primarily the written word and some graphics, with interactive capabilities. The Viewdata system will, in due course, bring to the general public a broad range of information service facilities, which the modern computer, if properly harnessed to the aids of society, can provide simply and economically.

† Research Department, Telecommunications Headquarters
* Teletext information services are broadcast by the Independent Broadcasting Authority, and the British Broadcasting Corporation

VIEWDATA SYSTEM TRIAL

At present, the Viewdata system is undergoing pilot trials, the purpose of which is to enable the BPO and industry to develop the system and study the ways it can fulfil the objectives set for it. On the BPO side, it entails amongst other activities the provision of an experimental service, which may be accessed by industry and other users, mainly professional at this stage, but including some lay groups, so that they may, after adequate exposure to a working system, feed back comments and suggestions. This subjective assessment by users will be of great assistance in the definition of the specifications of a follow-up system that may be offered for market trials.

PARTNERSHIP WITH INDUSTRY

The experimental system was inaugurated in September 1975. It is based on a small computer centre, installed at the BPO Research Centre, Martlesham, which is accessible through the public switched telephone network in the UK and in Europe to a host of interested parties.

In the development of the Viewdata service and of the system required to support it, the BPO is working in close partnership with industry, which, in this context, involves 2 major groupings:

(*a*) On the one hand, there are the manufacturers of television receiving equipment who will wish to develop equipment to adapt the domestic television set for the reception of Viewdata and teletext. They in their turn are supported by the electronic components industry; in particular, the designers and manufacturers of large-scale integrated circuits. It is these large-scale integrated circuits which, when developed for teletext and Viewdata, will enable the television receiver industry to transform the domestic television receiver into a pleasing and attractively-priced Viewdata receiver, capable of displaying the written word and of being used to send and receive written messages across the telephone network.

(*b*) The other major grouping in industry is the 'information providers', whose business it is to collect, collate, edit and prepare information to be offered to the public, using existing media. To them, Viewdata is a potential new medium with national and international coverage, through which they can offer their products to a considerable public, at low cost and at high speed.

Some information providers may wish all Viewdata subscribers to have access to the information they provide. Others,

FIG. 1—Viewdata receiver in a domestic setting

catering for specialized markets in business or the professions, will be interested in 'closed user groups'. They too could take advantage of the availability of Viewdata.

Finally, Viewdata may be of interest to another category of information providers who, although not set up specifically for the purpose of information dissemination, nevertheless need to communicate with large groups of people, for the purpose of imparting information of interest to their public about their own activities. They might include local authorities, Government departments, educational bodies etc. They too could find in Viewdata a versatile, flexible, efficient and low-cost medium capable of meeting their needs.

DESIGN OBJECTIVES

In the development of Viewdata, the first objective was to create a terminal capable of accepting computerized information and of imparting it easily and effectively to the user. It also had to be suitable for use in the home or in the office. Clearly, the many types of computer terminals used by professionals are inadequate in many respects. They are costly, rather awe inspiring to the lay person, and unnecessarily complex for this application. Their appearance and size are functional rather than aesthetic, and many of them are very noisy; thus, they are not likely to be acceptable as a piece of home furniture, or for that matter office furniture for the executive.

Although a great deal could be done to adapt existing computer terminals for home use, there remains the all-important question of cost, which for the majority of the public is far too high.

Several attempts have been made recently to interest the public in information systems based on voice response, which in their basic form do not need more equipment in the home than the telephone receiver. Unfortunately, voice-response systems have, at present, very limited communication capabilities, more so from the user to the computer than in the reverse direction, although even in the latter case vocabularies, syntax and style are still rather limited. Voice-response systems may well remain confined to the domain of science fiction for quite a few years yet, except for some very simple systems of limited applications.

Quite apart from the formidable technological problem of engineering adequate voice-response systems, for all but the simplest dialogues, there remains the problem that voice-response information is fleeting and thus needs to be repeated, possibly several times, to ensure adequate comprehension. This factor is likely to impose severe limitations on these systems for some considerable time, unless they are supplemented with the written word.

The one device that could, with a modest amount of development effort, be adapted to the needs of Viewdata, and meet the majority of the requirements, in particular the low-cost objective, is the domestic television receiver. With suitable additions, for example, small hand-held keypads, circuits to adapt to commercial audio-cassette recorders, and low-cost matrix printers (now beginning to become readily available), the domestic television receiver is almost the ideal home terminal for the wide range of facilities offered by Viewdata.

Fig. 1 shows a Viewdata receiver for use in the home. This has an integral adaptor, which accepts information from the computer through the telephone line and an associated modem.

Figs. 2 and 3 show two different models of the keypads. The basic keypad (Fig. 2) is normally adequate for the majority of applications; a more versatile keypad (shown in Fig. 3) enables the user to compose messages on the screen for transmission by the computer to other subscribers. Fig. 4 shows a type of low-cost matrix printer that can be adapted to the format requirements of Viewdata. For office use, a Viewdataphone is proposed (Fig. 5). This is a combined instrument that can incorporate a telephone receiver and a Viewdata terminal in a single package. It may

FIG. 2—Basic keypad

FIG. 3—Keypad having facility for message transmission

perhaps also be the forerunner of a new generation of telephone instruments.

The second objective in the development of Viewdata was to design a computer system and its software that would be capable of being interrogated by, and of supplying information to, the lay person, without the latter having to master the skills of the professional computer programmer. In addition to this requirement, if Viewdata is to make any impact at all on the general public, the cost of gaining access to the computer must be substantially below current costs of, for example, that of time-sharing computer machines.

It is in these 2 areas that radical developments had to be made to current computer technology to attain these 2 objectives, without which it was considered that Viewdata would not become viable.

The computer system envisaged for the support of a Viewdata service consists of a network of computer stations strategically located at or near centres of population, and so distributed that, in the majority of cases, users can obtain the information they need from the local computer, thus minimizing telephone connexion charges. Information not in the local computer data banks would be obtained automatically for the user, by his local computer, through a hierarchy of computers. Similarly, for message transmission, the local computer would accept the message and thereafter arrange its transmission automatically without further interaction by the sending subscriber. A typical network of computers is shown in Fig. 6.

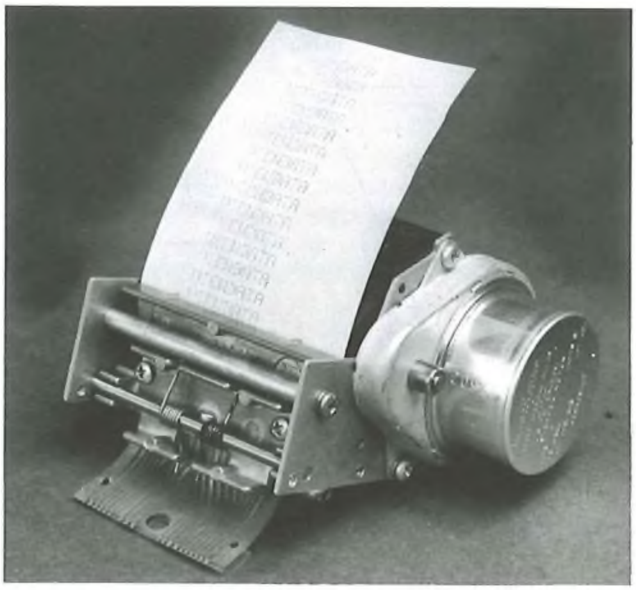


FIG. 4—Low-cost matrix printer

FIG. 5—Viewdataphone

To establish a connexion to the Viewdata computer, a user will dial the telephone number of the computer, as for a normal telephone call. When the connexion is established, the computer will generate a high-pitched tone (a frequency of 1300 Hz), which is heard in the telephone receiver. The user presses a button marked DATA on the telephone set, which switches the telephone line from the telephone set to the Viewdata receiver. The telephone receiver is then set by

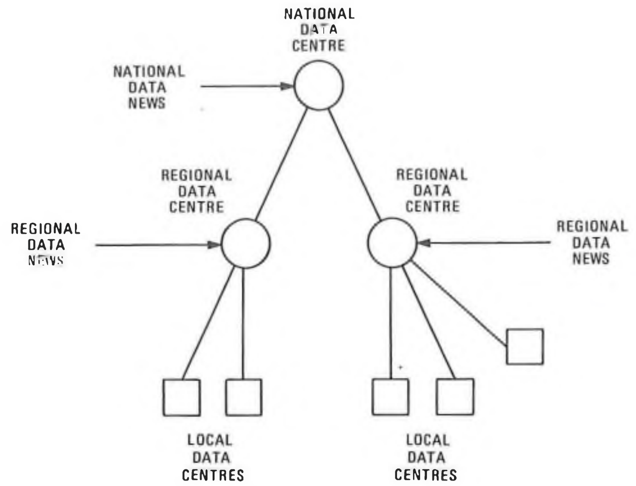


FIG. 6—Typical computer network for the support of a Viewdata service

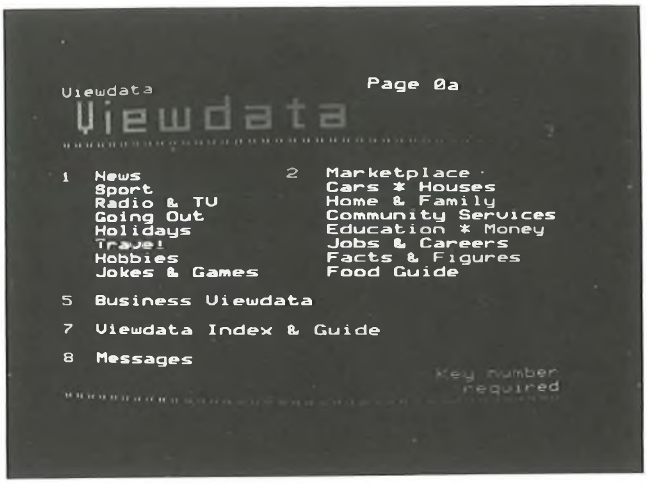


FIG. 8—User index

FIG. 7—First frame transmitted by a computer once a user has established contact with the Viewdata system

the side of the cradle. Once contact is established the computer transmits a first frame, which requests the user to identify himself by entering his user number (Fig. 7). In later models of Viewdata, the connexions to the Viewdata computer and the user identification may be done automatically by the push of a button on the keypad.

MAN-MACHINE INTERFACE

Computer Relationship

In Viewdata, as in a number of similar systems which have been experimented with in the past decade, the problem of how to enable users with no special computer training to gain access to and instruct a computer loomed large, mainly because computer programming has developed from the very beginning, and with very few exceptions, into an increasingly complex set of routines. These demand a great deal of concentration, attention to detail, and constant and continuous practice to be mastered effectively.

The situation is somewhat similar to that prevailing at the turn of the century when driving a car required a great deal of knowledge and expertise about engines. Today, the operation of a car has been so simplified that almost anybody can drive one, with very little instruction.

To quote from the originators of an earlier system[1], "There is the problem of how to communicate with someone who had only a high-school education or less". "How do you get them to operate a computer error free?". "Having done that, you must program the computer to respond satisfactorily to the communication by that customer. You also have to configure the hardware (and the software) consistent with customers who do not expect anything to break".

In Viewdata, the designers of the system have taken a substantially more enlightened view. They do not look down on the user as being 'naive', 'unsophisticated' or slightly below par as regards educational standards. Indeed, this is not the situation. It is rather a question of specialized training, which few people outside the ranks of those who do computer programming as a full-time occupation have the opportunity or even the willingness to acquire and maintain adequate fluency in at all times.

As in the case of the car, the first objective is to simplify the machine and its controls so that anyone with very little training can use it. The problem is not easy to solve because, unlike the motor car, Viewdata enables the user to do an immense variety of different jobs.

Computer Dialogue

The key to ensuring adequate communication between user and computer is the dialogue. The computer must first of all understand what the user wants. Although it is possible to design computers capable of understanding natural (human) languages, to a limited extent, a considerable amount of work needs to be done before they can engage in a free dialogue.

The usual and present approach to communicate with computers is to design a special programming language that the user has to learn and which the computer is programmed to understand. This approach works adequately in the conventional computer-programming field, but is clearly far too complicated in this application. Another approach is to use a prompting system wherein the computer offers a number of choices from which the user selects the one most appropriate to his requirements. This clearly limits the user's freedom somewhat as compared with the almost infinite capability of a natural language (for example, English) but nevertheless avoids many of the problems connected with formal computer languages.

The simplest of these dialogues is an index, from which the user selects the topic he requires (Fig. 8). The information available is classified in the form of a tree. The top of the tree is a list of main topics, each of which is subdivided to the piece of information required. Some of the branches in Viewdata may extend down to 8–10 levels, thus implying a potential choice from several million pages.

USER INSTRUCTIONS

The reason for the subdivision of topics is that, in the proposed Viewdata system, a small local computer centre may contain as many as 50 000 to 100 000 pages of information, and a progressive index provides the simplest and quickest means of finding the information required.

Other selection or retrieval systems are, of course, possible, but they are for the most part complicated and expensive to implement. They require the use of a much more complex keyboard than the basic keyboard normally provided (Fig. 2). This, incidentally, provides only 12 keys, which include the 10 numerals 0–9 and the 2 internationally-agreed symbols for pushbutton telephones * and #. Three additional keys may also be provided for the purpose of calling automatically the Viewdata computer.

In Viewdata, the user is given a simple set of instructions, which are engraved on the keypad, and thus always available. The instructions and keying operations are given below.

(*a*) *To return to the top of the selection tree:* *0#

This instruction is mainly used at the completion of one inquiry, when it is desired to start a new one. Alternatively, if the user finds himself perhaps on the wrong track, or cannot interpret the dialogue, he uses this to make a fresh start. Thus, it provides a fall-back option for unexpected situations.

(*b*) *To recall the previous page:* *#

The purpose of this instruction is to enable the user to check the contents of the previous page.

(*c*) *To recall the current page:* *00

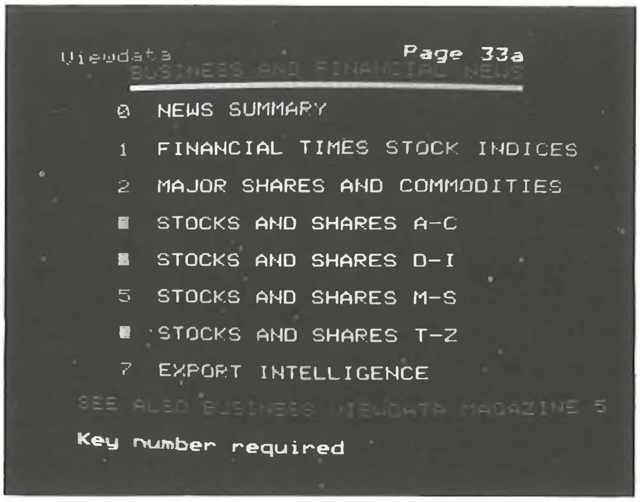
The purpose of this instruction is to cause the computer to retransmit the current page, in case some of the information has been corrupted. Interestingly enough, little evidence has been seen so far of serious data corruption during transmission.

(*d*) *To jump to a known page (number N):* *N#

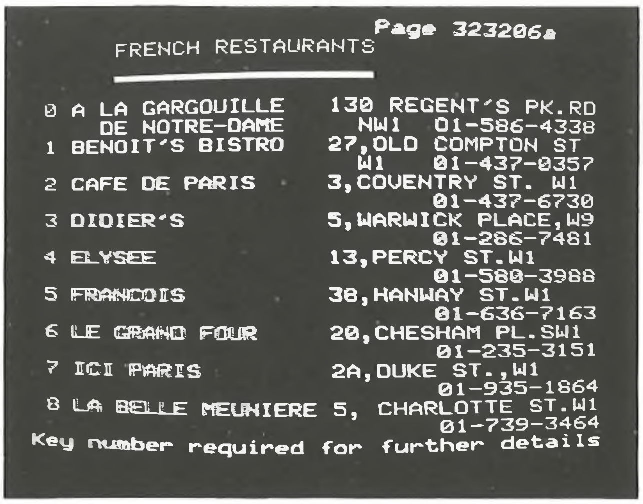
The purpose of this instruction is to enable the user to jump straight to a required page, thus bypassing the step-by-step approach.

(*e*) *To correct a miskeying error:* **

If an entry is in error, it can be erased by keying ** and a fresh start made.



(*a*) Financial news



(*b*) French restaurants

FIG. 9—Examples of topical information frames

APPLICATIONS OF VIEWDATA

The range of applications of Viewdata is theoretically unlimited. In practice, it will be determined primarily by the market; that is, what users want to have and what they are prepared to pay for.

There are 5 distinct service areas, each with their own specific requirements and each using the interactive capability of the system, that is, the ability of the user to respond to the computer to some degree.

Information Services

The largest area capable of immediate development is the information service. It has a number of subdivisions, with differing characteristics and treatments; for example, topical information, reference information (including general and professional), and classified advertisements and shopping aids.

The range of topical information covers a number of different items such as news, sports results, weather information etc. Each item may comprise a very wide spectrum; for example, news items can include local news, national and international events, business news, and items of interest to the domestic viewer or the business viewer. This section of the information data base is the one most closely related to that of teletext. The major difference being that, in teletext, the information is more likely to be in abbreviated or headline form because of the obvious limitation of the restricted total amount of information available. In Viewdata on the other hand, the information is in much more detailed form and covers a considerably greater scope and variety. It is intended to cover not only hard news as such, but possibly background details, comments etc. In the case of financial information, an immense amount of detail is possible if required by the user. Examples of topical information frames are shown in Figs. 9(*a*) and 9(*b*).

Reference information is also a very large field, which could cover items such as train and bus timetables, and perhaps air timetables, telephone directories, and 'Yellow Pages' of local and national interest (Fig. 10). It could also cover information on leisure activities such as games, hobbies and sports, do-it-yourself and gardening information, recipes, holiday and tourist information. Other topics of interest could be money matters and savings, tax information, jobs and careers information, and a wealth of specialist reference information for the businessman and professional user.

Classified advertisements are potentially a very important sector of the information spectrum, since, given adequate coverage, classified advertisements can be available in every-

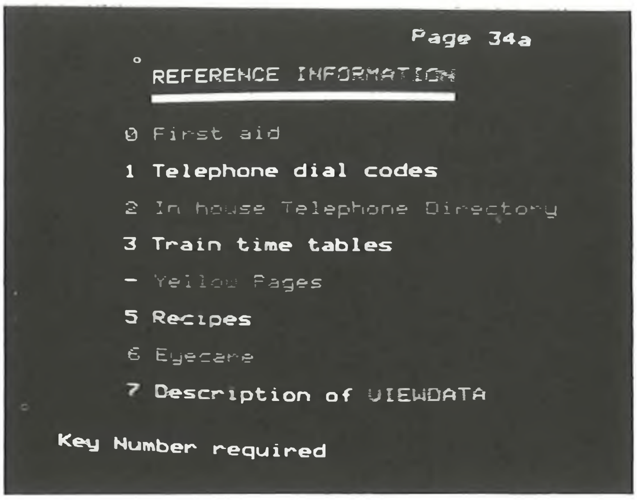


FIG. 10—Reference information

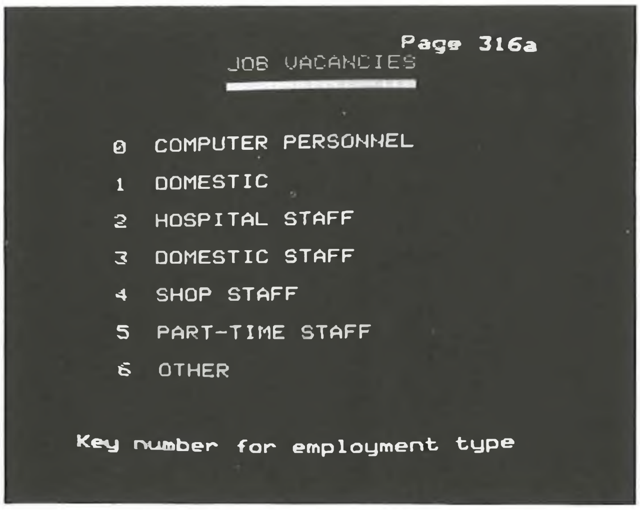


FIG. 11—Classified advertisements

body's home at the touch of a button when required, with an immediacy unrivalled by any other medium. By the same token, items no longer available for sale may be removed instantly from the data base, thus avoiding unnecessary inquiries and potential frustration (Fig. 11). A major benefit of the classified advertisement is that it could provide a useful revenue which, as is the case with newspapers, could be used to counterbalance a proportion of the expenses of running the service.

Shopping aids are, in some respects, a category of classified advertisements in that they may be used as an advertising medium for the trade, local or national. At the same time, the classification could encompass the great wealth of information from such areas as consumer associations, government departments etc. regarding quality, value for money, advice on getting the best out of certain articles and also precautions to take in certain circumstances.

The interactive capability of Viewdata adds an important dimension to the scope of the information services. It could be used, for example, to request further details about a product advertised or discussed and, in certain cases, to place a purchase order. Potentially, it is possible to do this without the need to make an additional telephone call.

Message Communication Service

Viewdata is clearly not only an information medium, but is also a message communication medium which has a store-and-forward facility; that is, the message entered in the computer can be transmitted as soon as communication with the intended recipient is established.

The simple message facility so far experimented with provides a number of options. In the simplest option, the user can select one or more out of a number of standard messages, mainly greeting messages (Fig. 12), but clearly many others are possible. After message selection, the user needs to supply the Viewdata number of the intended addressee. Thereafter, the action of the system is entirely automatic.

The message is sent to the local Viewdata computer, which places a telephone call to the addressee. If the telephone number is engaged the computer tries again; the number of tries can be specified by the sender. If the number is not engaged, but no reply is obtained to the call after a short ringing interval, a red light fitted to the Viewdata receiver is switched on to indicate that SOMEBODY HAS CALLED. Arrangements can be made for the local computer to attempt a call several times, and for the visual indicator on the Viewdata set to give a count of the unanswered calls.

When the call is answered, the computer causes a 1300 Hz tone to be connected to the line; this indicates to the user that the Viewdata computer is calling. Pushing the DATA button on the telephone set (assuming the Viewdata set has been switched on) causes the computer to send the message frame preceded by introductory frames to ascertain the user number.

A similar procedure applies when the addressee, on returning to his Viewdata set, finds the SOMEBODY-HAS-CALLED light on. On dialling Viewdata and after entering his user number, the message is delivered.

Another message option provides the user with the facility of inserting in the standard text one or more words, numeric or alphanumeric; for example, times of arrival in a "I shall be arriving on the *xxxx* train" message. Finally, users who have the alphabetic keypad, may be able to compose their own messages.

A simple extension of the message facility is the interconnexion with Telex. Viewdata benefits in the enhancement of its communication facilities by its interconnexion with an extensive Telex network with an international coverage. Telex benefits in 3 ways:

(*a*) it acquires a powerful store-and-forward capability,

(*b*) it acquires an additional number of customers, not normally on the Telex network, and

FIG. 12—Message communication

(*c*) it could relieve congestion in a Telex room at peak hours by repeating a Telex message direct to an executive's Viewdataphone on his desk.

Finally, because Viewdata displays messages visually on a domestic television receiver, it could provide a cheap and convenient way for deaf people to communicate at a distance, amongst themselves and with other people. This social benefit would be of great importance in lessening somewhat the heavy handicap of the deaf.

Education Service

Viewdata can be applied to the education field in 3 areas. The first is the conventional information service providing details of educational facilities; for example, what courses are available and where, details of qualifications required, who to apply to etc. This service could be structured under a number of different headings, such as subject titles, local facilities etc., and the usual method of access would be applied.

The other 2 areas cover the more exciting possibilities of using Viewdata to assist in the learning process. Many attempts have been made recently, particularly in the USA, to introduce this system of learning (computer assisted learning), which has many obvious advantages. It could relieve very considerably the day-to-day pressure on teachers and lecturers, who would then be able to devote more of their time to the individual requirements and difficulties of their pupils. The potential of this educational medium for home-learning is also of great importance.

Unlike conventional methods of learning, Viewdata, by taking advantage of interactive working, can provide the student with assistance when required and a method of self-monitoring and self-testing, which could greatly increase the speed of learning and provide the necessary intellectual stimulus to the student.

Calculations Service

The primary purpose of Viewdata is not to provide a calculations service but, as illustrated earlier, an information and message service. Nevertheless, the availability of a number of distributed computers, a local-call distance away, suggests that, for very little extra cost, a useful calculation service could be provided to students, small businesses and indeed all who might need its fairly limited, but potentially very useful, facilities.

Little would be gained if the calculation facilities were limited to those provided by the small mass-produced calculators. Such a service would be hopelessly uncompetitive. Neither would a great deal be gained by providing the sophisticated facilities of the now well established computer bureaux. The professional user of extensive computational facilities is already well catered for.

Rather, it is intended to fill the gap between the two, some of which is at present covered by the more expensive hand or desk calculators. Unlike these more complex and powerful machines, however, the Viewdata approach is to eschew all manuals and complicated instructions and so to organise the dialogue that users can, without any specialized training whatever, carry out the calculations they desire. Instructions for entering requirements are given by the system as and when they are needed, and the dialogue is arranged so that errors can be caught quite simply as they occur. An additional feature of the calculation program is a curve or histogram plotting facility related to the computations carried out.

Personal Information Service

Viewdata users are able to enter information into the system; for example, for message purposes. This facility could be extended by arranging that such information was accessible only to the user himself, or to one or more other persons nominated by him.

An extension of the personal information service is the use of the Viewdata network to store and provide access to information of interest to closed user groups on certain specific topics; for example, employees of a business house. A minimum degree of privacy will need to be provided, although absolute privacy is not an objective of the system, at least in the initial stages.

In the case of closed user groups, information and data may be collected for the benefit of groups having similar interests. For example, the source of supply of commodities used in certain categories of business such as, building supplies with current prices, availability etc.

Clearly, the range of potential services of this nature is open ended. Developments will no doubt take place in this area as the capability of this new medium becomes apparent through usage and experimentation.

CONCLUSIONS

Viewdata has been developed by the BPO as a versatile information medium with exciting possibilities for use by the general public[2,3].

The 3 major design features of the system: namely, the low-cost adaptation of the domestic television receiver for the visual display of the information; the use of a distributed computer system to decrease the cost of access to the information; and the simplicity with which the desired information can be obtained by the user, have been chosen to ensure a ready acceptance by the public.

In addition to its information capabilities, Viewdata lends itself to a host of other important applications, such as the sending and receiving of messages, classified advertisements, calculations for the student and the businessman, and education.

It is clearly too early, as yet, to predict with any confidence, or in detail, the likely impact Viewdata might have on the development of modern society, just as it was not possible to predict the extraordinary developments in society which were initiated and nourished by the introduction of printing in Western Europe. What is possible to predict is that Viewdata, or something like it, will very likely have an equally important impact.

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Measurement and Analysis Centres

Part 2—Processor Programming and Operation

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UDC 621.395.31:621.395.36:681.3.06

Part 1 of this article described the measurement and analysis centre system concept and the equipment used. In this part, description is given of the preparation and construction of the processor programs and of the types of output information made available to maintenance staff.

INTRODUCTION

Part 1 of this article* described the system concept of measurement and analysis centres (MACs) and the inter-relationship of the equipments used.

In this part, attention is directed to the MAC processor; the type of input information needed to compile the processor programs and the method of compiling processor programs are discussed. Description of the output information that is made available to MAC staff is also included; this information enables service to customers to be assessed in a manner not previously possible.

PROCESSOR INPUT DATA

Control software and data has to be input to a MAC processor for it to function correctly. The software is the equivalent of a facility schedule, and contains all the instructions necessary for a processor to carry out each step of its task. All MAC processors will have identical software and this has been developed by the General Electric Company (GEC) in co-operation with the Service and Development Departments of the British Post Office (BPO) Telecommunications Headquarters (THQ).

The input data defines the Telephone Area in which a processor will work. This data makes each processor individual to its own Area and is of the following 3 types.

System Data

System data defines an Area MAC service circuit network; it lists exchanges and test numbers and nominates the test-call sequences to be run at each unit. The system data also lists information common to all units, such as metering rates, control statistics and statistical confidence limits.

Exchange Data

Exchange data lists details of each telephone exchange in a MAC area, including names and types of exchanges, details of the access equipment and busy-hour identification.

Sequence Data

Sequence data enables a processor to construct the lists of test calls to be sent. Each list contains a set of test calls proportional to the traffic generated to each target destination by customers at the measured exchange; the processor arranges the test calls in random order.

A problem exists in collecting and assembling the sequence data. Difficulty arises in determining the destinations of the traffic, particularly on routes to exchanges used as tandems. A representative sample is required of the traffic generated by customers and the destination of that traffic. Several methods may be used to determine these patterns depending on local circumstances; for example,

(*a*) call samples derived from printer-meter-checking (PMC) equipment connected at selected points,

(*b*) route-recording information,

(*c*) automatic traffic-record readings,

(*d*) call-failure-detection equipment (CFDE) with associated printers, or

(*e*) analysis of telephone service observation (TSO) call distribution.

The system data, exchange data and sequence data is passed by Telephone Area management to a THQ Service Department duty. The information is then transferred to a magnetic-tape cassette using a key-to-cassette unit (see Fig. 10). This device can also perform certain checks to verify that the information complies with set standards. For example, it will check that the information is in the correct format and that unit descriptions use valid codes. The data is sorted by the THQ staff into batches depending upon the service circuit arrangements and the availability of access equipment. An initial batch of data will start the processor and updates are supplied at regular intervals (e.g. monthly) in order to load progressively the system. After all the data is loaded in the processor, it is necessary to update this information from time to time as the MAC Area changes; for example, if new traffic routes are opened or existing routes are amended. Changes to the Area description will be forwarded to the central bureau and an edit cassette produced. This cassette tape is read into the processor at the beginning of an operating month and when changes are required. To assist in determining the call-destination weighting factors, a monitor is included in each of the exchange access equipments; the monitor is known as the *digit monitoring analyser* (DMA) and was described in Part 1 of the article. The organization of the collection of the processor input data is the responsibility of local Area management.

PROCESSOR PROGRAMMES

Measurement Sequences

Using the basic data that has been input to a MAC via the magnetic cassette, the processor compiles a series of 9 measurement sequences (MSs) of test calls that are used to monitor the public switched telephone network (PSTN). Table 2 gives the MSs that are run, and includes the basic

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* SAPSFORD, B. G. Measurement and Analysis Centres, Part 1—System Concept and Equipment Description. *POEEJ*, Vol. 70, p. 243, Jan. 1978

FIG. 10—Key-to-cassette unit

description of the MS and the number of test calls to be sent on each MS each month.

The customers' spare line circuits are dedicated for MAC use. All 9 MSs will be run from 0800–1800 hours Monday–Friday and, in addition, MSs 1–3 and 9 will run during the evening from 1800–2100 hours.

Call failures detected during an MS are analysed by the processor into failure groups to provide a monthly performance index, similar to that given by the present TSO main summary (described later in this article).

Analysis Sequences

To assist the maintenance engineer in locating faulty equipment in the network, 2 analysis sequences (AS1 and AS2) have been included in a processor's program capability.

The AS1 sequence acts upon the call-failure information derived from the measurement test calls in MSs 1–9. When a call fails to mature or meter correctly, all details relating to the failure are stored in the MS failure-file rolling store and then copied into the AS1 store.

When a spare time-slot occurs in the MS sending pattern, an attempt is made to locate the failures stored in the AS1 memory. This is done by sending up to 10 test calls from the same access position as used on the failed call and using the same routing and test number information. The first of the 10 calls to fail is held at the access position for 30 min, and all relevant details are printed-out at the MAC centre to enable the fault to be localized and cleared. The facility also exists for these failed-call details to be printed out at the exchange unit concerned if a suitable printer is associated with the exchange access equipment. It must also be remembered that a call may be put into AS1 by means of a keyboard instruction and a series of up to 10 calls made in the normal AS1 manner.

The AS2 sequence has been provided specifically to permit the investigation of particular problems within the network. Programs of test calls for this sequence may be constructed in one of 2 ways:

(*a*) a copy may be made of all or part of an existing MS running at an exchange, or

(*b*) a completely new test-call program may be constructed using information obtained in the same manner used to construct the existing measurement sequences.

AS2 programs may be constructed in any length up to a maximum of 1000 test calls.

Because the AS2 programs make use of the spare-time capacity of the service circuits, after the MSs and AS1 repeat calls have been scheduled, the calls in the program will normally be sent at a faster rate than the other calls. However, in Telephone Areas where the maximum concentrator loading is used, it may be necessary to suspend AS1 and/or MSs 4–6, 8 and 9 to obtain sufficient time for the AS2 program to be run over a short period.

A service circuit terminating at a MAC can handle up to 900 calls/d.

TABLE 2

Measurement Sequences

Measurement Sequence Number	Sequence Description	Calls per Month
1	Own Exchange—from customers' spare line circuits to test numbers within the multiple of the same exchange	1000
2	Local Dialling Area—from customers' spare line circuits to test numbers in the multiple of exchanges to which non-STD access is provided	480
3	STD—from customers' spare line circuits to distant exchange test numbers obtained via the 2-wire switched STD network	280
4	STD Originating—from customers' spare line circuits to test numbers in the GSC served by the local exchange	480
5	STD Terminating—from incoming trunk selectors at GSCs (or incoming trunk units) to test numbers in the multiple of exchanges served by the GSC (or incoming trunk unit)	1000
6	IDD Originating—from register-access relay-sets in GSCs to test numbers in the UK international switching centres	200
7	Tandem—from first selectors in tandem exchanges (Director areas only) to test numbers in the multiple of local exchanges connected to the tandem exchange	1000
8	Transit Access—from register-access relay-sets in GSCs to test numbers in the home TSC and to test numbers in the dependent charging groups via a back-to-back route in the GSC	480
9	Transit Multi-Link—from register-access relay-sets in a selected GSC each month to test numbers in the multiple of local exchanges obtained via the transit network	1000

GSC: Group switching centre
TSC: Transit switching centre
IDD: International direct dialling

PROCESSOR OUTPUT

Mention has already been made of call-failure information being printed-out on the keyboard printer (see Fig. 11) at the MACs. Because failed calls are held for investigation, call-failure information is continually being made available to the engineers who staff MACs. However, other types of

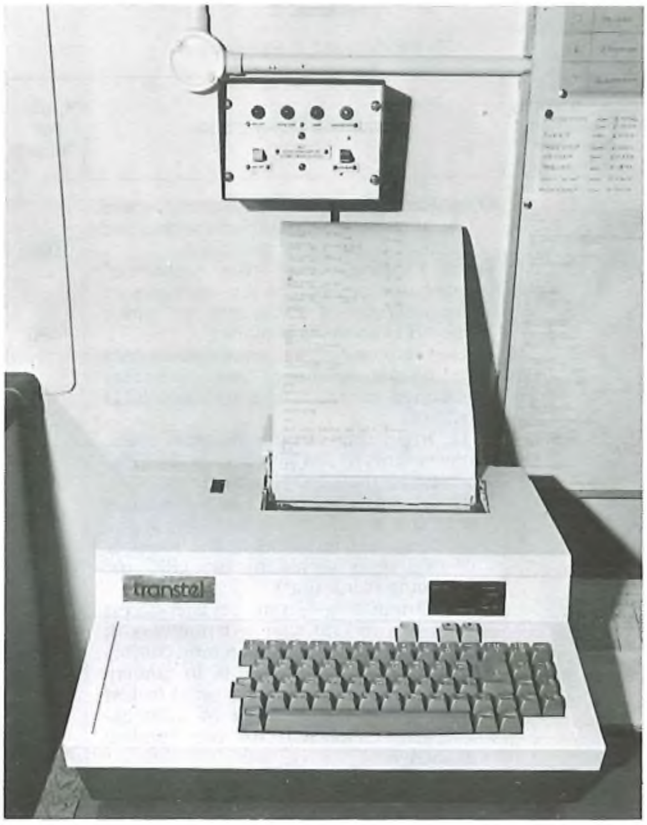


FIG. 11—Keyboard printer

print-out occur automatically, and many others may be obtained on demand. To present a logical picture of when print-outs occur and why, the activities which occur automatically on a daily basis are discussed first, followed by those that occur monthly. The print-outs that can be obtained for use on a day-to-day basis by the MAC staff will be included in a later article.

Daily Activities

The processor located in a MAC normally remains operative continuously, and is able to operate unattended for most of the time. Once in operation, the processor is able to complete its daily (and most monthly) activities without user intervention. The actions taken by the processor throughout a 24 h period are, briefly, as follows.

Midnight

At midnight, the processor automatically increments the date and, if it is a Friday, prints a report of the local traffic record for the previous week. Calls originated by the MAC are registered in the network as normal traffic calls and, in order that a check may be kept of the local traffic generated by a MAC, all such calls are classified into 3 groups; that is, level 0, level 1 and levels 2–9 traffic. The print-out shows the number of calls made in each of these groups.

0400 Hours

If more than one call to a test number in 24 h results in receipt of ringing tone instead of test-tone, then use of that test number is inhibited. At 0400 hours, the processor automatically zeros these counts of ringing-tone failures. Any numbers that have been inhibited remain so. Immediately following this action, the cumulative results of all measured units are calculated for all MSs, and the results are printed-out. These results are also retained so that they may be sent to the exchange printer in due course. A typical example of a daily cumulative-results print-out is given in Fig. 12.

DAILY CUMULATIVE RESULTS

TEST CIRCUIT 2

	SEQ	%PD	%PE	%WC	SS	SENT
CLARKTOWN	1	1·80	0·10	0·53	939	YES
	4	3·33	5·41	9·58	240	YES
CLARKTOWN	5	1·05	0·00	0·41	949	NO
	6	4·73	1·57	2·62	190	NO

SEQ: Measurement sequence
PE: Plant engaged
SS: Sample size to date
PD: Plant defects
WC: Wrongly charged
SENT: Indicates whether the information was sent to the exchange printer

FIG. 12—Example of daily cumulative-results print-out

At the end of the daily cumulative-results print-out, another report is printed which lists all the inhibited:

(*a*) test circuits,
(*b*) measured units,
(*c*) access positions,
(*d*) MSs,
(*e*) unmeasured units, and
(*f*) test numbers.

0430 Hours

At exchanges fitted with printers, the cumulative results are printed out.

0500 Hours

Between 0500–0745 hours on each working day, the processor checks the correct operation of the access equipments and the majority of test numbers. A check is also made of the level of the 1000 Hz test tone returned from each exchange access equipment. The checks run concurrently on all service circuits. Should any of the checks highlight defective equipment, the faulty service circuits or exchange access equipments are inhibited and relevant information printed out.

0745 Hours

Each day at 0745 hours, all information contained on the fixed disc is copied to the exchangeable disc. This is to permit the daily changing of the removable disc between 0755–0830 hours. (This copying of information is for security reasons.) The processor will continue with its call programs when the discs have been changed and the correct command given via the keyboard printer.

0800 Hours

At 0800 hours, the day session of working activities commences; at this time, the processor will automatically commence sending MS calls. Any calls left in AS1 from the previous day session are also sent.

0900 Hours

All calls remaining in AS1 from the previous day are expunged. Any AS1 calls identified since the start of the day session and not already sent, are retained in the store until a suitable time slot becomes available.

1800 Hours

1800 hours marks the end of the day session of activities and the start of the evening session. The sending of all calls on MSs 4–8 is ceased, as are any AS1 calls waiting to be sent. MSs 1–3 and 9 will continue if programmed.

2100 Hours

The evening session ends at 2100 hours, and the processor will then stop all MS calls automatically. AS2 calls may continue if specified to do so by the data input in the AS2 program.

Shortly after the end of the evening session, the details of the last 20 calls which failed during this session from each unit are printed out in chronological order, grouped by sequence and unit. The details of these failures are then erased from the processor's failures-file because these results are not compounded with the day-session results.

Night Print-outs

After the end of the evening-session failures print-out, other requested print-outs may occur. These are basic-format information programs or results sheets which, when the total Area's information is required, would take up too much printer time during the day or evening sessions.

MONTHLY ACTIVITIES

A measurement month may be of 4 or 5 weeks duration. A measurement-month normally finishes at the end of a Friday's evening session. The next measurement month normally begins at the start of the following Monday's day session; during the weekend between, the results of the preceding month are printed out and are output onto a magnetic-tape cassette. Once these functions have been performed and the commands to the processor for the next operational cycle have been entered, the processor will automatically start sending calls at the beginning of the day session on the first day of the new measurement-month.

Result Sheet

The fact that printed result sheets are made available at the end of each month enables individual unit managers and exchange staff to be notified of their past month's performance only 1 or, at the worst, 2 working days after the end of the measurement being completed. A result sheet is produced for the MSs run at each unit for:

(*a*) day sessions (0800–1800 hours),
(*b*) evening sessions (1800–2100 hours), and
(*c*) the busy period (up to 3 selected periods, made up of multiples of ½ h between 0800 and 1800 hours).

For MS1 only, the results of all local exchanges of each type (Strowger, electronic and crossbar exchanges) will be weighted to give a combined result-sheet showing the relative performance by type of exchange. Weighted Area results for each MS will also be produced, these being the aggregation of all unit results.

Using the information from MSs 3 and 4, results will be produced for each GSC on a combined basis of all local exchanges connected to that GSC for STD access.

A typical end-of-month print-out is shown in Fig. 13 for a local exchange running MSs 1 and 4. The failures are split into groups: plant defects (PD), plant engaged (PE), busy tone (BT), wrongly charged (WC), and poor transmission (XM). Each one of these groups is split into categories as shown in Fig. 13. Information is also given on the average time taken to receive dial tone for calls originated from MSs 1–4, and the average post-sending delay time is also included.

The failure rate of plant items shown against NDT/S in Fig. 13 is included in the overall PD failures when MSs 1–4 are run; this occurs because these are failures which lead to customers not receiving dial tone. When MSs 5–9 are run, the access used is a working-circuit interception access circuit, and access may at times be barred due to the required access position being engaged on a customer's call. Therefore, the PD results on MSs 5–9 do not include the failures to seize a working circuit.

UNIT SEQUENCE RESULTS

CENTRE: GUILDFORD AREA: 1 UNIT: CLARKTOWN
TYPE: TXS
FROM 03.10.77 TO 29.10.77 DAY SESSION

1	2	3	4	SEQUENCE
1000			480	STANDARD SAMPLE SIZE
0			3	INHIBIT TIME
1023			291	SAMPLE SIZE ACHIEVED 1
0			5	POST SENDING DELAY
1·50			5·00	% FAILURES DUE TO PD TARGET
1·46			4·80	% FAILURES DUE TO PD MEASURED
0·29			0·33	%NDT/S
0·19			3·08	%NU
0·19			0·33	%RT
0·39			0·33	%NT
0·39			0·68	%UR
0·00			0·00	%CPT
0·50			1·00	% FAILURES DUE TO PE TARGET
0·00			1·71	% FAILURES DUE TO PE MEASURED
0·00			1·37	%EET
0·00			0·33	%CA
			0·00	%RB
			0·00	%LEE
0·19			0·00	% FAILURES DUE TO BT
0·19			11·33	% FAILURES DUE TO WC
0·12			0·00	%ORD IC
0·42			23·07	%CCB IC
791			148	SAMPLE SIZE ACHIEVED 2 ORD
0·00			0·00	%PM
0·12			0·00	%FM
0·00			0·00	%OM
0·00			0·00	%NIM
25			135	SAMPLE SIZE ACHIEVED 3 ORD
0·00			0·00	%NSM
0·00			0·00	%SOM
232			143	SAMPLE SIZE ACHIEVED 4 CCB
0·00			0·00	%CIR
0·00			1·39	%FPT
0·00			0·69	%NPT
26			129	SAMPLE SIZE ACHIEVED 5 CCB
0·00			6·97	%EPT
3·84			16·27	%NSP
51			0	SAMPLE SIZE ACHIEVED 6
0·00			0·00	%PQT
2			0	MEAN LEVEL—dBm
0			0	STANDARD DEVIATION
		0		TIME TO RECEIVE DIAL TONE

NDT/S:	No dial tone or seizure	FM:	False metering
NU:	Number unobtainable	OM:	Over metering
RT:	Ringing tone	NIM:	No initial metering
NT:	No tone	NSM:	No subsequent metering
UR:	Unrecognizable result	SOM:	Subsequent over metering
CPT:	Continuous pay tone	CIR:	Coins incorrectly recorded
EET:	Equipment engaged tone	FPT:	False pay tone
CA:	Congestion announcement	NPT:	No pay tone
RB:	Register busy	EPT:	Early pay tone
LEE:	Local equipment engaged	NSP:	No subsequent pay tone
PM:	Premature metering	PQT:	Poor quality transmission
ORD:	Ordinary call	CCB:	Coin-collecting-box call

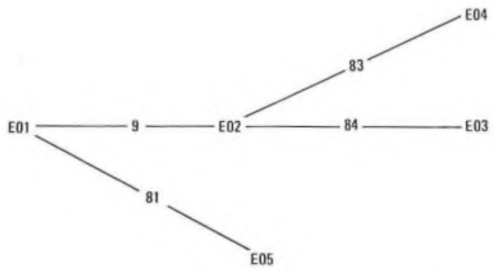
Note: The time taken to receive dial tone, and post-sending delay, is recorded in seconds, and that for inhibit time in hours

FIG. 13—Typical end-of-month print-out for an exchange running MS1 and 4

Route-Code Analysis For Local Calls

For MSs 2, 5 and 7, a print-out is provided each month with the results of the test calls arranged on what is termed a *route-code* basis. For example, during MS2 (local-dial area calls), many of the test calls will traverse a number of common routings defined by routing digits used to direct the test call, and route codes are allocated to combinations of routing digits (see Fig. 14). Alternatively, the route codes may be allocated to each local exchange in a Telephone Area.

The MAC performs a combined analysis of all the routes associated with the same route code. Therefore, it is possible to assess the performance of each local-exchange incoming service as seen from other exchanges in the Area, or to identify routings which affect the performance of a number of exchanges. Provided that no more than the 100 route codes are used, it may be possible, with careful planning, to make the best use of both options.



Destination Exchange	Routing Digits	Route Code
E02	9	01
E03	984	01
E04	983	01
E05	81	02

Note: Up to 100 route codes may be allocated in any one MAC area

FIG. 14—Allocation of route codes

Route-Code Analysis For STD Calls

Information obtained from MS3 is used to provide an STD route-code analysis. From any GSC on the STD network, the destination GSCs to which calls are made are identified by a *destination code*, and a result is given for each destination GSC as seen by the sending GSC. Routes will be coded in accordance with instructions given by THQ; the output will be in the format shown in Table 3.

TABLE 3

STD Route-Codes

Calls Originating From:
Blanktown—Code G0281

GSC Code	%PD	%PE	Sample Size
G0000			
G9999			

When all Telephone Areas are equipped with a MAC, it will be possible to aggregate all these results into a National result which will show the service offered by each GSC to those GSCs which route to that particular unit.

Cassette Recording of Monthly Results

Following completion of all monthly print-outs (which occur after the instruction PR RES, MONTH has been input to the MAC processor) an instruction, CASSETTE, is input to the processor, and the results of the test calls are copied onto a magnetic cassette. The cassette recorder is included as part of the MAC equipment. A second copy of the cassette is made for security reasons.

MAC NATIONAL ANALYSIS
REGION COMPOSITE SUMMARY—JUNE 1977—EASTERN REGION
SEQUENCE 1 DAY PERIOD
EXCHANGE TYPE TXE

% FAILURES DUE TO:	TARGET	APRIL	MAY	JUNE	1ST QTR AV.	QTRS 2-4	CU. AV.	PREVIOUS YRS AV.
AREA: A								
PD	2·8	4·2	3·0	1·2	2·8		2·8	2·8
PE	1·4	2·1	1·5	0·6	1·4		1·4	1·4
WC		0·8	0·5	0·2	0·5		0·5	0·5
XM		0·6	0·5	0·3	0·5		0·5	0·4
AREA: B								
PD	3·6	2·2	1·4	3·8	2·6		2·6	3·4
PE	1·8	1·1	0·7	1·9	1·3		1·3	1·7
WC		0·4	0·3	0·7	0·5		0·5	0·6
XM		0·3	0·1	0·4	0·3		0·3	0·4
AREA: C								
PD	2·8	3·2	2·2	2·2	2·8		2·8	2·2
PE	1·4	1·6	1·1	1·1	1·2		1·2	1·1
WC		0·6	0·4	0·4	0·5		0·5	0·4
XM		0·5	0·2	0·1	0·3		0·3	0·3
AREA: D								
PD	3·4	2·4	3·2	4·8	3·6		3·6	2·1
PE	1·7	1·2	1·6	2·4	1·8		1·8	1·4
WC		0·4	0·6	0·9	0·7		0·7	0·5
XM		0·2	0·5	0·7	0·5		0·5	0·5
AREA E								
PD	3·6	2·4	1·8	1·2	1·7		1·7	3·0
PE	1·8	1·2	0·9	0·6	0·9		0·9	1·5
WC		0·4	0·3	0·2	0·3		0·2	0·4
XM		0·3	0·2	0·2	0·2		0·3	0·5
AREA: F								
PD	3·6	2·4	1·8	1·2	1·7		1·7	3·0
PE	1·8	1·2	0·9	0·6	0·9		0·9	1·5
WC		0·4	0·3	0·2	0·3		0·2	0·4
XM		0·3	0·2	0·2	0·2		0·3	0·5

TXE: Electronic Exchange
QTR: Quarter
AV: Average
CU: Cumulative

PD: Plant defect
PE: Plant engaged
WC: Wrongly charged
XM: Poor transmission

FIG. 15—A typical example of a Regional composite-summary print-out

NATIONAL RESULTS

Each completed cassette of monthly results is sent by Datapost to a computer centre operated by the BPO Data Processing Service. From these cassettes, a high-quality magnetic tape is produced. From this magnetic tape, a film is produced that shows the Area, Regional and National results on a weighted basis. The film is sent to a reproduction centre with details of the number of copies of the various results to be sent to Area, Regional and THQ departments. A typical example of the information included in the print-out of a Regional composite summary is given in Fig. 15; results of the first quarter of 1977 only are shown in Fig. 15 and the cumulative average is based on those results. As other quarterly results become available, so the cumulative average is recalculated. Other results sheets will be very similar in appearance to those produced for the TSO results but will include the categories shown in Fig. 13; the failure categories are printed in full and are not indicated by initials.

THE FUTURE

The present phase of the MAC scheme entails the installation of 10 MACs by the end of 1978. Since the publication of Part 1 of this article, the BPO has announced its decision to install a further 51 MACs; thus enabling each Telephone Area to have its own MAC.

CONCLUSION

At the present time, experience has been gained on the operation of 2 MACs, to which are connected a limited number of exchanges. By mid-1978, it is hoped that a number of fully-operational MACs will be in service.

In this article, the collection of data, the formation of the test-call programs and the monthly and daily automatic outputs that are produced by a MAC processor have been discussed.

Additional information is also available from the processor (on demand, by use of the keyboard printer) and this, together with information from other sources, may be used to inform exchange maintenance staff of faults affecting service, and to assist the maintenance staff in the clearance of such faults. The methods that may be used to do this, and the type of information available to MAC staff on demand from the processor, will be reviewed in a further article that will include a summary of the activities essential to the smooth running of a MAC in a Telephone Area.

Book Review

Microwave Attenuation Measurement. F. L. Warner, C.ENG., F.I.E.E. Peter Peregrinus Ltd. (IEE Monograph series). xix + 338 pp. 158 ills. £14·0. (Overseas, excluding the Americas: £16·40.)

Claimed by the publisher to be "the first major book" on the subject, this work will undoubtedly take an important place on the microwave shelf. It does not seek to displace the more general treatments of microwave measurement techniques, but gathers together in one cover all the methods specifically related to attenuation in its various forms. It deals not only with the methods applied in development laboratories or in manufacture, but also with those that are used in national standards laboratories.

Frank Warner has been with the Royal Signals Research Establishment at Malvern for 35 years, including 10 years with the National Radio-Frequency and Microwave Standards Division. His book is therefore highly authoritative, especially in the treatment of the most accurate equipments, with their attention to residual errors and confidence levels. Readers whose requirements are more modest, however, need not be put off by the idea of 0·001 dB accuracy, since the author has managed at the same time to present the material in a methodical and readable form—indeed, the book itself grew out of his lecture notes for the IEE vacation schools on radio-frequency measurements. Abundant descriptive matter is backed up by mathematics which is concise without being so abbreviated as to be difficult to follow.

The book opens with a careful definition of all the various terms encountered in attenuation measurement, together with their algebraic relationships; this is an indispensible first step, since many microwave engineers use these terms rather too loosely and, as a result, some important sources of error go unrecognized.

A résumé of low-frequency attenuation standards prepares the way for the chapters on very accurate microwave measurements, including piston and rotary-vane standards, power-ratio methods, radio-frequency, intermediate-frequency and audio-frequency substitution, and the evaluation of low attenuation by reflection methods. While many readers may not wish to memorize the details of these sophisticated techniques, they do make interesting reading and should provide the practising measurement engineer with some food for thought.

The chapters on swept-frequency techniques and network analysers will be more familiar ground to most microwave engineers. Here again, the descriptions are not limited merely to basic principles, but set the measurement methods in a truly practical context. There is a section on components which risks becoming out of date fairly rapidly, especially in respect of sources and detectors, though it will serve to remind future readers of the constraints imposed by those components on contemporary techniques.

It is also a little unfortunate that this book was completed just before the 6-port-coupler method became widely known—this may turn out to be an important omission from the repertoire of network-analyser principles.

Research engineers with particular problems to solve (such as working with a limited range of components) may find help in the chapter containing brief descriptions of numerous other methods of measuring attenuation, including a section on the use of the Josephson junction. The book concludes with a short chapter on transfer standards, and one on the determination and expression of uncertainty, which includes worked examples. There are also 6 appendices which remove some of the mathematical chores from the main text.

The book is well laid out, and each chapter is supported by a selection of the principal references. It is a worthy addition to the IEE Monograph series, and should be of value both to practising and aspiring microwave engineers.

N. D. K.

Keybridge House Tunnel

J. J. PENDEGRASS†

Keybridge House, in South London, is intended to accommodate a major Telex centre. The ductwork between Keybridge House and London's deep-level cable-tunnel complex has recently been completed, at a cost of £600 000. This article describes the work of constructing one section of the ductwork: the lead-in to Keybridge House.

When planning a lead-in to an important telecommunications building, it is normal to arrange that the "fall" on the route is away from the building so that, in the event of flooding, water will flow away from the building and into adjacent manholes. As Keybridge House's cable chamber is below the level of existing cable plant, it was not possible to adopt this arrangement. Therefore, it was essential that the ducts should be as watertight as possible. This was particularly important because more than half of the lead-in would lie below the level of the ground-water table, some 4 m beneath the surface. After considering a number of alternatives, it was decided that a small-bore concrete-segment tunnel would be ideal for this job. Fig. 1 illustrates the layout of the tunnel works.

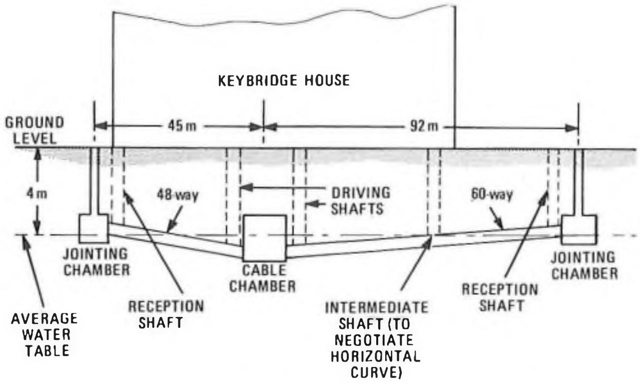


FIG. 1—Keybridge House lead-in tunnels

In June 1976, the first excavations began and, by November 1976, the steel cutting-shield was ready to be lowered and aligned in the first shaft. A low-output datum laser was used for this purpose, and also enabled the miner to keep the shield on the correct course throughout the drive (see Figs. 2 and 3).

Two sections of tunnel were necessary (see Fig. 1): one for a 48-way duct nest, and one for a 60-way nest. The latter needed an intermediate shaft so that a horizontal curve could be negotiated. Again, the laser was used to determine the line of the bend.

During the construction of Keybridge House, it had been found necessary to drive steel ground-anchors into the surrounding area temporarily to support the retaining walls. These anchors were found throughout the tunnel drive, and needed to be cut before the shield could progress. It was not expected however that some of the cast-steel grouting tubes, used to surround the anchors with concrete, would be left *in situ*, but this was the case. A 100 mm cast-steel grouting tube, filled with concrete and with a 25 mm steel cable inside, is not easy to cut in 2 places, particularly when one end is in water. The use of a thermic lance was considered, but was thought to be too dangerous in that situation, and so oxyacetylene cutting equipment was used (after a suitable ventilation system had been set up). Even so, it took 2 d to cut and remove each tube found.

Pumps in the shafts were able to keep the water down to a reasonable level, and the hood fitted to the front of the tunnelling shield reduced any hazard for the miner due to loose ground or running sand.

By January 1977, one section of tunnel was ready to receive its ducts. The method of installation to be used was a new concept in duct-laying, and proved to be an interesting exercise.

Sixty ducts were to be provided in this section, and it was decided to join each duct in the driving shaft and pull them into the tunnel in groups of 6 as the joints were made. A special 6-way hardwood clamp was made for this purpose by the Area power workshops, and was very successful (see Fig. 4).

After each group of 6 ducts had been pulled through the tunnel, each duct was pressure-tested to ensure that each joint was sound. Any faulty ducts could easily be replaced before the next group was pulled in. Each layer was arranged in the correct rectangular formation in the shafts and extended into the existing manhole, and to the duct-seal, at Keybridge House. Both ends of each duct were then sealed with caulking discs in the normal way. The ducts in the shafts

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FIG. 2—Shield, showing driving rams

FIG. 3—Aligning the laser

FIG. 4—The 6-way pulling clamp

were finally encased in concrete, and unused space in the tunnel was filled by pumping in a slurry of pulverized fuel ash and water. The whole procedure was repeated for the remaining 48-way section.

Although the existing manholes accumulate a considerable amount of ground water, the new ducts have remained completely dry, and the extensive cabling programme for Keybridge House is well advanced.

Novel Exchange Transfer for Southsea

I. R. BROWN†

The exhaustion of Southsea exchange, a satellite of Portsmouth, presented a difficult problem in catering for growth. It was not possible to obtain planning permission for an extension to the existing building, situated as it was in a residential area; nor was it possible to obtain a site in the vicinity of the new practical centre, over 1 km to the north of the existing exchange.

For some years, growth in the Southsea area has been met from Portsmouth Central exchange via tie cables to Southsea main distribution frame (MDF). This could be only a temporary expedient, limited by the exhaustion of terminating and lead-in space at Southsea, and duct space on the tie-cable route. Fig. 1 illustrates the geography of Portsmouth Central and Southsea exchange areas.

Portsmouth Central exchange, which was also exhausting rapidly, was to be extended by a new TXK1 unit for which accommodation was already available. It was decided to make the new unit large enough to cater for complete replacement of the Southsea satellite as well as for growth on both Portsmouth Central and Southsea. This decision made it necessary to transfer all the existing Southsea customers, plus the Portsmouth Central customers working via tie cables and the Southsea local-distribution network, onto directly-routed cables from former Southsea flexibility points to Portsmouth Central MDF. (The directly-routed cables were planned to pass near the Southsea practical centre, as it was envisaged that a suitable site could become available there in the future.)

Owing to the fact that Portsmouth Central exchange was itself badly out of centre, the proposed amalgamation of Southsea with Portsmouth Central produced a situation where all the conventional methods of transfer were considered unacceptable because of transmission and signalling-resistance limits. It was decided that the only practicable method was to transfer each primary cross-connexion point (PCCP) pair by pair, one line at a time. This would have resulted in a poor service for customers, who could not be told the precise date of transfer in advance. The transfer was planned to be carried out in 3 stages over a period of 18 months, so as to equalize the external workload and to make the best use of duct routes by using space made available by the recovery of cables at one stage for the provision of cables at a subsequent stage.

The search went on, however, for a method which would give better customer service. Eventually, it was suggested that use could be made of the direct-dialling-in (DDI) facility on the TXK1, so that all customers would be transferred hypothetically simultaneously while still being physically transferred one at a time. Southsea exchange would become in

† Portsmouth Telephone Area

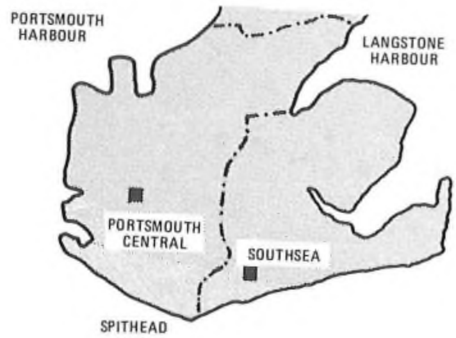


FIG. 1—Portsmouth Central and Southsea exchange areas

effect a DDI PABX off Portsmouth Central, and the telephone numbers on the new unit to be used for ex-Southsea customers would have an appropriate class-of-service identification in the new TXK1. Thus, a call made to a new number not yet physically transferred to the TXK1 would be rerouted to the old exchange, and thence to the customer over the old local-distribution network. The post-dialling delay involved would be about 6 s. The number change on transfer from Southsea to the new unit would consist of prefixing the old number with the digit 7.

To avoid excessive traffic on the new level-7 route from the group switching centre (GSC), customers were advised of their new numbers in 3 batches corresponding with the 3 stages of external work although, at any time after the opening of the new unit, a call dialled with the prefix 7 would be routed to its correct destination.

The operations involved in changing-over each pair were:

(*a*) identifying a new pair from Portsmouth Central to a joint near each PCCP, and verifying the A and B legs,

(*b*) identifying the old pair for the customer concerned from Southsea to the joint, and verifying the A and B legs,

(*c*) changing over the pair in the joint,

(*d*) terminating a pre-run jumper at Portsmouth Central,

(*e*) restoring the class-of-service marking at Portsmouth Central to normal,

(*f*) recovering the old jumper at Southsea exchange,

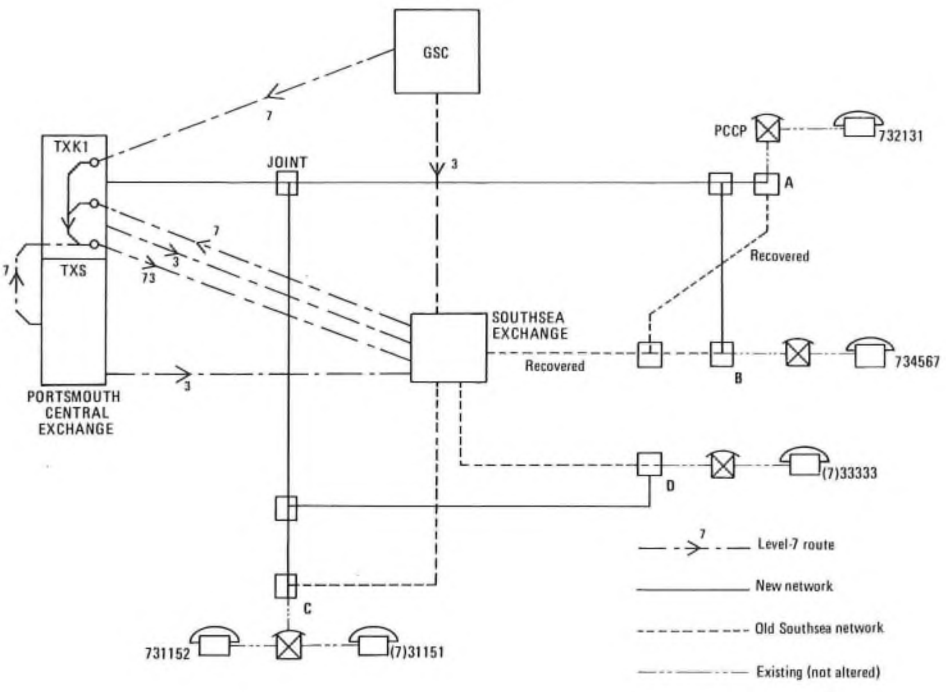
(*g*) connecting a changed-number announcement at Southsea,

(*h*) testing the new line from Portsmouth Central,

(*i*) calling the customer on the new number, and checking the ring back,

(*j*) taking the old and new meter readings, and

(*k*) amending records for the repair-service control, routing and records office, and billing purposes.



A & B: Completed
C: Partly changed-over. Customer 31151 connected to old cable; customer 731152 connected to new cable
D: Ready for change-over

FIG. 2—Routings during the transfer

TABLE 1

Progress of the Transfer

Stage	Period	Pairs Transferred	Customers Transferred from Southsea to Portsmouth Central	Customers Transferred from Tie-Cable Route to Direct Route
1	April–June 1977	3350	2021	378
2	July–August 1977	3000	1397	660
3	October–December 1977	3920	1302	772

The co-ordination of these operations was crucial to the smooth and satisfactory progress of the transfer. A control officer, initially a member of the external-planning team which planned the transfer, was stationed at Portmouth Central, and was provided with a small PBX giving him communication with internal staff at Portsmouth Central and Southsea, the jointers changing over the pairs, operational-programming staff reading meters and calling customers, the testing officer at Portsmouth Central, and the repair service control. Satisfactory working arrangements were soon established, and the co-ordination duty was then taken over by internal staff.

Any difficulty in transferring a pair could seriously delay the operation and, in the months leading up to the transfer, a special exercise was carried out by the external-planning team, with the cooperation of external-works jointers and installation staff, to achieve maximum accuracy of records. In the event, record accuracy was better than 97% and there were few delays; a transfer rate of up to 150 pairs/d, with an average of about 100 pairs/d, was achieved. The incidence of gas in jointing chambers proved to be a hazard to the programme, and this was overcome by planning the work so that jointers could be diverted from one PCCP to another until gas at the first had been cleared. The progress of the transfer is shown in Table 1.

In the particular circumstances of this transfer, the method adopted, making use of the facilities available on the common-control TXK1 unit, allowed a sound and economic engineering job to be carried out without degrading transmission and, at the same time, causing minimum inconvenience to customers. Both the old and new customers' numbers were operative until after the physical change-over of each pair. It was decided to leave Southsea exchange in service until after the following directory issue in order to provide the recorded announcement on former working numbers, and number-unobtainable tone on former spare numbers.

Fig. 2 illustrates the routing of calls at various stages of this unique transfer.

An Introduction to the CCITT R2 Signalling System

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UDC. 621.391.3: 621.395.345: 621.395.12

The growth of national and international telephone traffic throughout the world in recent years, coupled with development of new and improved switching systems, has created a need for fast and reliable signalling systems. These features are provided by the CCITT R2 signalling system, which has been developed for use within an international region by the present generation of switching systems. This article provides some historical background and summarizes the main features of the R2 system and its application at UK international exchanges.*

INTRODUCTION

Between 1957 and 1967, a group of European Administrations and equipment manufacturers established a draft specification for a new signalling system that would provide the fast and reliable signalling considered necessary for new and improved switching systems. A major factor taken into consideration was the need to minimize interworking between the national and international signalling systems used in setting up international calls. The existing international signalling systems recommended by the CCITT imposed an interworking requirement that was increasing with the steady growth of international traffic. The specification was, therefore, prepared to cover both national and international application of the signalling system, to facilitate integrated signalling with a reduced interworking requirement.

In 1967, the European Conference of Posts and Telecommunications Administrations (CEPT) accepted responsibility for finalizing the specification of this European multi-frequency-code signalling system. The increasing interest shown by countries, both within and outside Europe, was recognized by the CCITT Plenary Assembly in October 1968 by its recommendation that the system be introduced as an international signalling system within world numbering zones, or international regions, under the designation *CCITT R2*.[1]

SYSTEM APPLICATION FOR INTERNATIONAL WORKING

The CCITT R2 signalling system uses line supervisory signalling on a link-by-link basis, with end-to-end inter-register signalling using 2-out-of-6 multi-frequency (MF) compelled signals. Provided that its use in national networks of the region concerned conforms to the CCITT requirements, the system can be used for integrated international and national signalling. The system is suitable for automatic and semi-automatic working over a maximum of 4 international 4-wire links in tandem, plus up to 4 national 4-wire links in the destination country, provided that these comply with the specified transmission requirements. However, the R2 system is not suitable for use on circuits employing time assignment speech interpolation (TASI) equipment; also, it was not originally intended to be used on satellite circuits, but the possibilities of its restricted use are currently being studied by CCITT and CEPT.

Fig. 1 illustrates the principle of end-to-end inter-register signalling, which is a method of signalling between registers over a number of links in tandem, without signal regeneration in intermediate exchanges. In general, only the address information needed to route the call through an inter-

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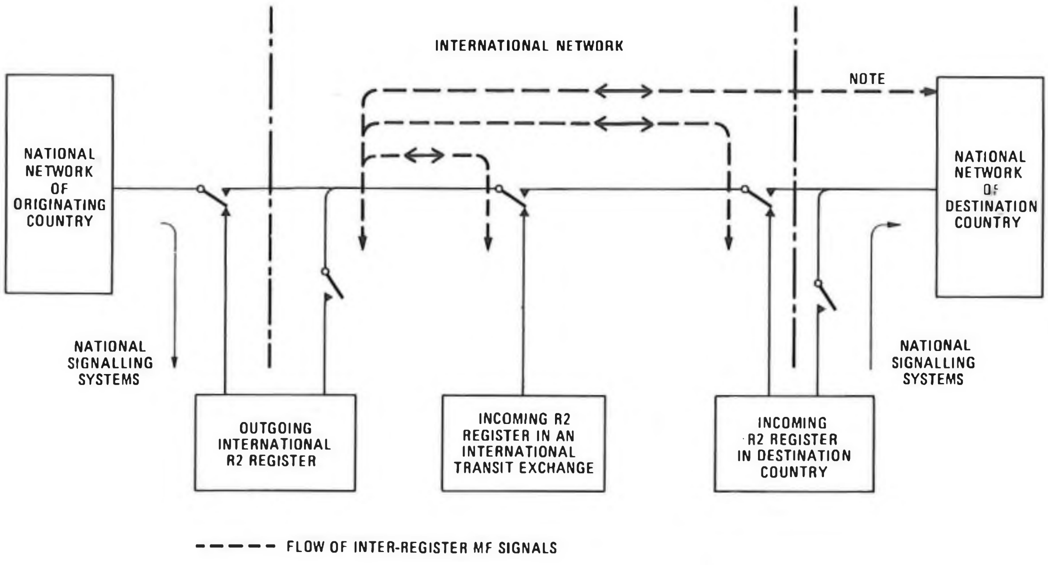

Note: This path is used when integrated signalling is possible

FIG. 1—Multi-link connexion using end-to-end inter-register signalling

mediate (transit) exchange is transferred from the outgoing register to the incoming register in a transit exchange. The transit exchange register is then released and the speech path is connected; thus enabling the outgoing register to convey routing information directly to the next exchange register. The outgoing international R2 register provides the necessary interface between the international network and the national network of the originating country and controls the call set-up over the international connexion; this register receives information from its national network by means of signalling systems that may include the R2 system. When the R2 system is used within the originating country, the interface permits both the economic provision of fewer signalling frequencies and the allocation of unique meanings to spare signals within the originating country. However, the outgoing international R2 register may be situated in a national exchange, provided that all the facilities required for international working are available.

The outgoing international R2 register, which uses all 15 combinations of the 6 signalling frequencies in each direction, sends forward signals to, and receives backward signals from, succeeding exchange registers. The incoming R2 register in the destination country may be located in an international exchange or in a national exchange. This register is the interface between the R2 signalling system and the signalling systems used in the national network of the destination country. Whenever the national network of the destination country uses the R2 system, and the specified requirements are met, the incoming R2 register in the destination country can act as a transit exchange register, allowing the outgoing international R2 register to work directly into the national network of the destination country.

LINE SIGNALLING

Two versions of line signalling are specified: an analogue version for signalling on frequency-division-multiplex (FDM) circuits, and a digital version for use with pulse-code-modulation (PCM) systems. In both versions, the number of signals sent is small because the associated inter-register signalling enables a large amount of information to be passed between registers. Neither version includes the *forward-transfer* signal, although this signal can be introduced by bilateral agreement between Administrations.

Analogue Line Signalling

Line signals are transmitted link-by-link using an outband, low-level, continuous tone-on-idle signalling method. Signals are sent to line by simple transitions from TONE-ON to TONE-OFF and vice versa, in accordance with the operating condition of the circuit, as shown in Table 1. The recognition time for a changed signalling state is 20 ± 7 ms. The change from RELEASE to IDLE state necessitates additional timing criteria, to ensure a defined release guard sequence, irrespective of the operating condition of the called line. The signalling frequency transmitted to line is 3825 ± 4Hz, at a send level of −20 ±1 dBm0.†

TABLE 1

Analogue Line Signalling Code

Operating Condition of the Circuit	Signalling States	
	Forward	Backward
Idle	TONE ON	TONE ON
Seized	TONE OFF	TONE ON
Answered	TONE OFF	TONE OFF
Clear-back	TONE OFF	TONE ON
Release	TONE ON	TONE ON or OFF
Blocked	TONE ON	TONE OFF

Interruption Control

In a tone-on-idle line signalling system, removal of tone corresponds to a *seizing* signal in the forward direction and an *answering* signal in the backward direction. Special pre-

† dBm0—indicates the actual level measured at, or referred to, a point of zero relative level

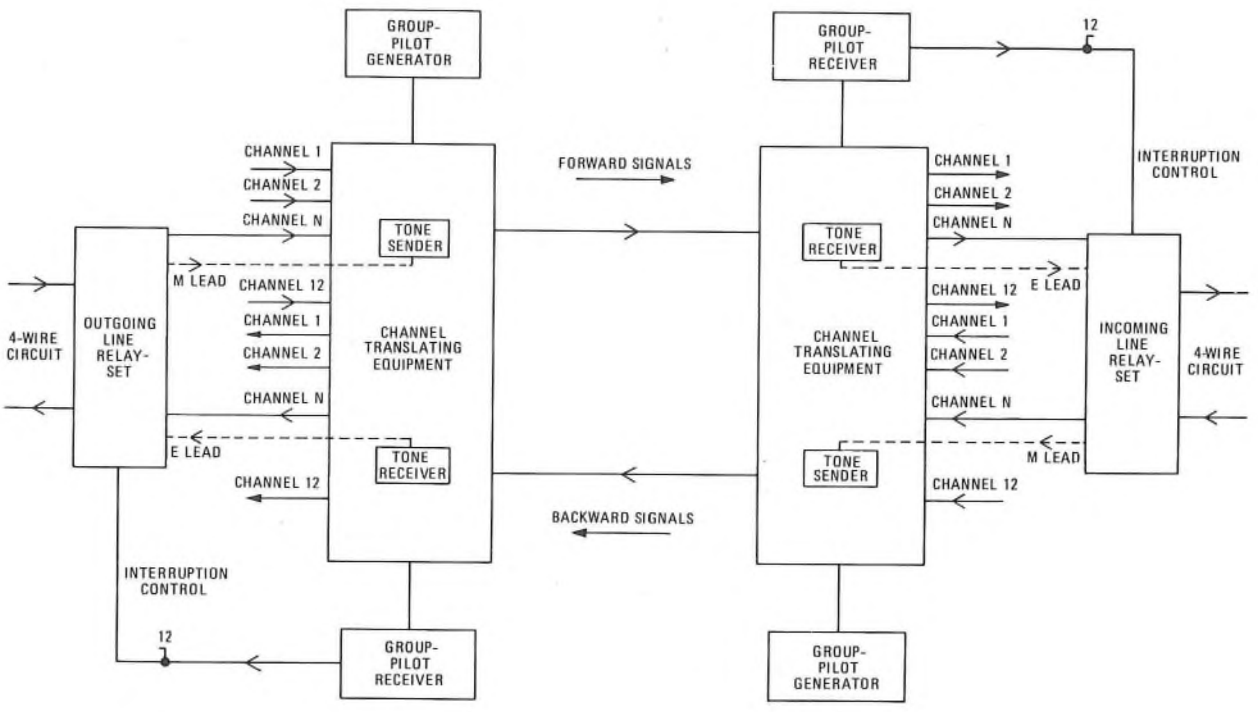

FIG. 2—Interruption control using group pilot

cautions are, therefore, necessary to prevent false signalling in the event of spurious signalling-channel interruptions. In the R2 system, protection against mass effects of such interruptions is termed *interruption control.*

Fig. 2 shows the basic arrangement for providing interruption control by monitoring the group pilot. For each direction of transmission, the equipment comprises a group-pilot generator at the outgoing end, and a pilot receiver and interconnexions for signalling the detected interruption at the incoming end.

Interruption of the associated signalling channels is assumed when a fall in the level of the group pilot to −29 dBm0, or below, is detected. Interruption-control equipment then prevents unwanted transmission of certain signals on those circuits that are in a seized condition, and ensures that idle circuits are blocked. To ensure correct control, the action initiated by interruption control must be completed before false recognition of the change of signalling state on associated channels occurs. Furthermore, on re-establishment of the group pilot, the control action must be maintained until after the associated signalling-channel equipments have reverted to normal.

The mode of operation of the interruption control is dependent on the operational state of the associated signalling channels at the time of the interruption. For example, when a circuit is in the IDLE state, the control action taken by interruption control, when an interruption occurs in the forward direction, is as follows:

(*a*) it removes the tone in the backward direction, by locking the incoming relay-set in the TONE-OFF state, to effect blocking of the circuit at the outgoing end;

(*b*) it locks the incoming receiving unit in its current position (that is, the TONE-ON state), to prevent incorrect recognition of seizure by the incoming equipment;

(*c*) on restoration of the group pilot, it ensures the normal return of the circuit to the IDLE condition by switching the tone-sending control element in the incoming relay-set to the TONE-ON state.

The group-pilot frequency used is 84·08 kHz although, by bilateral agreement and at the request of the receiving country, the 104·08 kHz pilot may be used. If the ends of a supergroup link coincide with the ends of the 5 associated group links, the supergroup pilot may be used for interruption control purposes.

Digital Line Signalling

The digital version of line signalling uses 2 signalling bits per speech channel in each direction of transmission. The increased signalling capacity this provides permits the use of simpler switching equipment, without timing criteria.

Table 2 shows the signalling code on the PCM line. The 2 signalling bits in each direction are referred to as a_f and b_f for the forward direction, and a_b and b_b for the backward direction. The a_f bit identifies the operating condition of the outgoing switching equipment, which is under the control of the calling party. The b_f bit provides a means for indicating a failure in the forward direction by a change to $b_f = 1$. The a_b bit indicates the called-party's line condition, and the b_b bit signals the idle or seized condition of the incoming switching equipment.

TABLE 2
Digital Line Signalling Code

Operating Condition of the Circuit	Code			
	Forward		Backward	
	a_f	b_f	a_b	b_b
Idle	1	0	1	0
Seizing	0	0	1	0
Seize Acknowledge	0	0	1	1
Answered	0	0	0	1
Clear Back	0	0	1	1
Clear Forward	1	0	0 or 1	1
Release Guard	1	0	1	0
Blocked	1	0	1	1

The recognition time for a signalling bit transition from 0 to 1 or 1 to 0 is 20 ± 10 ms, and the time difference between application of transitions of the 2 signalling bits in the same direction must not exceed 2 ms.

The continuous line-signalling system specified for the analogue version can be used on PCM systems, but with only one signalling bit in each direction. In this case, relay-sets designed to work with the analogue version on FDM systems can be used, provided that the interruption-control function is performed by action of the transmission fault control facility.

Transmission Fault Control

Protection against faulty transmission conditions in PCM systems, which cause degradation of the speech channels and signalling errors, is given by the facility known as *transmission fault control* (TFC). When an important PCM system function (such as frame or multi-frame alignment) fails, both PCM terminals take action to block idle circuits and to ensure that seized circuits go to an appropriate operating condition. Action must be taken before false recognition of signalling occurs on associated channels. Additionally, a local alarm is given to indicate a transmission failure, and this can be used for removal of the faulty circuits from service. When relay-sets designed for analogue line signalling are in use, the alarm indication can be used to provide the interruption-control facility.

Bothway Working

In principle, the R2 system is specified for unidirectional working, but bothway working can be undertaken with bilateral agreement between Administrations. In this case, certain specified additional arrangements are necessary to ensure that correct procedures are followed; for example, when a blocking signal is sent, or when double seizure occurs. Bothway working of the R2 system is not used on international circuits in Europe.

INTER-REGISTER SIGNALLING

After seizure of an outgoing link by the associated line signalling equipment, compelled inter-register signalling begins with transmission of the first forward signal by the outgoing R2 register. When the distant incoming R2 register recognizes this forward signal, an appropriate backward inter-register signal is transmitted. The backward signal serves as an acknowledgement to the received forward signal, and recognition of this signal by the outgoing R2 register causes cessation of the forward signal; when this event is recognized by the distant incoming R2 register, transmission of the backward signal is ceased. The next cycle of compelled inter-register signalling may then commence.

Besides being a functional part of the compelled signalling cycle, backward acknowledgement signals serve to convey information concerning required forward signals, to indicate certain conditions encountered during the call set-up, or to indicate a change-over of meanings of subsequent backward signals.

The inherent flexibility in the signalling procedures enables the efficient transfer of signalling information, adapted to the particular requirements of different types of call, traffic conditions and switching equipments. This flexibility is achieved primarily by the control of the signalling sequence by the incoming R2 register. For international working, the send level of each signalling frequency at UK international exchanges is -8 ± 1 dBm0.

Signalling Code

The compelled signalling cycle, described above, is achieved by the simultaneous sending of 2 out of n inband frequencies, where n can be 4, 5 or 6 frequencies. The MF combinations used in the signalling code are shown in Table 3. For reference purposes, each combination of frequencies is identified by a serial number, and the total number of combinations depends upon the number of frequencies used. For economy, in national networks, 4 frequencies may be used for backward signalling and 5 frequencies for forward signalling, giving 6 and 10 MF combinations respectively. This arrangement permits integrated end-to-end working in the case of incoming international traffic. Signalling between international exchanges requires the maximum of 6 signalling frequencies to be used, providing 15 MF combinations in each direction.

Each combination has defined signal meanings, which can be changed by the transmission of certain backward signals to provide 2 groups of signals in the forward and backward directions. The meanings of certain forward signals can also vary according to their position in the signalling sequence. The 2 groups of signals used in the forward direction are shown in Tables 4 and 5, and the 2 groups used in the backward direction are shown in Tables 6 and 7.

Compelled inter-register signalling always starts with a Group I forward signal, but a change to Group II signals occurs when requested by the backward signals A–3 or A–5. Change back to Group I signals is possible only when the change to Group II was requested by backward signal A–5.

Group I Forward Signals

Group I forward signals are shown in Table 4 and explained

TABLE 3

Multi-Frequency Combinations used for Inter-Register Signalling

Frequencies (Hz)		Combination Number														
Forward Direction (Signals of Groups I and II)	Backward Direction (Signals of Groups A and B)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1380	1140	×	×		×			×				×				
1500	1020	×		×		×			×				×			
1620	900		×	×			×			×				×		
1740	780				×	×	×				×				×	
1860	660							×	×	×	×					×
1980	540											×	×	×	×	×

TABLE 4

Group I Forward Signals

Designation of the Signal	Meaning of the Signal: Note 1	Meaning of the Signal: Note 2	Remarks
I–1	Language digit: French	Digit 1	Note 1: These signals comprise the first signal transmitted on an international link when it terminates in the country of destination of the call. When a link terminates in an international transit centre, however, these signals may be transmitted on the link after the country-code indication and the country code digits
I–2	English	Digit 2	
I–3	German	Digit 3	
I–4	Russian	Digit 4	
I–5	Spanish	Digit 5	
I–6	Spare (language digit)	Digit 6	
I–7	Spare (language digit)	Digit 7	
I–8	Spare (language digit)	Digit 8	
I–9	Spare (discriminating digit)	Digit 9	
I–10	Discriminating digit	Digit 0	
I–11	Country-code indicator, outgoing half-echo suppressor required	Access to incoming operator (Code 11)	Note 1: First signal on an international link when it terminates in an international transit centre Note 2: Other than the first signal on an international link
I–12	Country-code indicator, no echo suppressor required	(*a*) Access to delay operator (Code 12) (*b*) Request not accepted	
I–13	Test call indicator (call by automatic test equipment)	Access to test equipment (Code 13)	
I–14	Country-code indicator, outgoing half-echo suppressor inserted	Incoming half-echo suppressor required	
I–15	Signal is not used	(*a*) End of pulsing (Code 15) (*b*) End of identification	

TABLE 5

Group II Forward Signals

Designation of the Signal	Meaning of the Signal	Remarks
II–1	Subscriber without priority	These signals are used solely for national working
II–2	Subscriber with priority	
II–3	Maintenance equipment	
II–4	Spare	
II–5	Operator	
II–6	Data transmission	
II–7	Subscriber (or operator without forward-transfer facility)	These signals are used for international working
II–8	Data transmission	
II–9	Subscriber with priority	
II–10	Operator with forward-transfer facility	
II–11	Spare for national use	
II–12		
II–13		
II–14		
II–15		

TABLE 6

Group A Backward Signals

Designation of the Signal	Meaning of the Signal
A–1	Send next digit ($n + 1$)
A–2	Send last but one digit ($n - 1$)
A–3	Address-complete, change-over to reception of Group B signals
A–4	Congestion in the national network
A–5	Send calling-party's category
A–6	Address complete, charge, set-up speech conditions
A–7	Send last but two digit ($n - 2$)
A–8	Send last but three digit ($n - 3$)
A–9	Spare for national use
A–10	
A–11	Send country-code indicator
A–12	Send language or discriminating digit
A–13	Send location of outgoing international R2 register
A–14	Request for information on use of an echo suppressor (is an incoming half-echo suppressor required?)
A–15	Congestion in an international exchange or at its output

further below. Signals I–1 to I–10 are numerical signals, which are transmitted to indicate

(*a*) the address (country code and national significant number) of the called party,

(*b*) the language digit or discriminating digit, when the call is originated by an international operator or subscriber, respectively, and

(*c*) the location of the outgoing international R2 register in response to successive backward signals A–13.

Signal I–11 is a non-numerical address signal, whose meaning is dependent on its position in the sequence of address signals. When transmitted to an international transit exchange as the first forward signal, it indicates that: a country code will follow; the call requires echo suppressors; an outgoing half-echo suppressor has to be inserted. The use of this signal is subject to bilateral agreement in international working. When preceded by a language digit, it indicates the address of a code 11 incoming-operator's position.

Signal I–12 is also a non-numerical address signal whose meaning is dependent on its position in the sequence of address signals. When transmitted to an international transit exchange as the first forward signal, it indicates that a country code will follow and the call does not require insertion of echo suppressors. When preceded by a language digit, it indicates that the call must be routed to a code 12 operator's position. This may be to a particular group of operator positions, or to a particular operator, depending upon the digits that follow the signal I–12. When an outgoing international R2 register receives backward signals A–9 or A–10, which are for exclusive national use, or signal A–13 to which a response cannot be made, signal I–12 is transmitted to indicate that the request is not accepted.

Signal I–13 indicates a test call. When transmitted as the first forward signal, it occupies the position of the language or discriminating digit, and is followed by a second signal I–13, 2 address digits and signal I–15.

Signal I–14 is a non-numerical signal, whose meaning is dependent on its position in the sequence of address signals. When transmitted as the first forward signal to an international transit exchange, it indicates that: a country code will follow; the call requires echo suppressors; the outgoing half-echo suppressor has been inserted. In response to backward signal A–14, signal I–14 indicates that an incoming half-echo suppressor is necessary.

Signal I–15 indicates the end of a sequence of forward inter-register signalling in semi-automatic working, and the termination of the transmission of the sequence identifying the location of the outgoing international R2 register.

Group II Forward Signals

Table 5 shows Group II forward signals, which are calling-party-category signals sent in reply to backward signals A–3 or A–5. Signals II–7 to II–10 are used solely for international working, use of signal II–10 being subject to bilateral agreement. The remainder of the Group II signals apply only to national working.

Group A Backward Signals

Group A backward signals are used to acknowledge Group I forward signals and, under certain conditions, Group II forward signals. Group A signals also convey signalling information, as shown in Table 6, and as explained further below. In using signals A–1, A–2, A–7 and A–8, the digit *n* is assumed to be the latest address signal sent.

Signal A–3 indicates that the incoming R2 register in the destination country has received sufficient address information, and is ready to transmit a Group B signal to convey information relating to the condition of incoming exchange equipment or the called-party's line. This signal may be transmitted as a pulsed signal.

Signal A–4, which may also be sent as a pulsed signal, indicates congestion in national links, congestion in selection stages of terminal national or international exchanges, and time-out or abnormal release of an R2 register.

Signal A–6 indicates that the incoming terminal R2 register has received sufficient address digits and a Group B signal will not be sent. The call must be charged on receipt of the answer signal. This signal may be transmitted in pulsed form.

Signal A–11 is used in international transit calls only, in acknowledgement of any forward signal, to request transmission of a country-code indicator signal.

Signal A–13 requests, digit by digit, the country code and, possibly, the area code of the exchange where the outgoing international R2 register is located.

Signal A–15, which may also be transmitted as a pulsed signal, indicates: congestion on international links; congestion in selection stages at an international transit exchange, at a terminal international exchange or its outgoing links; time-out or abnormal release of an R2 register.

Use of Signals A–2, A–7 and A–8

One of the backward signals A–2, A–7 or A–8 may be sent by an incoming international R2 register in the destination country when the outgoing national link uses the R2 system with integrated end-to-end signalling. The backward signal to be sent, before register release and switch-through of the speech path, is determined from knowledge of the first address digit that the following national exchange requires; if necessary, signal A–1 or signal A–12 can be used for this purpose. When the address digit currently being received by the incoming international R2 register is the digit required by the following exchange, switch-through can occur without transmitting a backward signal.

Use of pulsed backward signals

Under certain conditions, it may be necessary to depart from the compelled inter-register signalling mode by sending pulsed signal A–3, A–4, A–6 or A–15 without a forward signal being received. Typically, this can occur when the incoming R2 register, after acknowledging a forward signal, is unable to complete the call (say, due to congestion), and the next forward signal does not appear on the circuit.

The duration of the pulsed backward signal must be 150 ± 50 ms, and the minimum delay between the end of transmission of the last signal in the compelled sequence and the sending of the pulsed signal is 100 ms.

On recognition of the pulsed backward signal A–3, the outgoing R2 register transmits a Group II forward signal, which is acknowledged by the incoming R2 register by transmission of a Group B signal. Recognition of pulsed backward signals A–4, A–6 and A–15 by the outgoing R2 register causes appropriate dismissal of the outgoing R2 register, without transmission of a forward signal.

Group B Backward Signals

Group B backward signals acknowledge Group II forward signals and are always preceded by the signal A–3, which indicates that the incoming R2 register has received all the required Group I forward signals. As detailed in Table 7, Group B signals also convey information about the condition of the switching equipment in the incoming exchange, or about the condition of the called-party's line.

The outgoing international R2 register can work directly into a distant national network that has allocated national meanings to spare Group B signals B–1, and signals B–9 and B–10. When these signals are received by the outgoing international R2 register, they are interpreted as signals B–6 and B–2 respectively. Signal B–6 indicates that the called line is free and the call should be charged. Signal B–2 indicates that the call cannot be set up and no other Group B signal is applicable. In general, this signal indicates a ceased number, but the required party can be reached by another number.

Signal B–7 indicates that the called-party's line is free, but the call should not be charged on answer. By using this signal, non-chargeable calls can be indicated without transferring no-charge information by line signals. Where no agreement on non-chargeable calls exists, this signal is interpreted as signal B–6 by the outgoing international R2 register.

TABLE 7

Group B Backward Signals

Designation of the Signal	Meaning of the Signal
B–1	Spare for national use
B–2	Send special information tone
B–3	Subscriber's line busy
B–4	Congestion (encountered after change-over from Group A signals to Group B signals)
B–5	Unallocated number
B–6	Subscriber's line free, charge
B–7	Subscriber's line free, no charge
B–8	Subscriber's line out of order
B–9	Spare for national use
B–10	Spare for national use
B–11	Spare for international use
B–12	Spare for international use
B–13	Spare for international use
B–14	Spare for international use
B–15	Spare for international use

CALL SET-UP PROCEDURE FOR INTERNATIONAL WORKING

Fig. 3 illustrates a typical signalling sequence for setting up a subscriber-originated call, via an international transit exchange, to a free subscriber's line in a destination country.

On seizure of the outgoing circuit to the international transit exchange, the outgoing international R2 register sends signal I–12 to indicate that country-code digits will follow

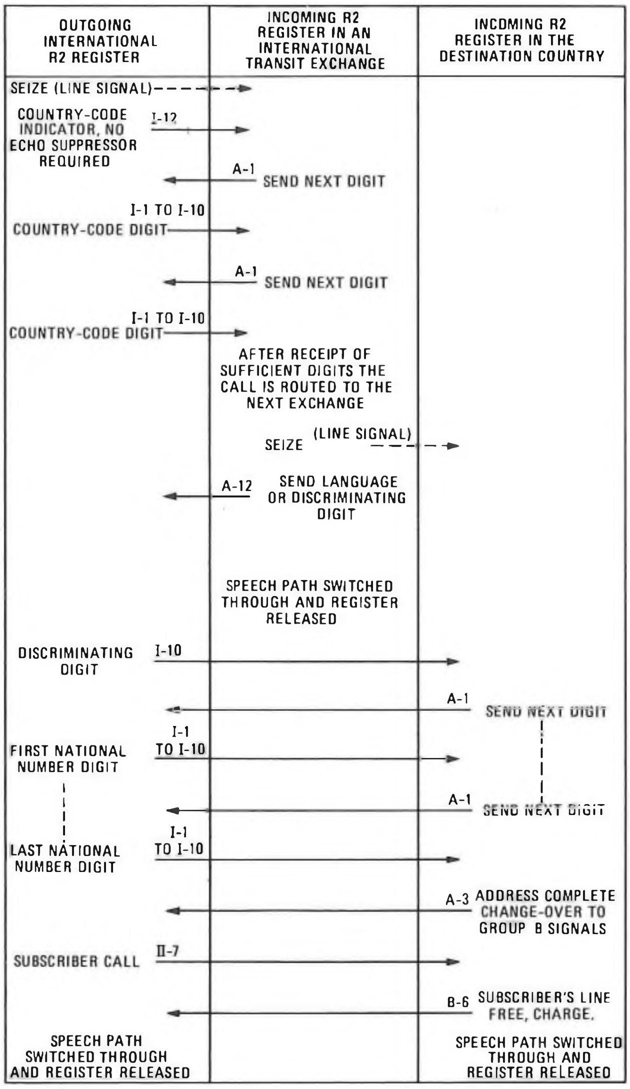

FIG. 3—Sequence of signals for a typical international transit call using R2 signalling

and that no echo suppressor is required. The international transit exchange register acknowledges receipt of signal I–12 by returning signal A–1, which requests transmission of the first country-code digit. The outgoing international R2 register sends this digit, which is acknowledged by backward signal A–1 to request the next country-code digit.

The international transit exchange equipment examines the received address digits and determines when sufficient digits have been received to route the call to the destination country. A line *seizing* signal is then sent to the destination country, and backward signal A–12 is sent to the outgoing international R2 register in acknowledgement of the second country-code digit and to request the language or discriminating digit.

At this stage, the international transit register releases and switches the speech path through to the selected outgoing circuit to the destination country. Consequently, the discriminating digit (signal I–10), sent by the outgoing international R2 register, is received by the incoming R2 register in the destination country. The acknowledgement signal A–1 is sent by the incoming register in the destination country; this and subsequent backward signals A–1 request the significant national number digits of the called subscriber. When sufficient digits have been received, the incoming register in the destination country sends backward signal A–3 to inform the outgoing register that the address is complete and that a Group B signal will follow to indicate the condition of the called-party's line. The outgoing international R2 register then responds by transmitting signal II–7, to indicate that the call was originated by a subscriber. Backward signal B–6 is then returned by the incoming R2 register to complete the compelled signalling sequence; this indicates that the called-party's line is free and that the call must be charged on answer. The incoming R2 register is then released and the speech path is switched through. On recognition of the last backward signal B–6, the outgoing international R2 register is released with switch-through of the speech path.

APPLICATION AT UK ISCs

The requirement to use outband signalling on international circuits, incurred by introduction of the R2 system, has necessitated development of new channel translating equipments (CTEs) by the British Post Office (BPO). Although similar equipment was already in use in the national BPO network for Signalling System AC No. 8, this equipment did not provide all the requirements specified for the R2 system. In addition, adjacent-channel interference problems, imposed by use of outband signalling, required development of through-group filter and audio high-pass filter equipments.

Control of line signalling between CTEs is vested in the line relay-sets, and conveyed to and from the CTE by leads designated by the letters *E* and *M*. Referring to Fig. 2, forward line signals are dependent upon earth or disconnect conditions applied to the M lead by the outgoing relay-set. These signals are received by the incoming relay-set via the E lead. Similarly, backward signals, applied to the M lead by the incoming relay-set, are received by the outgoing relay-set via the E lead.

Facilities are provided on the CTE to allow the option of setting the send and receive signalling channels such that the tone sent to, and received from, line can be signalled by earth or disconnect conditions on the E and M leads. E-lead and M-lead signalling at Mollison International Switching Centre (ISC)[2] uses the opposite convention to that used at Mondial ISC[3].

At UK ISCs, E and M leads between line relay-sets and CTE are connected by cables separate from those used to connect the speech circuits. This is to minimize interference effects on the speech pairs. Further precautions to reduce interference to other circuits due to inductive disturbances are provided by noise-suppression filters. At Mondial ISC, the line relay-sets are fitted with a series resistor and shunt capacitor connected to the M lead. Noise-suppression filters are not provided in relay-sets at Mollison ISC.

E-lead noise-suppression filters, similar to those used in relay-sets at Mondial ISC, are provided in the CTE at both ISCs.

CONCLUSION

The CCITT R2 signalling system has evolved since its conception in the 1950s to become a major international and national system in use, or planned for use, in many countries throughout the world. Within Europe, it has largely superseded the earlier CCITT No. 4[4] system for signalling on new international circuits. In the UK, the national inter-register signalling system based on the R2 system has been designated *Signalling System MF 6*.

Studies by CCITT and CEPT are continuing to update the system specification, especially the maintenance and testing aspects. Other items currently under investigation include the possible use of the system on domestic and international satellite circuits, and on the growing network of submarine cables equipped with channels having a bandwidth of 3 kHz.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to colleagues in the BPO Telecommunications Development Department, for their helpful advice given during the preparation of this article.

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Research at Martlesham

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UDC 62.001.007

This article was written as an introduction to the first issue of the Post Office Research Review: a new publication intended to give brief technical descriptions of some of the more interesting projects in hand at the British Post Office Research Centre, Martlesham Heath.

INTRODUCTION

"Research" means different things to different people, from cosmological speculation to doorstep interview. Our work is in the middle of this range: it supports the vast high-technology enterprise of British Post Office (BPO) Telecommunications and assists in the automation of the mail service. It is strictly purposeful and commercially oriented within the appointed domain of a Public Corporation. The objective is better service at lower cost to our customers—the public.

At one end of the range we engage in directed basic research, often probing far into unexplored territory in search of solutions to practical problems, or of understanding which will allow effective exploitation of new phenomena. The academic pursuit of knowledge, however intriguing, we leave to its proper sphere—the Universities.

The other end of the range takes us into the middle ground between research and development—conventionally bounded by demonstration of practical feasibility but usually stopping short of the prototype and field-trial stages.

We do not work in isolation of course, and we acknowledge with pleasure and gratitude the stimulating and rewarding exchanges with workers in Universities, Government Laboratories and Industry, both at home and overseas. This is part of the international freemasonry of research. We also supplement our own resources more formally by research and development contracts.

SCALE OF EFFORT

To put our effort in perspective, the annual Research Department expenditure of £14·5M represents a charge of about $\frac{1}{4}$ of one percent on the capital assets of BPO Telecommunications, or $\frac{1}{2}$ of one percent of income. In staff terms it means one professional engineer solving difficult field problems, exploring new ideas, or seeking new applications of technology to provide better and cheaper service, for each £10M worth of plant.

There are 1700 staff employed at the Research Centre; of these, 600 have a first-class honours degree and 190 have a higher degree; 200 members of the staff are corporate members of a professional institution. Included in the total complement are 670 staff of the engineering, technical and allied grades.

The BPO is a very big purchaser of capital goods, spending large sums of public money and bidding for a substantial part of the national productive effort. We at Martlesham strive to keep abreast of new technologies, processes and products and be ready always to advise on technical merit, value for money, durability and reliability.

† Mr. Ayers was a Deputy Director at the BPO Research Centre until his recent retirement

INTERNATIONAL ACTIVITIES

Telecommunications is a world-wide service. Technology has provided the means—radio, satellites and undersea cables—but the complex organization that enables a London businessman to dial directly his agent in Melbourne is only brought about by patient and dedicated international cooperation between administrators and engineers under the aegis of the organs of the International Telecommunications Union. We play a large part in this work, both in direct technical support and in the informal background exchanges with engineering and scientific colleagues that help to smooth the path across the conference table. Within the technical committees, an Administration's influence is directly related to the energy displayed by its expert delegates and the standing they command in the eyes of professional colleagues.

MANAGEMENT OF RESEARCH

Our applied research is geared to the needs of an active, growing and evolving business. Priorities are thus constantly changing against a background of demand always exceeding supply. In the interests of effective progress, research projects must be cushioned in some measure from the more transient fluctuations of the market-place, though reserves must always be available for "fire-brigade" activities. Nevertheless, our research programme must be continually remoulded to keep it in step with business needs; unsuccessful or superfluous projects must be weeded out and effort redirected to new lines, while holding a balance between short-term needs and laying foundations for the future.

The main programme is assembled annually as a collection of budgetted projects, selected in round-table discussions among sponsors competing for available resources. Most formal sponsorship arises from operational interests, though research and development itself sponsors a small proportion of exploratory studies which provide the seed for innovation. Operational need is the heaviest factor, but continuity to avoid fragmentation of effort and the availability of appropriate skills must also receive due weight.

A traditional line-management structure carries the responsibility for maintaining and administering the various specialized "resource centres"—groupings of staff, equipment, laboratory and office accommodation etc.—which together constitute the effort, skill and capability of the Research Centre. Orthogonal to this is a project-management structure with a project director and project manager assigned to each project in the programme, responsible for both technical and financial control and for close liaison throughout with the sponsors. They have to bid for specific allocations of resources from the resource centre managers. The structure is common to the whole of research and development—not solely the Research Centre—and project effort may be culled from anywhere in this area. The dual management structure is parallelled by dual budgetting, the 2 strands being reconciled, of course, in the overall programme.

AREAS OF STUDY

Though the spectrum of work at the Research Centre is wide and constantly changing in detail, some broad groupings can be seen, related to the underlying purpose of the Centre. About half our effort goes on engineering systems research, to sustain existing equipment, to evolve new systems to replace obsolete ones, and to explore technologies that will provide the next generation. Within this grouping the main areas are transmission systems, switching and signalling, and customer equipment. The balance of effort is gradually shifting away from the first of these, which has been well served by research. Another quarter of our effort is devoted to specialized support in the physics and chemistry areas (for example on materials and devices) and a further quarter goes to general support—mathematics, computing, workshops, clerical and administrative services.

Challenges abound in an organization whose interests range from cable ships to computers, from facsimile to fibres and from switching to satellites. Versatility is our watchword and variety our privilege. Life is rarely dull at Martlesham.

A Computer Aid to Junction Network Planning

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UDC 621.315 : 681.31

This article describes the use of a computer system that relates forecasts of junction network circuit requirements to a record of existing and planned line plant to produce an output that indicates future line plant shortages, thus enabling new plant requirements to be determined. The computer system is known as the CJP2 system. Circuit forecasts are input to the CJP2 system from another computer system that contains information relating to the annual schedule of circuit estimates. In the CJP2 system the junction circuit requirements are related to the availability of plant by comparison with a manually input circuit-routing file which remains under the control of the junction-network planner. The circuit routing information is also used to provide an output for circuit provision engineers; thus assisting in keeping circuit provision in step with planning aims.

INTRODUCTION

The planning of additional line plant to meet the needs of the British Post Office (BPO) junction network[1,2] is the responsibility of Telecommunications Regions. The line plant used is, principally, audio junction cables, cable ducts, pulse-code modulation (PCM) systems and audio transmission equipment, for which the total annual expenditure by the BPO is about £45M in direct costs. The procedures used by Telecommunications Regions to plan the provision of such line plant can be broadly divided into 3 categories: identifying where shortages of plant will occur in the future, selecting the most economic means of relief, and detailing the work that has to be carried out to provide the new plant. The first 2 activities are known as *network planning* and the third as *works planning*.

A computer system is used to assist in the network planning process; in particular to identify areas of possible line plant shortages. The computer system used is named *CJP2*.

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THE NEED FOR A COMPUTER-BASED SYSTEM FOR NETWORK PLANNING

Until the 1960s the planning of junction line plant was fairly straightforward, and audio cables with 0·9 mm diameter conductors met almost all the circuit-provision requirements. However, during the 1960s and early 1970s the availability and use of junction line plant changed dramatically; cables having 0·63 mm diameter conductors were introduced, and 24-channel PCM systems were installed in the junction network. The use of smaller-conductor cables and the need to improve circuit transmission performance increased rapidly the use of low-cost 2-wire repeaters. Crossbar and electronic-type telephone exchanges were being introduced, thus increasing the varieties of signalling equipment which had to work in conjunction with the line plant. With these extra complexities, a need for computer assistance to inter-relate the various planning requirements became apparent. Studies were first carried out by the Midlands Telecommunications Region and a computer system called *CJP1* was used by them in the late 1960s. The *CJP2* computer system was developed from the *CJP1* system by Telecommunications Headquarters for use by all Telecommunications Regions. *CJP2* has now been in widespread use for at least 3 years and in some Regions since 1972.

OBJECTIVES OF THE CJP2 COMPUTER SYSTEM

The principal objective of *CJP2* is to indicate to the junction network planner where future shortages of plant will occur; thus enabling relief measures to be planned in sufficient time to meet the shortage.

Another objective is to improve the co-ordination of 5 related functions of junction-circuit provision; these are

(*a*) audio junction cable planning,
(*b*) audio transmission equipment planning,
(*c*) PCM system planning,
(*d*) exchange signalling equipment planning, and
(*e*) circuit provision.

All these functions can be more easily and economically co-ordinated if they follow a common plan of plant utilization, and this can be achieved by use of the information provided by the *CJP2* computer system.

ESTIMATE OF THE FUTURE CIRCUIT REQUIREMENTS

In a system for identifying plant shortages it is necessary to have an estimate of future circuit requirements which, by means of specified routings, can be related to plant availability. In the BPO, an annual estimate is made of the public traffic circuits required for 5 years ahead. This forecast is known as the *annual schedule of circuit estimates* (ASCE). The ASCE information is held on file in a computer system which provides an input to the *CJP2* computer.

COMPUTER INPUTS

Data is input to the *CJP2* computer to create plant and routing files. In addition, an input is required to provide an interface between the ASCE and *CJP2* computer systems to enable circuits to be related to their routings; this input is called the *routing file-ASCE linkage*.

The junction network planner prepares inputs for the plant file, routing file and the routing file–ASCE linkage on specially-designed data documents. These documents are sent to a data conversion centre for the information to be transferred to punched cards and subsequently to magnetic tape. The information is retained on magnetic tape and can be used each year with new circuit quantities taken direct from the ASCE. It is necessary to update the information when changes take place to plant availability and circuit routings, and when new traffic routes appear in the ASCE.

PLANT FILE

The plant file is constructed in terms of *links* and *arcs*. A link indicates that 2 points are connected by line plant. An arc represents a particular plant type; for example, 0·63 mm cable pairs loaded with 88 mH coils at 1·83 km intervals, 0·9 mm unloaded cable pairs, PCM channels or PCM system bearer pairs. Fig. 1 shows an example of links between telephone exchanges. A simplified example of typical information contained in the computer plant file is shown Table 1.

A link may be made up from one or more arcs, and audio arcs can comprise more than one cable provided that each has similar physical and electrical characteristics. It is also possible that changes may occur in plant capacity during any year within the 5 year period covered by the ASCE; for example, due to cable pair rearrangements or the provision of new plant.

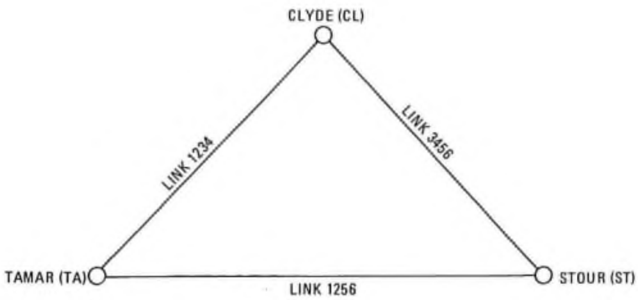

FIG. 1—Link diagram

ROUTING FILE–ASCE LINKAGE

Data relating to circuit estimates is obtained from the ASCE computer and input to the *CJP2* system. Circuits with common physical routings and electrical requirements are grouped together and allocated a routing file number. The routing file number relates to an entry in the routing file that describes how the circuits are routed over the links and arcs.

The type of information brought forward into *CJP2* from the ASCE computer system is shown in Table 2. The entries

TABLE 1

Example of Plant File Content

Link	From	To	Arc Number	Cable Number	Cable Pair Capacity	Loading (mH)	Spacing (km)	Length (km)	Diameter (mm)	Existing Private and Miscellaneous Circuits
1234	CL	TA	1 1	CJ1879 CJ2400	160 122	88 88	1·83 1·83	13·14 13·06	0·63 0·63	17 7
1256	ST	TA	1	CJ483	108	88	1·83	18·57	0·9	5
3456	CL	ST	1 2	CJ2364 CJ527	60 28	88 Unloaded	1·83 	5·91 5·90	0·63 0·9	10 15

CJ: Junction cable designation

TABLE 2

Data From ASCE Computer System

Circuits Between		Type of Circuit	ASCE Entry Number	Component Indicator (Note 1)	Circuit Requirements (Note 2)				
Exchange 1	Exchange 2				1978	1979	1980	1981	1982
Clyde	Tamar	Level 9	462500	O	37	40	43	47	51
		—	462500	I	81	86	96	104	114
		Level O Coin-Box	462501	O	5	5	5	6	6
		Level O Ordinary	462502	O	31	34	37	40	44
		Level 1	462503	O	15	16	17	19	20
Stour	Tamar	Level 9	462277	O	23	25	27	30	33
		—	462277	I	29	31	33	36	39
		Level O Coin-Box	462278	O	6	7	7	7	8
		Level O Ordinary	462279	O	19	20	22	24	26
		Level 1	462280	O	6	7	7	7	8

Note 1: The component indicator (O—outgoing, I—incoming or B—bothway) relates to the direction of circuit operation referred to exchange 1

2: The circuit numbers are total requirements in each year and not added growth

TABLE 3

CJP2 Routing File-ASCE Linkage

CJP2 Routing File Number	ASCE Entry Number	Component Indicator
4567	462500	O
	462500	I
	462501	O
	462502	O
	462503	O
4568	462277	O
	462277	I
	462278	O
	462279	O
	462280	O

in the ASCE are uniquely identified by a 6-digit ASCE entry number and a component indicator that indicates the direction of circuit operation (that is, O for outgoing, I for incoming and B for bothway).

The ASCE entry number and the component indicator are related to a *CJP2* routing file number. Table 3 shows how these are related to provide the computer input for the routing file–ASCE linkage.

ROUTING FILE

For each routing file number, the routing file states how the circuits are to be routed over the links and arcs. The circuit numbers can be divided, in percentage terms, between different paths. (A path is a specified physical routing between 2 points.) Up to 7 different paths can be catered for, and each path may consist of up to 5 link/arcs in tandem. When a path includes either a 2-wire or a 4-wire repeater, the routing file holds details of the repeater type and its location. A maximum number of circuits per path can be quoted, and a facility is provided to show different percentage divisions between paths in each of the 5 years under consideration.

An example of a simplified version of the routing file information provided to the computer is shown in Table 4. The planning engineer determines the routings that make the best use of available plant.

PROCESSING

The *CJP2* computer system is operated as a magnetic-tape batch process on an ICL System 4/70 computer, and all the programming was carried out by the BPO Data Processing Service. Files are created (and outputs produced) on a Regional basis; the outputs are provided in the autumn of each year. Extensive error-checking facilities are included in the computer system which give fault indications when the input information does not comply with certain rules.

PLANNING OUTPUT

For every arc, an output is provided that gives details of

TABLE 4

Routing File

Routing File Number	Circuits		Path Number	Percentage of Circuits on Path	Link/ Arc (Note)	Link/ Arc (Note)	Repeater Type	Sited At
	From	To						
4567	CL	TA	1	100	1234/1		Negative Impedance	TA
4568	ST	TA	1	67	1256/1			
			2	33	3456/1	1234/1	Hybrid	CL

Note: Up to 5 link/arcs in tandem are permitted

LINK 1234 — CLYDE (CL) – (TA) TAMAR

ARC	CABLES IN ARC	CABLE CAPACITY	LOADING MH	SPACING KM	LENGTH KM	DIAMETER MM	TRAFFIC ROUTINGS USING THIS ARC	ROUTE/ PATH	% ON ARC	EXISTING	ASCE FIGURES FOR 1978	1979	1980	1981	1982	ESTIMATE FOR 1984	1987	EXHAUST YEAR
1	CJ 1879	160	88	1.83	13.14	0.63	CL–TA	4567/1	100		169	181	198	216	235	268	318	
	CJ 2400	122	88	1.83	13.06	0.63	ST–TA	4568/2	33		27	30	32	34	38	44	52	
							MISC CH/PRS	K = 0·2		24	39	42	46	50	55	63	74	
								ARC DEMAND			235	253	276	300	328	375	444	
								ARC CAPACITY			282	282	282	282	282	282	282	
								ARC BALANCE			47	29	6	–18	–46	–93	–162	4

MISC. CH/PRS: denotes miscellaneous circuits (K factor is 0·2)

FIG. 2—Planning output

ROUTING FILE NUMBER 4568 — ASCE ROUTE IS STOUR–TAMAR — TRANSMISSION LIMIT IS 4·5 dB

A LEVEL	B LEVEL	AUTHORITY 1977/1978 O/G	I/C	B/W	INTERMEDIATE REQUIREMENTS O/G	I/C	B/W	REMARKS (YEAR 1 NOTES)
SECTION 2								
L 9		23	29	0				
L 0 CCB		6	0	0				
L 0 ORD		19	11	0				
L 1		6	0	0				

(Space for written comments about equipment availability)

ROUTING PATTERN AND CIRCUIT QUANTITIES

	1977/78 % CIRCUITS	1978/79 % CIRCUITS	1979/80 % CIRCUITS	1980/81 % CIRCUITS	1981/82 % CIRCUITS					
PATH 1	67% = 56	67% = 60	67% = 64	67% = 70	67% = 76	LENGTH (KM)	18·52	RES 1021	LOSS 4·27	
				LINK 1256 ARC 1		STOUR-TAMAR			CJ 483 0·90NL	
PATH 2	33% = 27	33% = 30	33% = 32	33% = 34	33% = 38	LENGTH (KM)	18·97 – 19·05	RES 2337–2346	LOSS 8·57	HYBRID AT CL
				LINK 3456 ARC 1		STOUR–CLYDE			CJ2364 0·63NL	
				LINK 1234 ARC 1		CLYDE–TAMAR			CJ1879 0·63NL	CJ2400 0·63NL

L—Level: O/G—Outgoing: I/C—Incoming: B/W—Bothway:
RES—Resistance: NL—Normal loading (88 mH at 1·83 km spacing)

FIG. 3—Routing output

the plant and the circuits using each arc. A simplified example of the planning output that would be produced for one of the arcs in the previous examples is given in Fig. 2; the 5-year ASCE forecast is included, and extrapolations are made for year 7 and a further optional year (year 10 in the example). An allowance is made for private and miscellaneous circuits by relating the number of such existing circuits to the number of traffic circuits at year 1 and producing a multiplying factor called the K factor. The K factor is then applied to all the forecast years to produce an estimate of private and miscellaneous circuits. A minimum value of $K = 0{\cdot}2$ is used. The circuit requirement for each year is totalled and subtracted from the plant capacity to show the resulting surplus or deficiency. The year of exhaustion is also shown.

At the end of the arcs forming a link, a link summary is provided and a link exhaustion year shown. For convenience, a listing is given of arcs and links exhausting at various years at the end of the output.

The planning output is used by the planning engineer as the basis of his investigations leading to proposed new schemes. In an ideal situation, sufficient plant would be available, or already planned, to carry all circuits up to the fourth year, and shortages would be shown in the fifth and subsequent years. In practice, shortages appear before the fifth year because of changes to circuit estimates or delays to planned plant. An advantage of the *CJP2* system is that a detailed check can be kept on the plans of previous years.

The planner will investigate arcs and links which exhaust at or before the fifth year and determine a strategy for relief. Proposals may involve respecifying circuit routings to make better use of existing plant, but when this is not possible new cables or PCM systems must be planned.

ROUTING OUTPUT

A printout is also produced which gives all the details of circuits and plant associated with a routing file number, and this output is provided to assist liaison between planning and utilization (circuit provision) groups. Fig. 3 shows a simplified example of the information which would be output for one of the routes considered in the previous examples. The top part of the output gives details of the ASCE circuits on that route number, and the lower part gives details of each path and the number of circuits to be routed on each of those paths. Path length, resistance and loss are calculated and, where appropriate, the position of repeaters is shown. When a circuit is to be provided, the printout is used to obtain the planner's recommended routing. Information relating to transmission equipment planning and signalling equipment planning is also obtained from this printout.

OPTIMIZATION OF ROUTINGS

The routing file data is undoubtedly the most important part of the *CJP2* system. A decision was taken that the routing information should be defined by the planner and input to the computer rather than programming the computer to produce the shortest or cheapest routings. There were several reasons for this:

(*a*) The junction network is dynamic, and the addition of new cables could invalidate automatically-derived routings. In practice, existing routings cannot easily be changed because circuit rearrangements are expensive. Manually-defined routings can take into account existing circuits as well as the best way to route new ones.

(*b*) Judged in isolation, an apparently cheapest or shortest routing does not necessarily produce the best network. Sometimes a planner deliberately chooses a longer routing to use plant that would otherwise lie idle, for instance if it had been provided for a forecast demand which had not materialized.

(*c*) A defined routing that will not change (or will only change under the control of the network planner) can be followed for other planning purposes. Thus, planners dealing with cables, PCM systems, audio transmission equipment and telephone exchange signalling equipment, and the circuit provision engineers, can all follow a common aim. Unified planning of this type can contribute large financial savings, although these are difficult to quantify. The general pattern that has emerged from the early stages of setting up the *CJP2* system is that Telecommunications Regions have adjusted the defined routings to optimize the use of the available plant and have thus reduced the amount of new provision.

STATISTICS

The *CJP2* system contains a wealth of data about the junction network. A recent development has been to copy the *CJP2* files to an IBM 370/168 computer and use the rapid access management information system (RAMIS) to provide interrogation facilities via a computer terminal. Statistics from this source are particularly useful to assist finance planning and to provide information for asset utilization studies.

THE FUTURE

The *CJP2* computer system has been in operation since 1972 and the computer used will be phased out in 1980. A replacement system, called *CJP3*, is to be provided on a new computer and the opportunity will be taken to introduce improvements and new facilities. These will probably include printouts designed to assist with transmission equipment planning and to specify line characteristics for the purpose of planning exchange signalling equipment. Greater emphasis will be put on PCM planning and also on the supply of information to mangement.

The detail held within the *CJP3* computer system will form an important basis for other computer systems at present in the feasibility study stage. One of these will allocate plant and print circuit-provision advices, and this system will be known as the *junction network utilization system* (JUNUS). This system will be based on a system already in use in the London Telecommunications Region[3]. For public traffic circuits, JUNUS will access the *CJP3* routing file to ensure that the planned routing is attempted first. Automatically-derived routings will be used for private circuits; such routings will be used for traffic circuits only when spare plant is not available on the planned routing.

Another computer-based system concerned with plant utilization records is proposed. This system (to be known as *PURE*), will hold detailed information of cable pair and PCM channel allocations and of circuit advices. This system will be closely linked with the JUNUS and *CJP3* systems.

If work on these systems progresses as expected then by the early 1980s an integrated junction network computer system will be available to assist with the planning, utilization and management of an important part of the telephone network.

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Book Review

Analogue and Digital Communication Concepts, Systems, Applications and Services. W. D. Gregg, PH.D. John Wiley & Sons Ltd. xix + 603 pp. 263 ills. £14·70; $25·25.

This book is written by a professor of the University of Texas. Its form, not surprisingly therefore, reflects a little of its antecedents. It is written as a textbook and, to quote from the preface, "is designed for junior and senior undergraduates—but the practising professional will also find it useful".

Part 1 deals with the concepts and theory of analogue systems, and Part 2 with those of digital systems. Each of the chapters generally has an introduction to the concepts, followed by a theoretical exposition, and concludes with exercise problems on the matters dealt with. The relevant mathematical formulae are presented but are not always derived, only the results being quoted.

The book is structured as for a series of lectures; for example, amplitude and angle modulation are dealt with in separate chapters, and the corresponding demodulation processes again appear separately. A better arrangement for the reader might have been to deal with modulation and demodulation for each process together. The author attempts to distinguish between quantized, unquantized and encoded signals on pp. 268–9, and the explanations are, as he implies, not particularly precise. Also, on p. 441, there is some confusion on the one hand between encoding aural information into 2400 bit/s data and, on the other, of the capability of transmitting 2400 bit/s over a telephone circuit.

Apart from blemishes of this type, the treatment is nevertheless logical, extensive and essentially mathematical. The amount of information on applications and services, however, is small. The value of the book to the professional is therefore likely to be as a reference on theory and not as a guide to current problems associated with the engineering of analogue and digital networks.

There are 8 appendices containing information that is, for the most part, fairly easily obtainable elsewhere; for example, trigonometrical identities, common Fourier transforms and Bessel functions.

The book is a work of some scholarship but seems to fall between being a textbook and reference book on the mathematics of communication. It will appeal to postgraduate students; as a reference for the practising engineer, it will have a limited application.

G. D. A.

A New Maintenance Aid for Repeater Stations

J. E. SPENCER, D. A. POTTER and A. J. GOFF†

UDC 621.395.724

The development of a new measuring set has made possible a new approach to taking measurements on frequency-division-multiplex transmission equipment. This article describes the measuring set and the method used to obtain access to the various test points on the equipment in Leicester/D telephone repeater station.

INTRODUCTION

The test equipment in common use for measurements on frequency-division-multiplex (FDM) transmission systems in British Post Office (BPO), repeater stations at present consists of a variable-frequency oscillator and a selective level-measuring set (SLMS). An SLMS is a direct reading decibelmeter that can be tuned to measure signals at particular frequencies. The SLMSs in common use have 2 calibrated dials, which are adjusted to select the desired frequency to be measured. The frequencies commonly measured are those corresponding to the group and supergroup pilots throughout the line-frequency spectrum, and the frequency is determined by reference to a line-frequency chart (A 458). The SLMS is normally mounted on a test trolley and moved around the station as required.

A new generation of SLMSs is now being supplied to the larger repeater stations, and one of these sets, the SLMS 3745A (Fig. 1), is described in this article. This SLMS has one major disadvantage: it is considerably larger and heavier than sets previously supplied and, with the associated equipment, created difficulties in mounting on the standard test trolley. This disadvantage made the new approach to transmission measurements necessary.

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Fig. 1—SLMS 3745A

TEST ACCESS ARRANGEMENTS

The use of test trunks in repeater stations is standard practice for audio applications, but has not been used for high-frequency (HF) applications because of the problems of frequency response and the risk of high tapping losses on circuits due to unterminated trunks being left connected. The access system described below is based on the test-trunk principle, but each trunk extends a test point on the particular equipment back to the SLMS and is individual to that test point; when not in use, the trunk is terminated by the correct impedance at the switching unit.

Fig. 2 shows the access system at present in use at Leicester/

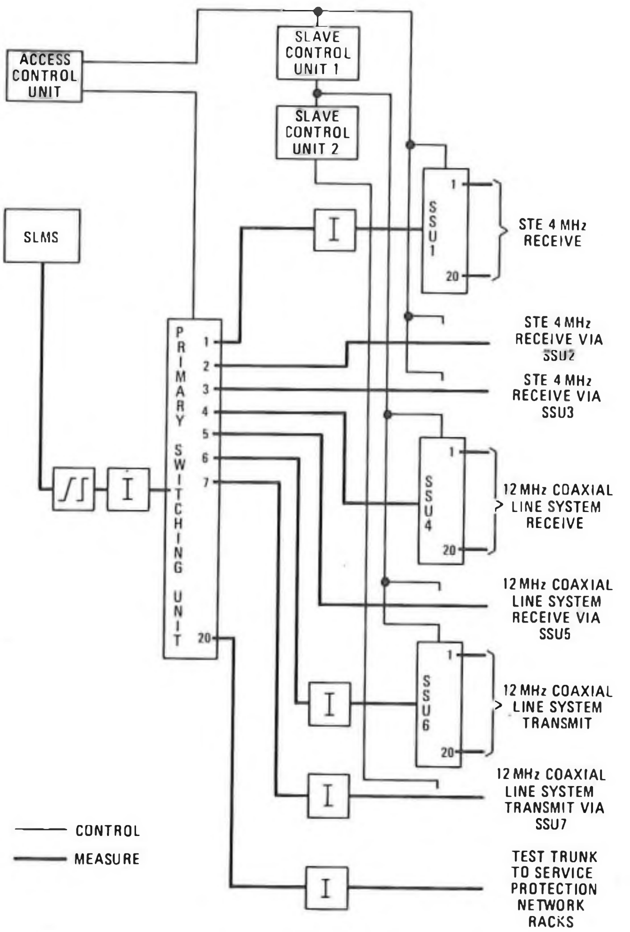

Fig. 2—Block diagram of access system

D telephone repeater station (TRS). The access system has a maximum capacity of 60 receive terminated hypergroups, each of 4 MHz bandwidth, and both the transmit and receive traffic of 40 coaxial line systems, each of 12 MHz bandwidth. Provision is also made for 3 test trunks. The access system uses 8 Switching Units 1003A (Fig. 3), one as a primary switching unit (PSU), and the remaining 7 as secondary switching units (SSUs). Three SSUs are used for 4 MHz access to terminated receive hypergroups, and 4 for access to 12 MHz bandwidth coaxial line systems. Attenuators are used to give suitable levels at the SLMS, and a 12 MHz equalizer compensates for high-frequency attenuation in the cable runs between the access system and monitoring points. The switching units are controlled by a digital access control unit (ACU), shown in Fig. 4, which also displays the code number of the selected input to the SLMS.

FIG. 3—Switching Unit 1003A

4 MHz Receive Hypergroup Access

The 4 MHz bandwidth, terminated hypergroup output is obtained from a hybrid unit, which is part of the normal receive traffic path of supergroup translating equipment (STE). This output is designed for extraction of both the 60 kHz national standard reference pilot and the 1552 kHz hypergroup reference pilot, and is normally cabled out to the supergroup distribution frame (SDF); the output is wideband and thus suitable for complete hypergroup observation. The nominal traffic level is −30 dBm† and the extraction points are jumpered at the SDF to appropriate inputs of SSU Nos. 1–3. The switching units are mounted on the SDF, as shown in Fig. 5. The output of each SSU is routed via a 3 dB attenuator to the PSU, thus making the traffic level at the PSU −33 dBm.

12 MHz Access, CEL 4000

The output of the 12 MHz bandwidth signal (three 4 MHz hypergroups) is obtained from the appropriate coaxial line system test point. The Coaxial Equipment Line (CEL) 4000 is the latest fully-transistorized system, and contained within the equipment are built-in hybrid units, both in the receive and transmit traffic paths. The outputs obtained from the hybrid units are wideband and suitable for monitoring purposes. The receive-traffic hybrid-unit output presents a nominal traffic level of −33 dBm and is cabled as required to SSU Nos. 4 and 5 and then to the PSU; the level of −33 dBm is retained. Transmit traffic via the hybrid unit is at a nominal level of −36·5 dBm and is cabled to SSU Nos. 6 and 7. The outputs of SSU Nos. 6 and 7 are presented to appropriate inputs of the PSU via a 1·5 dB attenuator, thus giving the level of − 38 dBm at the PSU.

† dBm—decibels relative to 1 mW

FIG. 4—Access control unit

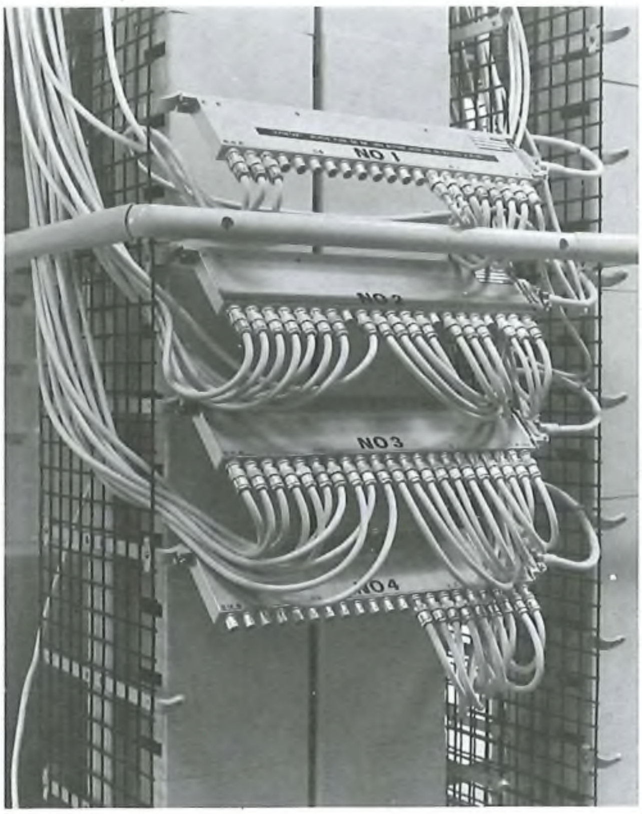

FIG. 5—Switching units mounted on SDF

12 MHz Access, CEL 1007

The earlier CEL 1007 is also a transistorized line system, but is not normally equipped with hybrid units suitable for traffic monitoring on either the transmit or receive traffic paths. It was therefore necessary to modify both traffic paths to include suitable hybrid units. A suitable hybrid unit, the Branching Unit 1001, was installed within the frame of the station cable equalizer card, in the transmit and receive traffic paths. There was ample room to accommodate the hybrid units within the cards, but because they had an insertion loss of 3·5 dB, the attenuators in the station cable equalizer cards were adjusted to make good the loss. Output levels are as before: the transmit traffic at −36·5 dBm and the receive traffic at −33 dBm. The outputs are cabled to the SSUs in a similar manner to the CEL 4000.

Equalization

Equalization is carried out using one 12 MHz equalizer; this is made possible by locating the SUs so as to keep all the cabling as equal in length as possible. In Leicester/D TRS, an additional distribution frame was used and positioned between the 3 suites of coaxial line systems, their monitoring points being cabled to this frame. SSU Nos. 4, 5, 6 and 7, together with the slave switching units are mounted on this frame (Fig. 6). The equalizer, together with its associated attenuator, is mounted on the SDF test rack, and adjusted to give a flat response and a total loss of 7 dB between the PSU and SLMS.

Nominal Levels at the SLMS

The nominal signal levels at the SLMS are as follows:

4 MHz receive terminated hypergroups	−40 dBm
12 MHz receive traffic at coaxial line systems	−40 dBm
12 MHz transmit traffic at coaxial line systems	−45 dBm
Test trunk loss	10 dB

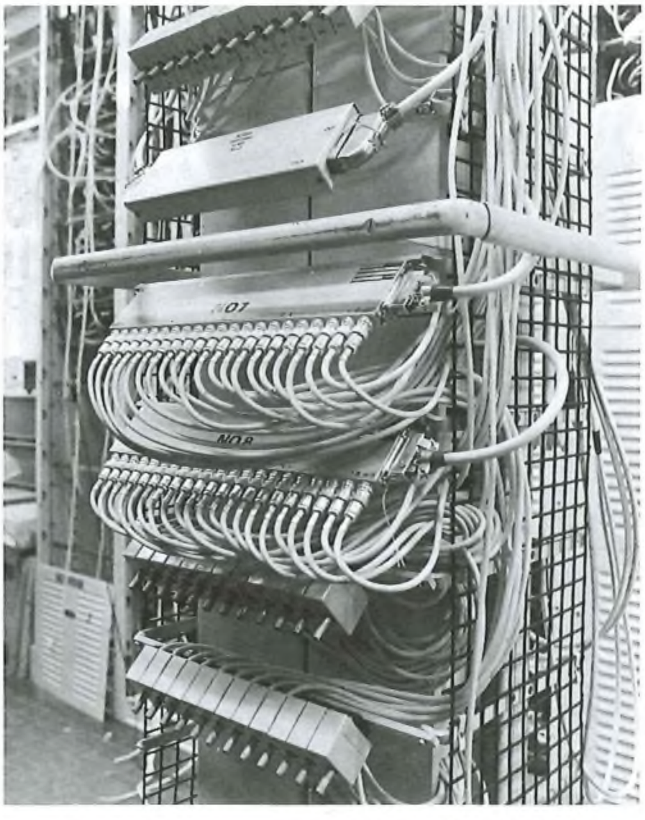

FIG. 6—Slave switching units

A level between −40 dB and −50 dB does not require the use of amplifiers, and allows the access system inputs to the SSU to be reduced in level by means of attenuators to reasonable working levels at the input of the SLMS. The levels are such that the range of measurements to be made on a channel within the FDM system is still above the noise threshold of the SLMS.

Test trunks are provided as shown in Fig. 2, a 3 dB attenuator being included in each path to give a total insertion loss of 10 dB. It was decided that the levels at the transmit and receive points should be different to prevent operator error.

Overall Performance Specification

The overall performance specification of the access circuits is as follows.

Spread, coaxial line system to SLMS:	within ±0·25 dB
Crosstalk ratio:	greater than 85 dB

ACCESS CONTROL UNIT

Originally, the switching units were to be controlled by a set of key switches, but it was decided that a digital keyboard would be a far more convenient method of selecting the required input to the SLMS. Therefore, a digital control unit was designed to operate the switching relays. A 4-digit code is allocated to each hypergroup such that, on entry of a particular code, the relevant relays operate to connect the associated hypergroup to the SLMS. A 4-digit code is required as there are 20 inputs on each switching unit and 2 digits are needed to define a particular input of a switching unit: the first 2 digits select the required input of the primary switch; the second 2 digits select the required input of the secondary switch. This method of control gives a 20 × 20 matrix; this allows a maximum of 400 valid codes and enables up to 400 hypergroups to be selected with a fully-equipped system.

The basic operation of the control unit can be shown with the aid of the simplified block diagram shown in Fig. 7. The keyboard has 11 keys: 0 to 9 and CLEAR ENTRY (CE); the CE key is depressed before entering a code to ensure that the control circuit is ready to accept the data. Pressing the first digit key causes data to enter the first store under the command of the control circuit. The first store is capable of storing 3 digits, and so the first 3 digits entered remain in the first store until the fourth digit is entered. When the fourth digit key is depressed, the control circuit causes the data in the first store to be transferred to the second store, along with the fourth digit. The data for the 4 digits is then held in

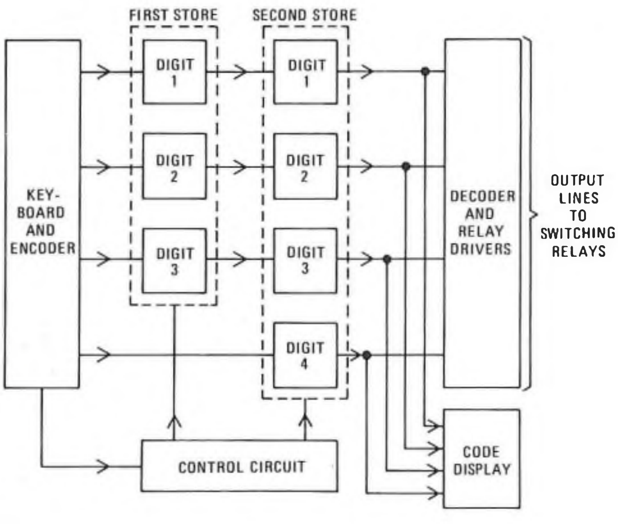

FIG. 7—Block diagram of control unit

the second store until another 4-digit code is entered. The use of 2 stores in this manner ensures that hypergroup switching occurs only after the full code for that hypergroup has been entered. Data held in the second store is then decoded to control the relay driver circuits to operate the relevant switching relays. An output is also taken from the second store to feed a circuit that gives a visual display of the code stored.

SLAVE UNIT

As the access control unit can operate a maximum of only 3 SSUs due to the current-handling capacity of the switching transistors, every additional 3 SSUs must be operated by a slave unit. The slave units are solid-state devices, having a high-impedance input and a low-impedance output.

SWITCHING UNITS 1003A

Switching Units 1003A are standard BPO stores items and have been specially designed for the access system at Leicester/D TRS by the Service Department of Telecommunications Headquarters (THQ). Each switching unit mounts horizontally on the standard distribution frame used in TRSs, and provides a total of 20 inputs, which are normally terminated internally in 75 Ω resistors. Each input port has associated with it a reed relay which, when energized, switches the input from the 75 Ω termination to the output of the switching unit; the reed relays are operated from a 28V DC supply. The inputs and outputs use BNC-type connectors.

SELECTIVE LEVEL MEASURING SET 3745A

The SLMS 3745A is a high-quality tunable power meter for use in the measurement of FDM systems and conforms to CCITT† recommendations; it consists of a tunable receiver, using a synthesized local oscillator controlled by a processor. A keyboard is used for measurements, these being in the form of one of the 3 standard FDM plans selectable. The SLMS can also be programmed to scan continuously any frequency bands, in any step size, within the frequency range of the instrument (1 kHz to 25 MHz). The level range of the instrument is +15 dBm to −125 dBm, and depends on the bandwidth in use. Power levels can be displayed in dBm or decibels relative to a reference level. The standard is derived from thermopile sensors, and autoranging attenuators and amplifiers limit the range of signals applied to these sensors. Before each measurement, a self-calibration sequence is carried out and any detected error is corrected in the final digital readout. The overall frequency accuracy quoted is $1 \cdot 5 \times 10^{-7}$ parts per year of the master-oscillator operating frequency of 10 MHz.

All entered program information and final measurement levels are digitally displayed, with additional information when channels are being investigated to indicate the identity of the sideband. Measurement limits can be set and the display shows any level found to be out of the preset limits; when in the scanning mode, the scanning sequence can be halted when an out-of-limits measurement is found, and an audible alarm can also be given if required.

When in the scanning mode, a visual display in *xy* co-ordinate form can be made available from the associated visual display unit. The unit will store up to 256 measurements on the presentation screen. Using the preset limit controls, a print-out of any level measured, which is found to be out of limits, can be obtained on the thermal printer unit. Thus, fault dockets can be made available to maintenance staff.

† CCITT—International Telegraph and Telephone Consultative Committee

OPERATION

Consider the need to measure the transmit group reference pilot of say the Birmingham–Leicester 950 to establish if the level is correct leaving the repeater station. From the station records, this particular group is found to be group 1 of supergroup 3 of the Leicester–Birmingham 1000 hypergroup. A chart is consulted, which gives the access code for the hypergroup as 0501. To measure at the TRAFFIC IN point on the 12 MHz system this code is keyed into the access control unit. The first 2 digits of the access control unit relate to the switching of the PSU only, while the second 2 digits control all the SSUs. Thus, if the first 2 digits selected are 05, then the sixth input to the PSU is switched to the output, all other inputs to the PSU remaining terminated in 75 Ω. The second 2 digits, 01, will switch input number 2 of all SSUs to the outputs. However, as the PSU has selected only the sixth input from SSU No. 7, only number 2 input of this switch appears at the output of the PSU and is presented to the SLMS. All other inputs to the PSU are terminated in 75 Ω. The SLMS is keyed with the relevant input information (that is, hypergroup 1, supergroup 3, group 1) and, as the information is keyed in, the figures are displayed on the light-emitting-diode (LED) arrays. The MEASURE key is depressed and the measured level and the frequency are also displayed on the LED arrays.

The power and flexibility of the SLMS are such that a comprehensive description or its potential uses cannot be given here; for this reason, only the simple measurement above has been described.

CONCLUSIONS

The new SLMS and its associated access system has provided a reliable, quick and accurate method of making measurements on FDM equipment in a repeater station. It will not completely replace the normal SLMS, but has made possible the ability to scan hypergroups on systems and obtain a print-out of all pilots that are out of limits, the average time taken to check all group pilots in a 12 MHz system being 3 min. The final outcome will be a new look at HF path surveillance and maintenance methods.

ACKNOWLEDGEMENTS

The authors are indebted to the help given by THQ Service Department (Sv 7.2.1), who were initially responsible for provision of the SLMS and the coaxial switches. The SLMS in use at Leicester/D TRS is the Hewlett Packard SLMS 3745A.

Optical-Fibre Transmission Systems: The Martlesham–Kesgrave–Ipswich Optical-Fibre Cable Installation

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The techniques adopted for installing and jointing optical-fibre cable for the Martlesham–Kesgrave–Ipswich feasibility trial are described.

INTRODUCTION

Earlier articles[1,2,3] have described the system operation aspects of the optical-fibre transmission system feasibility trials undertaken by the British Post Office (BPO) in the vicinity of the BPO Research Centre in Suffolk. This article describes the installation of the cable used for the 8·448 Mbit/s feasibility trial and of a similar cable containing a better quality fibre capable of supporting higher bit-rate transmissions. To date, 22 km of optical-fibre cable have been installed successfully in the existing duct network between the BPO Research Centre at Martlesham Heath and Ipswich.

CABLE DETAILS

Early in 1976, consideration was given to purchasing optical-fibre cable for installation in the existing BPO duct network as part of the exercise to establish the feasibility of installing and operating optical-fibre transmission systems in a typical engineering environment.

Two grades of optical-fibre were commercially available; each had a typical loss of 4·5 dB/km but had different bandwidth capabilities. For a 1 km length of fibre, one grade of fibre afforded a bandwidth that was not less than 200 MHz and the second grade of fibre afforded a bandwidth not less than 400 MHz.

A contract was placed with BICC for the supply of 21 km of 2-fibre cable. The contract was for 14 km of cable containing 200 MHz.km fibre and 7 km of cable containing 400 MHz.km fibre.

The 21 km of optical-fibre cable was to be used as follows:

(*a*) 6 km for installation between the BPO Research Centre, Martlesham and Kesgrave, and 8 km for installation between Kesgrave and the group switching centre at Ipswich; these cable sections (with bandwidth of 200 MHz.km) were planned to support the 8·448 Mbit/s optical-fibre transmission system feasibility trial.

(*b*) 6 km of cable (with bandwidth of 400 MHz.km) were scheduled to be installed between the BPO Research Centre and Kesgrave; this section of cable was planned to support the 140 Mbit/s optical-fibre transmission system feasibility trial. The remaining 1 km length of this type of cable was to be used on-drum for laboratory experiments.

The constructional details of the BICC 2-fibre cable are shown in Fig. 1. (The cable has the trade designation *PSP*, which is derived from the manufacturer's description of its construction—*plain*, *simple* and *practical*.) The cable comprises 2 parallel solid-steel strength members sheathed with polyethylene; between these strength members are 2 cavities each of which contains one fibre. The fibre was manufactured by Corning Glass Company and has a graded refractive-index profile, a nominal core diameter of 62·5 μm and a numerical aperture of 0·15. The weight of 1 km of the PSP cable is approximately 50 kg.

† Research Department, Telecommunications Headquarters

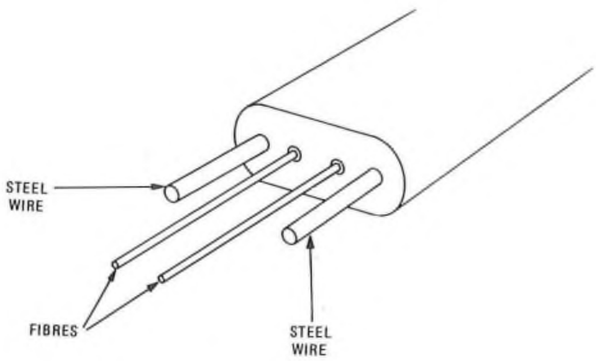


FIG. 1—PSP optical-fibre cable

CABLE ROUTE

Fig. 2 shows the route adopted for the feasibility trial. The cable route length between Martlesham Heath and Ipswich is approximately 11 km; the route was divided into 14 cabling sections of less than 1 km to facilitate the installation of the cable in 1 km lengths. The lengths of the 14 sections are detailed in Table 1.

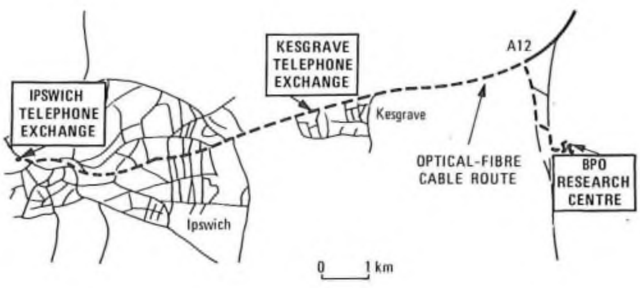


FIG. 2—Cable route Martlesham–Kesgrave–Ipswich

TABLE 1

Cable Section Lengths

Section	Section Length (m)	Section	Section Length (m)
1	728	8	821
2	668	9	803
3	870	10	875
4	860	11	799
5	865	12	863
6	739	13	888
7	592	14	914

A 0·5 mm diameter multipair metallic-conductor cable was included in the cable route to provide supervisory facilities for control and data collection. Because this cable could be used to provide an excellent indication of temperature stability, it was desirable that it be placed in the same bore as that proposed for the optical-fibre cable. Therefore, the task facing the planning and installation group of Colchester Telephone Area was the installation of 2 cables between Martlesham and Ipswich, one being a 20-pair copper-conductor cable and the other a 2-fibre optical cable. In addition, the second optical-fibre cable between Martlesham and Kesgrave was also to be installed, making a total of 20 km of optical-fibre cable. Since there was only one remaining cable length (1 km) available which was required for on-drum tests, it was imperative that no fibres were broken during installation.

Cable-route surveys revealed considerable variations in the construction of the duct routes. Four sections of the duct route involved the use of new, large multiway duct nests with considerable spare capacity, while the remaining 10 sections were old and very congested. Bore depth varied from 1–10 m and, although the route was generally straight, there were some tortuous sections. For instance, section 14, in the very centre of Ipswich, involved 10 changes of direction in excess of 45°.

While it was desirable to have an empty bore allocated for the purpose of a controlled experiment, it was particularly challenging to use bores already occupied. For the Martlesham–Kesgrave–Ipswich route, 10 of the sections involved occupied bores, and for the Martlesham–Kesgrave route, the bores in 3 sections were occupied.

PRE-TRIAL INVESTIGATIONS

During 1976, some installation and mechanical handling tests were undertaken by the BPO Operational Programming Department (OPD) at their trial grounds in Smallford, using 600 m and 300 m lengths of cable of the type to be used for the feasibility trial, but which contained no fibres. These dummy lengths, which could be joined to simulate a 900 m length of cable, were used to establish the tensions involved in the various duct conditions that were available at Smallford.

In addition, OPD cooperated with members of the Colchester Telephone Area and Research Centre staff in dummy installations on selected sections of the Martlesham–Kesgrave route. During the latter investigations, both mechanically-aided and manual installation techniques were undertaken, and estimates of cabling tensions were obtained by using various mechanical and electronic tensile transducers.

A conventional method of installing cable into an underground bore is to install a light-weight draw-rope which is then used to pull the cable into position. The draw-rope may be put into position by one of the 2 following principal methods:

(*a*) A rod may be pushed into a duct from point A to point B, the draw-rope is tied to the rod at point B, and the rod and rope are pulled back to point A. Two types of rod are available: one is made-up by screwing together many short lengths of rods[4] and is manually installed; the other is a long continuous rod[5] that may be injected by mechanical means from a standard BPO rodding and light cabling vehicle.

(*b*) Two mechanically-coupled bags are inflated and deflated alternately by air from a compressor and the bag assembly is forced along the bore, pulling a draw-rope. This facility, called the *duct motor* method, is also available on a BPO rodding and light cabling vehicle.

Using these methods, the number of twists incurred between an installed draw-rope and already existing cable were observed. The continuous-rod method produced significantly less twisting of the draw-rope than the duct-motor method. Therefore the rod method was used subsequently for the installation of draw-ropes for all optical-fibre cable.

During trials with the duct motor, bags were punctured in a particular cable section and, since there was the possibility that some of the ducts may have been badly damaged, the services of the London Telecommunications Region (LTR) tunnel-investigation group were obtained. In their investigations, the LTR group used a television camera mounted in a cylindrical case approximately 30 cm long and 5 cm in diameter. The camera was pulled by a draw-rope into the bore under examination, a power and signal cable was trailed behind the camera and this cable terminated at a television monitor mounted in a light vehicle. Visual examination of the suspect bores revealed a 20 m zone which contained many cracks. However, the damage was considered to be insufficient to warrant excavation, and the bores were subsequently used for the trial.

To provide a convenient means of coupling the draw-rope to the optical-fibre cable, an eye was formed at the cable end; the eye was produced by folding back about 50 cm of the cable and taping the fold. A rope-to-cable coupling is illustrated in Fig. 3. The addition of the swivel reduced the twisting of the cable when under tension.

By late December 1976, it was considered that it should be possible to install successfully the optical-fibre cable by entirely manual means. The method proposed was first to install a dummy cable into an allocated bore and, provided that this was achieved without difficulty, to use the dummy to pull the real cable into position. A cable which has a very similar structure to the optical-fibre cable employed in the trials is the BPO Cable Drop Wire No. 4.[6] A 1 km length of this cable was used as the dummy cable, and proved to be most suitable for the task.

The final task was to put the proposal to the test and attempt a real installation using a sample of PSP cable containing fibres. Fortunately, there was a 1 km length of PSP cable containing 2 experimental fibres available at the BPO Research Centre; both these fibres had been manufactured at the Research Centre. On 24 December 1976, this cable was successfully laid in a bore parallel to that allocated for section 1 of the Martlesham–Ipswich cable.

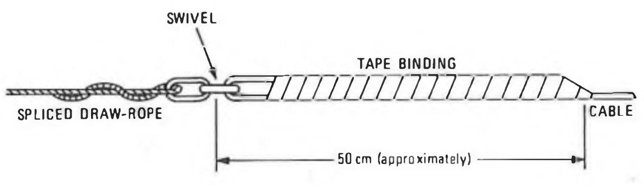


FIG. 3—A draw-rope-to-cable coupling

CABLE INSTALLATION

Early in 1977, sections 1–6 of the Martlesham–Ipswich cable (for use at 8·448 Mbit/s) were successfully installed. Sections 1–6 of the high-capacity cable (140 Mbit/s) were then laid, followed by sections 7–14 of the low-capacity cable (8·448 Mbit/s). Fig. 4 shows one of these installations in progress.

A cable drum containing 1 km of fibre cable was sited about midway along the section concerned, and the cable was drawn into the allocated bore in one direction. When sufficient cable was available at the jointing point, the remaining cable was removed from the drum and coiled in loops of about 30 m. The free end thus obtained was then drawn into the allocated bore in the opposite direction to the first half—thereby installing 1 km of cable in two 500 m pulls.

At the 3 terminal stations, the cable was taken directly to the rear of the equipment racks. In Kesgrave, the terminal equipment was situated immediately over the cable chamber. At Ipswich, the equipment was sited in the repeater station on the first floor of the exchange and about 30 m of internal cabling was involved and, since the PSP cable sheath was made of polyethylene, fire protection was afforded by means of flexible metal tubing. At Martlesham, the terminal equipment was sited on the third floor of the main laboratory block, requiring nearly 200 m to be cabled internally. Protection was provided by means of 51 mm × 51 mm metal trunking.

Mobile test vehicles were developed at the Research Centre to enable measurements of loss and bandwidth to be undertaken in the field, and to allow joints to be made under conditions convenient for the operator. The fibres were jointed by Research Department staff; measurements were made on each section length in sequence to enable cumulative measurements of loss and bandwidth to be obtained. Details will be given in a later article in this *Journal*.

FIBRE BREAKING AND JOINTING

When light emerges from a fibre, the size and shape of the power distribution in the beam depend on the dimensions of the fibre and on the form of the refractive-index profile. A low-loss joint between 2 fibres is possible only if these characteristics of the emitting and receiving fibres are closely matched. Fortunately, improvements in fibre technology have resulted in better control over dimensions and refractive-index profile as well as lower attenuations. Nevertheless, joint losses caused by manufacturing variations in fibres (described as *intrinsic losses*) are beyond the control of the user and can be very significant.

FIG. 4—Cable installation by Colchester Telephone Area staff

Calculations show that, in extreme cases, even where the technique is perfect and the fibres of high quality, a loss of 2 dB is possible, although the great majority of random joints will be much better than this[7].

The remaining contributions to joint loss, known as *extrinsic losses*, are introduced by imperfections in the jointing technique, such as misalignment of the fibre ends, the inclusion of dirt or a lack of refractive-index matching between the fibres.

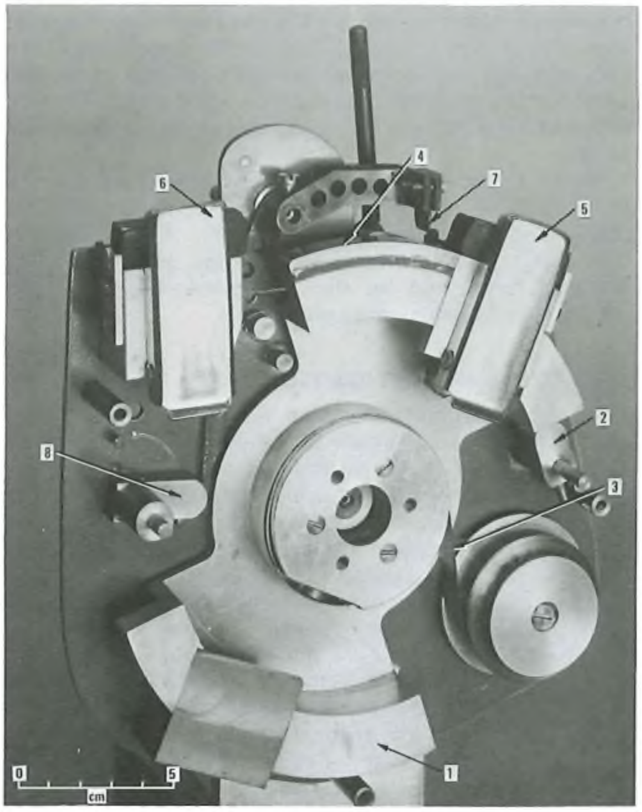
FIBRE END PREPARATION

At any point in an optical-fibre transmission system at which light enters or leaves a fibre, it is important that the fibre end be mirror-finished and perpendicular to the axis. Although it is possible to achieve this by cutting and polishing, controlled fracture is easier and generally yields better results.

The technique used to break a fibre to produce a mirror-finished end is, in principle, just the same as that used to break thick glass-rods. The break is initiated by a scratch which may be made by a diamond, a tungsten carbide blade or even a spark. Tension is applied so that no part of the fibre cross-section is in a state of compression, otherwise a lip is formed at the break point. Provided that the distribution of stress is correct (that is, nowhere should there be enough energy released for the crack to fork), a mirror-finished end is produced.

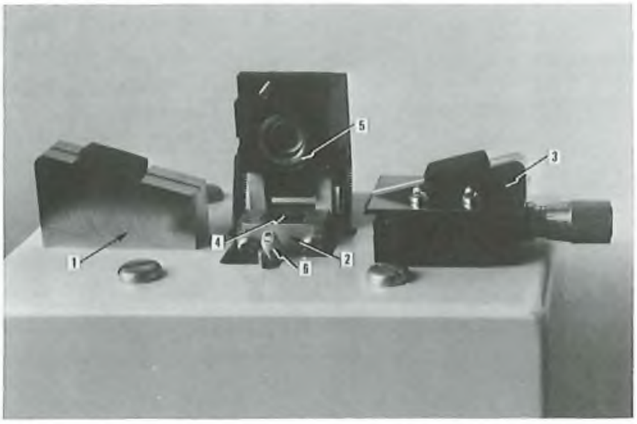
Fig. 5 shows the type of tool (with its cover removed) used to prepare fibre ends for the Martlesham–Kesgrave–Ipswich installation. (For ease of reference, numbers have been used in Fig. 5 to identify the constituent parts of the fibre-breaking tool, and these numbers are also used in the following text.)

The fibre is held by a pair of toggle action clamps (5, 6)



1: Segmented drum
2: Cam
3: Spring
4: Polished upper surface
5: Clamp
6: Clamp
7: Tungsten-carbide blade
8: Cam

FIG. 5—Fibre-breaking tool



1: Fixed inclined-block
2: Central pillar
3: Movable inclined-block
4: Groved substrate
5: Glass pressure plate
6: Ejection lever

FIG. 6—Fibre-jointing machine

across the polished upper surface (4) of a segmented drum (1). When a cam (2) is turned, a tension of about 120 g is applied to the fibre by a spring (3) which works against a small oil-filled dashpot. A second cam (8) releases a tungsten carbide blade (7) which is lowered gently onto the fibre under a load of about 2 g. Finally, a small movement of the scribing lever causes the fibre to part.

When the fibre ends have been prepared, it is essential to keep them clean. During the Martlesham–Kesgrave–Ipswich jointing exercise, immediately prior to use, the fibre ends were dipped in an ultrasonic cleaning bath containing a grease solvent and were always re-cleaned if they touched any surface inadvertently.

The fractional power loss due to reflection at a step change in refractive index from n_1 to n_2 is

$$\left[\frac{n_1 - n_2}{n_1 + n_2}\right]^2$$

which, in the case of a glass–air interface, amounts to about 4%, or 0·17 dB. Thus, a joint without index matching would introduce at least 0·34 dB loss. This can be reduced to a negligible level by allowing an adhesive, which is used to fix the joint and which provides a reasonably good match to the glass, to flow between the fibre ends.

JOINTING

A low-loss joint is made by butting together 2 clean, flat fibre ends in accurate alignment with each other. A straight forward way of doing this is to press the fibres into a carefully made V-shaped groove and then bring the ends together with a suitable adhesive between the end faces. Such a technique aligns the fibre claddings rather than the cores; thus, good core centrality and uniform cladding diameter are important. To give an idea of the accuracy required, the core diameter of the fibres used is nominally 62·5 μm, and a lateral displacement of 10% causes a loss of about 0·2 dB. For the Martlesham–Kesgrave–Ipswich cable installation, joints were made using grooves pressed in thin pieces of copper of dimensions 10 mm × 5 mm. These copper substrates remained with the joints to provide mechanical strength.

The 3 principal parts of the jointing machine shown in Fig. 6 (parts are numbered for ease of reference) are a fixed inclined block (1), a central pillar (2) which can be raised and lowered by a cam and lever, and a movable inclined block (3). Each block has a coarse groove to locate a fibre and is machined (to the depth of this groove) near the centre of the incline, to accommodate a magnetic pad. The right-hand block is mounted on a small micrometer slide having 5 mm of travel parallel to the fibre. The upper part of the central pillar hinges back to reveal a recess in which a grooved substrate (4) is located. The blocks are positioned so that all 3 grooves lie accurately in line. The hinged lid houses a photodiode, beneath which is a glass pressure plate (5) mounted on the end of a free-sliding tube. The lower part of the pillar is kept at a temperature of about 100°C by a small electrical heater, insulating hinge pieces being used to protect the photodiode.

A copper substrate is cleaned using a degreasing agent in an ultrasonic bath and is then placed, groove upwards, in the recess. The fibres to be jointed are prepared using the breaking tool, and are fixed in the blocks using the magnetic pads such that their ends overlap the substrate by about 3 mm. On raising the central pillar, the fibres come to lie in the substrate groove with their ends about 1–2 mm apart, their natural springiness pressing them lightly downwards. A very small quantity of epoxy resin is placed in the gap between the fibre ends and a thin perspex cover plate is placed on the joint. The upper part is moved forward on its hinges causing the pressure plate to rest with a force of a few grams on the cover plate, thus preventing the fibre ends from buckling upwards when they meet. Using the micrometer slide, the right-hand block, and hence the fibre on it, are moved towards the centre until the fibre ends touch. This can be detected in 2 ways: most simply, the fixed fibre can be seen to bend but, if a light source is connected to one fibre, the photodiode in the hinged lid may be used to detect the spill of light from the joint; the illumination at the joint drops abruptly to a low level when the ends meet. Most of the Martlesham–Kesgrave–Ipswich joints were made this way because a test van equipped with a helium-neon laser

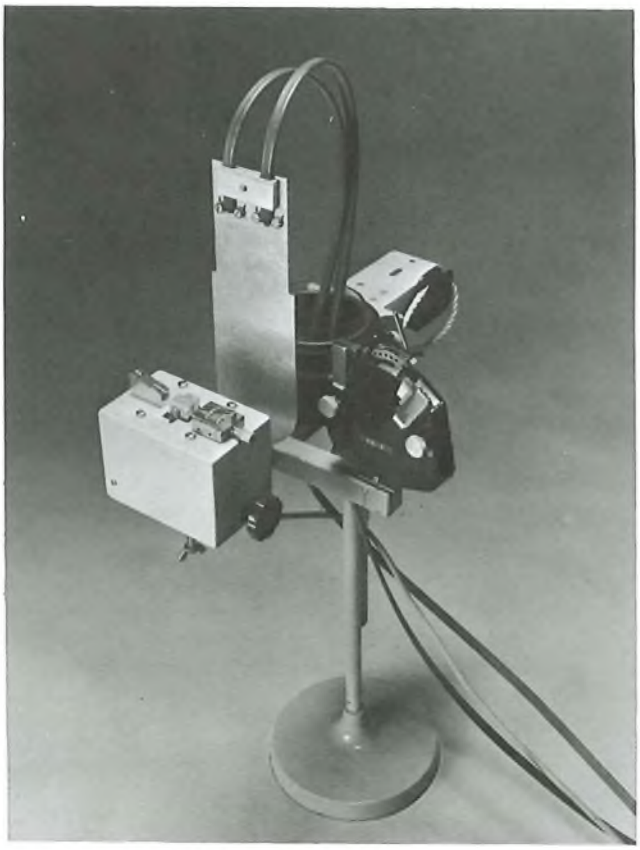


FIG. 7—Jig, supporting fibre-breaking tool and jointing machine

was available at the remote end, and measurements could be carried out when the joint was completed. The heater brings the epoxy resin to handling strength in a few minutes, after which the joint can be lifted from the recess using the ejection lever (6) at the front. For use in the field, the 2 machines described above were mounted on a jig, as shown in Fig. 7.

Standard BPO jointing sleeves (code: PE 31A) were used to house the joints after mounting on a metal plate, as shown in Fig. 8. To protect the fibre from atmospheric attack, the primary plastic coating on the fibre, which had to be removed in the vicinity of the joint, was restored using quick-setting epoxy resin. The base of the sleeve was sealed using a resin pack, and a desiccant was enclosed before mounting in the manhole. These sleeves were far larger than was necessary, but their ready availability with all accessories made them a convenient choice for use in the experiment.

FIG. 8—Joint housing

CONCLUSIONS

The trial has shown that not only is optical-fibre cable installation feasible but that there are several particularly attractive features in the use of such cable. Fibre cable is essentially small, light and capable of being installed in relatively long lengths, possibly as long as 2 km. Therefore, it is not necessary to provide specialist mechanical aids for the installation work, there can be a reduction in the number of joints, and the use of optical-fibre cable could result in considerable reduction in duct congestion. For some time to come, the links will continue to provide a test bed for system experiments, jointing and measurement studies. In the laboratory, further work will be aimed at refining the techniques described here and re-engineering them to improve their applicability in the field.

Work is in hand to improve the jointing and terminating techniques to ensure ease of assembly and reliability, and several new types of cable are being assessed.

A later paper in this series will discuss some of the difficulties in making accurate fibre-attenuation measurements, from which it will be clear that the calculation of a small joint-loss from the difference of 2 relatively large fibre losses is not practicable. Laboratory measurements using the same or similar fibres lead us to believe that the average joint loss is about 0·2 dB, a value which is low enough to be completely acceptable in relation to present fibre losses but which may well be unacceptable in the future. More sophisticated techniques are under development which will make it possible to examine the performance of an individual joint in a cable run in a direct and non-destructive manner.

The first transmissions at 8·448 Mbit/s between Martlesham and Kesgrave took place on 4 February 1977, and transmission between Martlesham and Ipswich took place on 21 February 1977. The first transmissions at 140 Mbit/s between Martlesham and Kesgrave were made on 7 February 1977. The links are now in continuous use providing transmission facilities for the systems currently under development in Research Department.

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Fire Damage to Customer's PABX

G. W. HARRIS and A. W. BROOKS†

On Saturday 12 November 1977, a fire occurred in the apparatus room of a large PABX No. 3 installation. The PABX consists of over 500 extensions, 20 exchange lines and 20 inter-switchboard circuits to other premises throughout the UK.

The cause of the fire has not been fully established, but it was not electrical. Although no equipment was damaged by flames, some cables were affected by heat. Involved in the fire was a coil of PVC cable, which completely filled the room with fumes and dense black smoke. Unfortunately, the fire-fighting activities involved the use of water, as well as BCF.* The fire burned for approximately 1 h before being finally extinguished.

Engineering staff and supervising officers were soon on the site. When entry to the apparatus room was gained, it was noted that the fire had destroyed the AC power-supply cables and the main DC distribution cables serving the exchange bus-bars.

The first task was to provide some form of communications for the customer. This was achieved by converting the existing exchange lines to loop-calling at the local exchange, and providing telephones at strategic points on the premises. This aspect of the work was completed quite quickly.

An inspection of the PABX revealed the following.

(*a*) Water from the fire-fighting activities lay in pools on the floor of the apparatus room, and the racks themselves had obviously been sprayed with water.

(*b*) The ceiling, walls and equipment were covered with a greasy black deposit.

(*c*) Lights were not working, and power was not available.

(*d*) Overhead-rack cabling had been affected by heat; there was adhesion between sheaths, and sheathing on some of the smaller cables had split. The wires and insulation appeared sound.

(*e*) The battery fuses were blown, but the battery appeared in good order and in a fully-charged condition.

(*f*) Selector-bank-multiple wiring was found to be in good order.

(*g*) The main distribution frame and jumpers were unaffected by the heat.

In view of the difficulty in providing the service required by the customer with a temporary PABX No. 1 or 2, it was decided to reconnect the battery to the exchange, attempt to locate faults on the existing equipment and, at the same time, start to clean up damaged apparatus. New battery cables were provided, and power was restored to the PABX approximately 2 h after the fire had been extinguished.

It was readily apparent that problems existed at the jack points of all selectors and relay sets, due to smoke and water contamination. Ringing-supply fuses continually blew due to low-insulation faults on selector jacks. The exchange ringing machines were isolated from the final-selector racks to enable the ringing-control relay-sets to be faulted, and manual ringing was introduced from the switchboard.

A team of Technical Officers and Technicans 2A was by now on site. Priority was given to establishing what action was required to restore quickly a reliable service. The team was divided; some staff were allocated to general cleaning duties to obtain a better working environment, and the remainder tackled faults on different types of equipment to establish whether any common type of fault existed. It was as a result of this action that the major problem was established as being the breaking-down of insulation on the selector jacks. At first, this problem was dealt with by changing the separators between the affected jack springs, but it was soon apparent that this action had only a short-term effect due to the presence of moisture in the insulating block of the jack. Consequently, individual faulting by the majority of staff was abandoned, and systematic replacement of all the insulation on all the jacks in the exchange was begun.

At this time, it was noticed that all the selector-bank contacts were covered with a hard crystalline deposit, presumably caused by the fire-fighting activities. The normal bank-cleaning procedure did not remove this contamination, and systematic cleaning of banks with abrasive tape was started. After cleaning a few banks with abrasive tape, and then with normal bank-cleaning tape, a close inspection revealed no apparent damage to the bank contacts, and cleaning was therefore continued.

By now, it was obvious that, although the exchange could be saved, the work involved was going to be quite extensive if a fairly reliable service was to be provided by the Monday, when full staffing of the premises would recommence. The staff on site had by this time achieved some expertise in the working of a PABX No. 3, and it was decided that a system of shift working should be introduced. Work continued on this basis until the Monday morning, when we were able to offer the customer a fairly good service.

Subsequent work continued, involving the overhaul of most selectors. Numerous interrupter and N-spring assemblies had to be changed, and individual faults on high-speed relays corrected.

Throughout the whole restoration period, staff worked under very difficult conditions. The general contamination created by the burning PVC was appalling. It was necessary for masks to be worn, and the whole building had to be well-ventilated to prevent a health risk. The advice of the Area Medical Officer was sought both during and after the restoration period, and it was confirmed that the precautions taken were quite adequate.

To assess the long-term implications and possibilities for permanent repair to this PABX, staff of the Service Department, Telecommunications Headquarters, visited the site and discussed the situation with Area staff. Contamination of equipment by hydrochloric acid, formed by the combination of water with gases given off by burning PVC at high temperatures, is considered a greater hazard to service than direct destruction by fire (Telecommunications Instruction H1 W0010 refers). It is this aspect which is now being evaluated. All fault reports and subsequent remedial work are being recorded and monitored. Also, building repair and redecoration work is in hand by the customer and, upon completion, further assessment and reinstatement work will continue as necessary.

The cooperation and assistance of the Customer Works Groups and other divisions was very much appreciated by the maintenance staff, and contributed to the rapid restoration of service to the customer.

† Plymouth Telephone Area

* Bromochlorodifluoromethane: a fire-extinguishing chemical vapour, effective in confined spaces

The Associate Section National Committee Report

HONORARY MEMBERSHIP SCROLL

Three scrolls have been awarded by the National Committee, one each to J. Hannah, T. H. Hopkins and C. F. Newton for the many hours of service they have given since the inception of the National Committee until they resigned their positions on the Committee.

The Secretary holds a number of these scrolls for resale to centres at £1·80 each. They were designed by the Newcastle Centre for presentation by any centre to a member deserving recognition of services rendered.

RULES REVISION

At the 1977 annual conference, a vote was taken in favour of forming a National Executive Committee (NEC) that could meet twice a year, and also that the annual conference should be a full meeting of the delegates from each Region.

Unfortunately, there were no rules to cover such an idea, and so 2 delegates were asked to prepare a set of rules governing the formation of an NEC.

These rules have been looked at and amended by the General Purposes and Finance Committee, which met during October; the Assistant Secretary has since circulated all Regions with the proposed rules and the amendments. Regional committees have been asked to send their own amendments to the Secretary for the General Purposes and Finance Committee to consider.

It is hoped that, by this year's annual conference, there will be a reasonable and acceptable set of rules to enable an NEC to be voted into office. The main reason for establishing the NEC is the ever increasing cost of accommodation and travelling to meetings; with fewer members attending, we can operate on a much lower budget.

ASSOCIATE SECTION TIES

The Secretary now has a new batch of ties (of a better quality than the previous batch); they measure 137 cm × 102 mm × 32 mm, are fully lined and sell at £1·35 including value-added tax.

DIRECTORY

A new directory has been issued by the Secretary to all centres in the British Isles that were listed in the old directory. Being a loose-page folder, it will be very easy to update at regular intervals, provided the information is forwarded by Regional delegates to the Secretary.

M. E. Dibden
General Secretary

Associate Section Notes

ABERDEEN CENTRE

The 1977–78 session began in October with the first round of the Scottish Regional Quiz. The Aberdeen quiz team, consisting of G. S. Allan, W. D. Buyers, A. J. Christie, D. Lorimer, I. Pyper (Captain) and M. E. Ross, were successful in contests against Motherwell and Ayr Centres, but were defeated in the final by Edinburgh.

The November meeting took the form of a day visit to the hydro-electric generating station and dam at Pitlochry, and was followed in December by a visit to the Glengarioch distillery, near Aberdeen.

I. Pyper

COLWYN BAY CENTRE

The Colwyn Bay Associate Section celebrates its founding 25 years ago this spring. The officials elected to office in January 1953 were: Mr. J. Rowlands, Chairman; Mr. D. Edmund Jones, Secretary; and Mr. J. C. Davies, Treasurer. This was after an inaugural talk on the aims of the Associate Section given by the then Area Engineer, Mr. T. A. P. Colledge.

The occasion is being commemorated by a special meeting on 14 April 1978. The lecture to be given at this meeting will be on Concorde, and it will be delivered by a senior pilot with Concorde experience. It will cover general aspects, including the aircraft's communications system, and will be illustrated by films. A special booklet is being produced for the occasion, for which most of our speakers of recent years are providing articles updating their talks or personal anecdotes. The meeting will be held as usual in the Royal British Legion Club, Llandudno, with a buffet meal at a very reasonable cost.

Any success we may have achieved can be put down to a regular hospitable venue, a choice of good general-interest subjects interwoven with the technical ones, and luck with the speakers, many of whom were asked back for a return visit. If a prospective speaker sounded dry and uninteresting during a "sounding out" telephone call, then he was not engaged.

At the first annual general meeting in 1954, concern was expressed at the absence of external staff at meetings. I am glad to report that they now occupy about half the seats at meetings, and a lecture attended by less than 50 members is rare.

E. Doylerush

DUNDEE CENTRE

Before the commencement of this year's session, some of our members were involved in a telephone exhibition organized by the Senior and Associate Sections of the Scottish Telecommunications Board. The exhibition was held in Edinburgh during the Edinburgh Festival of 1977, and Associate Section members from the various centres acted as guides for the 3-week period to over 1300 visitors.

The session properly started with a quiz night, when the Senior Section pitted their wits against the Associate Section. Justice was perhaps not seen to be done as the Senior Section, ably assisted by one newly promoted expert, defeated the team chosen for the National Quiz.

After this, the team went forward into the Scottish heats, only to be defeated by a Glasgow team. Dundee will claim beginners' luck, as this was the first time a full Glasgow team had been entered for the competition.

G. K. Duncan

EDINBURGH CENTRE

Our 1977–78 session opened with our annual golf outing to West Linton. Twenty-five members attended the outing and enjoyed themselves immensely whilst competing for our centre's 2 trophies. The winners were: V. Smith, a Postal Engineer (Handicap Trophy), and A. Martin, an Instructor from the engineering training college, Muirhouse, (Scratch Trophy).

In an attempt to increase attendance at visits, we combined 2 requested visits into a single-day outing in October. We spent the morning at the National Engineering Laboratories at East Kilbride, where we were shown examples of research into office-equipment noise, stress and strain tests on large ropes used in shipping, tests on safety belts as used by our own overhead staff, and a working demonstration of wave-energy extraction.

Our afternoon visit to the Ravenscraig Steel Stripmill proved just as interesting. Prior to being shown round, the entire process was explained to us using wall-charts. The enormous size of the complex matched the level of interest reflected by the many varied questions asked by our members. Thirty-one persons attended this visit including members from the Falkirk and Stirling area.

The Scottish Quiz final, held in November, was hosted by the Dundee Centre. In what must rank as one of the most exciting matches to date, Edinburgh narrowly beat Aberdeen by 33·75 points to 33·50 points after 2 supplementary questions. We were pleased to have in the audience the General Managers from Aberdeen, Dundee and Edinburgh, and all credit must be given to the Dundee Centre for the very welcome buffet which they provided.

In the preliminary round of the National Quiz, held in December, we very narrowly beat Oxford Centre, 26·5 points to 26 points.

At the time of writing, our next game will be a "home international" against Wales, represented by Swansea Centre.

J. L. M. Alexander

LONDON CENTRE

Lectures in the early part of the session have proved a little disappointing, with the cancellation of our first 2 talks. However, during December, the Associate Section had a very good paper read, covering the first 25 years, of the Associate Section. The paper was presented by the Chairman of London Centre Associate Section, Mr. Ron Gray. This was followed in January by a talk entitled *Aviation Fire Hazards*, given by Mr. N. Clark, the Treasurer of the London Centre Associate Section. Both talks were very well received.

All Areas of the London Telecommunications Region are very active, with visits covering a variety of interests. London Centre visits so far planned for 1978 are: Vauxhall Motors at Luton in March and the Fire Service College in May.

London's *New Quarterly Journal* has a new editor; his name is Peter Corrigan and he is based in the North West Area. We of London Centre would like to take this opportunity to wish him well in his new post. Peter would like to hear from any Associate Section members having any items they might wish to be printed in the *New Quarterly Journal*. We would like to say, "Well done" to Mr. Berney Gardner for the years during which he produced the *New Quarterly Journal*.

Anyone wishing to contact the new editor should do so on 01-204 1112; should he not be available there, then contact me on 01-205 4144, and I will pass on your message.

Meetings of the Associate Section London Centre have taken place monthly, and the session will finish with the annual conference, to be held at the Institution of Electrical Engineers, on Friday 12 May.

Quizzes within the London Telecommunications Region are going well, the Trainee Technician (Apprentice) quiz being of a very high standard. I feel relieved at being the scorer, and so not having to answer the questions.

The main quiz battles on, with a great deal of fun being had by all involved, but we are also keeping one eye on the results of the National Quiz with the hope that this might be our year to win.

L. Wood

LONDONDERRY CENTRE

On 19 December, the Londonderry Associate Section decided to have a change from the usual technical lectures, and instead have a novel evening.

For this, we decided to have a demonstration on preparing a turkey for Christmas. Sergeant Williamson, from the Army Catering Corps, came along and did a Turkey Ballantine, which involved de-boning the turkey and stuffing it. This was expertly done and everyone really enjoyed the evening, particularly at the end when a prepared turkey was duly eaten.

G. Ming

SOUTHAMPTON CENTRE

On 21 September, we were given a talk on the problems involved in building the extension to the main telephone exchange in Southampton. The talk, illustrated by slides and a film, described the methods used in driving and testing the many piles required to support the building.

In October, a small party of members visited Chilbolton Observatory, where we were shown the workings and controls of the dish aerial, and had the kind of work carried out at the establishment described to us. Later in October, there was a talk on the quality-assurance testing carried out in manufacturing and service industries. We were asked by the speaker to give our interpretation of quality in relation to the telecommunications industry, to aid him in finding the criteria for measuring quality in this field.

On 22 November, our General Manager, who is also our centre's President, gave an interesting and informative talk on *Management Today*, in which he described some of the modern management techniques and their use in managing a Telephone Area.

Future events include a visit to the British Airways European Division engineering base at Heathrow Airport in March, and a visit to a South Wales coal-mine in April.

P. E. R. Bates

Notes and Comments

CORRESPONDENCE

External Works Section,
London Telecommunications Region,
Camelford House,
London SE1 7TS.

Dear Sir,

Your attention will no doubt have been drawn to a misprint in my article *Tunnelling into History*, in the October 1977 issue, where the date of the Great Fire of London is given as 1665 AD.

Whilst the Fire was planned and programmed for late 1665, the project had to be deferred until 1666 due to the unprecedented incidence of sick leave in 1665, which was so severe that it subsequently became known as the year of the Great Plague. I would be grateful if you would set the record straight, lest any of your readers inadvertently repeat the error when doing their childrens' history homework.

Yours faithfully,
R. Harper

Computer Research Applications Division,
Research Department,
Martlesham Heath.

Dear Sir,

An error has been pointed out to me in the article *Programming and Microprogramming of Microprocessors*, published in the January 1978 issue of the *POEEJ*. The example given on p. 238 of a procedure declaration and call would be correct for the programming language PL/1 but is incorrect for PL/M. In PL/1, parameters are called by reference; that is, by passing the address of the variable to the procedure, as explained in the penultimate paragraph of the section entitled "Procedures of Subroutines".

In PL/M, parameters are called by value; that is, the value of the variable is passed to the procedure. However, in the example quoted (a procedure for doubling the variable), we want to change the value. Therefore, the address must be passed as if it were a value, and a different technique is required, as shown in the following program fragment.

```
DOUBLE: PROCEDURE (PTR);
  DECLARE PTR ADDRESS;
  DECLARE X-BASED PTR ADDRESS;
  X = X + X;
END;
DECLARE A ADDRESS;
CALL DOUBLE (.A)
```

PTR stands for *pointer*, which is the address of the variable, also denoted by *.A*, which means "take the address of *A*". Thus, the value used by the procedure is the address of *A*. The final line of the program causes the address of *A* to be passed to the procedure.

Yours faithfully,
K. J. Maynard

Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering, technical or other aspects of articles published in the *Journal*, or on related topics. Letters of sufficient interest will be published under Notes and Comments.

Letters intended for publication should be sent to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

TECHNICIAN EDUCATION COUNCIL

The publication of tables of references continues in the *Supplement* to this issue for TEC units at levels 1 and 2. References are made to model answers (previously published in the *Supplement* or in the *POEEJ*'s series of model-answer books) that most closely match the TEC syllabi. These references can be used to provide practice and tutorial material until the *Journal* begins to publish guidance material for TEC units in model-answer form, which it expects to do next winter.

There has been a slight change to the presentation of the tables of references. Instead of listing topics under arbitrary numbers (as was done in the January 1978 *Supplement*), the codes allocated in the TEC's published standard units have been used. In these codes, a topic area (e.g. "Circuits") is denoted by a capital letter, a general learning objective (e.g. "the student should be expected to solve series-parallel DC circuits") by an integer, and the specific objective (e.g. "the student should apply Kirchhoff's laws to problems involving 2 unknowns") by a decimal. In the example quoted, which is taken from Electrical Principles 2, the code is B2·5. A table of equivalents is given in the *Supplement* to this issue, allowing the arbitrary codes allocated for those units covered in the January 1978 *Supplement* to be related to the codes allocated in the standard unit.

CONTRIBUTIONS TO THE JOURNAL

Contributions to the *POEEJ* are always welcome. In particular, the Board of Editors would like to reaffirm its desire to continue to receive contributions from Regions and Areas, and from those Headquarters departments that are traditionally modest about their work. The editors also would be pleased to hear of readers' reactions to the way in which Regional and Area contributions (formerly called "Regional Notes") are now presented.

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

GUIDANCE FOR AUTHORS

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

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

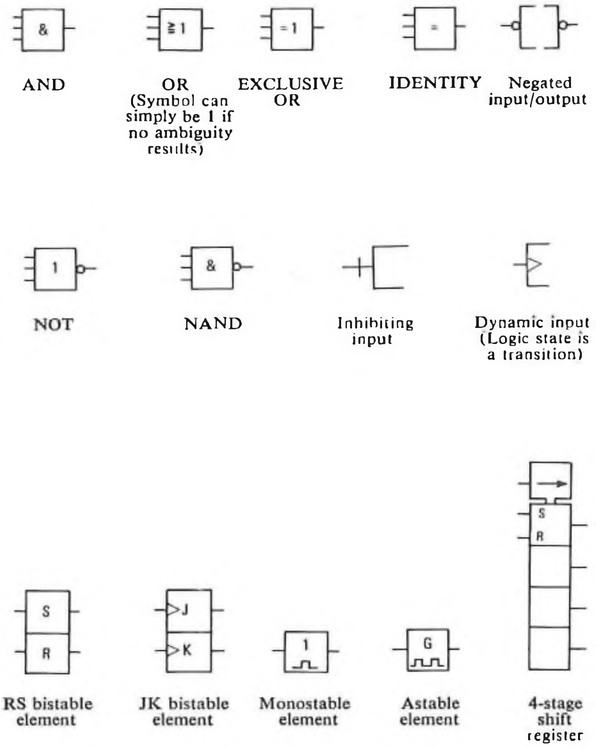
As a guide, there are about 750 words to a page, allowing for illustrations, and the average length of an article is about 6 pages, although shorter articles are welcome. Contributions should preferably be illustrated by photographs, diagrams or sketches. Each circuit diagram or sketch should be drawn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

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

Contributions should be sent to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

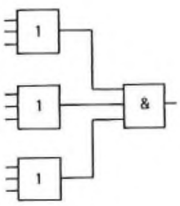
GRAPHICAL SYMBOLS FOR LOGIC ELEMENTS

Section 21 (Binary Logic Elements) of British Standard 3939: *Graphical Symbols for Electrical Power, Telecommunications and Electronics Diagrams* has been revised. The major change is the adoption of a rectangular outline for gate symbols. The qualifying symbols, which describe the gates' functions, have not been altered. Some examples of common gate symbols are shown in sketch (*a*). (The uppermost box of the 4-stage shift register represents the control element.)

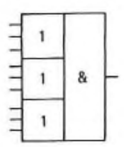


(*a*)

The revised standard also provides for symbols to be assembled to represent complex logic functions without the the need to draw interconnecting paths. For example, sketch (*b*) shows conventionally the outputs of 3 OR gates connected to an AND gate; sketch (*c*) shows the same arrangement with the symbols combined.



(*b*)



(*c*)

The revised standard implies that, in Boolean expressions, the algebraic symbol for an OR function is the plus sign, that for an AND function is the omitted dot, and that for a NOT function is the superior bar. Thus, the familiar EXCLUSIVE OR function has the algebraic expression $F = \bar{A}B + A\bar{B}$. (The generalized symbols for dyadic Boolean operations are given in BS 3527; these differ in form from those used in Boolean algebra.)

APRIL AND OCTOBER 1975 ISSUES

The editors would very much appreciate the return of spare and unwanted copies of the April and October 1975 issues of the *POEEJ* (Vol. 68, Parts 1 and 3). Surplus copies, complete with the model-answer *Supplements*, should be returned to Mr. Hunwicks, Ground Floor Lobby, 2–12 Gresham Street, London EC2V 7AG.

SECTOR SWITCHING CENTRES AND THE 60 MHz TRANSMISSION SYSTEM

Copies are still available of the October 1973 special issue on the 60 MHz frequency-division multiplex transmission system, and the April 1974 issue covering sector switching centres. The April 1974 issue also contains articles on the basic principles of light propagation in optical fibre, SPADE, and the construction of steel masts and towers.

Back Numbers

Back numbers can be purchased, price 80p each (including postage and packaging), for all issues from April 1973 to date. Copies of the July and October 1970, and the April 1972, issues are also still available.

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

July 1970, October 1970 and April 1973 Issues

The July 1970 issue contains the following articles.

Progress in Postal Engineering—A General Survey.
Medium-Range Ship-to-Shore Radio.
Post Office Technical Training College, Stone.
Local Transmission Planning.
Echo Suppressor No. 7A.
Transit Network—Multi-Frequency Signalling Equipment.
Lives of Plant and Depreciation.
Transmission in the Switched Telephone Network.
Metal-Oxide Integrated Circuits—Simple Logic Circuits.
Interfaces for Digital Data Transmission.
Line Simulator for Data Transmission.

The October 1970 issue contains the following articles.

Progress in Postal Engineering—Packets and Parcels.
Concrete Tower for Purdown Radio Station.
Gas Turbines for Power Plant.
Standard Video Transmission Equipment.
Call-Failure Detection Equipment.
Speed Monitoring of Stand-by Engine-Generators.
Transit Network—Line-Signalling Systems.
Local Telephone-Cable Design.
Control and Supervisory Systems for Microwave Links.
Identification of New Cable Pairs.
Electrical Contacts—Design of Switching Circuits.
Anti-Jamming Device for Conveyor Belts.

The April 1973 issue contains the following articles.

Letter Sorting—The Code-Sort Translator.
Time Interval Measuring Equipment.
Facsimile.
Transmission Equipment Construction Practice.
Efficiency in Motor Transport.
Frequency-Division-Multiplex Equipment.
Maintenance of Transit Routes.
Group-Delay Measuring Sets.
Heavy Cabling Equipment.

Past Model Answers

A list showing which back numbers contain model answers to particular CGLI examinations is given on the last page of the *Supplement*. Also shown is where to find tables of references for TEC units.

Institution of Post Office Electrical Engineers

INSTITUTION TIES

Institution ties are now available to members. There is a choice of 2 designs: plain blue or with green stripes; both designs bear the Institution's crest. These ties are of excellent quality, and can be purchased at the special price of £1·50 while present stocks last. Members wishing to avail themselves of the offer should apply to their local-centre secretaries, or direct to the Second Assistant Secretary, Mr. A. F. Foster (01-272 1427).

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A. B. WHERRY
Secretary

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The books listed below have been added to the IPOEE library since the publication of the 1974 Library Catalogue. Any member who does not have a copy of the catalogue can obtain one from the Librarian, IPOEE, 2–12 Gresham Street, London EC2V 7AG. Library requisition forms are also available from the Librarian, from honorary local-centre secretaries, and from Associate Section centre secretaries and representatives.

Alternatively, the adjacent panel, or a photocopy, can be used (only by members) to borrow any book listed in the catalogue or in the updating lists published in recent issues of the *POEEJ*. The form should be sent to the Librarian at the address above; a self-addressed label must be enclosed.

5220 *Theory of Waveguides*. L. Lewin (1975)

Reviewed in the *POEEJ*, Vol. 68, p. 158, Oct. 1975.

5221 *Questions and Answers about Tape Recording*. H. Burstein. (USA, 1975)

The material is based on genuine queries from enthusiasts, and is classified for easy reference.

5222 *Modern Communication Systems*. R. F. W. Coates (1975)

Reviewed in the *POEEJ*, Vol. 69, p. 78, July 1976.

5223 *Data Communications via Fading Channels*. Edited by K. Brayer (USA, 1975)

The subject is traced from the fundamentals of propagation to the theoretical and practical error-performance of signalling systems. The use is discussed of diversity techniques to eliminate post-signalling residual errors.

5224 *Telecommunication Transmission Handbook*. R. L. Freeman (1975)

This ITT publication is designed for advanced-level students and practising engineers. The book analyses the essential concepts and techniques common to point-to-point transmission principles.

5225 *Modern Guide to Car Tune-Up and Emission-Control Servicing*. P. Dempsey (USA, 1975)

The aim of this book is to increase the reader's understanding of the work involved and the correct procedures for tuning and servicing.

IPOEE Central Library

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Author ....

Title ....

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5226 *The Complete Car Radio Manual.* F. C. Palmer (1975)

The car owner or mechanic is instructed in fitting car radios. Avoiding and overcoming radio interference is discussed.

5227 *How to Build Your Own Electronic and Quartz-Controlled Watches and Clocks.* B. B. Babani (1975)

Step-by-step instructions are given for the benefit of enthusiasts.

5228 *Practical Solid-State DC Supplies.* T. D. Towers (1976)

This book covers, in precise detail, the design and construction of the wide range of DC power supplies which forms an integral part of modern electronic equipment.

5229 *Introduction to Electric Circuits* (Fourth edition). H. W. Jackson (USA, 1976)

This is a well-illustrated and comprehensive textbook for the student, instructor and practising technician.

5230 *Switching Circuits for Engineers.* M. P. Marcus (USA, 1975)

Both the logic design engineer and the student of switching circuits are catered for by this book, which contains an extensive list of related literature for further study.

5231 *Complete Guide to Electronic Test Equipment and Trouble-Shooting Techniques.* J. Douglas-Young (USA, 1975)

This is a practical guide to modern test equipment and how to use it.

5232 *Printed-Circuit Assembly.* M. J. Hughes and M. A. Colwell (1976)

The characteristics of the various bases used in printed-circuit systems are described. The reader is guided through the stages of translating circuit diagrams into printed-circuit layouts.

5233 *Fundamentals of Solid-State Electronics.* R. D. Pascoe (USA, 1976)

Written for technician-level students, and assuming a background in AC and DC theory, this book gives the student a foundation in solid-state devices and circuitry.

5234 *Electrical Communications: Theory, Worked Examples and Problems.* R. G. Meadows (1976)

A summarized-note form of presentation is used, with worked examples and problems (with answers) on electrical communications. This book is suitable for students following degree and diploma courses.

5235 *Telegraphy.* R. N. Renton (1976)

Reviewed in the *POEEJ*, Vol. 70, p. 125, July 1977.

5236 *Sir William Preece* F.R.S. *Victorian Engineer Extraordinary.* E. C. Baker (1976)

Reviewed in the *POEEJ*, Vol. 70, p. 20, Apr. 1977.

5237 *Protecting Buildings.* S. A. Richardson (1977)

Sub-titled "How to Combat Dry Rot, Woodworm and Damp", this practical book shows how to identify, treat and protect against weather damage, insect pests and fungi.

5238 *Computer Architecture.* C. C. Foster (USA, 1976)

The complex subject of computer-system design is broken down into a step-by-step progression. Plain language is used, so that the book can be followed by anyone with only a basic knowledge of computers.

5239 *Electronic Circuits for Technicians.* L. Temes (USA, 1977)

This book is primarily for trainee technicians. Each chapter covers a different topic, and is concluded with questions and answers. A knowledge of algebra and AC and DC circuitry is assumed.

R. Cross
Librarian

Post Office Press Notices

AWARDS FOR OUTSTANDING WORK

Awards for work of outstanding quality have been made to 8 members of the British Post Office (BPO) Research Centre at Martlesham Heath, near Ipswich.

The awards—small cash payments, but highly prized by Research Department staff for the prestige attached to them—were the 1977 Papers and Craftsmanship Premiums of the Gordon Radley Fund (Christopher Columbus Prize). Awarded annually, they were presented this year by Mr. Richard Cannon, Managing Director of Public Telecommunications, Cable and Wireless Ltd. He was introduced by Mr. Charles May, Director of Research, who is a trustee of the fund.

Premiums for papers are awarded to scientists and engineers under 30 for research described in papers published in scientific or technical journals, or in a comparable way. This year, 4 Papers Premiums were awarded, to: Mr. Michel Eve (£30) for work on the propagation of light in optical fibres, Dr. Graham Davies (£10) for studies of the dielectric absorption mechanisms of liquid organic materials in the millimetric frequency range, Mr. John Davis (£10) for investigating the lifetimes of aluminium integrated-circuit interconnexions subjected to high-current-density impulses, and Mr. Robert Walters (£10) for work on evaluating the system used in determining the performance of computers.

The Craftsmanship Premiums are presented to technical staff for precision engineering work displaying originality in design or particularly high skill in execution. There were 3 awards for 1977, to: Mr. John Bowie (£30) for making the machine used for joining optical fibres, and for the equipment used to test the joints, Mr. Ken Bilton and Mr. John Jones (£10 each) for the delicate work of machining accurately-dimensioned components in graphite, and Mr. Tony Barrell (£10) for machining to close tolerances a 100 kg forging in aluminium-bronze for use in the cut-and-hold grapnel used in recovering deep-sea telephone cables.

In addition, Mr. Anthony King, this year's youngest entrant, was highly commended for a special project: making a sensitive drilling machine, which involved original design work carried out with minimum supervision.

The Gordon Radley Fund dates from 1955, when the Christopher Columbus International Communications Prize was awarded by the City of Genoa jointly to Sir Gordon Radley, then Director-General of the BPO, and Dr. Mervin Kelly, President of Bell Telephone Laboratories, New York, for their work on the first transatlantic telephone cable. The Genoese intended that the prize should also reward the scientists, research workers and technicians who contributed to the planning, manufacture and installation of the world's first transoceanic telephone cable. Sir Gordon Radley used his share of the prize to found the Christopher Columbus Prize Fund, from which the 2 annual premiums (for scientific research and craftsmanship) were to be paid as prizes to Research Department staff. Following Sir Gordon's death in 1970, the fund's trustees gave the fund its present name to perpetuate Sir Gordon's connexion with it.

VIEWDATA AND ALEXANDER GRAHAM BELL

The world's first demonstration of a new telephone communication system which can be used by deaf people was presented recently by Mr. Peter Benton, the British Post Office's (BPO's) new Managing Director: Telecommunications.

The system is a development of Viewdata, a market trial of which will start in 1000 homes and businesses this June.

The latest refinement of Viewdata, still in the prototype stage, will enable people to type messages to each other over the telephone network, each message appearing in words on the television screen. Apart from the commercial advantages of this facility, the development is also of particular significance for the deaf. By making the television set a visual extension of the telephone, it allows them to communicate with others, including normally-hearing people, over the telephone network.

Unveiling the new system, Mr. Benton was taking part in a ceremony to mark the first century of telephone development. On 14 January 1878, Alexander Graham Bell, inventor of the telephone, demonstrated his invention to Queen Victoria at Osborne House on the Isle of Wight. Commemorating that historic event, Queen Victoria's great-grandson, Admiral of the Fleet the Earl Mountbatten of Burma, K.G., O.M., Governor and Lord Lieutenant of the Isle of Wight, made a transatlantic telephone call from Osborne House to Bell's grand-daughter, Mrs. Lilian Grosvenor Jones, at the British Embassy in Washington.

Afterwards, a glimpse of things to come in the second century of telephone history was given when a Viewdata conversation was demonstrated in an exchange of messages across the Atlantic between Dr. Alex Reid, BPO Viewdata project manager, and Dr. Latham Breunig, President of the Alexander Graham Bell Association for the Deaf in Washington.

Mr. Benton commented, "Viewdata, invented here in Britain, would have given particular pleasure to Bell, who had a life-long interest in helping the deaf to communicate. It is a marvellous new technology, available to layman and specialist alike. It can provide a huge store of easily accessible facts and information and allows 2 people to communicate visually and instantaneously across thousands of miles."

The BPO has already exported Viewdata to West Germany, and is having discussions with the telecommunication administrations of other countries with a view to selling its Viewdata expertise more widely.

BEYOND THE EPSS

A study group has been set up by the British Post Office (BPO) to help in preparing for a future data service. It will define requirements for customer connexions to a public packet-switched service complying with CCITT Recommendation X25.

The 20-member group includes representatives from computer users and equipment manufacturers, as well as BPO data-transmission experts. It will produce a draft document setting out the interface requirements for terminal devices connected to an X25-based service.

The document will reflect the collective views of users, manufacturers and the BPO. It will greatly assist the BPO in preparing a technical guide giving the detailed requirements for customers' terminals using an X25-based public packet-switched service. The document will deal with electrical requirements and operating and data-assembly procedures. It is hoped the work will be complete by mid-summer 1978.

Recommendation X25 has been adopted internationally as the standard for public packet-switched data services. It is now the basis for planning most national and international data services that will use packet switching, such as EURONET.†

The BPO has been a world leader in packet switching with its experimental packet-switched service (EPSS), which started formally last April. The EPSS was implemented before Recommendation X25 was drafted, and its standards and operating procedures differ from those of X25. The BPO is now looking at possibilities for a permanent packet-switched service to follow the EPSS, and the study group will be contributing to this work.

With the EPSS, the BPO has established close working relationships with industry which have been a great help in planning and commissioning the service. The BPO has been able to build on these good relations in setting up the study group.

Industry will be given every opportunity of commenting on the study group's first drafts. Equipment manufacturers and suppliers, computer users and trade associations who would like to receive copies of the drafts should contact: New Data Services, Data Communications Division, Post Office Telecommunications, Freepost, London EC2B 2TX.

† KELLY, P. T. F., and LEE, E. J. B. The Telecommunications Network for EURONET. *POEEJ*, Vol. 70, p. 208, Jan. 1978.

Book Review

Technician Physical Science 1. R. G. Meadows, M.SC., PH.D., C.ENG., M.I.E.E., M.INST.P., A.R.C.S. Cassell and Co. Ltd. (Cassell's TEC series). 253 pp. 138 ills. £2·75.

This paperback textbook has been written to meet the general and specific objectives of the level-1 Technician Education Council (TEC) Physical Science unit U75/004. The syllabus allows a choice of objectives according to the TEC programme being studied; the author has chosen those objectives appropriate to the mechanical and production engineering programme. For the telecommunication student, this means the omission of only 2 specific objectives, both concerned with angular velocity, which are included in the objectives of the telecommunications programme. It does mean, however, that there are many objectives included concerning such topics as fluids, chemical reaction and light, which the telecommunications programme does not require a student to study.

The author has kept fairly rigidly to the specific objectives of the syllabus, straying outside its confines, with advantage, on only a few occasions. Each section starts with a statement of a general objective, and each sub-section with a statement of a specific objective. Worked examples are given only where required by the specific objective, but a number of problems are set, with answers given, at the end of each section. The style of writing is clear and easily understood, and the figures are well-drawn, though a little on the small side in some cases. Only a few insignificant errors are noticeable. At this level, I would like to have seen at least a table of base and derived SI units, with their symbols.

Writing a textbook to specific objectives in this way may not be the best way of presenting a subject to a reader, and the value of the book may well be diminished by future syllabus revisions. It will, however, appeal to students, who are left in little doubt as to what is expected of them, and it should be a useful textbook for telecommunication students.

R. H.

NEW PABX

An advanced design of PABX, using digital switching under stored-program control, has been selected by the British Post Office (BPO) as its new standard for the 1980s.

Designed by the BPO, the new system is intended for smaller PABX users needing up to about 100 extensions. Like existing BPO PABX systems, it will be offered to customers on a rental basis.

The new PABX is called the *Customers' Digital Switching System No. 1* (CDSS1). It was selected after discussions with the UK telecommunications industry, and following a full consideration of modern proprietary PABX designs.

The CDSS1 results from the work of BPO research and development teams since early 1976. Its development has now reached the stage of involving the manufacturing expertise of the industry. Plessey Telecommunications Ltd. and GEC Telecommunications Ltd. are working jointly with the BPO on the final engineering of the new PABX and the assembly of production prototypes.

Based on the latest technologies, the CDSS1 is wholly electronic with microprocessor control, and is consequently much smaller than present electromechanical systems. Designed to operate in normal office accommodation, the equipment is contained in a single unit about the size of a filing cabinet, and can be associated with a modern style of cordless desk-mounted switchboard. Its design is modular, enabling it to be enlarged progressively from smallest to largest size (simply by plugging-in more units inside the equipment cabinet) to meet customers' growth needs for more exchange lines and extensions.

Designed to cater principally for the basic needs of business users, the new PABX, when fully developed, will have alternative software packages providing many of the more advanced features at present available only on the larger and more complex PABX designs. These include such features as information logging, short-code calling, call diversion, and ring-when-free facilities. CDSS1 users will be able to reprogram some features themselves.

SAFETY AT SEA

Life on the high seas was made safer for thousands of merchant seamen from 1 February 1978, thanks to a world-wide "guardian-angel" scheme in which the British Post Office (BPO) is playing a vital role.

Several-thousand merchant ships are normally at sea at the same time, and the internationally-available automated merchant-vessel reporting (AMVER) system means a round-the-clock check can be kept on them. The AMVER system is operated by the USA Coastguard Service, and maintains vital ship-movement information on a computer in New York.

The BPO's part in the scheme involves its coastal radio stations, which will take reports from ships and pass them twice a day via its long-range station at Portishead, Somerset, to the computer in New York. The BPO will use its 11 medium-range coastal radio stations to collect the reports, and the AMVER computer can then accurately calculate the positions of all ships throughout their voyages.

If a ship taking part in the scheme goes missing, the AMVER computer will be able to estimate her position, based on information already supplied on the ship's course and speed.

Vessels taking part in the scheme supply sailing details, such as their position, course, speed, destination and estimated time of arrival. This information is passed to the AMVER computer, with other details, such as tonnage, nationality, facilities and equipment.

If there is a distress call from a ship, the computer information will identify the nearest vessels that can help. It will also know which of these can give specialist aid; for example, those that have surface-search radar or rescue equipment, and those with a doctor or other medical facilities aboard.

The participation of the BPO's coastal radio stations in the scheme will be particularly valuable, enhancing AMVER facilities for reporting and alerting ships, particularly on the busy North Atlantic routes. Portishead radio station has world-wide coverage using high frequencies.

The stations already play a major part in the Department of Trade's UK Search and Rescue Organization, as does HM Coastguard, the Royal National Lifeboat Institution and the Armed Services' helicopter units.

SERVICE-PROTECTION NETWORK

The stand-by telephone network, designed to ensure that telephone service is maintained even if major STD links break down, was completed by the end of 1977. The network is known as the *service-protection network*.

The network's main function is to improve service to customers by ensuring that more calls are successful and that calls do not fail because of breakdowns on main-network routes, or through engineering work. The service-protection network will benefit the British Post Office (BPO) financially because revenue will be obtained from calls that would not have got through otherwise, and engineering repairs can be planned and carried out more efficiently.

It has cost £10M to provide the network, and this is only part of the £1000M the BPO spends each year (£3M each working day) on improving and expanding the UK's telephone service.

The BPO began establishing the service-protection network in 1970. Before then, a breakdown in one STD main route meant that many callers could not get through, and congestion often lasted for hours.

Now it takes usually only 15–30 min to bring a protection link into service. Because the high-speed change-over switching of protection and service routes does not affect service, a repaired section can be brought back into use at any time convenient to maintenance staff.

The service-protection network is part of the UK's vast system of telephone cables that links the towns and cities of Britain. Within each cable are several pairs of coaxial tubes, one pair of which is set aside for use as part of the protection network.

The service-protection network can be used to maintain service when planned engineering works are necessary on service routes. This type of work used to cause interruptions to service, and work had to be done when it would cause least inconvenience to customers—at night or on Sundays. If work was done at night, service usually had to be restored each morning.

In 1976, the service-protection network was used for 1000 planned works lasting a total of nearly 200 000 h.

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Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 55p per copy (80p per copy including postage and packaging); annual subscription: £3·20; Canada and the USA: $6·50.

The price to British Post Office staff is 36p per copy.

Back numbers will be supplied if available, price 55p (80p including postage and packaging). At present, copies are available of all issues from April 1973 to date; copies of the July 1970, October 1970 and April 1972 issues are also still available.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

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Remittances for all items (except binding) should be made payable to "*The POEE Journal*" and should be crossed "& Co."

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All correspondence relating to advertisement space reservations, copy, proofs etc., should be addressed to Paul M. Johnstone, Advertisement Manager, The Kemps Group, 1–5 Bath Street, London EC1V 9QA (telephone: 01-253 5314 or 01-253 3871).

Distribution and Sales

Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG.

Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the *Journal*. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

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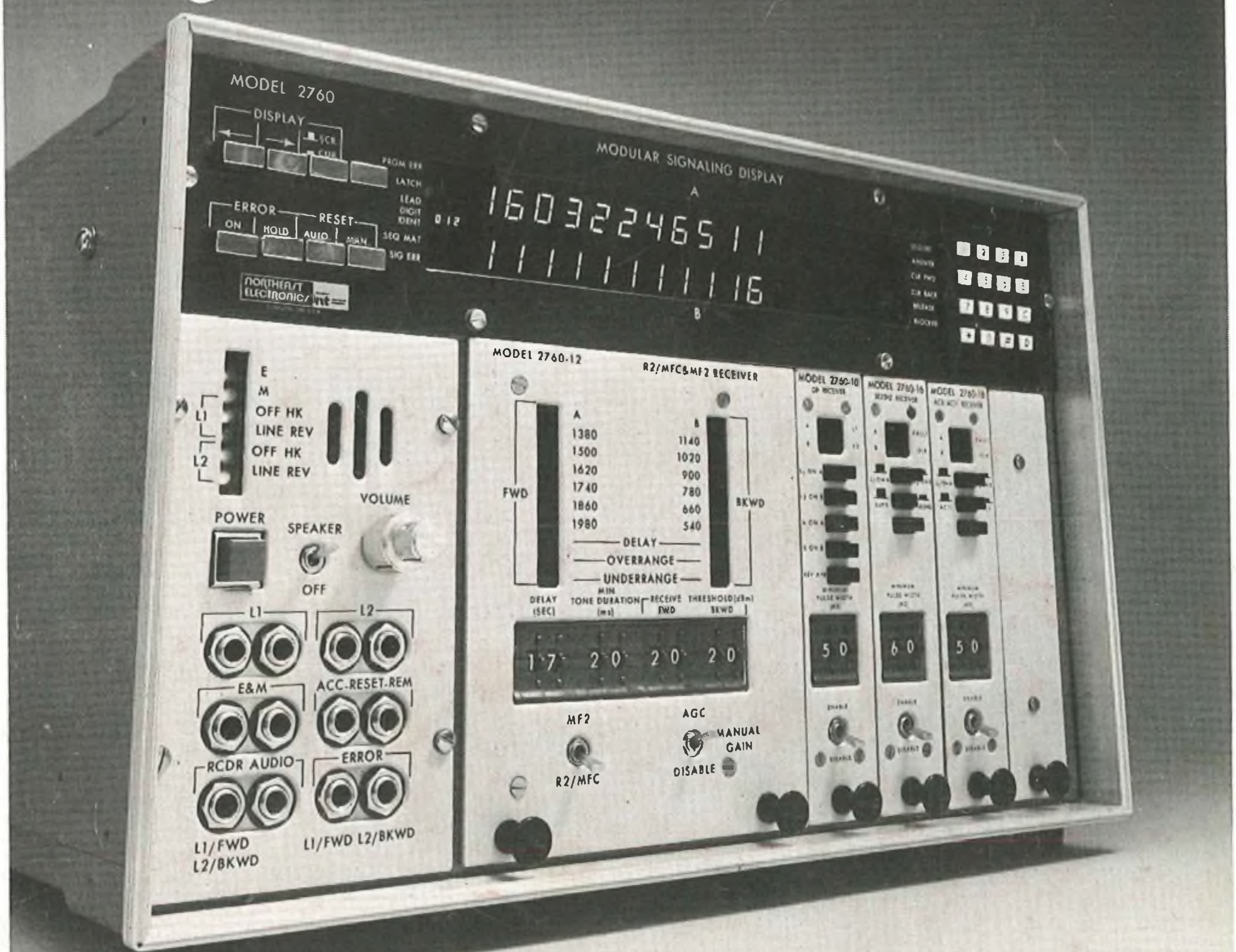
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RCDR AUDIO
ERROR
L1/FWD
L2/BKWD
L1/FWD L2/BKWD
5 0
6 0
5 0