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EDITORIAL

The telephone, for many years the simple dial instrument, is undergoing rapid change. Press-button dialling is now commonplace, and enhanced facilities such as memory and last-number recall are widely available. For the business user, the telephone is changing at a greater pace. Featurephones are available for most communications systems, and integrated voice and data terminals such as the Merlin Tonto and QWERTYphone are rapidly finding applications in the business world.

For many years, the design of the transmission circuit for the telephone had been a matter of compromise for the sake of economy. In recent years, however, the development of the fully-electronic telephone has enabled circuit designers to reassess the means of achieving the necessary transmission parameters required by analogue telephones for use in the modern network. Historically, in the UK, the design of telephones changed very little for periods of 10–20 years, and only then after lengthy deliberation. An article on p. 260 of this issue of the *Journal* gives a brief insight into the issues faced in those early days and shows how the climate has changed for the present generation of electronic telephones. A further article on p. 266 reviews the factors involved in the design of the speech transmission circuit for the new electronic telephones.

November 1986 marked the 50th Anniversary of the beginning of the 405-line 'high-definition' public television service in the UK. An article on p. 283 of this issue of the *Journal* outlines the contribution British Telecom has made to the growth of this public service over the past 50 years.

Telephones—A Background

R. R. WALKER, B.SC.(ENG)., C. ENG., F.I.E.E.†

UDC 621.395.6

This article concentrates on the factors that have influenced the design, development and manufacture of telephones in the UK during the past 40 years, particularly in relation to British Telecom's evolution from a Government Department to a public company.

INTRODUCTION

Telephones are not big business in the context of British Telecommunications plc*. Yet since the vast majority of the Company's revenue begins and ends with a telephone instrument; they are the prime interface to the customer and their performance and reliability are crucial to the whole operation.

It is easy to design and manufacture a telephone; any telephone, the sort that you might buy in the Far East for $5 (slightly more if you want it tested). Such telephones may well work on the UK network, for some customers, in some situations, and for some calls. British Telecom (BT), however, is in the business of having satisfied customers for as much of the time as possible. As far as the telephone instrument is concerned, that is an achievable aim. The designer has simply to recognise that the customers come with loud voices and soft voices, with varying degrees of hearing ability, with their own individual ways of holding handsets. He will know that the situations in which telephones are used vary widely in terms of background noise and room reverberation. He will realise that a data bank of 1800 different types of connection on the UK network is never up to date and does not include some of the really awkward cases. Moreover, the designer, the development engineer, the production engineer and everyone else involved in getting a new telephone to market will recognise that a commitment to the highest quality at the lowest cost, and to production on the day that it is required and not the day after, begins on the day when someone first puts pencil to paper. Good telephones are an art.

Telephones are changing; so too is the environment in which telephones are designed and made. Before personal memories diminish forever, it seems worthwhile for someone who was there when much of it happened to draw on the volume of unpublished material and set some of it down for the record. Without malice, and with criticism of none, this is how things were done. This was the only way that the system permitted things to be done. The men who created the telephone service on which everyone still largely depends today were not pygmies, they were giants in their day: other days, other customs.

This then, is not a history of the telephone—that has been told already in the pages of this *Journal* and elsewhere—it is, to borrow a phrase, a sidelight on that history.

THE CLIMATE

For most of its history, the telephone service in the UK has been subject to certain constraints, not necessarily of its own making.

Telephones were the junior partner in a Department of State. Parliamentary elections were not won or lost on the availability of telephone connections, so telephone revenues could be deployed in more sensitive areas. A quotation from an article[1] written in 1956 sets the scene for much of the post-war period.

Immediately after the war 'plans were made and put into operation for a considerable increase in engineering staff; for gearing up the manufacturing industry for greater output; and for a large increase in telephone exchange building. By mid-1947, the foundations had been laid for overtaking the bulk of arrears... Unhappily, the financial crisis in the autumn of 1947 made postponement of this scheme inevitable... and urgently needed exchange equipment was allocated to export orders.'

'There were indications in 1948 that the position was becoming easier, but the financial crisis of 1949 again brought severe restrictions... The expanded national defence programme the following year added to BPO problems.'

Forward planning and capital investment in the telephone service were not helped by the ease with which the Government of the day could influence tariffs. There were long periods during which the cost of service declined in real terms, each terminated by a sudden large increase in prices as in 1957, 1970, 1975 and 1980.

Earlier issues of the *Journal*[2] have recorded the activities of the British Telephone Technical Development Committee (BTTDC). This was a joint committee of manufacturers and BPO staff which allocated contracts for both development and production. Development was paid for by the manufacturer concerned. Costs were hopefully controlled by cost investigation teams from the BPO at the contractors' works.

Meetings of the BTTDC were preceded by separate meetings of the contractors and the BPO. In consequence, the main meeting was something of a formality. The chairman (Post Office) might say, 'The BPO requires 50 000 Jacks No. 9A'. The vice-chairman (contractors) might reply, 'Messrs. X will be contracting for supply'.

As the dominant customer for telephones, the BPO followed customs which may not have contributed to the long-term health of the industry nor, in the end, have given the BPO the instrument it really needed.

It required, as nearly as possible, a universal telephone adaptable to every possible condition and facility. This resulted in a basic instrument with additional tags and wiring and mouldings that was not the cheapest possible for

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† Formerly, Technology Executive, British Telecom Engineering and Procurement

* In 1969, the British Post Office (BPO) ceased to be a Department of State and became a Public Corporation. In 1981, the telecommunications business of the BPO was split from the Post Office to became a separate corporation trading under the name British Telecom (BT), and in July 1984 it became a public company, British Telecommunications plc.

either home or export markets.

For many years the BPO bought telephone components (dials, microphones, cords, etc.) in bulk and issued them free to the various telephone manufacturers. As a result, no one manufacturer knew the true cost of a telephone and no manufacturer was totally responsible for the performance of a telephone.

The placement of annual orders for telephones was a distinctly erratic affair: one million one year, half a million the next, then two million the next year. The BPO did not do this out of spite; in its turn it was having its tariffs and its capital investment dictated by the Treasury. During these ups and downs of supply, the BPO survived by reason of its vast stocks (in March 1980 its stocks of telephones amounted to a year's demand) and by refurbishing recovered instruments.

Whether the number of telephones in the UK is a consequence of this climate or of other factors is not entirely clear. Fig. 1 shows the number of telephones per hundred population for a number of countries. The cheering fact for telephone designers and manufacturers is that there are some 600 million telephones in the world at about 12 per 100 of the population. The potential market is vast.

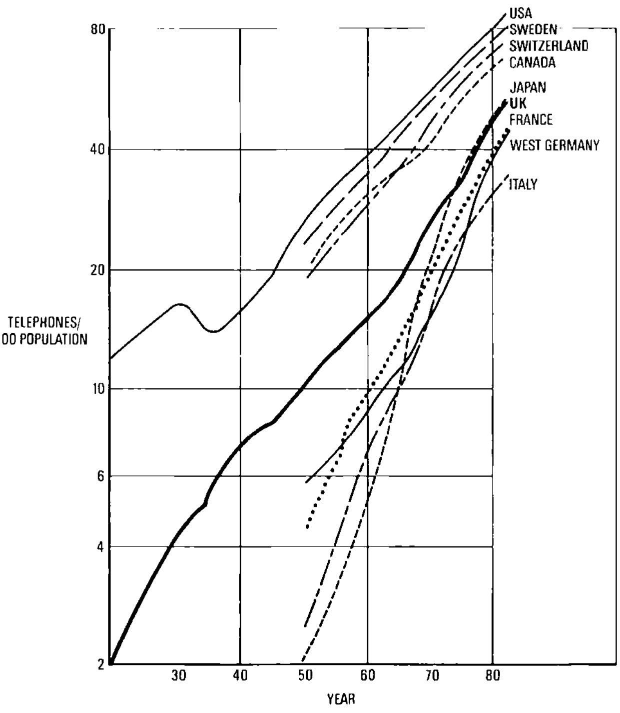

Fig. 1—Telephone density in a range of countries

CARBON GRANULES

For nearly a hundred years, telephony throughout the world depended on the carbon granule transmitter; it was cheap, relatively reliable and did not require an amplifier. Many men of high ability devoted the best years of their lives to studying the microphonic action of granular carbon and produced almost as many theories to account for that effect.

The purpose of those studies was not solely the quest for knowledge. The BPO wanted to know how to specify carbon granules, how to avoid the troubles that carbon microphones were prone to, and how to make even better microphones.

The carbon transmitter has several commonly-known disadvantages that affect performance. They are, in order of seriousness:

(*a*) it is liable to severe falls in sensitivity, a phenomenon known as *packing*, normal sensitivity can be restored by shaking it.

(*b*) the resistance of the transmitter gradually increases until it exceeds the permissible limit for signalling purposes. (It will be appreciated that the transmitter forms part of the loop across the exchange line for signalling and holding purposes.)

(*c*) a small percentage of transmitters become noisy in service.

This last factor led to a situation where it was difficult to obtain reliable data on in-service faults. The folklore said that if an engineer visited a customer who had complained of noise on the telephone, then the carbon inset was always changed, just in case, even though the cause of the noise, which had probably cured itself by the time that the engineer got to the customer's premises, may have been in the line plant or the exchange.

The average service life of a carbon transmitter was assumed to be about 10 years; it varied from a few months in kiosks at busy railway stations to over 20 years in quiet residential locations. It was commonly thought that the carbon transmitter was the most fault prone component of a telephone, but this is not borne out by the statistics. A typical set, produced in 1968, shows one fault per telephone per six years, and the most common reasons for complaint to be the following:

microphones	10% of total faults
receivers	6%
dials	10%
bells	10%
case breakage	10%
other causes	54%

Apart from the question of packing, it might be argued that the reliability and average life of the carbon transmitter were not unreasonable. Packing, however, became a serious problem in the 1960s and much effort was expended in an attempt to understand its causes and to find out why some transmitters became noisy in service. Tribute should be paid to a great deal of unpublished work on this problem by Dr. A. Fairweather and Dr. G. H. Metson at the Post Office Research Station at Dollis Hill.

In the early days of the telephone, every user knew that the carbon granules packed and that the first thing to do before the telephone was used was to shake it. This state of affairs lasted until about 1930 when the situation was changed radically by the introduction of the Transmitter Inset No. 10 and the handset telephone. The Transmitter Inset No. 10 (thought to have been the work of Wigan and Sutton) was especially designed as a non-packing microphone with its electrodes immersed in free-flowing carbon granules. The theory was that even if the granules had packed overnight, the act of picking up the handset would result in complete unpacking. The transmitter was very successful, and a few years later, with modifications, it became the Transmitter Inset No. 13.

During the next 30 years, granules were manufactured by at least four different suppliers and, as far as is known, all their products were satisfactory. Then, in 1959, two new factors were introduced: one manufacturer of microphones moved his factory, and in so doing apparently lost the secret of producing satisfactory granules; at the same time the 700-type telephone was introduced with a spark-quench circuit which permitted heavy current discharges through the transmitter during dialling. Penetration of the new telephone into the network was at first slow (in those days advertising to stimulate demand was unthinkable, situations always had to be under control!). Thus it was some years before a significant number of transmission complaints began to filter back to BPO Headquarters. Suspicion initially fell on the regulator circuit because it was a totally new item. Consequently, Research Branch at Dollis Hill, which had designed the regulator, had to spend a great deal of time trying to prove a negative. Finally, in 1963, it was established that all the Transmitter Insets No. 13 made by the manufacturer that had moved his factory (and by that time there were a million in service) exhibited severe packing propensities with an accompanying drop in sensitivity of at least 20 dB.

After this discovery, an intensive study of carbon granules was started by the BPO at Dollis Hill and by industry. One of the early conclusions was that dialling surges in the 700-type telephone aggravated packing. In addition, as a safety measure, the BPO decided not to buy granules except for one particular grade from one particular manufacturer, fervently hoping that this manufacturer would not lose his skill in the black art of converting anthracite into granules. But despite all the research effort, no specification for carbon granules was ever written.

There are two other stories that are relevant to the history of the carbon granule.

At a meeting of the Subscriber's Apparatus Development Sub-committee of the BTTDC in January 1947, the BPO informed the manufacturers of its desire to introduce a completely new telephone within three or four years. A new receiver was already under development by industry, and the BPO proposed shortly to issue a target specification for a new transmitter. In June 1948 the specification was issued and development allocated to a manufacturer. In October 1950, the first preliminary samples were received for test and in 1961 (11 years later) the new transmitter went into quantity production as the Transmitter Inset No. 16.

What happened between 1950 and 1961? Technically there were problems, as there are with most new developments; first packing problems, then noise. Hints at more fundamental reasons for the slow progress of development can be found in the minutes of various meetings. At a meeting in 1953, the Engineer-in-Chief stated that, if the new transmitter proved to be more expensive than the Inset No. 13, it would be ruled out completely since, although its improved frequency and amplitude characteristics made it pleasanter to listen to, this did not enable any economies in line plant to be made. At another meeting in 1954, the Director of Research to the BPO estimated that it would be another three-and-a-half years before the new microphone could go into production, and queried whether the manufacturer should be encouraged to continue development.

The final story concerns the demise of the carbon microphone in the UK's telephone network, although such reports must not be exaggerated; BT does not issue carbon microphones for new work, but it has no control over foreign telephones that are sold in shops.

Research in the BPO on alternatives to carbon granules goes back to the 1960s. An early promising contender was the electret, but it took many years to establish a repeatable method of charging the film and more to prove the long-term stability of the resulting microphone. When this had been done, it had to be proved that a total package of electret and amplifier, assembled as a drop-in replacement for the Inset No. 16, could be manufactured for the same whole-life cost as the carbon microphone. The battle was won in 1981 when the Microphone Inset No. 21 made its appearance, just as fully electronic telephones, such as Viscount and Statesman, were being introduced. Linear microphones, such as the electret, give improved speech quality and better reliability than carbon microphones, but have a subtle side-effect: they amplify quiet sounds as much as loud ones. Carbon microphones, on the other hand, are less sensitive at low sound levels. This means that a telephone with a linear microphone may make room noise more obtrusive than one using carbon.

EARLY TELEPHONES

Since the BPO took over the National Telephone Company in 1912, there have been many variants of telephones for special purposes, but the tale is quickly told if discussion is confined to the main-stream instruments.

In the Edwardian period, telephones were magnificent affairs of brass and mahogany and had handsets that are being copied today. These, of course, were for magneto signalling, and local batteries supplied the power for transmission. In other words, the customer turned a generator to call the exchange and to signal when a call had finished (hence the expression, 'to ring off').

All carbon microphones at that time were of the so-called *solid back* type. They consisted of two flat electrodes with a loose charge of carbon granules between them; they only worked with the microphone close to the vertical; if they were turned into the horizontal plane they became an open circuit. Once central battery signalling was introduced, with the exchange loop completed through the microphone, handset telephones had to go.

In 1912, the candlestick Telephone No. 2, which became Telephone No. 150 without major change, was introduced.

In 1929, the BPO's first handset telephone[3] for central battery working was introduced—the Telephone No. 162. It appears to have been based largely on a design by Siemens, although the general shape of the case undoubtedly followed a slightly earlier French design which was the definitive telephone shape throughout the world for a few years. The microphone overcame the problems associated with solid back transmitters by immersing the electrodes in the carbon granules. This telephone was the first large-scale application of 'bakelite' moulding in the UK.

Telephone No. 232 was externally identical to the 162, but incorporated for the first time an anti-sidetone balance network as part of the induction coil.

In 1938, the first combined telephone and bell set (the 300-type[4]) was introduced in a case similar to the one shown by Ericssons at the Stockholm Exhibition of 1932 (where the Prince of Wales bought two for his private use). There were grave reservations within the BPO about the acceptability of a combined instrument in the residential market.

Consideration of a more sensitive design of telephone after the war was prompted by the desire to increase the local loop resistance from 600 Ω to 1000 Ω and thus increase the potential area served by individual exchanges. Action had to be deferred until the early-1950s for three reasons: industry was opposed to radical change while it recovered from wartime activities; new and more sensitive transducers were not available and had to be developed; and the transmission performance of the existing BPO network was just not known with any accuracy.

Originally the BPO had intended to bring out its new telephone in the 300-type case because the administrators saw no financial advantage in a change (see Fig. 2). How-

Fig. 2—Original 700-type telephone in 300-type case

ever, in April 1956, when the circuit and components were ready and the field trials were about to commence, the BPO informed industry that it wanted a new case. By October 1956, several models had been submitted and a design by Ericssons was accepted in June 1957. The 700-type[5] telephone was finally offered to customers in mid-1959, initially at a premium to limit demand.

Fig. 3 shows the prime costs of some of these telephones at 1982 prices. It is interesting to note that, apart from the distortions due to war, the factory gate price of a telephone has generally declined at around 7% per annum. The 700-type telephone lived long enough to see this trend bottom out; it then suffered a step increase in cost as a result of an exercise to improve its reliability (the vogue term was value analysis).

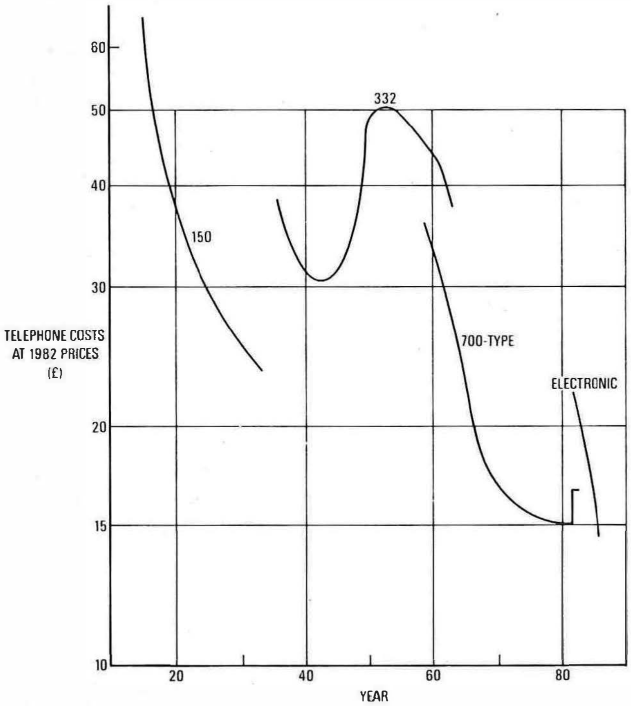

Fig. 3—Prime costs of various telephones

THE TRIMPHONE

The *Trimphone*[6] was first made available to customers in 1966 as a premium telephone at extra rental; by 1980, there were 1·6 million in service out of a total telephone population of 27 million.

In 1961, the BPO decided that it needed a luxury telephone to add to its range and so informed industry. Several firms were developing telephones for export, out of their own resources, that might have met the BPO's requirements and several models were submitted for test in 1962. There followed a period of two years during which various performance and reliability tests were made and block models used to test market reaction.

Towards the end of 1963, one manufacturer, STC, decided to start tooling up for export and all the other firms withdrew. This left the BPO with two options: to accept the STC design substantially as it stood or pay for development to its own specification. It chose the former, and in 1964 placed a contract for 10 000, see Fig. 4.

Obviously the *Trimphone* was liked by a substantial number of customers, and its transmission performance was very close to that of the standard 700-type telephone, but it had a number of interesting characteristics.

Fig. 4—*Trimphone*

It was light in weight, 0·8 kg compared with 1·4 kg for the 700-type telephone and 2·6 kg for the 300-type telephone. This led to complaints that, on slippery surfaces, the telephone turned with the dial.

It had a hollow handset, as opposed to the solid mouldings of earlier telephones. Thus, if the user attempted to place a hand over the microphone in order to make a confidential aside, the sound was still transmitted inside the handset with embarrassing results. (The same effect occurs in nearly all modern telephones for exactly the same reason.)

The *Trimphone* had a luminescent dial which glowed green in the dark. The effect came from a small glass tube of tritium gas which gave off beta radiation and made the dial fluoresce. Although the radioactivity was equivalent only to that given off by a wrist watch, and although no one was likely to be so closely or continuously associated with a telephone as they might be with a watch, it was felt wise to withdraw this facility as public concern over radioactivity grew.

AMBASSADOR, VISCOUNT AND STATESMAN

This is a story of diverse parts of the BPO and industry each trying to do what it thought was best with the resources available to it and in circumstances changing rapidly from monopoly to commercial competition.

Design of the *Ambassador* range[7] of telephones started around 1973. It was to be a new universal telephone with options for dial or keypad, and bell or tone caller. Its initial design was for the conventional circuitry of induction coil and carbon microphone with a later change to fully electronic form.

Development contracts for the various parts of the telephone—case, cordage, printed wiring board, electrical components—were let to a number of manufacturers while the BPO retained overall control. The aim was to bring out a modern adaptable telephone at a lower cost than the existing press-button versions of the 700-type telephone.

In 1979, when the *Ambassador* programme was well advanced, the Research Department of the BPO was asked to make proposals for a fully electronic telephone with the same whole-life cost as a dial telephone. A few months study suggested that the idea was feasible. After some discussions with industry, a method of working was evolved that was novel at that time within the BPO. A contract was let to STC to define a new electronic telephone. The duration of the contract was two months and its output was a document that defined precisely the performance and characteristics of such a telephone, its unit cost in quantity production and the start date for production. Immediately following this definition phase, a development contract was let with STC on the understanding that a production contract would follow if milestones were achieved and provided that the new telephone met all the criteria of the definition document: performance, time and price. It did, and *Viscount* went into production in April 1982, Fig 5.

Fig. 5—*Viscount*

These events did not go unnoticed by the remainder of the UK telephone manufacturing industry, three of which collaborated to produce a design which they called the *Inexpensive Telephone*. This they proposed to bring into production at a price and timescale closely similar to *Viscount*; and they did. This telephone is still in production as *Statesman*, Fig. 6.

Fig. 6—*Statesman*

Thus, for the first time, there was true competition in the production of telephones in the UK. It was healthy and invigorating. It happened not just because of the imminent threat that the BPO would lose its telephone monopoly, more because half-a-dozen people in industry and the BPO were in the right jobs at the right time. There may have been weeks when they did not speak to each other, but there can never be any doubt about the mutual respect.

SCEPTRE

The *Sceptre* telephone[8] was an accident of history. In September 1980, the BPO's Research Laboratories at Martlesham Heath had an open week. A few months beforehand, a few of the engineers thought that they could produce an interesting exhibit by using an existing microprocessor to control an advanced facility telephone. They faced a major problem—a naked telephone on its printed wiring board does not make an eye-catching display.

Happily, at exactly the right moment, they discovered that a technician was amusing himself in his lunch break by carving new designs for telephone cases out of wood with his penknife. This was stopped immediately and he was put onto making up one of his designs in glass fibre and resin. The resulting telephone was shown at the open week as *Microtel* and attracted substantial interest. Nine months later it was in production as *Sceptre*, Fig. 7.

TRIBUNE AND VENUE

The *Tribune*, Fig. 8, and *Venue* telephones, Fig. 9, are the

Fig. 7—*Sceptre*

Fig. 8—*Tribune*

Fig. 9—*Venue 24*

second generation plain and fancy telephones; both were launched in 1986.

They are the product of teams—marketing, design, development, production—that have become much more professional during the past four years. In the days when new telephones were introduced by the BPO every 10, or even 20, years there was little opportunity for people to learn their craft and apply the lessons that they had learned. Just as important, the co-operation and trust between development and production staff had to be re-established every time.

THE FUTURE

The plastic case has always been on the critical path in telephone development. Computer-aided design of plastic mouldings may well change that. Mould tools can now be cut directly from the information on a tape produced by a computer, and the flow of hot plastic in these moulds is known with precision before they are ever made. *Tribune* is the first UK telephone to employ these techniques.

Telephone production and testing is now a highly automated process. So, incidentally, is the circuit design. From a few electrical and acoustical measurements of a completely new telephone design, it is possible to predict with confidence the subjective opinions of customers about its transmission performance over the diverse range of circuits found in the UK telephony network.

For the future, one thing can be said with complete confidence. There is no reason inherent in the UK, its people or its climate, why telephones should not be designed and made here equal in quality, cost and performance to anything made elsewhere in the world. History, however, teaches us humility; poor management can ruin anything.

ACKNOWLEDGEMENTS

Many people have unwittingly contributed to this article in unpublished papers and in conversations, some of which go back many years. In particular, in the section on carbon granules, F. E. Williams may recognise some of his own carefully constructed prose.

By great good fortune during the past 30 years I have been given staff who were world experts in their varied disciplines. My job was merely to see that they could pursue their craft in as calm an environment as possible. Sometimes the waves were too great and life became exciting for everyone. From retirement I pay tribute to those who were more capable than I.

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Biography

Ron Walker joined the BPO as a Youth-in-Training at the Research Station at Dollis Hill and spent most of his 44 years service in communications research. He worked in defence communications and helped design the National Health hearing aid in the 1940s. He had a spell in radio research—at Cardiff and Bristol in the 1960s, and designed the 1963 version of the speaking clock. He retired as Head of Consumer Products at BT's Research Laboratories at Martlesham Heath in July 1986 and now lives in Somerset where he has turned his energies to restoring Victorian coach houses.

Speech Transmission Design for Electronic Telephones

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UDC 621.395.6 : 621.396.218

This article outlines the elements of speech transmission design appropriate to electronic telephones in the local network with particular reference to 2- and 4-wire switched call routing apparatus.

INTRODUCTION

The development of 'fully electronic' telephones for the UK network in the early-1980s afforded the opportunity to review the fundamental speech transmission parameters of the telephone and, more significantly, their realisation. With the benefit of field experience since the introduction of such telephones as Viscount[1] and Statesman[2], this article reviews the design of analogue electronic telephones in the modern network environment.

Speech transmission circuits based on the carbon microphone and a wound transformer hybrid for separation of the send and receive signals had been prevalent since the 1930s and had reached a peak of elegant and economic design within the UK in the late-1950s with the introduction of the 700-type telephone. A circuit design philosophy was adopted that ensured that components served more than one function; for example, the capacitor used for spark quench during signalling formed part of the anti-sidetone circuit during transmission, and blocked DC from the receiver. While such an approach led to economy of design, it also gave rise to compromises which, together with the use of the carbon microphone, meant that the impedance the telephone presented to line was not well controlled, and independent design of the major telephone parameters was not feasible.

PRIMARY TELEPHONE CHARACTERISTICS

The performance of any telephone largely depends on the choice of its primary characteristics (see Fig. 1):

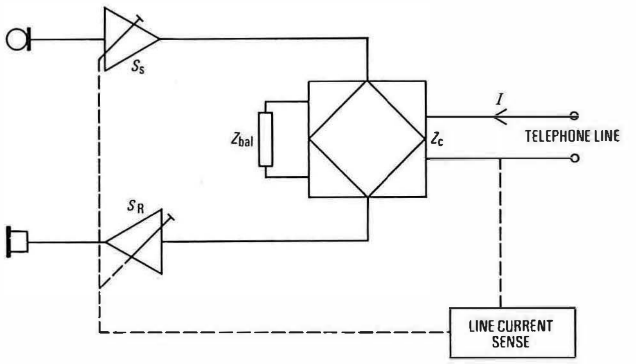

Fig. 1—Primary telephone characteristics

S_S—the sending sensitivity;
S_R—the receiving sensitivity;
Z_C—the impedance that the telephone presents to the line; and
Z_{SO}—the line impedance for minimum sidetone.

Each of these is potentially a function of both frequency and line current.

The sensitivities depend on the frequency response of the transducer/handset combination and the gain introduced by the sending and receiving paths of the telephone set. The sending frequency response is designed to have a rising characteristic within the speech band to increase the intelligibility of the transmitted speech and to avoid overload of line transmission systems. Above 4 kHz, it falls rapidly to prevent unwanted out-of-band components being sent to line. Fig. 2 shows the limits set for the sending frequency response in British Standard BS 6317:1982, together with a characteristic typical of a modern electret microphone. The receiving frequency response is nominally flat within the audio band, and rolls off at low frequencies to reduce the effects of mains interference and at high frequencies to exclude the unwanted products of pulse-code modulation (PCM) transmission systems. Limits from BS6317:1982 together with a typical response are shown in Fig. 3.

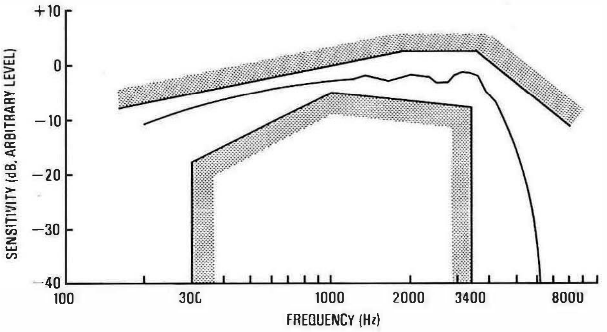

Fig. 2—Sending sensitivity limits for line lengths of 0 km with typical sending sensitivity response

Developments in these areas with the introduction of electronic telephones are generally smoother frequency responses, particularly for the microphone, and a better control of production spreads. Modern linear microphones do, of course, overcome the noise problems that have always beset the carbon microphone and do not suffer from granule

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† Technology Applications Department, British Telecom Engineering and Procurement

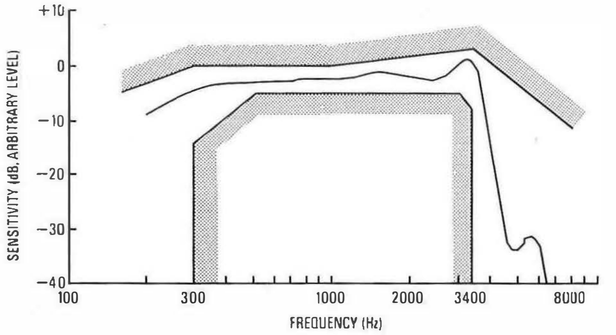

Fig. 3—Receiving sensitivity limits for line length of 0 km with typical receiving sensitivitiy response

packing with its associated reduction in sensitivity. Linear microphones do not emulate all the characteristics of carbon microphones, however, as will be discussed later.

The gain introduced into the sending and receiving paths is chosen to ensure that the telephone set has a sensitivity in accord with the transmission plan of the telephone network. Loudness ratings, as discussed in the next section, are the appropriate units of measurement. It should be noted here that the gain varies as a function of the line current so that the sensitivity of the set reduces at the higher line currents associated with short exchange lines. The sending and receiving sensitivities are each reduced by around 4 dB.

The impedance that the telephone should present to line, Z_C, is chosen from a network viewpoint to restrict the range of impedances that a local telephone circuit, comprising local cable and the instrument itself, presents to the local exchange. This reduces the level of any echo signal presented by the local end on both national and international calls, and allows a better control of sidetone on short-line own-exchange calls than was possible with the 700-type telephone. Historically, the design impedance adopted (though rarely realised) was 600 Ω. For the development of the Viscount telephone, a complex impedance was adopted, as shown in Fig. 4. This impedance, which is the preferred design value within British Telecom (BT) for all telephone instrument designs, is included as an option in BS6305:1982 (Fig. 5 of that document).

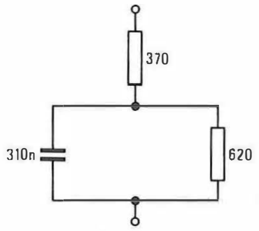

Fig. 4—Design aim for the impedance that a telephone should present to line (Z_C)

The line impedance presented to the telephone for minimum sidetone, Z_{SO}, is a little more esoteric and warrants some further explanation. One important task of the transmission circuit in any telephone is to combine the 4-wire handset path into the 2-wire path that connects to the exchange line, and to achieve this with minimum coupling of the microphone signal into the receiver. Any coupled signal, known as *sidetone*, if not adequately controlled over the range of exchange connections encountered by the customer, causes transmission difficulties and gives rise to complaints. A review of the topic is to be found in a previous article[3].

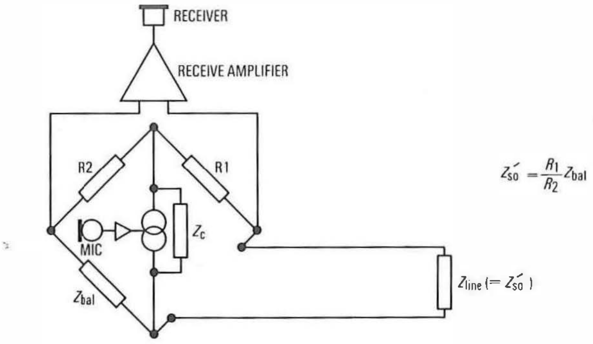

Fig. 5—Telephone bridge circuit

Most telephone designs achieve sidetone cancellation by using some form of bridge circuit, as shown in Fig. 5. If Z_{SO}' is regarded as the *average* impedance presented by the telephone network, then a fixed compromise balance impedance, Z_{bal}, can be chosen to minimise the sidetone level when an impedance Z_{SO}' is placed across the telephone terminals. Complete acoustic sidetone cancellation is possible only where there is no acoustic or seismic coupling between the microphone and receiver in the telephone handset; in practice, minimum values of coupling must be met by the acoustical and mechanical design of any handset.

The value established for Z_{SO}' for the present UK network, taking into account the range of local cables, junction circuits, trunk circuits and exchange terminations, is shown in Fig. 6. This value was established by considering direct exchange line connections only and does not take account of any call routing apparatus introduced into the local telephone connection. The wide variation of characteristics encountered in the latter case precludes sensible choice of any single compromise value of impedance and, as argued later in this article, an appropriate design methodology needs to be adopted for all customer apparatus equipment. Establishing the value of Z_{SO}' is a fundamental step in that methodology.

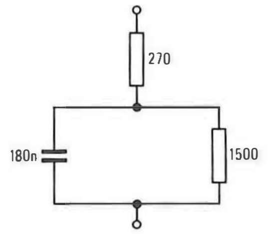

Fig. 6—Line impedance for minimum sidetone (Z_{SO})

The approach of specifying the primary characteristics was first adopted for the Viscount telephone and is a departure from the historical method of specifying performance over the local telephone system and still adopted within the British Standards appropriate to telephone instruments connected to the UK telephone network.

LOCAL TELEPHONE SYSTEM AND LOUDNESS RATINGS

The performance of a telephone over the local telephone system is assessed by making measurements between the instrument itself and a 600 Ω impedance terminating the feeding bridge in the local exchange, the latter nominally representing the impedance of any ensuing junction circuit. Laboratory measurements are made by using artificial cable

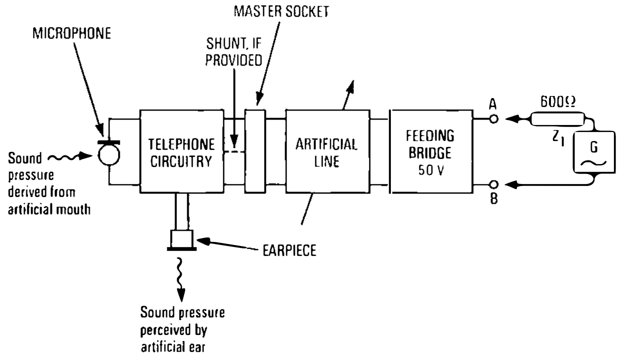

Fig. 7—Local telephone circuit

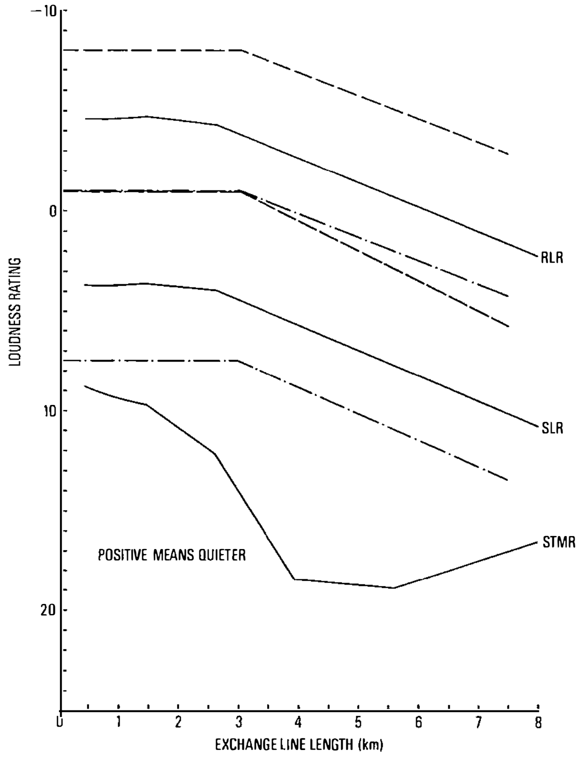

Fig. 8—Loudness ratings of an ideal telephone

and a feeding bridge as shown in Fig. 7, which is taken from BS6317:1982. The characteristics of the artificial cable are chosen to represent 0·5 mm copper cable and the characteristics of the feeding bridge are those appropriate to a Stone Bridge. The telephone handset is held in a prescribed manner (CCITT† Recommendation P.76 Annex A) and the sending and receiving characteristics are established as follows:

(*a*) known sound pressure levels are applied to the microphone and the resulting junction voltages are measured; and

(*b*) known junction voltages are applied and the resulting sound pressure levels from the receiver are measured.

Measurements are made as a function of frequency and at each of a number of lengths of local cable. To establish the sidetone performance of the telephone, a further measurement is made at each line length of the sound pressure level that appears in the receiver when the microphone is stimulated.

Loudness ratings (LRs) are calculated from these values of voltage and sound pressure for each line length. A loudness rating is a single number representation of the sending, receiving or sidetone performance of the telephone in the local telephone circuit being a weighted average of the appropriate sensitivity characteristic. The formulae for calculating loudness ratings are given in Appendix 1.

The values of the sending, receiving and masked sidetone loudness ratings (SLR, RLR, and SMTR) calculated for a telephone having the ideal impedance characteristics described previously and appropriate sensitivities are shown in Fig. 8, together with the appropriate masks taken from BS6317:1982. The reduction in sensitivities at the higher currents associated with shorter exchange lines on conventional voltage feed exchanges, known as *regulation*, is apparent in this figure. On constant-current feed exchanges the telephone adopts an appropriate fixed value of sensitivity (high) and the regulation function is carried out on the exchange line card.

The BS specification for sidetone performance calls for a masked rating of quieter than 7 dB (or 1·5 dB below the SLR). Quieter in loudness rating terms means numerically greater. The 'ideal' telephone of Fig. 8 clearly meets this requirement, but it should be appreciated that the criterion can be met with a wide range of values chosen for the telephone balance impedance, Z_{bal}, which would result in a correspondingly wide variation of transmission performance on the real telephone network.

Although a limit of 7 dB is set for the STMR within the BS specifications for telephone apparatus, this may well prove insufficient in modern noisy office environments. There are two components to sidetone that need consideration: talker sidetone and listener sidetone. The former, largely discussed in reference 3, relates to that level of sidetone which a telephone user can detect while talking. If it is uncomfortably loud, the talker reduces his vocal level to compensate; this is clearly undesirable on lossy connections. Generally, talker sidetone is detectable, though not objectionable, for an STMR of 5 dB or less in a quiet room.

Listener sidetone, however, relates to the level of room noise, modified by the directional properties of the telephone handset and microphone, that couples via the sidetone path of the telephone and reduces the receiving signal-to-noise ratio. If this becomes excessive, the user complains of poor received speech level. Listener sidetone becomes much more significant with the 'linear' microphones used in modern electronic telephones since, unlike the carbon microphone, they are equally sensitive to both the user's speech and the prevalent ambient noise level. The carbon microphone is less sensitive to low sound pressure levels, and so, while the telephone user is listening, little room noise is coupled via the sidetone path to the telephone receiver. As a consequence, it becomes more important to control the sidetone level with electronic telephones. A recent CCITT contribution[4], introducing a new measure called *sidetone room noise rating* (STRR), suggested that electronic telephones using linear microphones require an increase in STRR (and hence STMR) of 3–8 dB for the same subjective performance as a carbon microphone in a traditional handset. A more appropriate design aim for STMR, certainly where telephones are for business use, would be around 12 dB rather than 7 dB.

The point is illustrated further in Fig. 9, where the subjec-

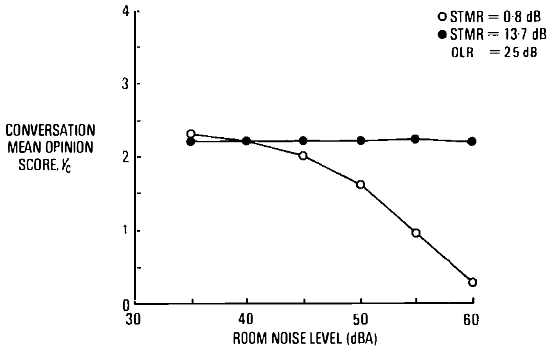

Fig. 9—Effect of room noise on conversation mean opinion score

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† CCITT—International Telegraph and Telephone Consultative Committee

tive model CATNAP[5] has been used to plot conversational mean opinion score against room noise level; the telephones have STMRs of 0·8 dB and 13·7 dB respectively. The opinion score falls rapidly with increasing room noise on a lossy connection if the sidetone is poor; however, with good sidetone on the same connection, the level of room noise has little effect. Fig. 10 shows how the user of a telephone with poor sidetone tends to raise voice level with increasing room noise level.

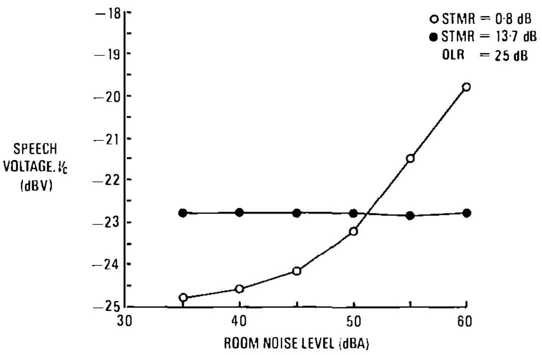

Fig. 10—Effect of room noise on speech voltage

Adequate control of both talker and listener sidetone is an important consideration if transmission complaints are to be avoided and a design aim of around 12 dB is recommended as target.

TRANSMISSION CIRCUIT ARCHITECTURE

As implied in the introduction, the use of active electronics in the design of a speech transmission circuit allows greater independence in setting and controlling the characteristics of telephones, although differing circuit realisations will have their own merits.

To meet the requirements for signalling, the DC impedance must be lower than the AC impedance of Fig. 4; therefore, the circuit must behave as an inductor at low frequencies, and care must be taken to ensure that it becomes capacitive over the audio band.

The sending and receiving amplifiers are relatively straightforward in design. The sending amplifier usually provides a constant current drive to line and is typically combined with the DC shunt regulation circuit. The AC impedance may be synthesised by using current mirrors around the output stage or can exist as a physical impedance across the line driver.

The receiving amplifier needs to amplify the incoming signal from the exchange line, but to cancel the sidetone component of the signal originating from the microphone; this may be achieved by using a differential amplifier of adequate common-mode rejection and presenting a replica of the signal sent to line on the negative input. The function is best viewed as a Wheatstone bridge circuit, shown in Fig. 5. The impedance that the telephone presents to line, Z_C, is realised across the sending amplifier on the bridge diagonal and the resistor R1 is chosen to be very small, typically 50 Ω, so as not to reduce the power transfer of the signal sent to line or affect the presented impedance. The balance side of the bridge is chosen to be high impedance for the same reasons. The value of resistor R2 may be 10 to 50 times that of resistor R1 and, since balance occurs when

$R_1/R_2 = Z_{\text{line}}/Z_{\text{bal}}$ at all frequencies in the audio band, the value of Z_{bal} is a scaled value of the line impedance. In realising a circuit design, the value Z_{line} would be equated to the value Z_{SO}' of Fig. 6.

The particular advantage of the architecture described so far is that both Z_C and Z_{bal} can be set independently and, more particularly, any tolerance errors in their circuit elements do not interact. Thus tight control of these important impedance characteristics is possible in production.

Other circuit realisations use summing receive amplifiers (phase cancellation) or current mirrors to control the sidetone level and, in such an approach, not only is a greater control of the active circuit elements necessary, but the telephone output impedance appears in parallel with the line impedance as shown in Fig. 11. The balance impedance now becomes:

$$Z_{\text{bal}} = (Z_{\text{line}} \parallel Z_C) R_2/R_1,$$

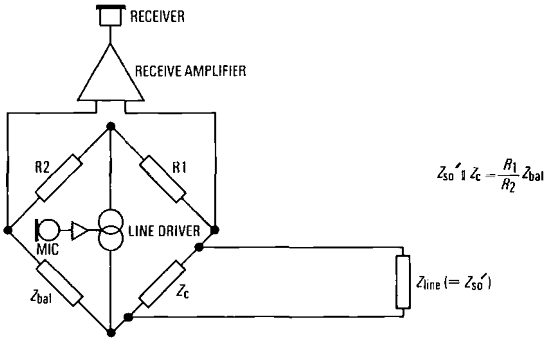

Fig. 11—Alternative circuit architecture

and the control of the production spread of the sidetone performance of the telephone becomes critically dependent on the tolerance of the circuit elements used for impedances Z_C and Z_{bal}. Furthermore, should the modulus of Z_C, through tolerance or design, become less than that of Z_{bal} (allowing for any scaling of R_1/R_2), then the value measured for Z_{SO} of the telephone has a negative real part; this may prove both difficult to measure and confusing.

The only advantage of the approach is that, by removing the resistor R1 in series with the transmission circuit, lower-voltage operation becomes possible; however, in general, this architecture is not preferred.

Now that the transmission design of the electronic telephone for direct exchange line working within the UK network has been discussed at some length, the effects of introducing additional customer premises equipment into the local telephone circuit can be examined. Most of this equipment takes the form of a switch or PBX; two categories require examination: the 2-wire and the 4-wire switch.

TWO-WIRE SWITCHED CALL-ROUTING APPARATUS

The main effect of introducing a 2-wire switch between the telephone and the local exchange is to isolate the telephone from the line current it would normally receive, as depicted in Fig. 12. From an AC viewpoint, a well-designed 2-wire switch appears transparent. In a typical installation, the telephones are connected to the switch by a minimal length of extension cable, and the main variation in performance continues to be the length of the local exchange line. For discussion here the extension cable is considered to be of zero length.

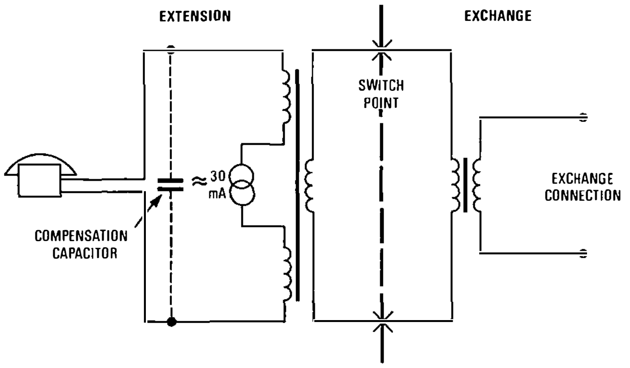

Fig. 12—Ideal 2-wire switch

To limit power consumption and reduce the production cost of the switch, the current fed to the telephone on the extension side is typically around 30 mA. (It has also been argued with some justification, that such a limited current feed improved the life and reduced the noise of carbon microphones.) At such values of current, the sensitivities of the telephone are at their maximum since gain regulation does not take effect until the line current exceeds some 40–50 mA. If the loudness rating calculations leading to Fig. 8 are now repeated, but with a fixed current feed to the telephone, the sidetone performance on short exchange lines becomes very much poorer and, in the absence of regulation, the sending and receiving loudness ratings are also high, as can be seen in Fig. 13. Indeed, the combined levels may be sufficient for the telephone handset to suffer 'howl round' when placed on a desk or table and will be uncomfortable to use, particularly in noisy office or factory surroundings.

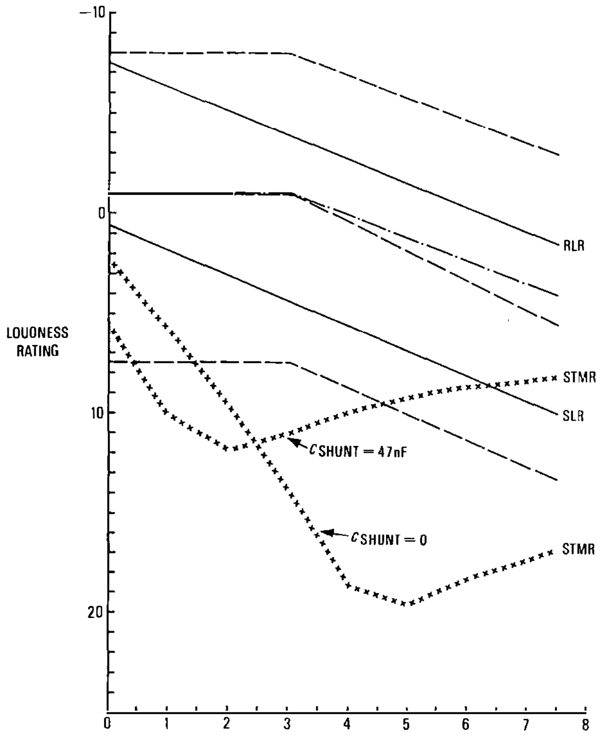

Fig. 13—Telephone performance on a 2-wire switch

For an ideal 2-wire switch, the problem could be surmounted most readily if the extension current feed mirrored the current fed from the local exchange; however, economics appear to preclude this solution and few practical designs approach the lossless transparent ideal. To restore the sidetone to an acceptable level, the input impedance to the switch must be modified to achieve a better match with the balance impedance chosen for the telephone. The latter, following the arguments presented so far, is set from consideration of the performance on direct exchange line connections. Indeed, the match must be improved by some 8 dB to compensate for the combined increase in sending and receiving gains that results from operating the telephone at low current levels.

In Fig. 13, calculations are also included for the STMR when the ideal 2-wire switch has its input shunted by a 47 nF capacitor; these calculations show that the level of sidetone can be restored to an acceptable value for short exchange line lengths; however, it is made worse at longer line lengths. Ideally, the input impedance could be switched between, say, two values depending on the length of the exchange line. The shunt capacitor on the input to the switch also modifies the impedance of the telephone and switch as seen by the local exchange; although this is comparable with the impedance that would be seen for a telephone and short length of local cable.

Real switches possess both loss and finite input/output impedances, and appropriate care must be taken in their detailed design. Indeed, the 47 nF capacitor used to shunt the input of the hypothetical switch could well worsen the transmission performance in practice. The principles discussed, however, still apply.

FOUR-WIRE SWITCHED CALL-ROUTING APPARATUS

The introduction of a 4-wire switched PBX between the telephone and the exchange in the local network increases the opportunities for upsetting the overall network transmission plan manifold, as consideration of Fig. 14 will reveal. Two further 2-to-4-wire converters are introduced with associated input and balancing impedances, and gain is required in the 4-wire path to compensate for their inherent loss.

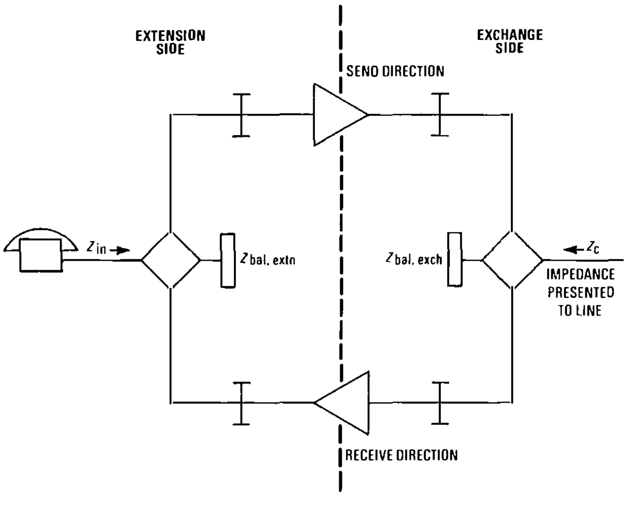

Fig. 14—Schematic of 4-wire switch

A unique solution to impedance and gain plan design is not possible if the switch is to operate over the full range of local network conditions. The gains must be altered to compensate for the loss of different line lengths, and care must be taken to ensure that the impedance presented to the telephone results in a well-controlled level of sidetone if the customer is not to experience any transmission difficulty.

Reference to Fig. 14 shows that the impedance presented to the extension telephone is controlled by the input impedance of the extension line card, Z_{in}, and the degree of mismatch at the exchange card 2-to-4-wire converter between its balance impedance, $Z_{bal,exch}$, and the impedance presented by the telephone network. Similarly, the impedance the switch (and telephone) presents to line is determined by the output impedance of the exchange line card, Z_C, and the mismatch between the extension card balance impedance, $Z_{bal,extn}$, and the impedance of the telephone and its associated wiring. For the latter case, the design aim impedance is again Fig. 4 of this article (that is, Fig. 5 of BS6305:1982).

Thus there are four impedances of interest, and studies have shown that judicious choice of these impedances allows good control of the transmission performance of a 4-wire switched PBX within the local network. The following table suggests values of these impedances which can provide a reasonable match to the BT network and telephones meeting BS6317.

EXTENSION CARD

Input Impedance	*Balancing Impedance*
Table 1—Input Z	Fig. 4

EXCHANGE CARD

Output Impedance	*Balancing Impedance*
Fig. 4	Long Lines: Table 1—Input Z Short Lines: Table 1—Balancing Z

Note that the short/long line transition occurs for a local cable length of 2 km.

TABLE 1

Four-Wire Switch Impedances

Frequency		Input Z (Ω)		Balancing Z (Ω)	
No.	Hz	Real	Imaginary	Real	Imaginary
1	200	1280	−293	1057	−220
2	250	1237	−349	1022	−259
3	315	1174	−411	973	−300
4	400	1087	−469	909	−335
5	500	987	−510	839	−358
6	630	869	−531	762	−368
7	800	744	−524	683	−363
8	1000	637	−494	616	−348
9	1250	547	−447	556	−325
10	1600	469	−387	500	−297
11	2000	419	−333	458	−270
12	2500	383	−284	423	−243
13	3150	357	−241	393	−218
14	4000	338	−206	369	−196

Repeating the calculations of Fig. 8, but with a 4-wire switch having the above impedances included in the local telephone system, results in the performance shown in Fig. 15. The sidetone level is well controlled as are the sending and receiving loudness ratings; appropriate masks are also shown. Such performance can only be obtained, however, if the impedances, both telephone and switch, are well controlled—a suitable design aim is for a return loss at any frequency of 25 dB. A production tolerance would be 20 dB.

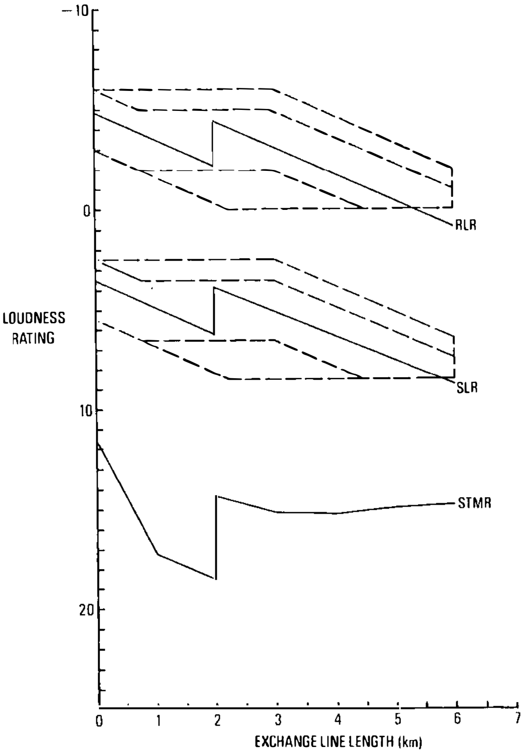

Fig. 15—Telephone performance on a 4-wire switch

CONCLUSIONS

The elements of speech transmission design appropriate to electronic telephones in the local network have been reviewed in this article and particular emphasis has been laid on the importance of adequate control of the level of sidetone. It is recommended that for business use an appropriate design aim is an STMR of around 12 dB.

The telephone has been described in terms of its primary characteristics and an approach to specifying the performance in these terms, particularly for the sidetone balance impedance, has been exposed. Circuit architectures for electronic telephones have been discussed and the advantages of the simple bridge approach, particularly from the viewpoint of production tolerance, have been discussed.

The effects of introducing 2- and 4-wire call routing apparatus between the telephone and the local exchange have been reviewed. The need for control of the switch input impedance, particularly when the telephone is operated at reduced current feed, has been highlighted and a set of impedance design aims which ensure good transmission performance has been published.

There is no 'right' answer in setting the impedance characteristics for customer premise equipment; however, it is the author's contention that universal adoption of the *same* set of compromises will greatly reduce the level of customer dissatisfaction in any liberalised telephone network.

ACKNOWLEDGEMENTS

A number of the author's past and present colleagues have contributed to, sponsored or inspired the collective thoughts presented in the article. The aim has been merely to present a tutorial summarising the accumulated wisdom. The author particularly thanks, however, Elissa Sabine and Douglas Brace, who have worked closely with him over the past two years and who have provided much of the detail upon which this article is based.

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[4] ELLEMTEL STRR, A Listener's Sidetone Rating. CCITT Study Group XII, Contribution 224.

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Biography

Ian Groves joined the Post Office Research Station at Dollis Hill in 1968 after graduating from University College, London, with a B.Sc. in Electrical Engineering. He spent the initial part of his career with the Trunk Circular Waveguide Division, where, as an Executive Engineer, he had responsibility for the development of millimetre-wave solid-state oscillators and modulators. During this time, he obtained his Ph.D, again in collaboration with University College, London, for his work with IMPATT diodes. He moved to Martlesham Heath in 1970, and became a Head of Group in 1973. In 1976, he transferred to the Speech Terminals Division at British Telecom Research Laboratories, working initially on audio teleconference systems. He was appointed as Head of Section within that Division in 1980, leading the development teams responsible for the Viscount and Sceptre telephones, and has subsequently had involvement in all the telephone products developed specifically for the BT range. For the past two years, he has had personal responsibility for speech transmission problems with customer premises equipment. He was promoted to his present position of Head of Consumer Products Division in July 1986 on the retirement of Mr. R. R. Walker.

APPENDIX 1

CALCULATION OF SENDING, RECEIVING AND MASKED SIDETONE LOUDNESS RATINGS

The sending loudness rating (SLR) in decibels is given by the equation:

$$\text{SLR} = -\frac{10}{0{\cdot}175}\log_{10}\sum_{n=1}^{14} 10^{0{\cdot}0175(S_{\text{mj},n} - W_{\text{S},n})} \quad \ldots\ldots(1)$$

where $W_{\text{S},n}$ = sending weighting factor given in Table 2, and
$S_{\text{mj},n}$ = sending sensitivity at the n^{th} frequency point.

TABLE 2

n	f_n	$L_{\text{E},n}$	$W_{\text{R},n}$	$W_{\text{S},n}$	$W_{\text{M},n}$
1	200	8·4	85·0	76·9	86·4
2	250	4·9	74·7	62·6	81·9
3	315	1·0	79·0	62·0	78·5
4	400	−0·7	63·7	44·7	78·2
5	500	−2·2	73·5	53·1	72·8
6	630	−2·6	69·1	48·5	67·6
7	800	−3·2	68·0	47·6	58·4
8	1000	−2·3	68·7	50·1	49·7
9	1250	−1·2	75·1	59·1	48·0
10	1600	−0·1	70·4	56·7	48·7
11	2000	3·6	81·4	72·2	50·7
12	2500	7·4	76·5	72·6	49·8
13	3150	6·7	93·3	89·2	48·4
14	4000	8·8	113·8	117·0	49·2

The receiving loudness rating (RLR) in decibels is given by the equation:

$$\text{RLR} = -\frac{10}{0{\cdot}175}\log_{10}\sum_{n=1}^{14} 10^{0{\cdot}0175(S_{\text{je},n} - L_{\text{E},n} - W_{\text{R},n})} \quad \ldots\ldots(2)$$

where $W_{\text{R},n}$ = receiving weighting factor given in Table 2,
$L_{\text{E},n}$ = real ear loss, again in Table 2, and
$S_{\text{je},n}$ = receiving sensitivity at the n^{th} frequency point.

And the masked sidetone loudness rating (STMR) in decibels is calculated from the equation:

$$\text{STMR} = -\frac{10}{0{\cdot}225}\log_{10}\sum_{n=1}^{14} 10^{-0{\cdot}0225(L_{\text{MEST},n} + L_{\text{E},n} + W_{\text{M},n})} \quad \ldots\ldots(3)$$

where $W_{\text{M},n}$ = sidetone weighting factor given in Table 2,
$L_{\text{E},n}$ = real ear loss, again Table 2, and
$L_{\text{MEST},n}$ = sidetone loss in decibels as given by the following equation:

$$L_{\text{MEST},n} = 20\log_{10}\left|\frac{P_{\text{m},n}}{P_{\text{e},n}}\right| \quad \ldots\ldots(4)$$

where $P_{\text{m},n}$ = free field sound pressure at the mouth reference point (in pascals),
$P_{\text{e},n}$ = sound pressure generated in the artificial ear (in pascals) measured at the fundamental frequency of stimulus in accordance with CCITT Recommendation P.64.

Merlin Tonto

S. P. HOLMES, B.SC., C.ENG., C.PHYS., M.I.E.E., M.INST.P., A.F.B.I.S.†

UDC 681.31-181

This article describes British Telecom's new customer terminal, Merlin Tonto, a multi-functional desk-top workstation that provides in a single unit the comprehensive facilities of sophisticated featurephone, advanced text messaging terminal, computer access terminal, and personal and business computer.

INTRODUCTION

Merlin Tonto is a revolutionary new customer terminal which combines, for the first time in a British Telecom (BT) product, the well-established principles of telephony with the developing technology of personal computers; together they make an unbeatable combination. The concept of the convergence of voice services, data services and computing is a cornerstone in BT's drive towards comprehensive office automation; many of the switch and modem products are now supporting this approach, and Tonto is the first customer terminal to do so.

BACKGROUND

The Merlin Tonto (see Fig. 1) is the result of a co-operative venture between BT and International Computers Ltd. (ICL), together with Sinclair Research Ltd. The concept was first conceived in 1983, when BT was looking into the possibility of marketing an intelligent telephone/workstation. The Sinclair QL computer was being developed at this time, and seemed to offer BT some interesting possibilities, with the QL's advanced central processor and unique Microdrive storage units. ICL was also investigating this field, and had established valuable contacts with Sinclair; it thus seemed natural for BT and ICL to come together in a collaborative venture.

The extent to which BT contributed to the development of the Tonto hardware and software has never been fully documented, because the project was, naturally, kept secret in the early stages and, later, BT was prohibited from disclosing details because the launch of ICL's version of the product—One Per Desk—coincided with BT's flotation on the stock-market. Suffice it to say that BT engineers made a most valuable contribution over a period of two years, and this is fully recognised by ICL.

Fig. 1—Tonto multi-functional workstation

OVERALL DESCRIPTION

As stated above, Tonto is very loosely based on the QL computer; it inherits much of the basic hardware and the Microdrives of the QL, but the software is entirely new.

The two main system elements are a base unit containing the processor, memory, keyboard and Microdrives, and a monitor (black-and-white or colour) containing the display screen and the power supply. Plugged into the base unit are the telephony module (serving two independent telephone lines and a data modem) and the program expansion unit (the ROMpack) housing the optional XCHANGE business applications software (see Fig. 2). Additional programs sup-

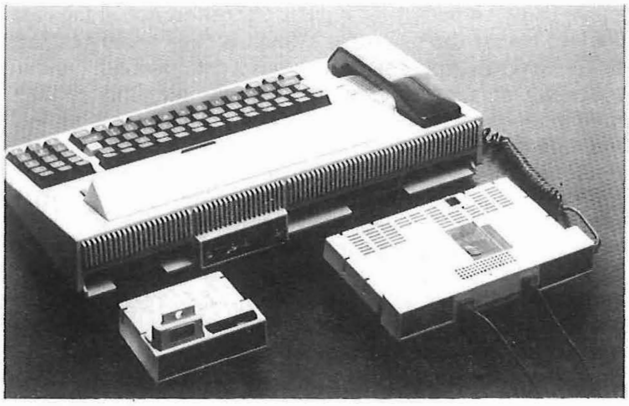

Fig. 2—Rear view of Tonto: the ROMpack expansion unit is on the left, and the telephony unit on the right

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† Text Products Business Unit, British Telecom International Products Division

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QL and Microdrive are registered trademarks of Sinclair Research Ltd.

XCHANGE is a registered trademark of Psion Software.

One Per Desk is a registered trademark of International Computers Ltd.

T-Link is BT's brand name for the Networking Protocol from Microcom Inc.

VT is a trademark of the Digital Equipment Corporation, Maynard, Massachusetts, USA.

plied as 'capsules' can be plugged into the ROMpack to increase Tonto's flexibility and usefulness. A printer (either dot-matrix or daisy-wheel) can be plugged into the back of the base unit.

TONTO HARDWARE

At the heart of Tonto is an advanced microprocessor, the Motorola MC68008, running at 7·5 MHz. The processor handles 32 bit words internally, but accesses memory in 8 bit bytes. The operating system and associated utility programs are held in 128 Kbyte of read-only memory (ROM), and, if the XCHANGE software is fitted, this is held in a further 144 Kbyte of ROM. The standard Tonto has 128 Kbyte of random-access memory (RAM), and, to ensure that certain vital system parameters are not lost in the event of a mains power failure, a further 2 Kbyte of battery-backed RAM is provided. Three uncommitted-logic arrays (ULAs) are used to control the RAM and to drive the display and Microdrives.

The telephony module has a processor of its own, the Intel 8051. The program for the telephony processor is held in ROM within the processor chip, which also contains a small amount of RAM for working storage. Communication with the main processor is via a serial link. The main processor instructs the telephony processor to carry out a function and then proceeds with its own work; when the telephony processor has carried out the command, it interrupts the main processor to give the result.

Data storage on the standard Tonto is provided by two Microdrive units. Microdrive cartridges contain 500 cm of video-quality magnetic tape, 1·6 mm wide, driven in an endless loop at 70 cm/s. Data is recorded on two tracks, and each cartridge holds up to 100 Kbyte of formatted data.

The screen display with Tonto can be either a 9 inch monochrome or a 14 inch colour monitor; in each case, the elemental resolution of the screen is 512 pixels horizontally by 256 pixels vertically. In this mode, four shadings (black, red, green and white, or the equivalent grey scale) can be displayed. It is also possible to switch to a 256 × 256 pixel mode, where eight shadings (black, blue, red, magenta, green, cyan, yellow, white) plus 'flashing' can be displayed. The bottom area of the screen is used by Tonto to show date and time information etc., and the extreme edges are not used (to improve image sharpness); the effective resolution available to programs is therefore 480 × 240 pixels.

TONTO SOFTWARE

The programs that a user would need to control Tonto are located in ROM, and are thus available immediately upon power-up. As on any personal computer, these programs are controlled by an operating system; the difference in the case of Tonto is that the operating system is fully multi-tasking; that is, several programs doing different jobs can be run apparently at the same time. For example, this enables Tonto to receive an incoming electronic mail message while it is loading data from Microdrive, carrying out a spreadsheet calculation, controlling a telephone call, and, all the time, keeping the clock up-to-date. Changing from one application to another is achieved with at most two keystrokes.

Access to programs is by menus; options at a given level are presented to the user as a numbered list, and are entered by the appropriate number being typed. Once entered, programs are controlled by the use of function keys whose use is prompted by 'footnotes' at the bottom of the screen display. The whole system has been designed to be as 'user-friendly' as possible so that even a beginner can make good use of Tonto straightaway.

Extra applications programs can either be loaded from cartridge, or supplied as program capsules which plug into the ROMpack. Alternatively, users can write programs in the BASIC programming language for one-off problems; these can be presented as applications, or loaded while BASIC is being run.

FEATURES

Tonto is designed to help improve the way people work. Many things that formerly required paper records and manual methods can now be handed over to Tonto. The best way to consider Tonto's capabilities is to divide them into a number of categories, as below:

Tonto as a Sophisticated Featurephone

Tonto provides a personal telephone directory with full editing features, and permits calling by shortcode or by searching on keywords. Once a telephone number has been found, the user has the benefit of hands-free dialling and the repeat last number and 're-dial one of the last six numbers' facilities. Dialling is by means of press-buttons, and offers multi-frequency or loop-disconnect operation, with full PABX recall capability.

Tonto gives the user independent use of two telephone lines, each of which can be used for either voice or data communications. When a line is in use for a voice call, the call can be put on HOLD (so that the distant party cannot overhear conversations at the caller's end), and a second incoming call can be answered without the first being lost. If two voice calls are in progress, the user can 'shuttle' between them to carry on two conversations.

A call-timing facility with automatic totalisation in each of BT's charging categories is also provided. The charging category to be used for a particular call can either be contained in the directory entry for that number, or entered by the user when the call is made. When call timing is in operation, the duration and cost of the call are continuously displayed on the screen.

If the user is not available, Tonto can answer the call by using a voice synthesiser. The message can vary according to the time of day, and is constructed by the user from a fixed repertoire of words.

Tonto as an Advanced Messaging Terminal

Users can send desk-to-desk text messages, with T-Link error-corrected transmission. A full on-screen editor enables messages or notes to be composed in the user's 'notepad'. Messages are automatically sent (using shortcodes) from the users 'out-tray', to multiple addresses if desired, and are received, unattended, in the user's 'in-tray'.

If any message should fail to be sent, owing to machine or network problems, it is automatically retried up to six further times.

Tonto as a Versatile Bureau and Computer Access Terminal

When a distant computer is accessed over the telephone network, Tonto provides an integral modem operating at 300 baud full duplex or 1200/75 baud half duplex. Viewdata and basic teletype modes of operation are built-in, and an optional plug-in capsule provides DEC VT100/VT52 operation. BT's Data Communications Adaptor enables

Tonto to be connected directly to mainframe computers or local area networks at up to 9·6 kbaud. In all cases, connection to computer services is made simplicity itself by the use of shortcodes and programmable function keys for user identifications, passwords, etc.

Tonto has a directory for storing computer service numbers, and a profile store for connection details (speed, parity, etc.) so that users have to enter details only once. There is also a page store for retaining information found while on-line. Optional software transfers this information to the XCHANGE suite for further processing, or to the electronic mail program for onward transmission.

The Data Communications Adaptor, or optional software on the standard Tonto, gives a both-way file-transfer capability. This can be used, for example, to transfer to Telecom Gold some text prepared off-line (thus saving connection charges) or to receive a telephone directory from a colleague.

Tonto as a Powerful Personal and Business Computer

A very popular option for Tonto is the business applications suite XCHANGE. This consists of a word processor, a spreadsheet, a database manager and a business graphics package. Comprehensive facilities are available that enable data to be transferred between applications, so that, for example, users can see, displayed as a graph, sales figures that have been calculated in a spreadsheet.

The BASIC programming language, featuring full window-based commands, is provided as standard, and there is a four-function calculator with memory and percentage operations which uses a full-screen display.

Extras now available from third-party suppliers are an action diary, a project management system and spreadsheet template software; to enhance the memory, optional twin 3½ inch 720 Kbyte disc drives, and the 128 Kbyte memory expansion unit are also available. Program development facilities are available for writing third-party applications in 'C', Microsoft-compatible BASIC or 68000 Assembler.

CONCLUSION

This article has described a sophisticated terminal that has been specifically developed for the business user who requires a multi-functional desk-top terminal or workstation that is responsive to the many and varied office needs of today. While Tonto has obvious attractions for larger business users, it also has considerable appeal to small businesses and self-employed individuals with communications and computing needs.

Tonto terminals are now available through BT's Districts, which also provide in-field support. Training courses of various durations and depths are available, as are self-teaching packages.

Three books have been produced by Century Communications Ltd., in conjunction with Newtech Publishing and BT Business Systems, entitled *Introducing the Merlin Tonto*, *Business Communications with the Merlin Tonto* and *Business Computing on the Merlin Tonto.* These books give further insights into Tonto, and include many useful hints and tips towards its profitable use.

Biography

Steve Holmes joined the then Post Office in 1970 as a Post Office Student. After graduating with Honours in Physics with Electronic Engineering from Manchester University in 1974, he joined the newly formed System X Development Department, where he worked on local exchange strategy. In 1978, he joined the Small Processor Group, where, in conjunction with GEC, Coventry, he took a major role in the specification and testing of the operating system. In 1980, he became British Telecom's Technical Group Leader for the System X maintenance control subsystem, and, working with Plessey Ltd., designed and implemented a program to deal with the complexities of multi-processor-cluster working. In 1984, he became head of the Tonto Development Group in BT Business Systems, working with ICL Ltd. to develop and test the multi-functional workstation described in this article.

QWERTYphone—A Low-Cost Integrated Voice/Data Terminal

G. M. DURKIN B.ENG.†

UDC 621.395.6 : 681.3.022 : 621.394.4

This article outlines the rationale behind British Telecom's latest low-cost integrated voice/data terminal, the QWERTYphone, and describes the design and development of the instrument.

INTRODUCTION

The QWERTYphone*, a joint development between British Telecom's (BT's) Communications Terminal Products Group and Rathdown Industries, came onto the market in November 1986. QWERTYphone is a full hands-free loudspeaking telephone (LST), incorporating a large directory. In each of two secure directories, 250 numbers, names and addresses can be stored. These directories are then available at the press of a button. QWERTYphone is programmed with the main system features of the most popular BT PABX systems (including Monarch, Merlin DX and Regent). An integral V.21 modem gives access to Telecom Gold and other dial-up electronic mail, databases and display pager systems. Its built-in 'memotyper' facility allows off-line preparation of messages and, with the optional printer, doubles up as a simple electronic typewriter. Also included are the functions of call timer, calendar, clock and calculator. More advanced features include its ability to be controlled by a personal computer either as a modem or as a sophisticated computer-controlled telephone, and future upgrades include a 2-line manager/secretary option and faster modems. A complete list of features is given in Appendix 1.

INITIAL CONCEPT

The initial concept of the QWERTYphone grew out of a study by BT's Human Factors Division[1] at Martlesham Heath into directory usage. It was also influenced by work on the Merlin Tonto[2] workstation which suggested that the sort of telephony facilities provided by Tonto should be made available at a much lower cost and in a more user-friendly manner. At this stage, the product was known as the *Directoryphone* and as such its main feature was seen as providing easy access to a large directory for autodialling. Previous experience of autodialling systems led to the view that the best way to access a directory entry was by name via a full typewriter-style (QWERTY) keyboard rather than by some kind of shortcode or other reference system. Therefore, the two major elements of the QWERTYphone hardware, the keyboard and display, were justified by its base function.

A handset and telephony keypad were necessary to provide the integrated function of a featurephone rather than an autodialler. It was at this point that it was realised that, with the addition of a modem, all the components of a simple low-cost terminal were present.

The next step was to put all these components together into a package that would be attractive to the end user. Several sketches were commissioned to evaluate possible shapes for the equipment, and the best two were made up into wooden block models. In parallel with this activity, a computer simulation of the equipment was built so that some of the user-interface concepts could be tested.

CONCEPT TESTING

The wooden block models and computer simulation were taken to a company that specialises in concept testing, a form of market research to test the viability of completely new products. One of the main advantages of using such a company was that its staff had no background in telephony and therefore had no preconceived ideas or prejudices about the market.

The company prepared dummy sales literature and tested the products on panels of prospective customers. Their research showed that with well targeted marketing the product was viable but, significantly, showed an acute price and timing sensitivity. That is, the product had to be designed and manufactured under a specific price and be made available as soon as possible. The company also came up with a suggested name for the product, QWERTYphone, which has remained throughout its development and introduction into service (see Fig. 1).

Fig. 1—QWERTYphone

DISTRICT TESTING

The computer simulation was next taken on a tour of selected BT Districts and shown to the business system managers and other interested parties. The aim was to get comments

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† International Products Division, British Telecom

* QWERTYphone® is a trademark of British Telecommunications plc

from the Districts on the features and operation of the product and to get some support before money was spent on development. Response from the tour resulted in a development contract being placed. Examples of the comments received from this tour and incorporated into the development phase of the project were the inclusion of a full handsfree LST version and another that supported two lines with manager/secretary type facilities.

DEVELOPMENT

The development contract was placed with Rathdown Industries which had already produced the computer simulation and had played a significant part in specifying the user interface. The contract had a number of regular outputs which began with a very early hardware version with no mouldings and which went right through to final pre-production samples. This allowed the software to be thoroughly tested and refined before the hardware was finalised. The software was developed in a modular form with each particular function being added separately, again to aid the software testing and approval. Any faults or software bugs were logged, in addition to suggested improvements to the user interface, and each new version of software was thoroughly tested to ensure that all previously reported bugs had been removed and would not recur.

Because of the severe price sensitivity highlighted during the concept testing, the development contract included a fixed price for the final product to prevent any changes being implemented which would increase its final price. In addition, tight control was kept on the project's timescales by using project planning techniques with well-defined milestones and fixed outputs. This scheme worked very effectively and the project ran no more than one month over schedule in 18 months.

The circuit (see Fig. 2) comprises five major components:

(*a*) the main processor board,
(*b*) the telephone circuit board,
(*c*) the telephone line interface circuit,
(*d*) the display module, and
(*e*) the serial interface board.

Main Processor Board

The main processor board contains an Hitachi 6303 microcontroller which has on-chip memory, timer circuits and parallel and serial ports. This controller drives the V.21 modem and multi-frequency (MF) dialler chips directly in addition to accessing the program and directory memories.

One of the first major decisions of the design to be made was how to implement the directory memory. The choice was seen as being between battery-backed CMOS static random-access memory (RAM) or electrically-programmable read-only memory (EPROM). The main considerations were cost and integrity, or non-volatility, of the stored directories. As the additional expense of providing any form of backup by using either tape or disc was out of the question, and some concern was expressed over the integrity of a battery-backed system, after careful consideration the EPROM option was adopted.

The main disadvantage of using an EPROM is that each location can be written to only once, so that once an entry is made into the directory, any subsequent editing or deleting of the entry does not free memory space but, in fact, uses up more. However, this disadvantage was discounted by careful design of the user interface to encourage an entry to be edited before the EPROM was programmed. By allowing a maximum of 250 entries to be addressed at one time, a generous amount of editing space can be provided in one 16 Kbyte EPROM. Also, the provision of two directory sockets and a *copy and compact* option in the directory menu means that, if all the space in a directory is used up, then another directory module can be purchased and the directory information copied into it, thereby making all the editing space available again. From the information in the initial Human Factors report and experience to date, it seems very unlikely that filling directories in this way will be a problem to most users.

A directory module consists of an EPROM in a plastic carrier, which protects the pins from being damaged on insertion or removal from the special socket, and prevents damage from electrostatic discharges (ESDs). This system allows directory modules to be removed from the QWERTYphone, carried in the pocket, and plugged into other machines as required. Directories can be mass copied by using a modified EPROM programmer.

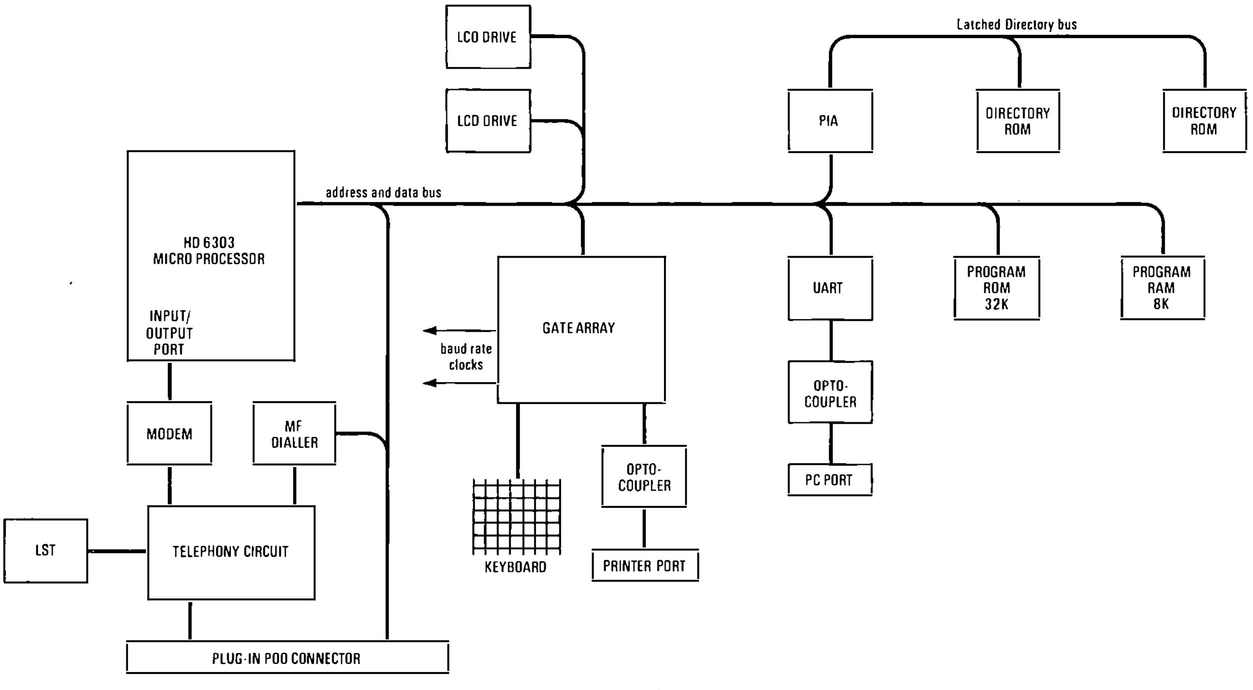

Fig. 2—Block diagram of the QWERTYphone

Another major decision was the use of a gate array for keyboard decoding, baud rate generation, printer port driving and other logic elements. This gate array was designed by Rathdown Industries using the facilities provided by SGS, and was a very critical part of the design. It functioned at the second attempt well within its allowed design time.

Telephony Circuit

The telephony circuit was designed to meet the requirements of the British Approvals Board for Telecommunications (BABT). As the equipment was to be mains powered, the first decision was the placement of the barrier between the 240 V mains supply, the user accessible ports and the telephone network. The usual method is to interface the non-speech sources to the network by using a barrier transformer. This limits the quality of the design of the transmission circuit and adds the not inconsiderable cost of an extra transformer. Therefore, the decision was taken to use the mains transformer as the principal barrier, with a secondary barrier provided for the ports by using opto-couplers.

A transformer with two secondary windings isolated from one another was designed specifically for the task. One winding supplied the telephone and the main board, the other the isolated serial ports. The primary winding of the transformer is separated from the rest of the equipment by careful design of the transformer seating in the moulding. The whole of the remainder of the equipment except for the peripheral side of the serial ports is then referenced back to the telephone network. An interlock designed into the moulding ensures that the telephone line is disconnected before the equipment can be opened to access the directory modules.

The telephony circuit is based on a transmission integrated circuit (IC) from Texas Instruments (TCM1715) which not only interfaces the speech circuit to line, but also the MF dialler, LST and modem. It was decided at an early stage in the development that the incremental cost of an LST version was so small as to make the production and stock control of two separate versions uneconomic. The circuit used for the LST was largely based on a circuit developed by the Advanced Terminals Section of BT's Technical Applications Department at Martlesham Heath, which assisted in its integration into the overall design. This circuit uses a Motorola MC3418 IC which incorporates the necessary amplifiers, attenuators, and control functions to implement the half-duplex hands-free telephone function. There is a microphone amplifier, a power amplifier for the speaker, transmit and receive attenuators, a monitoring system for background sound level, and an attenuation control system which responds to the relative transmit and receive levels as well as the background level.

Telephone Line Interface

The different circuits to be interfaced to the telephone network are selected by the microcontroller via an array of analogue switches. These are also used to allow the MF tone generator to produce the various ring tones via the loudspeaker, saving a tone-caller IC and a transducer. A selection of six different ring tones is available to allow for personal choice or differentiation of instruments in an open-plan environment.

As the whole circuit including the microcontroller and interfacing ICs are referenced to the telephone network, great care was required in the design, particularly of the loop-disconnect signalling and earth-loop recall circuits, to ensure that the potentially high transient voltages would not damage any of the sensitive components. The line interface parts of the circuit are actually provided on a separate board, the telephone line interface board, which is situated in a pull-out drawer-type pod external to the main moulding. This effects the interlock with the part of the moulding which opens to allow access to both the directory modules and the batteries which provide power for the telephone in the event of a failure of the mains supply. This pull-out pod connects to the main board by means of a 64-way connector which, in addition to the telephone interface, carries the whole bus system, thereby allowing other pods to be plugged in to provide enhanced functions. Additional functions already available are a V.23 modem option and a 2-line manager/secretary option.

The design of the speech transmission circuit is fairly standard, but incorporates a new handset styled to match the instrument and designed to be easy to assemble at a low cost. A low-cost electret microphone is used with a plastic microphone holder that acoustically shapes the frequency response thus saving on electronic filter components. The mechanical design is greatly simplified by including a magnet in the handset to activate a reed cradleswitch. This design is possible because the cradleswitch simply provides a signal to the processor rather than having to carry line current which would require a much more robust switch.

Display

The decision on what type of display would be used had to be taken early on in the development of the QWERTYphone. As the main consideration was cost, it was soon apparent that the best choice was a liquid-crystal display (LCD). The LCD adopted uses a custom display glass and proprietary driver ICs housed in a custom module which formed an integral part of the top half of the case moulding. This afforded a low-cost easy-to assemble solution.

Serial Interfaces

The QWERTYphone has two S5/8 serial ports provided with their own power supply and isolated from the remainder of the circuitry by high-voltage opto-isolators. The first of these ports is a serial printer port which operates at up to 9000 baud and is configurable for number of bits, parity and flow control. These options are chosen from a screen menu and allow the QWERTYphone to be used with a minimum of compatibility problems with virtually any available serial printer.

The second serial port is a fully bi-directional serial port and allows the QWERTYphone to operate in three different modes. The first of these modes is a simple terminal mode so that the instrument can be used in a variety of ways; for example as a terminal on a multi-user system. The second mode allows the QWERTYphone to be used as a modem by any external computer. The instrument is controlled by using the Hayes® standard command set which is implemented in terminal software on most popular personal computers. The third mode of operation is called *PC control.* This allows an external computer to control all the hardware of the instrument and take back responses from the keyboard, modem and other functions. One use of this feature is in end-of-line testing during manufacture. A test set-up controlled by a computer brings up various options on the LCD prompting the operator to press keys and read the display. This enables the keyboard and display to be fully functionally tested and enables the test set-up to exercise all the hardware and software functions. Other uses of PC control mode are to provide for future upgrade paths as described later.

Case Design

The physical design of the unit was constrained by the need

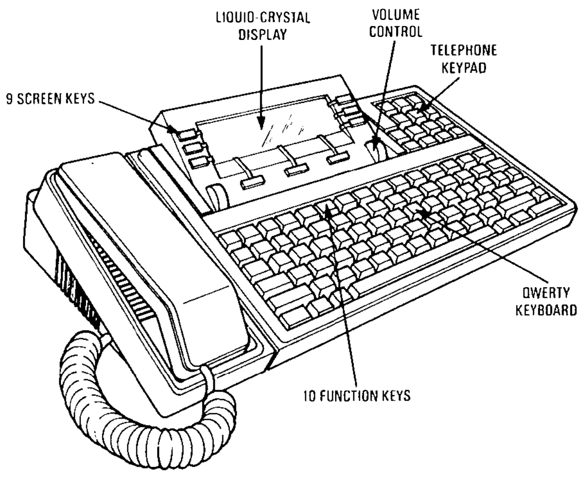

Fig. 3—Keyboard layout of QWERTYphone

for a keyboard, display and handset with the minimum possible footprint (see Fig. 3).

The keyboard was designed from scratch to provide a low-cost unit with a good tactile response. This was achieved by using a touch-sensitive contact mat topped with an elastomeric rubber pad and moulded keys to give the correct weight and travel to the key action. The moulded key tops come in a single assembly from the moulders and the whole keyboard can be printed with the correct key legends in one action by using sublimation printing, an advanced form of ink transfer system. This overcomes the quality assurance problems associated with placing the right key in the right place.

The main moulding is in two halves, the bottom half houses most of the circuitry and provides a safe housing for the transformer and shrouds the mains cable connection. The top half of the moulding houses the display module and keyboard. These are connected to the main circuit board by separate connectors.

The handset rest area is a separate moulding which hinges forward to give access to the directory modules and battery compartment. This moulding is restrained as mentioned earlier by an interlock which ensures that the telephone line is disconnected before access is given.

The line interface is situated in a removable pod at the rear of the bottom moulding. This pod can be substituted with upgraded versions, and a larger pod has been designed to accommodate the 2-line version and other options that require more space than provided in the standard pod.

The serial ports are presented at the rear as S5/8 standard 8-pin DIN sockets.

The handset is constructed of a two-piece moulding comprising front and back. The two halves clip together and are secured by a single screw. Internally, the construction of the handset is very simple. The receiver is held in place with a form of high-integrity double-sided adhesive tape of the type previously used in the automotive industry. The microphone clips into its specially designed acoustic filter housing which, in turn, is secured to the handset with double-sided adhesive tape. This tape is also used to secure the cradleswitch magnet and an extra weight in the form of a steel bar. The use of this tape rather than a complicated arrangement of mechanical clips means that the handset is easy to put together and can be produced at low cost.

ALPHA TRIAL

As mentioned previously, the development had several fixed outputs. One of these outputs was a quantity of 100 samples with almost finalised hardware so that the software could be tested with a wider selection of users; this became the alpha trial. The samples were given to potential users within BT, both technical and non-technical, and these users asked to complete a form to report any software bugs, misoperations of the unit or plain dislikes of the user interface. Over 250 of these forms were returned and logged and any required changes were noted and passed on to the software development team. Most bugs were cured by the next release of software, and, as these were at approximately monthly intervals, new software was tested as fast as it was written. Several significant changes to the user interface were made at this stage as a result of suggestions by the triallists.

Some of these later samples of the QWERTYphone were shown to a selection of BT Districts to increase their awareness of the product and to elicit further feedback. Examples of changes made as a result of this feedback included the addition of a weight to the handset to improve its feel, changes to the handset rest area to overcome complaints that the handset could be knocked off its rest too easily, and a lightening of the keyboard action to counter complaints that it was too heavy.

FUTURE PLANS

Some of the future growth plans for the product have already been mentioned. The first of these to appear is called the *keyboard interface adaptor.* This extra piece of hardware plugs into the serial port of the QWERTYphone and comes in several versions—currently an IBM PC version and an Apple Macintosh version. The adapter plugs into the keyboard connector and the serial port of the relevant computer (see Fig. 4). Pressing the PC key turns the QWERTYphone into a combined keyboard and modem, while pressing the EXIT key returns the QWERTYphone to its native mode of a feature telephone. This combination works with all the standard software packages on these computers and new software is now under development by leading software houses to exploit the more advanced features available for specific applications such as Tele-selling and Tele-marketing.

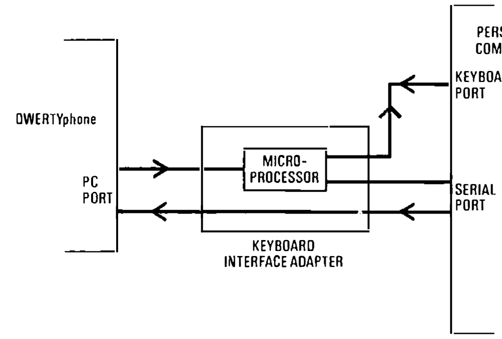

Fig. 4—Connection of QWERTYphone to a personal computer as a keyboard and modem

The second upgrade to appear will be the 2-line manager/secretary option. This product expands QWERTYphone's voice and data capabilities to allow two QWERTYphones to control two telephone lines, either PABX or direct exchange lines, as a fully featured planset (see Fig. 5). A full hands-free intercom connection is provided independent of the telephone lines and can be used without interfering with any calls in progress. Pressing the BOSS/SEC key on the

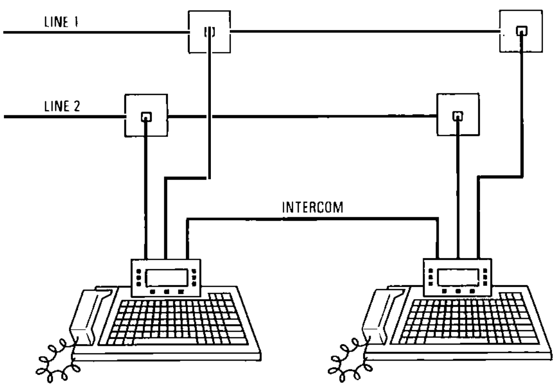

Fig. 5—Connection of two-line QWERTYphone as a manager/secretary system

QWERTYphone will give a full screen display of the status of the lines and the options available. Calls can be made and received on either line, held, transferred or three-party conferences set up.

Other upgrades under development include V.23 and V.22 modem options. Other suggested uses of the add-on pod system, including a card-wipe option and a Telex interface, are under consideration.

There is scope for marketing the product internationally, but this will entail development of new line interfaces and, in some instances, new language versions. Interest has already been shown in Italy, West Germany, Canada and the USA.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in BT and the QWERTYphone development team at Rathdown Industries on whose work over the past two years this article is based.

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Biography

Martin Durkin is an Executive Engineer working in the Communications Terminal Products Group of BT's International Products Division. He Joined BT in 1980 with an honours degree in Electronic Engineering from Liverpool University. He has worked on various aspects of terminal equipment including in-house development, equipment specification, approvals and technical support. At present he is responsible for ongoing development of the QWERTYphone and its derivatives.

APPENDIX 1

QWERTYphone Product Features

Advanced Telephone

Pulse and/or tone dialling, earth-loop or timed-break recall, choice of six ringing tones, last number redial, call timer, clock calendar, batteries provide basic telephony and protect configuration details if mains power fails (directories in nonvolatile store are not dependent on mains or battery power).

Directory and Autodialler

Capacity for 250 entries in non-volatile directory module, character-string searching over all parts of each entry, autodialling from directory, modules can be copied for use in other QWERTYphones, socket for second (optional) directory module.

Password Security

A programmed password can be used to prevent unauthorised access to the information stored in the QWERTYphone. Local security prevents the QWERTYphone from being used other than as a simple telephone; that is, by lifting the handset.

PBX Featurephone

For BT PBXs: DX, Monarch/IT440, Viceroy, Kinsman and Regent (four special commands enable features for other PBXs to be stored in the directory), it provides single key access for the PBX's most commonly used features.

Function Keys

Ten function keys give instant access to the QWERTYphone's features; seven of them are user programmable.

Screen Keys

Nine keys associated with the screen change their function according to the facilities in use; the funtions currently in operation are indicated on the screen.

Calculator

Four functions—available as screen key options plus (with printer option) printing calculator.

Messaging Terminal

Sends short text messages to other QWERTYphones.

Receives text messages from other QWERTYphones, Merlin Tonto and M2105 terminals or any terminal with a V.21 modem, interactive messaging is available between QWERTYphones allowing text-based conversations for speech-impaired users.

Remote searching of directories in other QWERTYphones (users who wish their directories to remain confidential can lock them).

Memotyper

Produces and edits memos line by line with the optional printer; text is also stored in a buffer for reprinting or later transmission via the internal modem or RS232 serial port, line length options of 32,40,69 or 80 characters available to accommodate other printers. Used with a printer it becomes a simple electronic typewriter

Computer Terminal

Terminal with simple glass teletype emulation, can access mainframe computers via the integral modem or via the RS232 serial port and an external modem, host or DOV unit, configurable for speed, word length, number of stop bits and flow control, text may be prepared off-line by using memotyper, and logon details may be stored and sent by using the programmable function keys.

Modem for PC

The integral modem can be controlled by a personal computer connected to the serial port using Hayes† smartmodem control codes.

Manager/Secretary System (Option)

Two QWERTYphones working together as a plans system, one or two lines, full intercom, hold, transfer, conference, do not disturb, and line status display.

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† Hayes® is a registered trademark of Hayes Microcomputer Products Inc.

Customer Apparatus Review

Telecom Topaz and Voice Control

A system that enables car telephones to be controlled by voice alone has been introduced by British Telecom (BT). It is the first of its kind in the UK. With the new system, callers will be able to 'dial' numbers simply by speaking the name of the person they are calling. All BT's car telephones have a facility that enables users to hold a telephone conversation without their having to hold the handset. With Voice Control, BT has taken that concept a stage further; BT sees this as a significant improvement in road safety.

By using Voice Control, customers pre-program the Cellphone's memory with names and corresponding telephone numbers. Thereafter, to dial one of those numbers, they simply need to say the words 'phone office' to be connected; thus, 'phone home' becomes a reality rather than a science-fiction fantasy.

Voice Control is one of the features of a new top-of-the-range BT Cellphone called *Telecom Topaz.* Telecom Topaz can link-up with the latest data transmission units, and features a 'Call-Bank' which records callers' numbers. It is the most advanced cellular car telephone in the UK. It can store up to 99 numbers in its memory, all of which can be accessed by using Voice Control. It also features standard BT Cellphone facilities such as press-button dialling and, of course, hand's free speech. Topaz also has a built-in clock/calendar with alarm, and a high-visibility dashboard display for in-car use. Moreover, Telecom Topaz can also be used away from the car as a transportable.

Telecom Topaz

Venue 24 Telephone

Venue 24 is one of the latest feature telephones in British Telecom's (BT's) range. It has a radical yet elegant design and offers an impressive range of features designed to save time and money.

Venue 24 has a capacity for 24 16-digit telephone numbers, which can be accessed by pressing two or three buttons. It has a see-as-you-dial visual display unit, with built-in clock and call timer. The telephone also features a last-number redial facility whereby, if one or two buttons are pressed, a number can be redialled; a notepad facility that stores the next number to be dialled and a secrecy button for secret asides. It also incorporates an alarm facility and an adjustable tone caller.

Venue 24

The style-conscious will surely covet Venue 24's ultra-modern look. Its handset fits elegantly across the back of the base unit to create a streamlined shape that is very pleasing to the eye. Venue 24 is available in white/grey and brown, and is a versatile and attractive aspect of any room setting.

Tremolo Telephone

British Telecom's (BT's) Tremolo telephone is designed specifically for the large and lucrative 'basic' sector of the market. It is an attractively-styled modern press-button telephone offering a range of time-saving features which set it apart from its competitors in the basic telephone sector. These include a facility which allows the user to redial numbers at the press of

Tremolo

a button; a silence button, which enables remarks to be made to someone else in the room without the caller overhearing; and a tone caller with a high/low volume control.

For wearers of post-aural hearing aids, Tremolo's inductive coupler in the ear-piece improves the clarity of incoming speech, and for fast accurate dialling Tremolo offers large press buttons, a facility which is especially useful for the elderly.

Tremolo has proved to be extremely successful on the North American market, and is manufactured exclusively for BT in the UK. Tremolo offers consumers a reliable, stylish, quick and easy-to-use telephone which can be bought at an attractive price. With the added benefits of BT's reliability and quality assurance, BT believes that Tremolo has enormous potential as a mass-market telephone.

Tremolo is available in three subtle colours—Almond, Blue and Biscuit with a distinctive matt finish. It complements any room decor, and can be wall-mounted without requiring an extra bracket. Two new bold colours—red and black—are to be introduced this year.

Kingfisher Telephone Answering Machine

Kingfisher is a telephone answering machine designed specifically for the business user. It offers the highest possible guarantee of technical quality and incorporates a wide range of features at a very reasonable price.

A multi-function remote controller is one of Kingfisher's most notable features, for even when the user is out, the user can call in to pick up messages, and save, erase or rewind them. The Kingfisher's call-screening facility enables the user, when in, to listen as incoming calls are answered, and to decide whether to reply personally once the caller has been identified.

A message counter has also been incorporated, as has a message memo facility, which allows two-way communication between several users who move around a great deal but need to keep in touch. Kingfisher also offers a message length controller and a ringer control facility.

Kingfisher

Freeway Cordless Telephone

Freeway is a sophisticated cordless telephone from British Telecom (BT) offering a host of facilities at a very reasonable price. Freeway gives the user the freedom and mobility to take or make calls anywhere inside or outside the house, within a 100 m radius of the base unit (under ideal conditions), and has a built-in security code which prevents other users of cordless telephones from accessing the base unit.

Freeway

An impressive array of facilities make Freeway the ultimate in flexibility. Together with press-button dialling, Freeway offers a last-number redial facility which, at the touch of a button, automatically redials a number; and a follow-on button which, when pressed, instantly clears the telephone line. A secrecy button is also provided for discreet asides, and a paging device in the base unit allows a person in the house to attract the attention of the handset user, who may, for example, be busy in the garden. Furthermore, cordless Freeway offers advantages to older less agile or disabled people who cannot always easily reach the telephone.

Available in two-tone grey, Freeway blends well with any interior, modern or traditional, and the compact base unit can be wall-mounted.

British Telecom's Contribution to 50 Years of Television

UDC 621.397 : 654.1

To commemorate the 50th anniversary of public broadcasting in the UK of high-definition television, this article looks at the involvement of British Telecom in the growth of television and shows how, from those early days, it has provided the broadcasting companies with outside-broadcast facilities and main distribution links between the studios and transmitters.

INTRODUCTION

The first public demonstration of television in the UK was given to the Royal Institution on 26 January 1926 by John Logie Baird using a low-definition 30-line system[1]. After prolonged negotiations with the British Broadcasting Corporation (BBC) and the Postmaster General, Baird was given a licence to broadcast in the medium waveband using the BBC's transmitters (at a fee of £5 per half hour). The licence permitted broadcasting outside the normal hours for the BBC's sound broadcasts. The inaugural broadcast of vision alone followed by sound was made on 30 September 1929. The first simultaneous sound and vision broadcast (using two transmitters) was made in March 1930. The 30-line low-definition service continued until 11 September 1935.

The Postmaster General's Television Advisory Committee[2] recommended that a high-definition system of not less than 240 lines should be adopted. British Telecom (BT) engineers (then part of the British Post Office (BPO)) at the Post Office Radio Laboratories, located at the Research Station at Dollis Hill, assisted in testing the two high-definition systems: the Baird 240-line system and the Marconi-EMI 405-line system[3]. To evaluate the two systems, public broadcasts of each system were made on alternate weeks from studios at Alexandra Palace in North London.

Ultimately the Marconi 405-line system was chosen as the preferred standard and the full 405-line service opened in November 1936.

The equipment used by the Baird Company had been designed and build at its workshops at Crystal Palace, in South London—this whole complex was destroyed by the disastrous fire on 30 November 1936 and the company lost all of its equipment.

The television service closed down in September 1939 for the duration of the war and re-opened in June 1946.

COUNTRY-WIDE SERVICE

Initial broadcasts from Alexandra Palace served only the London area. To serve the Midlands, the BPO provided a 900 MHz radio link from London to Birmingham[4] with 1 inch coaxial cable extensions to the studios and transmitters at each end. The radio link was originally designed to be amplitude modulated, but it was subsequently changed to frequency modulation at the installation stage. Intermediate stations were provided at Harrow, Dunstable, Charwelton and Turners Hill. Service from the Sutton Coldfield transmitter began on 17 December 1949. A 1 inch coaxial cable system was also provided between London and Birmingham[5] in 1950. Expansion of service throughout the country quickly followed. A coaxial cable link to Manchester[6] enabled service to start from Holme Moss on 12 October 1951. Coaxial cable was also used to service the Wenvoe transmitter in South Wales. The Manchester–Kirk O'Shotts radio link[7] provided service to Edinburgh and Glasgow.

In the autumn of 1952, the BBC decided to set up, in time for the forthcoming coronation, a temporary television station to serve Belfast. The nearest point to the existing network was the Kirk O'Shotts transmitter, but it was not feasible to provide a link to Belfast in the time available. Tests carried out by the BPO indicated that the signal picked up directly from the Kirk O'Shotts transmitter was of sufficient quality to be retransmitted by the temporary television station. A BPO receiving station[8] was built near the summit of Black Mountain and the signal passed on for retransmission by the BBC from their temporary transmitter at Glencairn.

INDEPENDENT TELEVISION

In May 1952, the Government announced the intention of setting up a new commercial television service under the control of the Independent Television Authority (ITA). Because of the need to build new transmitters and to award franchises for the programme contractors, it was difficult to plan the network in advance. However, a certain amount of work could be done on the main intercity routes. It was also decided that repeated modulation and demodulation of the video signal should be avoided as far as possible. This ultimately led to the concept of links being switched at video frequency at specially engineered network switching centres[9].

The new intercity network made use of the 900 MHz London–Birmingham radio link originally provided in 1949 to extend the BBC's service to the Midlands. This link became spare when service was transferred to the coaxial cable. New modulators were fitted and the system reterminated on the new video distribution racks. Most of the cable network made use of Coaxial Equipment Line (CEL) No. 4A, but the cable link between Manchester and Glasgow was the first use of the new CEL No. 6A for television transmission. This new system incorporated a 4092 kHz pilot to regulate the intermediate amplifiers.

Commercial television began transmissions in the London area on 22 September 1955.

625-LINE COLOUR TELEVISION

The 'Report of the Committee on Broadcasting, 1960' [the Pilkington Report] recommended that the BBC should open a second channel (BBC2) in the UHF band using the new 625-line standard. It also recommended that BBC1 and ITA services should transfer to 625-line transmissions with the ultimate aim of transmitting colour pictures.

As a matter of policy, BT decided to provide all future circuits to the full 625-line standard. However, as the encoding system for the colour signal had not at that time been decided, BT set a design standard that would be adequate for any system then being considered. This meant that the BT Development Group had to design new video transmission equipment and provide a new radio and cable network between the studios and the new transmitters.

BBC2 opened in April 1964, and the first regular colour transmissions began on 2 December 1967.

In order to maintain the existing 405-line transmissions, it was decided that all programmes would be carried as 625-line systems and converted to 405 lines at the transmitting stations. To meet this requirement, BT had to duplicate the 405-line distribution network, about 11 000 km of main vision links, with 625-line circuits.

The BBC1/ITA colour service was due to open in Spring 1970, but it was advanced under pressure from the Radio Industries Council to November 1969 so that service would be available before Christmas. It was not possible to complete the installation of the main radio systems on this revised timescale, so the initial service was provided on a number of temporary radio links which were developed at short notice to 625-line full-colour standards by BT and the contractor.

The first phase of duplication went into service on 15 November 1969 when BBC1 and ITA 625-line colour programmes were broadcast to some 50% of the population from the joint BBC/ITA transmitters at Crystal Palace, Sutton Coldfield, Winter Hill and Emley Moor. This had not been without its problems at Emley Moor. Earlier that year, on 19 March 1969, the performance of the ITA channel between the Leeds network switching centre and Emley Moor was deteriorating and it was suspected that the aerial mounted on the main transmitter mast at Emley Moor had been damaged. On inspection, the main mast was found to be heavily iced and conditions were too dangerous to effect immediate repairs. In the late afternoon, the 1250 ft mast collapsed. Alternative arrangements were made by BT for the video circuits so that service could be resumed when the temporary BBC2 transmitter became available on 21 March and the ITA transmitter on 23 March.

A coverage of 62% was achieved on 13 December 1969 when phase two of the project was completed with the opening of the Kirk O'Shotts, Rowridge and Dover transmitters. In all, BT provided 86 channel hops of microwave equipment covering some 3200 km and 184 video circuits totalling 880 km.

In August 1982, BT completed a new nationwide distribution network[10] for the ITA's (now Independent Broadcasting Authority (IBA)) Channel 4 service. Unlike the earlier networks, the new service opened in November 1982 with a full nationwide service.

OUTSIDE BROADCASTS

In June 1932 Baird rented a landline between Epsom race course and the Metropole Cinema, Victoria, London to show the finish of the Derby to a capacity audience.

When the 405-line transmission started, outside broadcasts were made from the grounds of Alexandra Palace, but it was not until 1937 that the first major outside broadcast was made—the Coronation Procession of King George VI. When the London television service opened, it became apparent that there was a need to include live transmission of events that were taking place some distance from the transmitter; thus a system capable of carrying television systems back to the transmitter was required. To serve the points of interest in Central London, BT provided a low-loss balanced-pair cable linking several major places of interest, with tapping points at a number of places en route. This cable was in place in time for the Coronation on 12 May 1937. A coaxial cable was installed in 1946 to coincide with the reopening of the television service after the war. This was first used for experimental purposes for the test match at Lords on 22 June 1946. A new coaxial network was provided throughout the London's West End during the mid-1960s.

INTERNATIONAL LINKS

Live international broadcasts became a reality in the late-1950s by using the cross-channel microwave radio link to France. The greatest advance, however, came in July 1962 with live television transmission to the USA, via the TELSTAR satellite, from BT's earth station at Goonhilly Downs[11]. These early transmissions were restricted to the duration of the mutual visibility of the orbiting satellite. In November 1963, the Goonhilly earth station was hurriedly activated from stand-down status when news came of President Kennedy's assasination. Within three hours of the event, television pictures were being transmitted all over the world.

The fiftieth anniversary year proved to be a particularly busy one for BT. For the World Cup in Mexico in June 1986, BT provided 24-hour satellite links for the UK broadcasting companies. In addition, coverage was made available to parts of Europe and Africa via the Eurovision link.

On 23 July 1986, pictures of the Royal wedding of Prince Andrew and Sarah Ferguson were distributed to nearly every country in the world. BT provided 64 vision links, some using optical-fibre cable, and free-roaming manpacks to carry the pictures from the many television crews. As well as the main earth stations at Goonhilly Downs and Madely, transportable satellite terminals were used for some destinations.

The following day, interest was transferred to Edinburgh where the Commonwealth Games were due to start. Digital transmission links were used between Edinburgh and the main distribution network at Kirk O'Shotts. Service to Canada was given via a transportable earth terminal located in Edinburgh. It had been possible to make use of this link for the Royal Wedding the day before by transmitting the pictures from London to Edinburgh over a land-line link.

ACKNOWLEDGEMENT

The editors would like to thank Mr. J. Haworth, now retired from BT's TV Planning Division, for his assistance in preparing these few notes on the first fifty years of television.

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Telex Transmission Modernisation

D. J. WILLINGTON, C.ENG., M.I.E.R.E.†

UDC 621.394.4

The UK inland Telex network is at present being extensively modernised. This article describes the new multiplex and local transmission equipment being introduced.

INTRODUCTION

A typical customer-to-customer inland Telex connection is shown in Fig. 1. For individual and multiplexed Telex circuits, use is made of a variety of line plant which is generally common to the public switched telephone network (PSTN).

Until recently, all individual telegraph circuits between customers and their local Telex exchange required a metallic circuit. This generally consisted of pairs in the telephone exchange local cable network (CL), together with pairs in junction cables (CJ). The telegraph multiplexors used on the denser customer line routes, as well as on Telex trunk routes, used various audio or carrier systems as bearers.

Multiplexors are used when the savings on CJ cable pairs (number of pairs × length × cost/km) justify the additional cost of the multiplexing equipment and associated bearer circuits. Multiplexors are always cost effective on Telex trunk routes because of the number of circuits required and the distances involved.

Owing to the relatively small number of Telex exchanges compared with telephone exchanges, and to the growth in the number of Telex lines, most circuits for customers in telephone exchange areas remote from the local Telex exchange are now carried on multiplexed routes.

A number of the large Strowger Telex exchanges have recently been converted to stored-program control (SPC) exchanges, and several of these have absorbed a neighbouring Strowger Telex exchange. This has increased the number of multiplexed routes. A further SPC exchange is due to be brought into service in London shortly.

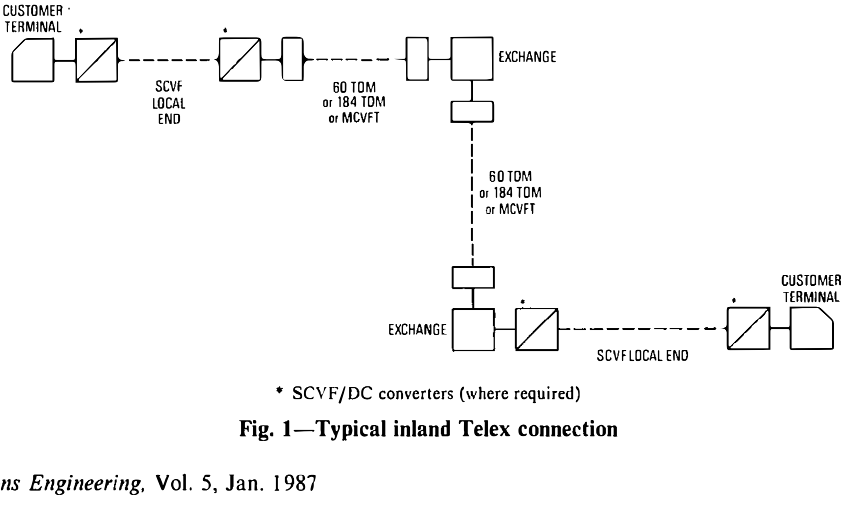
INDIVIDUAL TELEX CUSTOMER LINES

The earliest type of customer line transmission used in the UK for Telex was a form of amplitude-modulated voice-frequency telegraphy (AMVFT)[1]. This was used between 1932 and 1954 (initially at 300 Hz but changed to 1500 Hz in 1936) when the PSTN was used to carry telegraph signals. When a dedicated Telex network was set up after the Second World War, the familiar high-level DC ± 80 V signals were adopted. The teleprinter electromagnets then in use could be driven directly over fairly long metallic circuits, and earth return working was possible, so that only one cable pair was needed for two-way transmission. Interference with telephone circuits using the same cables was generally kept within acceptable limits by the use of low-pass filters.

This system has served British Telecom (BT) well, but in recent years it has become incompatible with modern equipment and services. The high voltages and high power dissipation associated with this system give rise to problems in the design of electronic terminal, multiplex and switching equipment, and the necessary components are no longer economically obtainable; also, long metallic circuits are not so readily available. Other problems include interference with modern data services and non-compliance with modern safety standards. A new low-level system was therefore required.

Single Channel Voice Frequency

The system chosen, *single channel voice frequency* (SCVF), uses speech-band frequency-shift keying (FSK) on a single pair, with frequency division of the two directions of transmission. It has been adopted by several other countries and is now established as CCITT* Recommendation R.20, as well as CEPT‡ Recommendation T/CD1-9. It is based on the frequencies standardised for use at low data rates set out in CCITT Recommendation V.21. (The principal difference between Recommendations R.20 and V.21 is that the former defines performance. This is given in terms of the telegraph distortion which is acceptable on a single link in a chain of transmission equipment in a Telex connection. This is not so critical for point-to-point applications for which Recommendation V.21 is applicable).



* SCVF/DC converters (where required)

Fig. 1—Typical inland Telex connection

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† Business Network Services, British Telecom Inland Communications

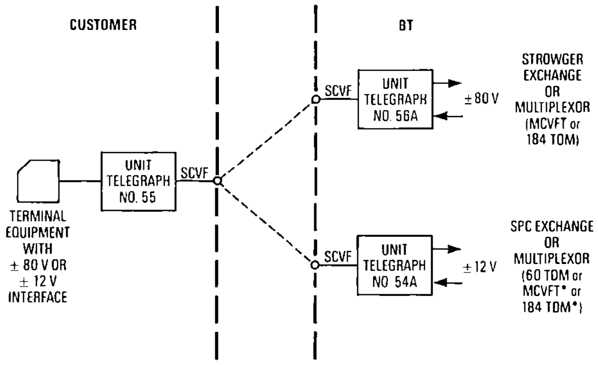
* CCITT—International Telegraph and Telephone Consultative Committee

‡ CEPT—European Conference of Posts and Telecommunications Administrations

As well as overcoming many of the disadvantages of high-voltage DC transmission by giving compatibility with modern equipment, safety standards and line plant, other important advantages of SCVF include immunity to pair reversals and freedom from dependence on good earth connections. Line wetting is provided on all circuits to reduce the effects of dry joints in the local cable network and as an aid to pair identification .

The system can be operated at rates up to 300 baud while at the same time retaining the features of speed and code independence so that future enhancement of Telex or private telegraph services becomes possible.

A number of DC/SCVF converters have been developed for interfacing with various switching, multiplexing and terminal equipment. Their applications are illustrated in Fig. 2 and their primary features are summarised in Table 1.



* Not used with these equipments in practice

Fig. 2—Applications for SCVF/DC converters

Two converters have been developed to provide the new interface with the local end of the customer's circuit at the BT station; these are the Units Telegraph Nos. 54A and 56A. The former provides 12 V/SCVF conversion for modern switching and multiplexing equipment and uses TEP-1E equipment practice. The latter provides 80 V/SCVF conversion for the older equipment and therefore uses 62-type equipment practice. Two other converters have been provided for special purposes; these are the Units Telegraph Nos. 55 and 57A.

TABLE 1

SCVF/DC Converters—Summary of Features

Feature	Unit Telegraph No.			
	54A	55	56A	57A
Equipment practice	TEP-1E 8VU	Case (Desk or wall mounting)	62-type	TEP-1E 4VU
Modems/unit	4	1	2	1
Line wetting	Source or Loop	Loop	Source or Loop	Source or Loop
Reversible channels	Yes	Yes	Yes	Yes
DC levels	± 12 V	± 12 V or ± 80 V	± 80 V	± 12 V or TTL
DC output with carrier fail input (*Note 1*)	A or Z or False call or 0 V	A or Z or 0 V	A or Z or False call or 0 V	A or Z or 0 V
DC output with long F_A input (*Note 2*)	A	A or 0 V	A	A
CCITT Recommendation V.28 Cct. 109	Yes	Yes	No	Yes
Line output with 0 V input (*Note 3*)	F_A or F_Z	F_A or F_Z or Carrier fail	F_A or F_Z	F_A or F_Z or Carrier fail
Supply requirements	± 12 V, 5 V Wetting −50 V	AC mains	± 12 V, 5 V ± 80 V Wetting −50 V	± 12 V, 5 V Wetting −50 V

Note 1 The DC output condition in the event of a carrier fail is normally condition A (Space) to indicate a clear condition, but Z (Mark) condition can be provided for special applications. Additionally, 0 V can be provided for compatibility with some older equipment requiring three-condition signalling. Alternatively, when two-condition transmission equipment is involved (for example, MCVFT or 60TDM), a 'false call' (that is, A for 400 ms followed by permanent Z), can be simulated to cause the exchange to mark the line ABS (absent).

Note 2 The DC output condition following detection of a long duration of F_A is normally condition A (Space) to indicate a clear condition. The Unit Telegraph 55 has an option to give 0 V as required by some of the older terminal equipment.

Note 3 The line output condition in the event of 0 V appearing at the DC input is normally F_A to indicate a clear condition on Telex. Additionally, F_Z or a forced carrier fail is provided for special applications.

Various techniques have been employed by the four manufacturers in the design of these converters, including passive filters, operational-amplifier filters, digital filters and 'single chip' modems. However, all use a degree of digital technology for frequency generation at least.

The latest generations of switching, multiplexing and terminal equipment incorporate SCVF telegraph modems so that separate converters are not required.

All Telex terminal equipment now being approved by the British Approvals Board for Telecommunications (BABT) must incorporate a modem which is compatible with the BT modem. The necessary performance is defined in the appropriate British Standard (BS6403 for simple Telex terminals) in terms of operation in conjunction with a *test reference modem* (TRM) via a *test network*. The test network is simply defined in terms of insertion loss, balance return loss and noise. The test reference modem, however, is far more difficult to define. It must realistically represent the performance of modems likely to be encountered at BT's end of the local line and it must give the repeatability and stability necessary of reference equipment. For this reason, digital techniques are used for all basic modem functions.

When used for testing receiver margin, the TRM simulates a 'fox' test message generator (with predistortion), a modulator and a transmit filter. This provides an analogue test signal which represents a test message from a distant modem. When used for testing transmitter distortion, the TRM provides a receive filter and demodulator to give a baseband output suitable for distortion measurements on a separate telegraph distortion measuring set (TDMS). Further details are given in Appendix 1, Functional Description of BT Test Reference Modem No. 1A.

TELEGRAPH MULTIPLEXORS

Telegraph multiplexors have a long history. Indeed it was Bell's work on an early form of multichannel voice-frequency telegraphy (MCVFT) which led to his invention of the telephone. In the UK, AMVFT was first used on the Telex network. This was superseded by frequency-shift voice-frequency telegraphy (FSVFT), which is still in widespread use on Telex customer lines and trunks[2]. Both of these systems rely on frequency division multiplexing (FDM) and can generally be carried on speech-band circuits. These need to be 4-wire analogue presented, but they can be made up of standard telephony audio or carrier plant. Twenty-four 50 baud Telex circuits can be carried, or proportionately fewer at higher rates.

Another type of telegraph multiplexor which makes use of analogue speech-band circuits is 46TDM[3] to CCITT Recommendation R.101 (CEPT Recommendation T/CD3-1). This is a speed and code dependent TDM system using bit interleaving. It is not used in BT's inland network, but is used on international circuits from the UK where the advantages of bandwidth efficiency outweigh the disadvantages of code dependency. Up to forty-six 50 baud Telex circuits can be carried, and higher rates are possible on some variants.

On the UK inland network, 184TDM[3,4] was introduced to make use of 2 Mbit/s digital line systems (DLSs) provided initially for pulse-code modulation (PCM) telephony systems. This is a code and speed independent TDM system using dibit coding to enable the three states of a Telex customer's line to be transmitted. This equipment is in widespread use for multiplexing Telex customer lines, but it can also be used for Telex trunks. Normally 184 Telex circuits (50 baud) are carried, but 100 baud is possible.

The need for a new system arose from the increasing cost of FSVFT and the possibility of improving on the cost effectiveness of the 184TDM after 64 kbit/s bearers became available.

60-Channel TDM

With the general change-over from analogue to digital bearers in the network, and in particular the emergence of 64 kbit/s digital bearers to succeed speech-band analogue bearers, the opportunity was taken to adopt a new internationally standardised telegraph multiplexor. Initially, the most important source of 64 kbit/s bearers has been KiloStream[5], but time-slot access (TSA) on 30-channel PCM and indeed on 184TDM has been significant. Also, on very large routes, a number of 60TDM systems can be combined on a 2 Mbit/s DLS.

The system adopted is based on CCITT Recommendation R.111 (CEPT Recommendation T/CD3-2) and has sixty 300 baud channels. Like the SCVF system described above, this multiplexor retains speed and code independence up to 300 baud. In fact, 240 50 baud Telex circuits could have been accommodated on a 64 kbit/s aggregate with one variant of the R.111 TDM, but this would have resulted in partially-equipped equipment on a majority of routes and would have prevented the 300 baud capability inherent in the SCVF local ends from being utilised.

The most important features of the equipment developed for BT can be summarised as follows:

(*a*) channels code and speed independent up to 300 baud;
(*b*) choice of channel interface; for example,
  (*i*) 12 V (CCITT Recommendation V.28 compatible), or
  (*ii*) SCVF (CCITT Recommendation R.20);
(*c*) wide choice of aggregate interface; for example:
  (*i*) CCITT Recommendation X.24 at 64 kbit/s,
  (*ii*) CCITT Recommendation G.703 at 64 kbit/s co-directional,
  (*iii*) Baseband modem at 64 kbit/s WAL2, or
  (*iv*) 1·5 or 2 Mbit/s for 8 × 64 kbit/s aggregates; and
(*d*) dual bearers with automatic change-over.

A general description of each of the units will be given with reference to Figs. 3 and 4. For a more detailed description see reference 6.

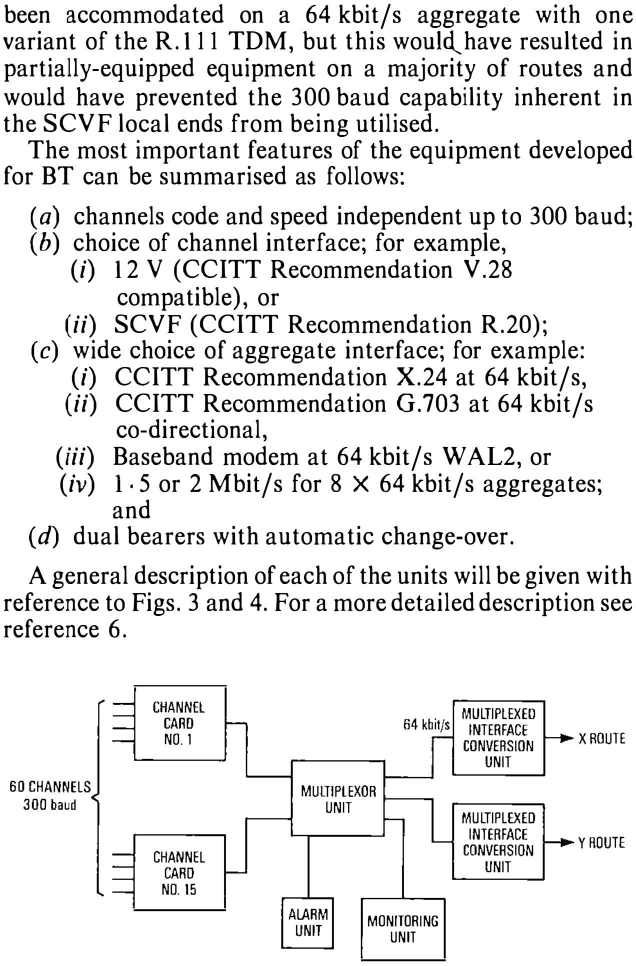


Fig. 3—Block diagram of 60TDM equipment

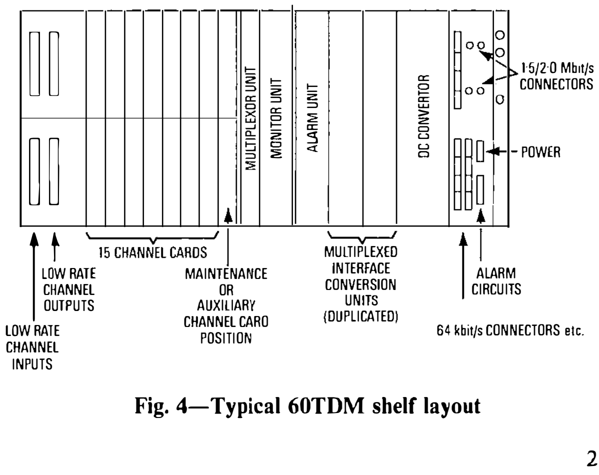


Fig. 4—Typical 60TDM shelf layout

The basic 60TDM equipment consists of a TEP-1E shelf housing the following units.

The 15 channel cards each convert the send and receive signals from four channels to logic level. Two types of channel card have been developed, one with a 12 V interface for connection to an SPC exchange port etc, and one with a SCVF interface for direct connection to a customer's line.

The multiplexor unit performs the common logic functions of encoding, multiplexing and aggregate change-over. Each of the 60 channels is sampled at 4 kHz and transition encoded into a 1 kbit/s bit stream. The channels are then multiplexed (along with the housekeeping bits) to form a 64 kbit/s aggregate presented at two output ports. In the receive direction, the multiplexor unit has automatic aggregate change-over which enables the equipment to be switched to the stand-by line if a fault on the working line occurs.

The *multiplexed interface conversion* (MIC) units are interface units between the 64 kbit/s aggregate outputs (CCITT Recommendation V.11) of the basic multiplexor and the other transmission interfaces required. MIC units have been developed for:

(*a*) 64 kbit/s co-directional interface to CCITT Recommendation G.703 for PCM time-slot access etc. A 3dB (300 m) limit applies.

(*b*) 64 kbit/s interface to CCITT Recommendation X.24 for adjacent KiloStream multiplexor; that is, KiloStream Plus.

(*c*) 64 kbit/s using a WAL2 baseband modem typically to KiloStream. A 40 dB (4–10 km) limit applies.

(*d*) 1·5 or 2 Mbit/s interface carrying up to eight 64 kbit/s aggregates. One tributary will be derived from the parent shelf and the remainder from up to seven others.

The alarm unit monitors alarm conditions from the multiplexor unit and the MIC unit.

The monitoring unit is the maintenance aid unit which permits faults on the multiplexor unit and channel card to be located.

The DC converter derives the logic (and 12 V signalling supplies for 12 V channel cards where fitted) from the station battery.

The GEC implementation of this equipment is shown in Fig. 5 and a description of the MCSL equipment is to be found in reference 6.

In the future, SPC Telex exchanges will have integrated TDM so that a direct aggregate interface (DAI) is provided at 64 kbit/s. In this case only the appropriate MIC unit from the TDM equipment is needed to provide a suitable interface with the bearer circuit.

Other possible future developments include the increased application of remote monitoring and test access using supervisory time-slots or designated channels. Further variants of the MIC units may be required to account for developments in the DLSs used; for example, 2-wire WAL2 baseband transmission. Aggregate rates other than 64 kbit/s may become attractive for some applications; for example, 9·6 kbit/s on small routes where a DLS is not available. Higher tributary rates are another possibility but their use is not foreseen at present.

SUMMARY

Transmission modernisation has been pursued to achieve compatibility with modern bearer and terminal equipment. Considerable cost savings have resulted, together with improvements in the quality of service. The SCVF system chosen for local line transmission and the 60TDM system chosen for multiplexing are both based on international standards and have potential for the use of higher transmission rates.

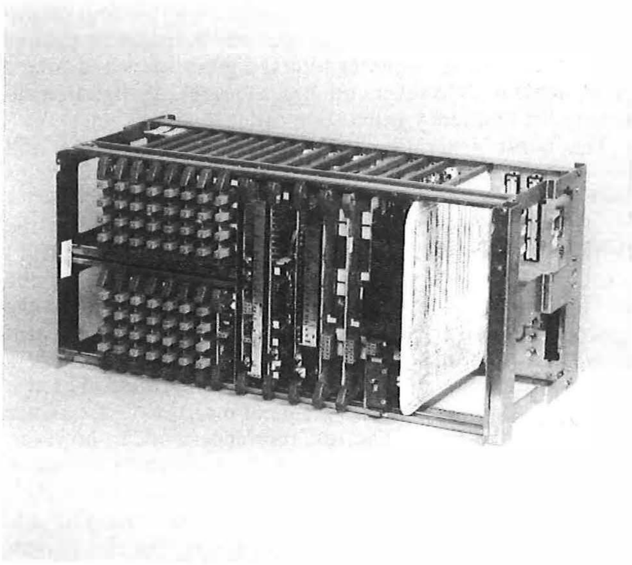


Fig. 5—60TDM equipment

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues, particularly Mr. D. T. Smith and Mr. D. J. Parsons, for their contributions to the development of the 60TDM and SCVF systems respectively. The test reference modem was the result of work by Dr. L. Lind of Essex University and BTRL. The 60TDM equipment described has been developed by GEC and by Marconi; the SCVF modems described have been developed by STC, GEC, Dowty/RFL and Databit.

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Biography

Dave Willington is a Head of Group in Business Network Services/Telex. He started his BT career at Dollis Hill in 1957 working on HF propagation simulation; later he worked on line simulation for telegraph and data transmission research. He was promoted to his present position in 1975, and is responsible for the development of telegraph transmission and related equipment.

APPENDIX 1
FUNCTIONAL DESCRIPTION OF BT TEST REFERENCE MODEM No. 1A
Outline Description

The Test Reference Modem (TRM) No. 1A has been designed specifically for testing the transmission performance of simple Telex terminals (STTs) to the requirements of BS 6403:1983 (British Standard Specification for Simple Telex Terminals Using Single Channel Voice Frequency Signalling for Connection to British Telecommunications Telex Network).

The TRM may be considered to consist essentially of a modulator and transmit filter, together with a receive filter and demodulator.

The filters are designed to:

(*a*) provide ample stop-band rejection,
(*b*) offer good passband amplitude performance,
(*c*) contain more group delay distortion than is usual in practice, and
(*d*) be reasonably simple to reproduce reliably.

The filters described have more selectivity than needed, and have poor group delay characteristics. This combination represents the realistic performance of modems likely to be encountered in BT's Telex exchanges.

The modulator and demodulator are assumed to be ideal compared with the filters.

Digital techniques are used within the TRM for all basic modem functions in order to give the stability and repeatability required of a Reference Modem. Calibration is not required.

Transmit Filter, Modulator and Test Message

The transfer function for the digital transmit filter, based upon an 8 kHz sampling frequency, is:

$$\mathrm{H}(z) = \left(\frac{z^2 - 1{\cdot}665z + 1}{z^2 - 1{\cdot}33594z + 0{\cdot}842}\right)\left(\frac{z^2 - 0{\cdot}505z + 1}{z^2 - 1{\cdot}08105z + 0{\cdot}842}\right) \times \left(\frac{z^2 + 0{\cdot}4z + 1}{z^2 - 1{\cdot}2217z + 0{\cdot}854}\right).$$

The filter transfer function is given as a product of biquadratic factors. However, to compute the time domain performance, it is usual to express the function in the form of a sequence of difference equations. Calculations have been performed off-line for the required sequence of samples with the filter preceded by a modulator receiving a pre-distorted 'quick brown fox' test message (CCITT Recommendation R.52). The results of these calculations have been stored in a read-only memory (ROM).

The digital/analogue converter output waveform is then applied to a standard reconstruction filter to obtain the analogue test waveform.

The TRM incorporates two selectable memory cards which enable the test message to be transmitted with either 33% or 35% alternate short/long start element distortion.

Receive Filter and Demodulator

The receive filter transfer function is:

$$\mathrm{G}(z) = \left(\frac{z^2 - 1{\cdot}215z + 1}{z^2 - 0{\cdot}3618164z + 0{\cdot}86}\right)\left(\frac{z^2 - 1{\cdot}9z + 1}{z^2 - 0{\cdot}52270507z + 0{\cdot}85}\right) \times \left(\frac{z^2 + 0{\cdot}3z + 1}{z^2 - 0{\cdot}19360351z + 0{\cdot}85}\right).$$

The TRM digital demodulator that follows the receive filter introduces less than 1% telegraph distortion.

A separate telegraph distortion measuring set (TDMS) is used to measure the distortion at the TRM baseband output.

Book Reviews

Telecommunications Primer (Second Edition). G. Langley. Pitman Publishing. vi + 170 pp. 138 ills. £6·95.

This second edition includes new sections on PBXs, PABXs, Keyphones and Centrex, Maritime Communications, Packet Switching, Local Area Networks, Voice Messaging, Credit Cards and Smart Cards and Corporate Communications. What was a very brief section on Binary Coded Decimal (BCD) has usefully been expanded to include a better comparison between decimal and BCD and hexadecimal, binary hex and biquinary code.

The chapters on Basic Principles, Some Fundamentals, Maintenance and Operation, Television and Digital Fundamentals remain unchanged.

The self-assessment exercises and reference to further reading, which students may have found useful, have unfortunately been dropped. Nevertheless, this book is a useful and very readable introduction to the field of telecommunications for those who are new to the subject or who require only a brief overview.

R. HARVEY

Stochastic Modelling and Analysis: A Computational Approach. Henk C. Tijms. John Wiley and Sons. xii + 418 pp. £19·95.

This textbook provides a very good introduction to the mathematical modelling of stochastic systems. Although firmly based in mathematics (with no mention of simulation modelling), it is very much oriented towards practical applications. Much of the text is devoted to examples of applications in teletraffic and computer systems performance engineering, inventory and production control problems, and reliability. Professor Tijms is with the Vrije Universiteit in Amsterdam, and the book is the outcome of many years of research and teaching in operations research and computer science.

The book is organised into four large sections covering renewal processes, Markov chains, Markov decision processes, and queueing models. Each section ends with its own bibliography and a good number of exercises.

The first two sections serve to introduce much of the basic theory. With the emphasis on examples and exercises rather than lengthy proofs, these sections are very readable.

The inclusion of a substantial chapter on Markovian decision processes is most welcome. This subject has perhaps received insufficient attention for telecommunications applications, and is now being increasingly applied to optimisation and dynamic control problems; for example, the optimal control of queues and memory sharing in processor systems.

The last and largest section deals with algorithms and approximations for queueing models. This is a good survey of the applicable theory although the coverage of queueing networks is fairly brief.

The book could be tackled by mathematically-inclined engineering undergraduates with some knowledge of probability theory, but it is perhaps best suited to postgraduate courses in operations research and related subjects. It is an ideal source book for anyone teaching in this field. (A warning to potential tutors—answers to exercises are not provided.) It is also a useful reference work, particularly in the fields of Markov decision theory and approximations for queueing models, although of course it does not cover all aspects of teletraffic theory.

D. J. SONGHURST

Matrix Switching in British Telecom's Customer Service Systems

P. CAMERON†

UDC 621.39 : 681.31 : 659.28

As part of British Telecom's policy of putting the customer first, major changes are being made in its computer facilities. The Severnside District in Bristol is now implementing the Customer Service System.

INTRODUCTION

Customer Service Systems (CSS) represent a new phase in the development of British Telecom (BT); it is part of the change from being a Civil Service Department to an outward-looking competitive private company. This has led to BT taking a different attitude to its customers, with the aim of making service of all kinds as efficient, and as easy to obtain, as possible—hence CSS.

This change is becoming evident in many aspects of BT's activities. One where it is crucial, but not outwardly visible, is in the communications and computing facilities of its various computing centres around the country.

CUSTOMER SERVICE

The Severnside District in Bristol, one of the three Districts created from the old South West Region, will be one of the first to have its CSS up and running on new IBM computing equipment, with comprehensive switching for its data communications to cope with every eventuality.

In this context, the aim of the CSS is to give customers just one telephone number to call for all queries—on bills, to arrange a change of address or number, report a fault, or order a new line. To do this, it was necessary to design a computer system which would present all the necessary information and controls to staff dealing with the incoming telephone calls, and to give these staff the means to implement customers' requirements.

To achieve this level of service, Severnside CSS is setting up a computer network with over 1300 visual display units (VDUs) in its various departments and for the engineers in all the telephone exchanges it serves. These VDUs, connected by 9600 bit/s synchronous links, allow engineers at the exchanges to check that a request is feasible, implement it, and report back. With all the engineers' transactions being logged continuously on a central IBM 3081 computer, staff answering queries from customers will at all times have up-to-date information available to them.

COMPUTER NETWORK

The system required to provide these facilities is necessarily complex. Up to 200 incoming circuits, from exchanges, offices and other computer sites and major offices in Severnside, must be connected to the three IBM 3725 front-end processors (FEPs) of the main IBM 3081 computer in such a way that any circuit can be connected to any FEP. In addition, there must be provision for spare devices to be switched into service in the event of equipment failure. Only a virtual matrix switch could provide the ease of switching needed to fulfil the requirements of such a system.

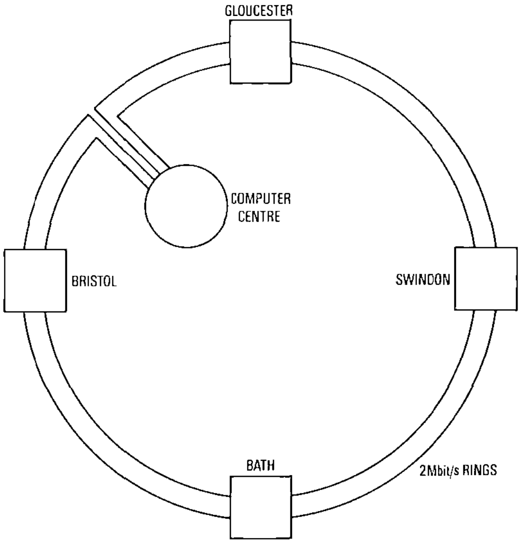

Fig. 1—Layout of the 2 Mbit/s communication rings

As well as the IBM 3081 which is used for customer services, the site has an NAS 8043 computer for internal management services, including electronic mail, computer development, and financial and manpower planning. This facility is available to management at all of Severnside's sites.

To guard against line failure, the communications link is effectively two 2 Mbit/s MegaStream rings. The layout of these is shown in Fig. 1. There are 180 incoming circuits, each of which handles up to 16 terminals, coming from all over the District and terminating on one of the two 2 Mbit/s rings. As the diagram shows, these rings link the computer centre on the outskirts of Bristol with a major office in the centre of the city, and with other offices at Gloucester, Swindon and Bath. Some of these links, where particularly heavy usage is anticipated, use optical-fibre systems.

MATRIX SWITCHING

The two 2 Mbit/s rings each feed into a Datel 7500 multi-

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† T-Bar International (Europe) Limited

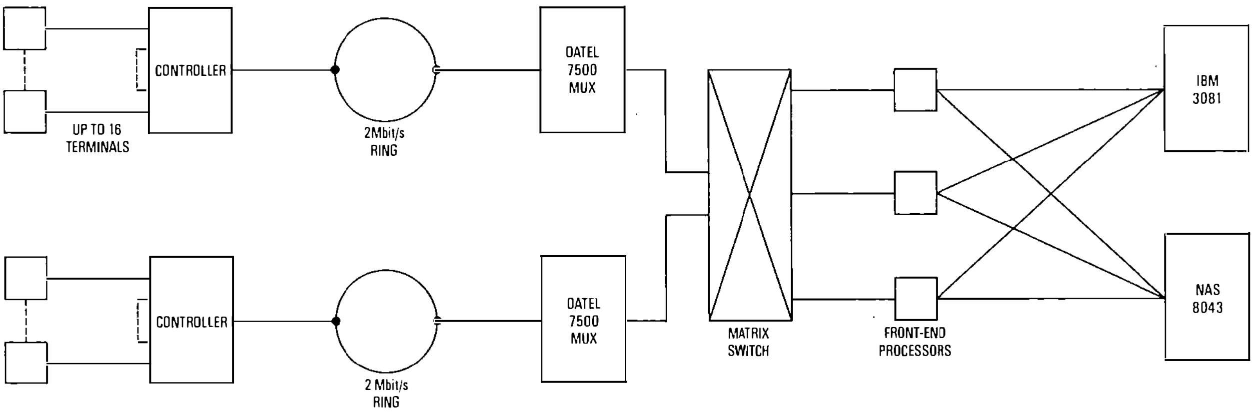

Fig. 2—Computer system configuration

plexor at the CSS computer centre (see Fig. 2). This multiplexor is connected to a T-Bar VSM matrix switch, which provides any-to-any transparent switching between the remote terminals and the IBM 3725 FEPs of the IBM 3081 mainframe. A matrix switch gives a number of benefits compared with A–B switching, even when the latter is controlled via a VDU. The VSM is a true matrix switch with totally non-blocking connections.

The same switching facility could have been achieved by a manual patching system, but the view was taken that this would not have been practicable. The complexity of the switching task if, for example, a FEP should fail is such that the manual switching into service of a replacement unit would probably cause more problems than it tried to solve. In a demonstration recently, a complete change-over from one FEP to another took only seconds under the control of the T-Bar VSM. Commands used with the VSM control system are in plain English, with labels used for the data terminal equipment (DTE) and data communications equipment (DCE) ports relating to the network rather than the switching equipment, and so making it easier for the operator to control the network.

It is in situations of complete equipment failure that the benefits of the VSM matrix switch are fully realised. Disc storage is used to maintain reconfiguration lists that have been carefully planned in advance to take into account worst case failures and preferred selected alternative data paths. Thus, if the network has failed as a result of the failure of a system or a peripheral, then by using these lists it is possible to reconfigure the total switch from the controlling terminal with just a few keystrokes.

The T-Bar VSM also provides switching for the NAS computer, again via the IBM 3725 FEPs, and it can switch the 20 or so synchronous circuits that come into the computer centre for various special purposes.

CONCLUSION

CSS at Severnside has taken a long look at the customer services it is seeking to provide. Although only a means to these better services, the computer network is the key, and the careful planning of system, hardware and software, directly contributes to the efficient and speedy response to customers' requirements. The comprehensive switching which is now part of the system will allow future changes to be accommodated as well as ensuring, in the short term, the efficient use of equipment and a good service to customers.

Customer Equipment for Radiopaging

D. J. WENZEL, B.SC., C.ENG., M.I.E.E.†

UDC 621.396.93 : 621.395.4

This article describes the customer equipment available from the British Telecom (BT) Radiopaging service. It describes the general technical requirements of radiopagers and the facilities offered by the BT range, and goes on to discuss the various services available for inputting paging calls.

INTRODUCTION

The British Telecom (BT) Radiopaging service was first opened in London in late-1976 and has now grown to be the largest national radiopaging service in the world with well over 300 000 pagers in use throughout the UK.

The range of services offered is comprehensive and includes Tone Page, Display Page (numeric message) and Message Master (alphanumeric message). For the hard of hearing, noisy environment or where a tone alert would not be practical, the Silent Page radiopager vibrates when called. The Safe Page has been tested to British Approval Service for Electrical Equipment in Flammable Atmospheres (BASEEFA) standards and can be used where dangerous gases may be present.

Pagers are bought competitively from a variety of British, European and Japanese manufacturers and, provided they meet strict performance criteria, BT does not generally influence their design. Thus, by encouraging manufacturers to seek a world market and by pursuing bulk purchasing agreements, pager costs are kept to a minimum.

RADIO TRANSMISSION

BT Radiopaging has been allocated three national 25 kHz radio channels in the 153 MHz band. Data is digitally encoded by using CCIR* Radiopaging Code No. 1[1, 2] and transmitted by using direct frequency-shift keying (FSK) modulation, non-return-to-zero (NRZ) with a deviation from the channel centre frequency of 4·5 kHz. Data transmission rates can be either 512 or 1200 baud.

Each pager is allocated up to four unique pager numbers (PNs) and responds only when the code for one of those PNs is input to the Radiopaging system.

PAGER REQUIREMENTS

By the very nature of its portability, a radiopager must be small, light and rugged. As it is a one-way communications device and must work accurately within buildings and fast-moving vehicles, it must be able to detect and correct errors in data broadcast to it.

Typically, a radiopager weighs 80–120 g and is small enough to fit unobtrusively on a belt or in a pocket. It must be capable of surviving at least six drops onto a concrete floor from a height of 1·2 m.

Sensitivity

To ensure good electrical performance, pagers are subject to calibration testing at the Electrical Research Association establishment. Here an 80% call success rate must be achieved with a field strength of 10 μV/m. This test is carried out with the pager attached to the body oriented in eight directions to simulate conditions as realistic as possible. In practice, this means that a pager has better than 95% probability of successfully receiving a message above ground level throughout the coverage area.

Battery Life

Paging transmissions are structured into eight sequential frames. The pager population is likewise divided into eight groups by assigning each pager to a particular time frame. To save energy and extend battery life, the pager need only be switched on during the transmission of the synchronisation signal and its own time frame. This results in an energy saving of just under 7/8 of that required for continuous reception and can prolong battery life to between 500 and 1000 hours.

Error Correction

Broadcast data (address and message information) is coded into 32 bit code words by using an algorithm that gives a Hamming distance of 5. This allows receivers to correct and respond to code words with 2 bit errors, and to identify all code words with 3 bit errors.

Where errors have been detected in message code words, incorrect characters are underlined on the pager display.

PAGER FACILITIES

Receivers have several separate 'addresses', each with a distinct tone alert. This enables a customer to differentiate between, say, a call from the office and one from home. Tone pagers can be linked by the Radiopaging system with a group of other tone pagers enabling a team of people to be paged with a single telephone call.

In addition to receiving tone alerts, Display Pagers can receive, store and display messages of up to 20 characters. The characters for this pager type are the digits 0–9 and the symbols U – ( ) and a space. Up to three messages can be stored and recalled, with the arrival of a fourth displacing the oldest in memory.

Message Master pagers can store and display messages of up to 90 alphanumeric characters, as well as symbols such as £ ? %. Up to ten messages can be stored, although this would be reduced if all the messages were very long. The top of the range Message Master Plus has a number of additional features such as a digital clock, which stamps the message arrival time, automatically switches the pager on or off at preset times and can act as an alarm clock. All pagers can be set to operate in silent mode, which suppresses the alerting tones.

INITIATING A PAGING CALL

Calls can be made in a variety of ways, the most common being by dialling a ten-digit number over the public switched telephone network (PSTN). The last six digits, which represent the pager number, are repeated by the trunk exchange to the paging control equipment.

To send a numeric or alphanumeric message, several options are available, and a user can choose the one that is the most convenient:

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† Mobile Communications, British Telecom Enterprises

* CCIR—International Radio Consultative Committee

Left to right, back to front:
QWERTYphone, Display Page, Silent Page
Message Master, Message Master Plus, MF keypad, Tone Page, Keypage 100 terminal

Selection from the BT Radiopaging range

(*a*) A 24 hour operator bureau can be called over the PSTN and messages are forwarded immediately to the paging system.

(*b*) For sending numeric messages, the multifrequency (MF) service can be dialled and messages input by using an MF telephone or an MF keypad held to the telephone mouthpiece. When this service is used, an automatic voice guidance and response system gives the caller instructions and confirms the message content.

(*c*) Full alphanumeric messages can be sent by national or international Telex, or by dial-up Datel service operating at 300 or 1200/75 bit/s; a service via Packet SwitchStream (PSS) is imminent.

KEYPAGE TERMINALS

To assist customers in gaining the fullest benefits from the paging input services, BT Radiopaging will be marketing a range of services and terminals using the banner *Keypage*.

Keypage 50

Keypage 50 services are designed for the small- to medium-sized customer with up to 50 pagers. The service will include provision of the BT QWERTYphone (described elsewhere in this issue of the *Journal*[3]), since its excellent range of features make it an ideal paging accessory for the medium-sized pager user.

Keypage 100

The larger customer with a heavy demand for paging service, may connect directly to the Radiopaging system either via leased lines or the PSS; a terminal purpose designed for this application is available. The terminal is based on a small mains/battery-powered computer with a full-travel QWERTY-style keyboard and eight-line liquid-crystal screen. Its directory can hold up to 150 entries which can be searched by entering the first letter(s) of the name. An individual can therefore be found and paged with just two or three key presses. Messages can be entered via the keyboard at the time of calling, and up to ten commonly-used messages can be stored and recalled via the function keys.

Should both mains and batteries fail, the memory is protected for up to 60 days by internally mounted rechargeable cells. A printer interface enables a written record of the directory to be made and a log of calls to be kept.

THE FUTURE

As general awareness of the value of mobile communications grows, prices will be kept low by a healthy and competitive market. It is likely that the significant developments in pagers will be ones that assist in reducing costs rather than add facilities, although there will always be a small market for pagers with enhanced features.

Improvements in component technology will help to extend battery life, as well as reduce pager size. Faster data transmission speeds will enable more pagers to be effectively loaded onto a single radio channel, and scanning receivers will enable a single pager to operate on several different frequencies or in different countries.

Paging applications will be integrated further and further into customers' business systems, and this will increase the ease and speed with which calls can be made and extend the uses to which paging is put.

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[3] DURKIN, G. M. QWERTYphone—A Low-Cost Integrated Voice/Data Terminal. *Br. Telecommun. Eng.*, Jan 1987 (this issue).

Biography

David Wenzel joined BT in 1970 after obtaining a degree in Physics. After an initial training period, he spent several years with Service Department, Telecommunications Headquarters, dealing first with the electronic telephone exchange system TXE4 and then later with System X maintenance and service issues. He moved to the System X Launch Department where, as Head of Group, he worked on the requirements for computer assistance in the operational management of digital exchanges. In 1985, he transferred to BT Enterprises where he is currently Radiopaging System Strategy Manager.

Directory Assistance System

BRITISH TELECOM PRESS NOTICE

INTRODUCTION

British Telecom (BT) has introduced the first phase of an £80M programme to computerise inland directory enquiries that will bring faster more-efficient response to callers' enquiries.

At the 186 centres where the directory assistance system (DAS) has been installed to provide nationwide coverage, BT's operators can now call up numbers on to a screen at the touch of a button. This has reduced the average time taken to handle an enquiry from 52 to 39 s.

The improvement in efficiency has led to a significant rise in directory enquiries. Before DAS started, directory enquiry calls were growing yearly by 3–4%; the growth rate has now almost doubled to 6–7%.

BT is now implementing phase two of the DAS project to meet this growth by doubling capacity to enable the system to handle calls through to the 1990s. Installation of extra computer power, by adding 74 computers to bring the total to 143, has already begun and should be completed by this summer.

DAS helps operators find the correct telephone number from much less information requested from callers previously, when records were held in books or on microfiche (see Fig. 1). Now, only an abbreviated form of name and address needs to be keyed into the terminals.

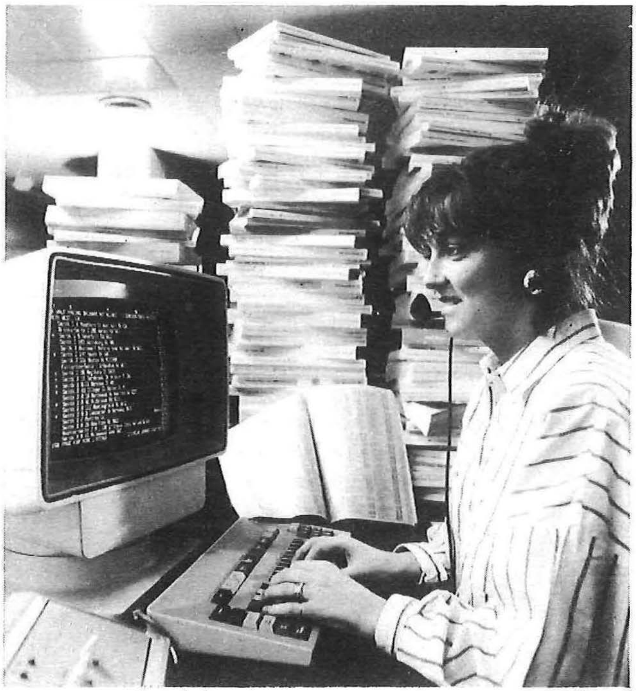


Fig. 1—DAS terminal. The background shows the directories replaced by DAS

The system searches its database and can usually display the number onto the screen within 1·5s. It can offer a choice of possible numbers from which the operator can select the correct one. Special facilities, including the ability to search for names which sound alike although spelt differently, enable operators to cope much more easily with complicated enquiries.

DAS also enables records to be updated more quickly and more often. The complete directory file of 23 million entries is updated daily from the system used by BT to compile its public telephone books. New entries can become available to operators within 24 hours as compared with two weeks or so when paper records were used. On average, 30 000 changes are made every day.

The DAS is one of the world's largest computer networks, which, when completed, will involve 143 computers, 4000 terminals, and the associated communications links; and will operate on-line 24 hours a day, seven days a week.

SYSTEM CONFIGURATION

The DAS was designed by Computer Consoles Incorporated (CCI) of Rochester, New York, and supplied to BT by STC Telecommunications Ltd. It was originally implemented at three computer centres—Leeds, Derby and Kensington; under the expansion plan, a fourth centre is to be added in Sheffield.

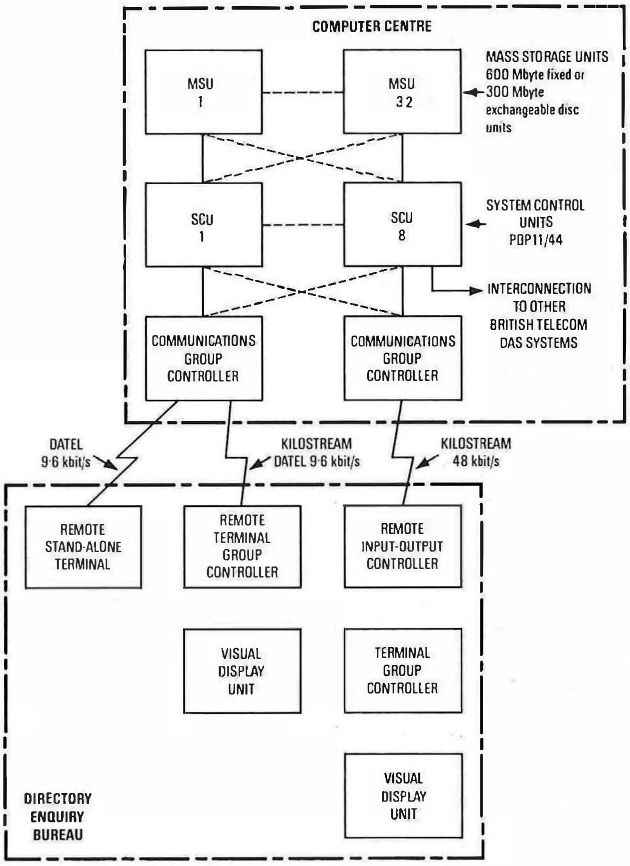


Fig. 2—Configuration of DAS

DAS serves 186 BT directory enquiry (DQ) bureaux, plus others in Jersey, Guernsey and the Isle of Man, involving a total of 3750 terminals. The basic building block of DAS is an individual DQ system, see Fig. 2. Each DQ system is a fully-resilient directory enquiry machine which, when equipped with the maximum of eight system control units (SCUs) and 32 mass storage units (MSUs), is capable of processing 50 000 searches an hour. The resilience of the system is achieved by interconnecting communications group controllers (CGCs), SCUs and MSUs so that the failure of any one unit does not affect performance, except near peak load.

The initial three computer centres have three DQ systems, giving a total of 65 SCUs. When the enhancement is completed, the four centres will have a total of 16 systems—four at Derby, three at Kensington and nine at Sheffield, plus updating, master and off-line support systems at Leeds. Each system serves a particular group of DQ bureaux and, in the unlikely event of a partial loss of the database, the relevant listing request is distributed within the computer centre to the other systems.

Communications between the DQ systems and the bureaux is through the CGCs which have a wide variety of communications options. This allows the network to consist, broadly, of 9·6 kbit/s Datel or KiloStream links to small/medium sized bureaux and 48 kbit/s KiloStream links to large bureaux. All bureaux are served by multiple links to provide for resilience. Fig. 2 shows the different communications equipment at the bureau level.

Leeds, the master centre, is linked to the others by multiple 48 kbit/s KiloStream circuits to allow on-line updating of each centre's databases and for the central gathering of statistics at Leeds.

FACILITIES

Operators use a visual display terminal (VDT) with a low-profile keyboard especially created for the job. The operator, by keying in very little of the information provided by the caller—no more than six characters in most cases—receives listings on the VDT from which the required number can be chosen.

More than 50% of all enquiries made by the operator are expected to be for the local area, and the system automatically homes in on this locality. However, if the enquiry is for some other town or area, keying a fragment of the town or area name, or in some cases pressing a single button, directs the system to search only there. Then, by keying in only the first four letters of the surname and perhaps the first letter of the forename and street name, the system usually has enough information to retrieve the correct listing from the 23 million entries. The particular choice from among the few alternatives on the screen is simply chosen by the operator from memory of the full name and address provided by the caller.

If there are many matches for the given search criteria, the operator can page forward through successive screens. Where more than two or three screens are involved, the operator would, however, add more information and initiate a new search.

In particularly difficult cases, the operator is able to call more powerful search methods into use, such as automatic phonetic equivalents (for example, 'Caines' for 'Keynes'). The system also deals simply with long indented listings common, say, for local authorities. An address-only search will be available for cases where a caller does not know the surname or business name.

Dial-code information will be provided to enable the operator to give the STD or local dialling codes where appropriate, and the relevant charging rate. The operator will have access to a number of locally-controlled 'service category' files which may be used to hold such data as emergency and frequently-called numbers.

DATABASE

An elegant design of database has been developed to achieve both the fast response time and low hit rate when a 23 million listing database using just five characters as a key is searched. Its structure is shown in Fig. 3. The database is physically divided into ten geographical regional segments, each comprising more than 600 files, of which the main types are residential (R), business (B) and government (G). The file in which a record is held is determined by its category (R, B or G) and the phonetic conversion of the first four characters of its finding name. This phonetic structure allows the automatic phonetic search.

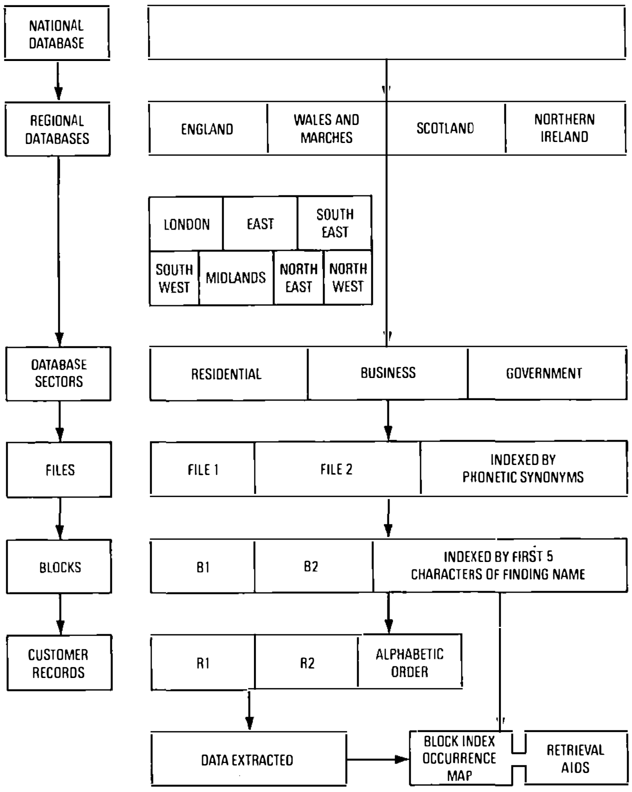


Fig. 3—Organisation of DAS database

Within each phonetic file, the records are held in alphabetical order and are indexed according to the first five characters of the record's first significant name. The indexes are used in conjunction with occurrence maps to identify those blocks containing candidate listings which are then retrieved for further matching against the search information input by the operator.

The occurrence maps reference finding information such as locality, initials, street name and house number, of which locality is the most important. The basic building block of the locality is the first five digits of the national telephone number (excluding the national access digit, 0) which are sufficient to delineate a telephone exchange area and correspond to a small geographical area. Real localities, such as a caller might specify, are a compound of a number of these building blocks. This creates a flexible way of defining the boundaries of individual localities and allows them to overlap each other.

FUTURE DEVELOPMENTS

BT has plans to give direct access to the DAS database to major business customers. This year, it intends to offer a pilot service which will enable users to connect their own terminals to the DAS network. In the longer term, BT hopes to provide users of Telecom Gold and Prestel with access to directory information.

ISDN in Europe—How, Why and When

T. IRMER[†]

UDC 621.395.34

This article outlines the evolution of the integrated services digital network (ISDN) and indicates the progress being made in its implementation in Europe. This article is based on a paper given at a presentation on the ISDN in Geneva, September 1986, courtesy of the Intel Corporation.

INTRODUCTION

The idea of service integration is not a completely new one: data transmission over the analogue telephone network is an example; but in those early days, technology and the technical parameters of the existing networks did not permit a global integration of services.

The advent of digital technology changed this situation entirely. Digital transmission and digital switching systems are now increasingly being implemented in analogue telephone networks, thus transforming them into digital telephone networks, a fact which, apart from other advantages, provides the basis for the integration of services by utilising the 64 kbit/s channel capacity of such networks.

It is, therefore, not surprising that the idea of an ISDN evolving from the digital telephone network matured at the same time at which this transition started in countries all over the world. The main ISDN principles were worked out between 1980–1984 in CCITT* Study Group XVIII and were adopted by the CCITT Plenary Assembly in 1984. These ISDN standards (I-Series Recommendations) must be considered as prerequisites for ISDN development and implementation.

When network providers became aware of the fact that the concept of the ISDN moved from a vision to reality, they responded accordingly. In many countries, the same philosophy emerged: as a first step, ISDN field trials were planned, to be followed by regular ISDN operation at a later stage. Against this background, the European Economic Community (EEC) estimates that by 1993 about 5% of telephone customers (some 20 million) will be ISDN users, most of whom will, of course, be business customers. Table 1 shows the ISDN evolution in selected European countries.

Japan is also on its way to ISDN (which is known there as *information network system* (INS)); it encompasses even more (for example, information processing) which, for regulatory reasons, cannot be part of the CCITT ISDN concept, but is using the CCITT Recommendations throughout. A large INS field trial in Mitake (near Tokyo) started in 1984 with 1500 terminals for different services.

The ISDN concept has also spread to the USA and, as a coincidence, just at a time when the 'deregulated' telephone companies were allowed to provide other services as well. Quite a few Bell Operating Companies (BOCs) have meanwhile announced ISDN field trials which will be operational soon.

TABLE 1

ISDN Evolution in Selected European Countries

Country	Pilot Projects			Public Operation		
	Start	Users	Services Terminals	Start	Forecast Users	National Coverage
Belgium	1988	1000	Tel, Fax, TTx, VT, PC	1990	–	–
Germany (FRG)	1986	2×400	Tel, Fax 4, TTx, VT, Da, PABX, Ta/b	1988	3 million (1995)	1993
France	1986	300+1000	Tel, Fax, TTx, VT	1988	3 million (1995) basic access	–
Italy	1987	2000	Tel, Fax 4, X.25, VT, PC, Ta/b	1990	30 000 1 million (1994)	1990
Spain	1987	2×500	Tel, Fax 2+3 TTx, VT, PABX	1988	–	–
Switzerland	1987	3×100	Tel, TTx, Fax 2–4, VT, X.25	1990	–	–

[†] Director, International Telegraph and Telephone Consultative Committee

* CCITT—International Telegraph and Telephone Consultative Committee

WHY ISDN?

It is true that for the implementation of ISDN, network providers are the first ones on the scene as they have to prepare and provide ISDN capabilities within their networks (see Table 2). But this does not mean that they are the only ones to benefit from ISDN; as is shown later, it is particularly the customer who will benefit.

TABLE 2

Motivation for ISDN at 64 kbit/s

Flexible provision of services (B + B)
New features possible (D)
Exploitation of the existing and capital-intensive local/subscriber network
Only few enhancements necessary
Wide range of competitive terminals
Support of terminal market liberalisation

Although ISDN is in the first place a technical concept, its commercial and economic success will depend solely on the customers' use of all facilities and features. The customer will not spend any extra money for sophisticated or brilliant technical gadgets unless such facilities and features are economically more attractive compared with those currently on offer in the existing networks (see Table 3). Therefore, the customer will be the decisive factor as to whether or not ISDN will be successful, and to what extent.

TABLE 3

ISDN Options for Customers

New user-friendly terminals
Cost-effective multi-service terminals
Universal access (ISDN plug)
More and comfortable features
Simple procedures
Attractive tariffs

MODULAR STANDARDISED INTERFACES—THE KEY FOR ISDN

Interfaces are essential for the evolution of ISDN. Through these interfaces, the services to be integrated are either entering or leaving the network, thus converting it to an ISDN. Taking into account the wide range of physical solutions for such interfaces, Recommendations for such ISDN interfaces are expected to be manifold as well.

It should not be underestimated that this potential difficulty has indeed been overcome. This was only possible because a modular interface concept was developed and agreed upon. The concept provides interfaces between the user installation and the network (user/network interfaces) and between networks (intra-network interfaces). For each of these two classes of interfaces, some sets of interface characteristics have already been, or will be, standardised. For the user/network interface, the basic access and primary level access have already been laid down in Recommendations. Both forms of access, although covering a wide range of applications, represent only two different physical interfaces. It is hoped that, by covering at the same time a wide range of applications, this restriction of physical types of interface will be maintained when the higher order user/network interfaces are defined (see Fig. 1).

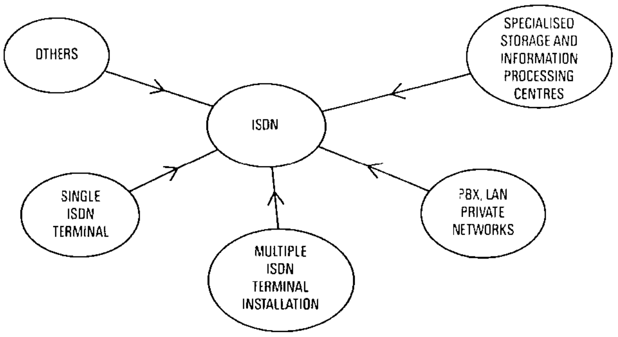


Fig. 1—ISDN user/network interfaces

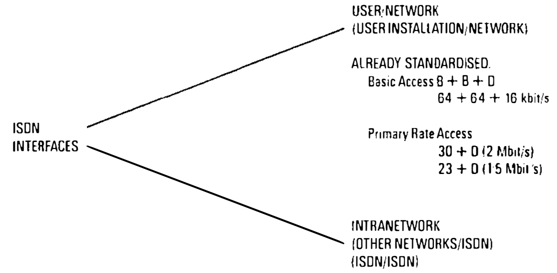


Fig. 2—Modular interface concept

Fortunately, detailed standards are now available for the user/network interfaces, whilst work is progressing for the intra-network interfaces (see Fig. 2).

It can be expected that the basic access (both as direct access or as passive bus) will find widespread application. This access is nearly ideal for the small and medium-sized business, and later on also for the private customer. It allows operation of all existing voice and non-voice services up to 64 kbit/s; both B-channels are transparent and can be loaded with any of the services mentioned. In addition, the features of the D-channel (go/return operation during communications) will particularly attract these customers. Equally important is the simplicity of interconnecting ISDN terminals to the network: no longer has the customer to worry about different plugs, sockets, procedures etc.—just plug any ISDN terminal into the standard ISDN socket and it will work. At the same time, the portability of terminals will no longer be a dream but a reality.

Summing up: technically, the ISDN supports the customer to an extent which has so far not been possible in such a universal user-friendly way. If the ISDN is supported by the network provider with attractive tariffs and by the terminal manufacturers with low-price terminals, ISDN is certain to be a success.

ISDN WORK IN PROGRESS

The basic standards for ISDN, like the modular interface concept, already exist—but much more work has yet to be done. A summary of current CCITT activities is given in Table 4:

It can be expected that, at the end of the current study period, standardisation of the 64 kbit/s ISDN will be complete—notwithstanding the fact that progress of technology will require an ongoing process of updating these standards in order to include better technical solutions as technology provides them. But apart from the 64 kbit/s ISDN, the next step is already in sight: the standardisation of the broadband ISDN, a task which is even more complicated than the

TABLE 4
Current CCITT Activities

Completion and updating of existing I-series Recommendations

- Broadband channel structures
  - H2 = 30... 34 Mbit/s
  - H3 = 60... 68 Mbit/s
  - H4 = 120...140 Mbit/s
- Service concept
- Intra-network interfaces
- Maintenance and operation
- Tariff principles and tariff structures
  (Tariff to be set up by competent national bodies)

previous one. It will also need a spirit of co-operation between network providers, industry and users—a spirit which proved to be so positive for the standard-setting process for the 64 kbit/s ISDN.

BIOGRAPHY

Theodor Irmer received his diploma in telecommunications engineering from the Technical University of Karlsruhe. After some years of work in the telecommunications industry, he joined the Deutsche Bundespost (DBP) in 1968 where he was responsible for the development of the first PCM transmission systems. Later, he was appointed Executive Director of the Transmission Systems Division and, since 1979, has been project manager for the digital transmission and switching systems in charge of implementation of digital technology in the DBP network and the development of the evolving digital telephone network towards an ISDN. In the international field, he has worked in several CCITT Study Groups. In 1972, he was elected Chairman of Special Study Group D which later became Study Group XVIII responsible for establishing the new I-Series of Recommendations for ISDN. He was elected Director of CCITT in 1984.

Book Reviews

Introductory Transmission Systems for Technicians. Oswyn Pereira. Longman. 76 pp. 29 ills. £3·95.

This book introduces the basic concepts of the transmission of information by means of electromagnetic signals. Its chapters cover: Frequency and Wavelength, Logarithmic Units and Power Calculations, Amplification, Noise, Multiplexing, Modulation, Filters and finally Pulse Modulation and Digital Transmission. The text has been written mainly for technician students studying on a telecommunications course, but the material is also suitable for mature students, and anyone wishing to learn about transmission systems. It is a useful supplement to correspondence course modules, or college-based learning.

The subject matter covers the objectives of the latest Business and Technician Education Council (BTEC) standard half-unit Transmission Systems Level 2. The chapter on logarithmic units explains the decibel clearly with the aid of worked examples. The chapter on multiplexing covers frequency-division multiplexing (FDM) and time-division multiplexing (TDM), and provides several useful diagrams. The modulation chapter explains the process of amplitude modulation (AM) and frequency modulation (FM), together with a description of the basic principles of phase modulation. The chapter on filters identifies the major types of filters, namely low-pass, high-pass, band-pass and band-stop, and gives attenuation/frequency graphs to help the explanation. The final chapter on pulse modulation discusses pulse-amplitude modulation (PAM) and its uses. It also covers quantisation, and this section is very well presented graphically. The section on digital transmission explains how, by using different forms of modulation, binary signals are transmitted. Each chapter has self-assessed questions to aid understanding. A more formal and comprehensive set of questions is included after chapters 6 and 9.

On the whole, the book is recommended for students for revision and as a quick reference book. Students requiring fuller treatment of the BTEC unit are advised to look at other books, in particular Transmission Systems 2 by D. C. Green, again published by Longman.

P. J. Ritchie

Power Supply Systems in Communications Engineering. Part 2—Equipment Engineering and Planning Instructions. Hans Gumhalter. John Wiley and Sons. 379 pp. 196 ills. £36·50.

This volume provides a great deal of technical information on telecommunication power equipment and practices used in West Germany.

The design of six models of central power supply equipment and their method of operation are covered in great detail. Extensive explanation of voltage and current monitoring, control and filtering is given. Very full reference is also made to voltage levels and tolerance limits. The problem of extending a live operational system is covered together with the use of distribution panels.

About 20% of the book is devoted to decentralised power supply systems using high-frequency switch-mode power supplies. Several particular items of equipment ranging from 150 W to 1000 V A are described in detail. This is a valuable section in view of the present trend to much greater use of decentralised power supplies in telephone exchanges, particularly in the UK.

No volume on power supplies would be complete without reference to the storage batteries used. A short description of battery selection methods and some manufacturers details are given, but, unfortunately, there is no mention of the modern gas-recombination sealed cell, which is becoming a major factor in decentralised power supplies.

There is a very useful section on the important aspect of functional and protective earthing, the need for potential equalisation and the effects of high resistance on voltage rises within the system under fault or fuse-blowing conditions. Details are given of the voltages to be expected and the means of protection.

The book is a useful guide for the student seeking information on some types of central power plant. The work, bibliography, standards (VDE or DIN) and specifications are essentially of German origin and this is a disadvantage for a book aimed at an international readership, and students should be aware that some of the practices described are particular to this equipment and the particular period of design.

R. New

From Time to Time

A Review of Past Journals

INTRODUCTION

From time to time, some of the events, innovations and equipment as reported in the *Journal* 25, 50 and 75 years ago will be reviewed.These extracts can present only a brief insight into the wealth of material contained in these early volumes as space is limited and time is spirited away as an enquiring glance at the text inexorably leads to compulsive reading. So it was 75 years ago when Mr A. J. Stubbs reviewed 'Jottings about Telegraph Street' published in the *Graphic* some 40 years earlier.

75 YEARS AGO—Vol. 4 April 1911–January 1912

On 1 January 1912, the telephone system in the UK was unified when the Post Office took over the operation of the then private National Telephone Company. The reviewer of 1911, in anticipation of this article, offers us the information that the Postmaster-General at the time of the takeover was the Right Hon. Herbert Samuel, MP., and that the Secretary to the Post Office was Sir Matthew Nathan, GCMG., who had previously been Governor of Natal. History (and a later issue of the *Journal*) was to confirm, however, that Sir Matthew was appointed to the Inland Revenue before the change-over and was succeeded by Sir A. F. King, KCB.

Telephones

The telephone network in London had grown to 69 035 stations by the end of 1910 and was generating some 168M calls per year; but it must be remembered that this did not include the National Telephone Company's system which had 130 000 stations—all on the manual system.

News of automatic exchanges was included in the *Journal* with an announcement of the proposals for their installation in some of its new telephone exchanges. Strowger exchanges were planned for Epsom and the GPO in London, and a Lorimer exchange for Caterham (although, subsequently, the latter seems to have been installed at Hereford).

A comparison is drawn between telephones in the UK and the USA, where about one half of the countries 8M telephones were operated by the Bell companies, the remainder by a number of independents. Despite the fact that they had been under development for 20 years, the Bell companies had not installed automatic exchanges and all the development had been done by the independent companies. Approximately 250 000 telephones were working through automatic exchanges, 95% being on the Strowger system manufactured by the Automatic Electric Co. Eight exchanges of 10 000 lines each were under construction in Chicago. The Bell companies, however, were prepared to concede that the switching equipment was reliable and had commissioned the Western Electric Co. to develop a semi-automatic system.

It was reported that rural communications, or 'farmer's lines' were somewhat primitive. In the early days, the lines comprised extended fence posts with fencing wire strung on broken bottles as insulators and often served 10–12 homesteads. The construction of the lines had improved, but it was often still carried out by the farmer.

The question of advertising of telephone services in the USA was discussed and several examples were shown.

Telephone advertisements in the USA

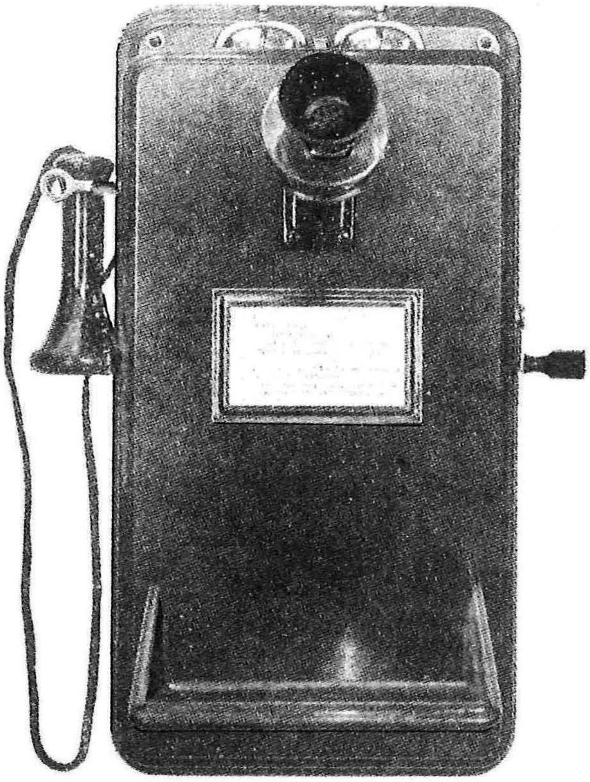
In contrast, the *Journal* published the views of an American visitor. His particular interest was in the use of the telephone to transmit telegraph messages. He was impressed with the ease by which the phonetic alphabet was used for difficult words, but commented that the use of code addresses slowed up delivery because of the need to refer to code books, and advocated the use of telephone addresses currently under consideration. It was also noted that the telegraph traffic, although still substantial, was falling in London as a result of increased use of the telephone.

New Ideas

In the new ideas section of the *Journal*, the Bell receiver was described in detail, as was a new wall-mounted telephone suitable for use on central battery and magneto systems.

External Plant

Practical hints were given on the erection of lead-covered aerial cables, and detailed information on the decay and preservation of timber, the use of desiccators, and the problems associated with diverting underground plant were discussed.



New wall telephone

Institution

Membership of the Institution stood at 848, and it was noted that negotiations were in hand to make use of the new lecture theatre at the IEE for meetings of the Metropolitan Centre.

It was noted that there had been a revision in pay and that Executive Engineers would receive £315–£405 with a London Allowance of £30 per annum. Skilled Workmen could expect to receive up to 47s. in London and 45s. per week in the Provinces. The cost of the *Journal* was one shilling.

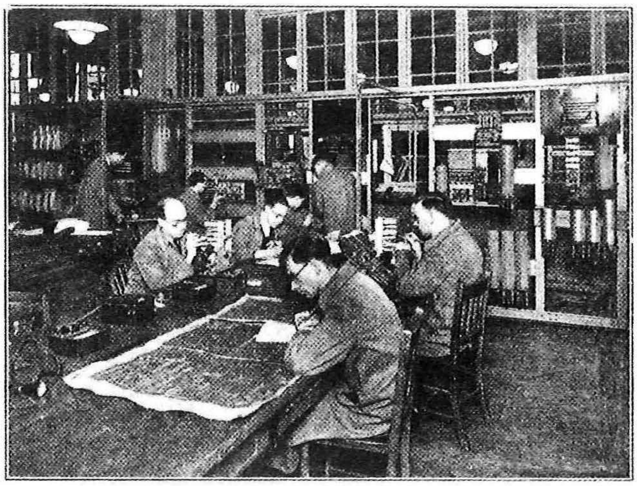
It was reported that a supplement to the Library Catalogue was about to be published. A short article on the Library detailed its nomadic existence as it was moved from one location to another. (It is now hoped that 75 years later the Library has finally moved to its permanent location. Unfortunately, the wooden bookcases provided for the original Library have failed to withstand the stresses of moving and have recently been replaced.)

50 YEARS AGO—Vol. 29 April 1936–January 1937

In August 1936, London's 100th automatic exchange was opened at Stepney Green, and in October the millionth telephone was handed over to the Lord Mayor. The death of King George V had resulted in a heavy demand for additional circuits by the press and broadcasting services. The 'pip' tone was provided on timed calls and call queuing was introduced at the larger directory-enquiry bureaux.

Switching

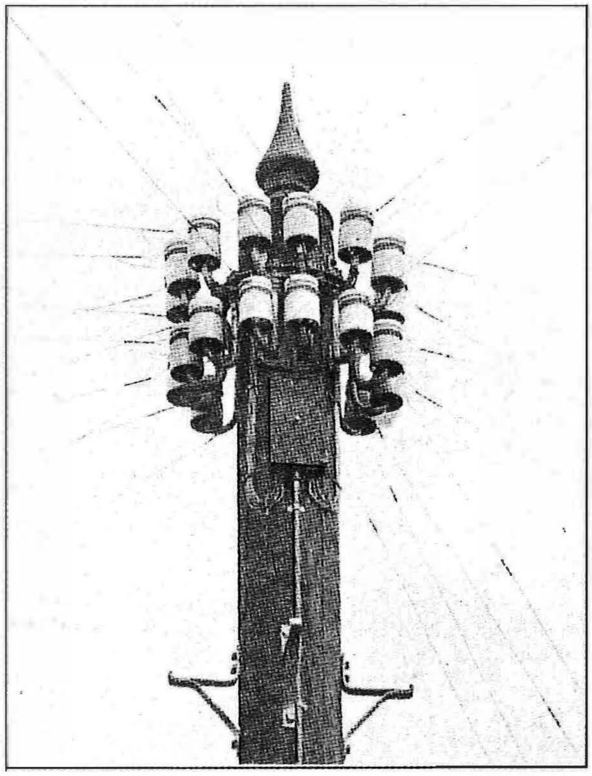
The development of the 2000-type selector was outlined in the *Journal*, and a description of the Unit Automatic Exchange (UAX13) was given. A new trunk and toll exchange was opened at Birmingham Telephone House. A brief history of the Post Office Circuit Laboratory is given and experimental work on automatic teleprinter switching is described. A London newspaper introduced a service whereby news could be broadcast to 100 subscribers. Meanwhile, 'TIM', the speaking clock was launched.



Part of the Circuit Laboratory

Customer Apparatus

The design and development of a new voice-switched loudspeaking telephone was described. The use of the new telephone was commended to residential customers: '..it will appeal to the subscriber who makes social calls and will no doubt tend to lengthen the duration and number of such calls since the art of telephoning is made so easy.' For the remaining telephone users, the quality of service was improved by the introduction of the new Transmitter Inset



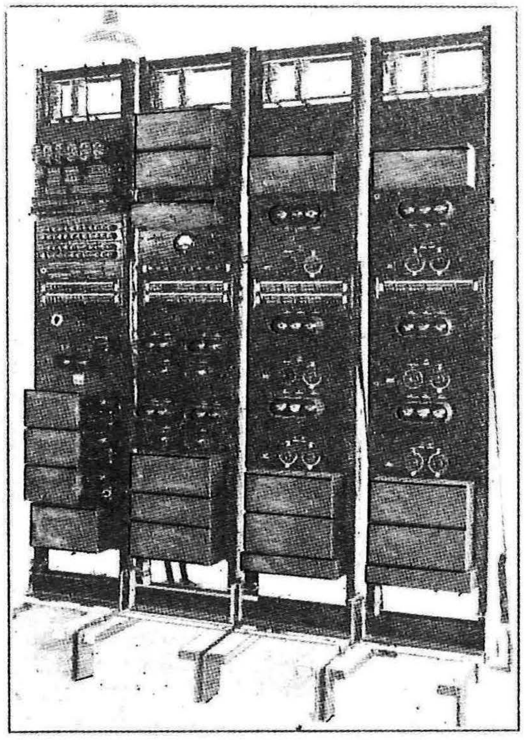
Ring-type pole head

No. 13. Methods of distribution to subscribers' premises were reviewed and details of a proposed ring-type pole head given.

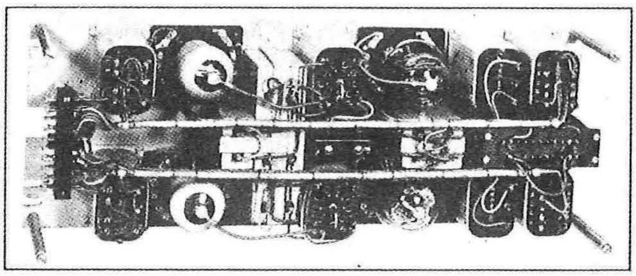
The 'Jubilee' kiosk (Kiosk No. 6), designed by Sir Gilbert Scott, was described, together with the latest developments in call-office equipment.

Transmission

Developments in transmission systems was being reported with descriptions of Carrier System No. 3 and Carrier System No. 4. A series of articles on carrier telephony dealt with the basic principles involved and included discussion of the Bristol–Plymouth 12-channel carrier system and the proposed London–Birmingham coaxial cable link.



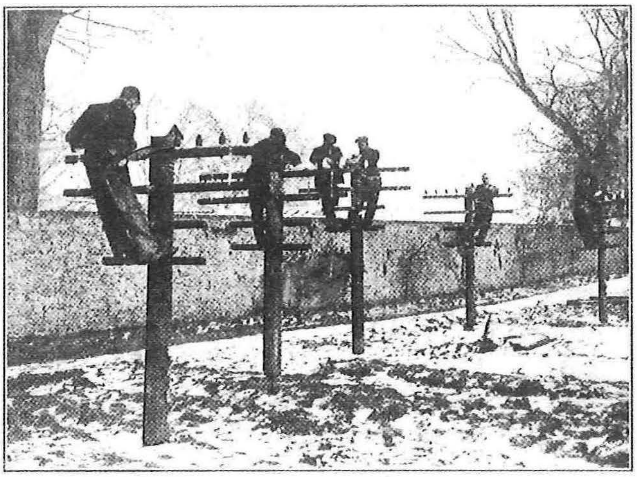
Carrier System No. 3



Repeater No. 36 (Carrier System No. 4)

Training

Recent increases in the Engineering Department's work had meant an increase in recruitment and training of workmen. The activities of the South Western District were described together with their training school at Shirehampton. For those of a more scientific nature, the *Journal* included a series on the principles of atomic physics.



External training on short poles

Postal Engineering

Details were given of the Transorma letter sorting machines that had been installed at Brighton Sorting Office. Each machine had five keyboard positions capable of sorting 50 letters per minute into 250 destinations.

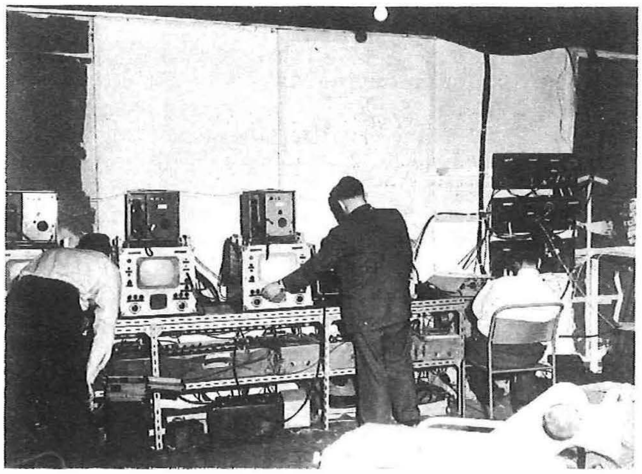
Institution

The layout of the *Journal* was modified in Volume 29 to include a summary at the begining of each article. The colour of the *Journal's* cover would be changed each year to identify the different volumes, and model answers for Civil Service Commission examinations were included in the Supplement. Circulation of the *Journal* was approaching 12 000 copies and was still priced at one shilling.

25 YEARS AGO—Vol. 54 April 1961–January 1962

1961 heralded the beginning of the change in telecommunications in the UK when the Post Office Act, 1961, removed financial responsibility for the Post Office from the Treasury, and digital transmission techniques began to be developed.

The royal wedding of H.R.H. The Duke of Kent, at York Minster, required the provision of 17 vision circuits and 9 miles of cable in and around the Minster.



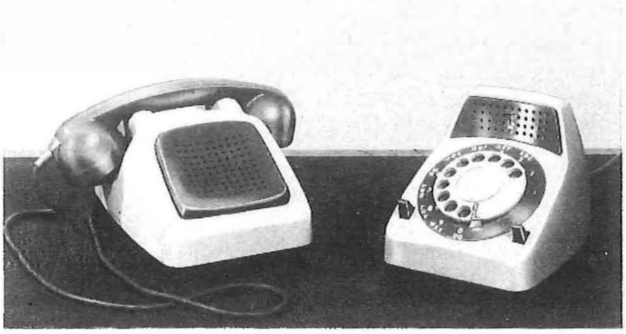
Preparations for the Royal Wedding

Switching

Changes were taking place in the design and layout of telephone exchanges. A trial of over-ceiling cabling techniques was underway and a unit method of exchange design was being considered. Progression towards fully automatic working and the introduction of STD meant that changes in the trunking arrangements of exchanges were becoming necessary. Methods of ventilating the apparatus room were discussed and the use of solderless wire-wrapped joints described. Some new methods of registering meter pulses by electronic means were considered and two experimental systems described. The experimental electronic director, the world's first electronic switching equipment to be used in an exchange, was finally recovered from Richmond exchange where the space was required for STD equipment.

Customer Apparatus

A new loudspeaking telephone was introduced. Initially conceived as non voice switched, a voice-switched instrument was also made available.



Loudspeaking Telephone No. 1

A new low-cost version of the STD pay-on-answer coin-box for subscriber's premises was introduced with a coin collecting box and a separate wall-mounted 700-type telephone.

Subscriber's coin box

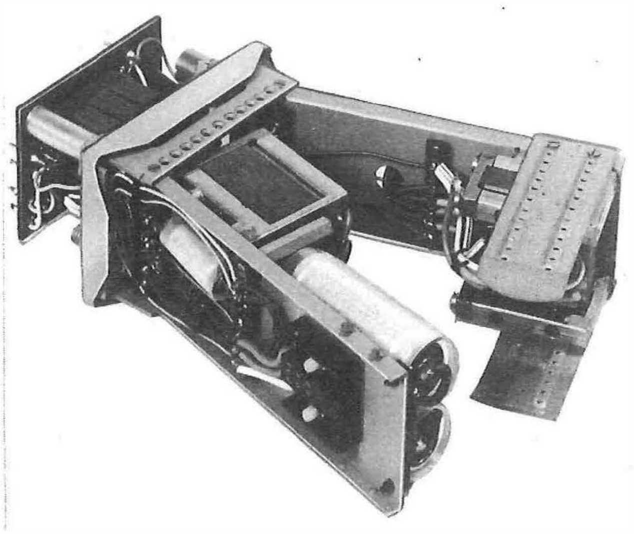
A calling aid for disabled subscribers was developed along with an amplified telephone for subscribers with weak voices and a battery-powered hearing-aid handset.

Trouble had been experienced with the feet of the telephone causing staining on table tops, and so a new non-staining material was developed.

Transmission

The first 12 MHz coaxial line equipment (CEL 8A) used on the London–Oxford–Birmingham route was described, as were the principles of pulse-code modulation (PCM) and a description of an experimental 12-channel system. The standard of performance was reported to be very high and it was concluded that 'The introduction of PCM techniques into the telephone network will depend largely on economic factors, and it remains to be shown whether PCM equipment can be manufactured and installed at a cost which will make it attractive for short-haul junction working.'

Supergroup derivation equipment was designed to give a measure of supergroup flexibility at intermediate stations, and the valve-type audio line amplifier (Amplifier No. 32) was superseded by the transistor line amplifiers (Amplifier No. 121 and Amplifier No. 135).



Amplifier No. 121

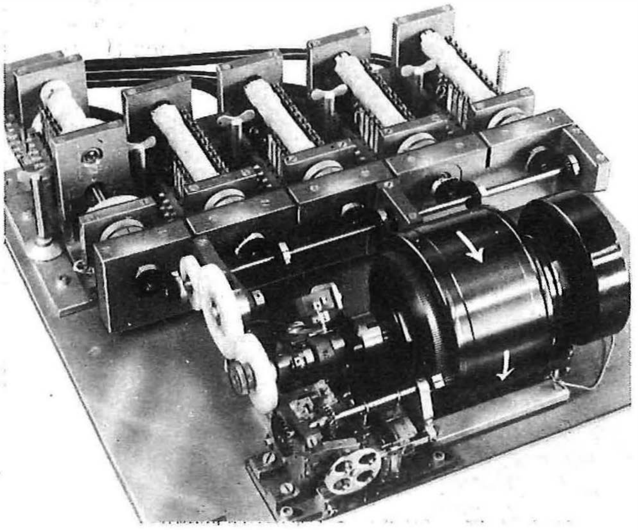
Telegraphs

The work of the Central Telegraph Office (CTO) was transferred to Fleet Building in anticipation of the closure of the CTO, which had been opened in 1874 when the telegraph office transferred from its Telegraph Street premises. Some 40 miles of pneumatic tube linked the CTO with the House of Commons in the west to Great Tower Street in the east. Initially, the telegraph equipment was powered by primary cells housed on some two miles of teak shelving in the basement. The building was progressively enlarged and a fifth floor added in 1930. The inside of the building was completely destroyed by fire in an air raid in 1940 and only the lower floors were considered safe for reuse. The building was finally demolished in 1967 and, after a brief archaeological excavation, development work on the site commenced for the new British Telecom Centre in 1980.

Automation of the Telex network was completed with the Fleet exchange which had just been brought into service. Preparations were now in hand to introduce subscriber-dialled Telex routes to European destinations.

Submarine Cables

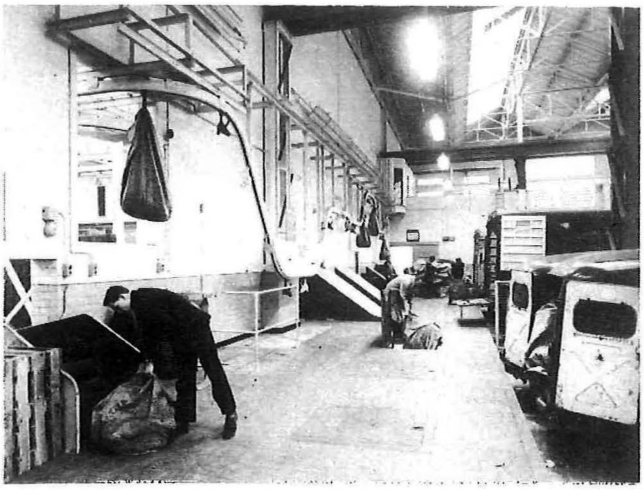
Submarine cables were in the news with the commissioning of *CS Alert*, and the inauguration of the CANTAT cable system between the UK and Canada. A description was given of an electromechanical time-division multiplex telegraphy system working over the speech channels on the TAT-1 cable.



TDM telegraphy receiver unit

Postal Engineering

Considerable developments had taken place in postal mechanisation. The Luton experiment for automatic letter sorting is described as is the use of phosphorescent code marks with its associated coding desks and readers. A report was given on the recently opened mechanised parcel-sorting office in Leeds which had a capacity of 240 000 parcels per week.



Leeds parcel sorting office

Institution

The annual essay competition for Members and Associate Section members continued to be well supported, the winning entry in the main section was on further education in the Post Office, and in the Associate Section on the electronic digital computer.

The Institution's Library continued to grow and numbered 2656 books; the price of the *Journal* was 2/6d.

75th Anniversary of Automatic Exchanges

CAN YOU HELP?

Readers are asked to help with the following appeal from Andrew Emmerson of the British Telecom Press Office.

1987 is the 75th anniversary of the first public and PABX (dial telephone) exchanges in this country and I am writing a booklet for the Telecom Showcase to make sure that the events do not go unrecorded.

The aim of this booklet is to cover some of the ground not normally covered, and there are a number of uncertainties which I hope that IBTE members may be able to clear up.

For instance, it was some years before ringing tone was standardised and dial tone provided. I would be most pleased to hear from anybody who has knowledge of this subject or can put dates on these events.

It is clear that Epsom and the Official Switch in 1912 were not the first automatic exchanges in Britain, and I am told that there were private Strowger exchanges before then. I have no details though; can anyone help?

Finally, I intend to list those museums where old auto equipment is preserved and would be grateful for details of anything in local collections. It would be interesting, too, if anyone would care to nominate the oldest private exchanges still in service, and it may be possible to prevent some unique museum pieces from going to scrap.

Please write to me at Room A361, British Telecom Centre, 81 Newgate Street, London EC1A 7AJ, or leave a message on 0604–844130; every response will be followed up.

ANDREW EMMERSON

UAX 13 Replacement by Digital Remote Concentrator Unit

A. J. HARRISON†

UDC 621.395.722

This article describes the replacement of two unit automatic exchanges housed in extended B-type buildings. Initially, it was planned to install the replacement electronic exchanges in new buildings on other sites, but careful planning showed that a digital remote concentrator unit, which was just becoming available, could be installed in the existing building.

INTRODUCTION

As part of the equipment modernisation programme in the Peterborough Telephone Area, it was proposed to replace the existing Strowger Unit Automatic Exchanges (UAX13s) at Sutterton and Stickney with electronic (TXE2) exchanges.

These two UAXs were housed in extended B-type buildings and, because of space restrictions, the replacement TXE2s had to be provided on new sites some distance away. These sites were purchased in late-1981, but required considerable site clearance and underground (U/G) cable work.

Shortly after the new sites were acquired, it became apparent that, because the development of System X was progressing rapidly, consideration should be given to replacing the UAXs with digital exchanges. The provision of new TXE2 exchanges was therefore delayed pending an investigation into the replacement of the UAXs by digital remote concentrator units (RCUs).

Unfortunately, even in mid-1983, the size and format that the new digital exchange would take was not known locally, but a decision had to be made to apply for planning permission to extend Sutterton exchange (Sutterton being of higher priority for replacement). The extension was intended to house some of the UAX units so as to obtain space within the existing building to accommodate the digital units.

Planning permission for the extension was duly granted in September 1983 for a period of five years. Shortly afterwards, information on the digital TEP-1H (Telecom Equipment Practice Type 1 Hybrid) rack sizes and quantities became available.

As the space required for the racks was now known, there was a remote possibility that the exchange change-over could be accomplished within the existing building.

PLANNING ASPECTS

The Initial Meeting

In February 1984, a site meeting was called at Sutterton exchange of all the groups that would be involved in the provision of the digital RCU; namely, Regional Headquarters Design and Specification, Internal Planning and Construction, Electric Lighting and Power (EL and P) Planning, External Planning and Works, Building Liaison, Local Exchange Maintenance, and Trade Union and Safety Representatives. It was decided unanimously that the three-rack TEP-1H RCU could be provided in the existing building. See Figs. 1 and 2.

U/G Cable Planning and Preparation

It was decided that the U/G cable feeds would be installed on the inside of the front wall of the exchange building by using seven ducts and cable risers. A section of the ceiling

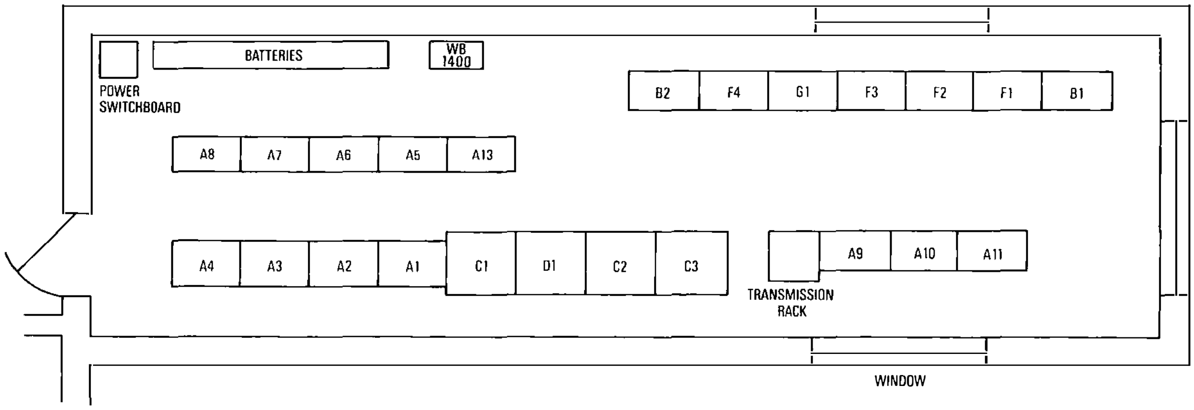


Fig. 1—Layout of Sutterton UAX 13 prior to modernisation

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† Mid Anglia District, British Telecom Inland Communications

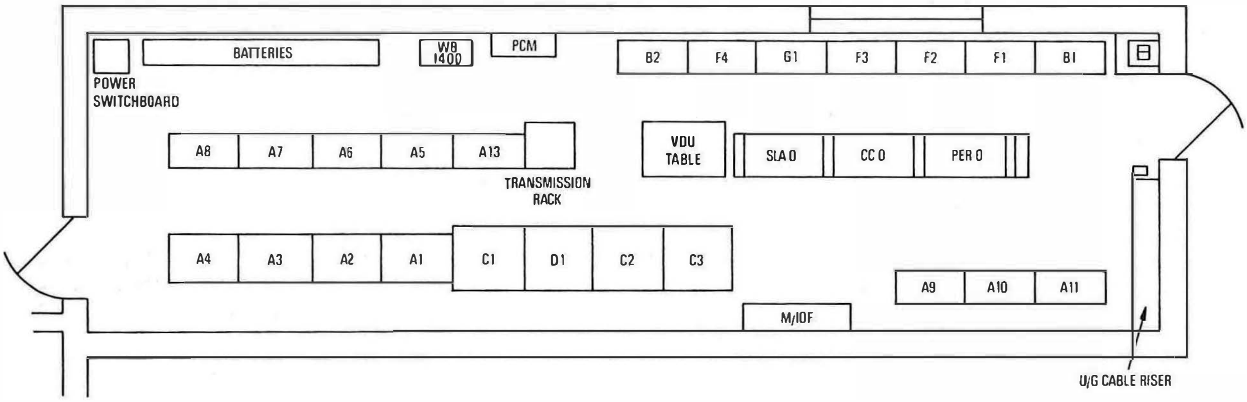


Fig. 2—Layout of Sutterton exchange prior to change-over

boards would be removed and a cable grid provided over the ceiling joists (see Fig. 3), so that the U/G cable could be run over the grid to the side wall where space would be created to provide a single-sided main/intermediate distribution frame (M/IDF) type 7B (8 verticals). This frame would be cabled from above with both the U/G and the internal cables.

It would be necessary to remove two windows from the building so that the cable riser and the new MDF could be installed. A door was also provided to ease the installation of the RCU racks.

After agreement had been reached on the method to be adopted, planning permission for the building work was again requested, and duly granted in May 1984.

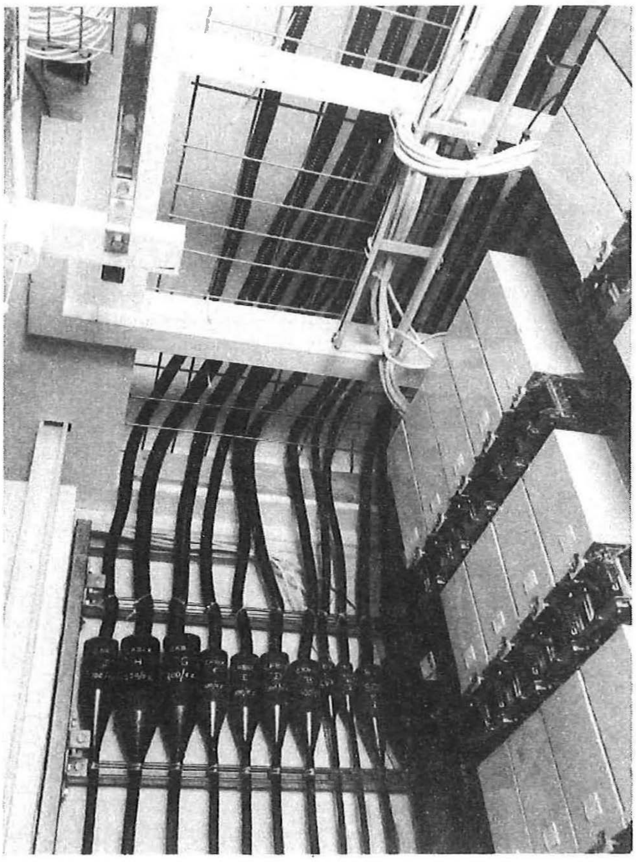


Fig. 3—U/G cable riser and ceiling cable grid

Preparatory Internal Construction Work

To obtain space for the provision of the RCU racks in the centre of the existing building, a 62-type transmission rack was moved and the internal cabling to A Units 9, 10 and 11 extended; this meant that they could be moved from the area in which the MDF was to be installed and, ultimately, towards the side wall whilst the RCU was being installed.

Thanks to the co-operation of the maintenance staff and the local union representatives, agreement on this procedure was reached.

THE WORK AT SUTTERTON

Internal Construction

The internal construction work commenced in July 1984 after the building alterations had been completed. The internal cables were extended and the A Units were moved later that year.

The provision of the M/IDF was delayed because the Frame No. 7B was not made available until November 1985. An additional locally-constructed MDF vertical was provided on the wall alongside the last vertical of the new Frame No. 7B and fitted with eight Strips Connection No. 170/10A (10 × 20) to provide the basis for the temporary tie-circuits between the old and the new exchanges.

Each Strips Connection was terminated with a 200-wire cable. The first seven were designated for the 700 multiple of the UAX (that is, 200–899) and were run to the relevant C Units in the UAX and terminated on top of the existing jumpers on the Protectors, Heat Coil and Test 40B. The eighth Strips Connection was designated for tie circuits 1–100 and was cabled to the existing IDF in Unit C3 to provide temporary connections for the miscellaneous and through circuits that used transmission equipment plus junctions etc. within the UAX.

Underground Cabling

Underground cabling work to the new MDF commenced in January 1986. This included the provision of temporary jumpers on the new MDF to the multiple tie-circuits (these were routed outside the permanent jumper rings, where practical (see Fig. 4), to avoid congestion later when the permanent jumpers were to be provided), and the recovery

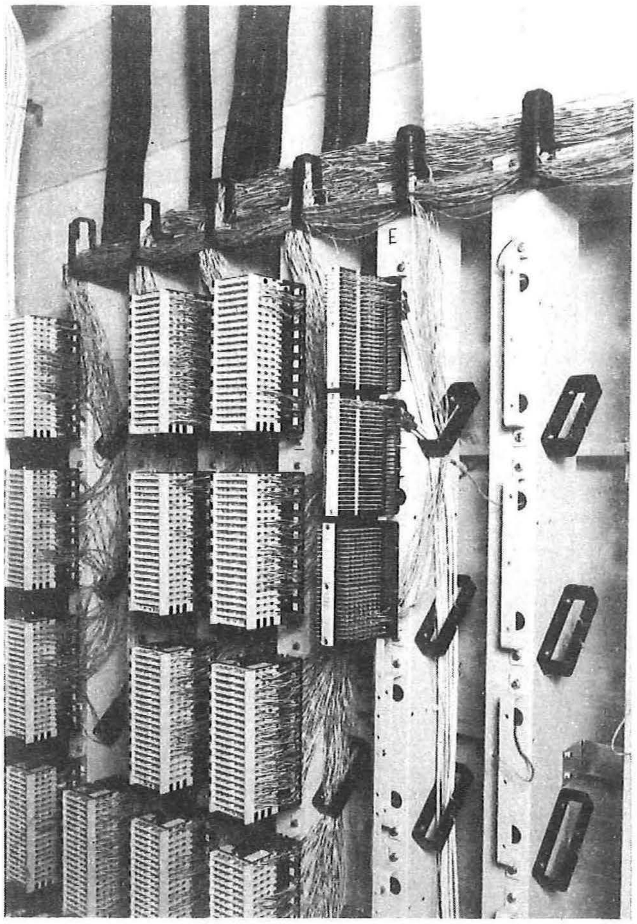


Fig. 4—M/IDF showing temporary jumpers routed outside jumper rings

of the existing UAX MDF jumpers, the old underground cabling and the fuse mountings in the C and D Units. This work was duly completed in April 1986.

Provision of Pulse-Code Modulation Equipment

During April 1986, the pulse-code modulation (PCM) line terminating equipment (LTE), in TEP-1E racks, and the digital line section (DLS) required for the RCU were installed and cabled to the new M/IDF.

RCU Equipment Delivery

The RCU digital switching equipment was delivered on 15 April 1986.

Electric Light and Power

The delivery of the RCU signalled the commencement of the work for the EL and P construction staff. They had to recover the existing lighting down the centre of the UAX building above where the RCU was to be installed and to provide the new exchange power equipment on the side walls of the building before the UAX units were moved there to allow space for the provision of the RCU down the centre of the building.

RCU Provision

Installation of the RCU began in mid-May 1986 when, initially, the existing UAX units were moved back towards the walls. This left just enough space for staff (albeit sufficient only for one of the smaller engineers) to work behind the units if necessary. After the UAX units had been moved, the centre of the floor was tiled and the RCU racks fixed in position.

After the change-over, the recovery of the Strowger equipment was started to clear space for the provision of a separate power room (see Fig. 5).

WORK AT STICKNEY

The work at Stickney UAX was carried out in a similar manner to that at Stutterton, but took place about two months later.

The planned brought-into-service (BIS) date for Sutterton was November 1986 coincident with the parent processor at Boston, and January 1987 for Stickney.

DISCUSSION

Probably one of the most helpful points that prompted the initial planning meeting to determine that an installation within the existing building was possible was the fact that it had been the policy of the Peterborough Telephone Area to provide only the odd numbered A-units in the UAX during the latter years of its life (for example, A11 and A13 wihout A12 and A14). This would not necessarily have been the Area's choice but for the fact that during the mid-1970s the Area experienced great difficulty in supplying enough A-Units to meet demand, bearing in mind that the A Units being installed were required to be polyvinyl chloride (PVC) wired (that is, manufactured later than 1953).

During this period of A-Unit shortage, one of the Area's internal planning groups measured final selector traffic in a cross-section of the UAXs by using portable traffic analysis equipment (PTAE). From the analysis of this extensive survey, it was determined that in 90% of final-selector groups whose traffic had been measured, no more than five final

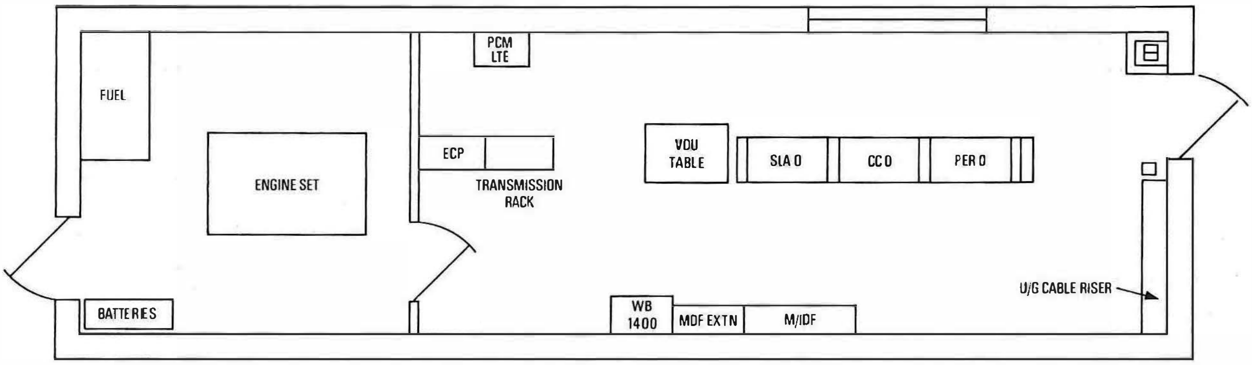


Fig. 5—Final layout of Sutterton RCU

selectors were required, and the 10% needing more than five final selectors to carry their traffic were associated with the long-established business PBX groups provided in the earlier units of the UAX. It was agreed within the Area, therefore, that the later groups of final selectors being provided in the UAXs were to cater mainly for residential customer demand. This meant that, if no PVC-wired A Units were available, only the 50 calling equipments and meters had to be provided.

These calling equipments and meters were installed on a B Unit or F Unit where space was available. Ten of these calling equipments were each wired to line-finder level 0 in each of five existing A-units which were capable of carrying the additional originating traffic by providing, if necessary, more selectors for link circuits.

It must be recognised that the same traffic would not be measured on the final selector groups today as it was in the mid-1970s. Traffic has obviously increased over the years, and it was found that one final selector group at each of the two UAXs had tended towards congestion with only five final selectors.

By measuring the traffic on all of the final selector groups in each of the UAXs, it was determined which of the existing groups carried the least traffic; then its selector bank wiring was cut and the last two or three bank positions as required were cabled away to extend the congested groups.

Although at both Sutterton and Stickney, site space, even outside of the UAX building, was at a premium, room was found to provide a sectionalised wooden shed 10 ft by 8 ft which was used for office, maintenance and welfare facilities for the duration of the installation of the RCU.

In conclusion, it should be noted that exchanges requiring modernisation within their existing buildings, whether extended B-type or any other type, should be considered on their own merits. By careful planning and co-operation well in advance of replacement, use of the existing building can become a viable proposition when initially it may have been thought impossible.

Timing is crucial, but the savings are substantial, and in this case the project proved very satisfying.

ACKNOWLEDGEMENTS

Acknowledgement is made to all those groups involved whose close co-operation contributed greatly to the success of the project.

Biography

Tony Harrison started his career as a Y2YC in 1949 in Boston and has spent all of his working life there. Until 1967 he was a T2A and TO on internal construction. He then transferred to exchange maintenance duties for two years and subsequently to internal planning before being promoted to AEE on the same duties in 1979. He now controls internal construction and planning in the north of the Mid Anglia District.

Book Review

Equalizers for Digital Modems. A. P. Clark. Pentech Press Ltd. xi + 468 pp. 123 ills. £35·00.

The author intends the book to be suitable as a reference and tutorial text for practising and student engineers engaged in the design and development of digital communication systems. Since the book is concerned only with a baseband analysis, it is equally appropriate for all types of linear transmission systems; for example, in radio and satellite systems as well as in the more common voiceband modems. The author is well qualified to write the book, having previously worked in industry on data transmission systems and being now Professor of Telecommunications at Loughborough University of Technology. This book is a companion to the author's previous book *Principles of Data Transmission.*

The chapters of the book begin with the necessary background theory and move on to discrete Fourier transforms, signal distortion, linear equalisers, and finally decision-feedback equalisers. The first chapters consider very briefly the practical application of equalisers and the properties of channels and then expand on the use of vectors, matrices and discrete Fourier transforms. The author successfully reassures the reader by beginning most chapters with the same basic transmission system diagram, which is then progressively enhanced. The book necessarily has a high mathematical content but the chapter on background theory eases the reader into the relevant concepts. The book's content reveals the author's research interest in the various possible forms of equalisation coupled with symbol-by-symbol detection and various alternatives using sequence detection without (or with incomplete) equalisation. The book provides revealing performance comparisons of the various systems. Relatively little space is devoted to the adjustment of the equalisers or the reference models: the adjustment process is important in practical systems where channel characteristics are usually unknown, so one would wish to supplement the book with other material. However, over the range of his subject matter, the author has achieved a commanding lucidity and will earn the grateful thanks of many students.

Considering the specialist and highly mathematical nature of the subject, the book is very readable; the subdivision of the chapters helps considerably here. Frequently, within the first chapters, worked examples with copious notes on the solutions are given. This makes the book particularly attractive to practising engineers who wish to widen their skills by private study. Experienced engineers will benefit from the many detailed comparisons of systems and the extensive references at the end of each chapter.

Overall, the author has achieved his aims in providing a tutorial and reference text relevant to all methods of digital communication, but this has created a text lacking reference to practical systems (other than in the chapter on background theory). With only this minor reservation, the book can be thoroughly recommended to the student and to the engineer wishing to extend his knowledge of equalisers for digital modems.

C. Hoppitt

A Step-by-Step Guide to Using Formal Methods

M. T. NORRIS, B.SC., PH.D., C.ENG., M.I.E.E., P. J. NEWMAN, B.SC., and P. JAMES, B.SC.†

UDC 681.3.06 : 51

This is the second of two articles about using mathematical techniques for system design. The first was concerned with the background and characteristics of the techniques that have been developed. This article illustrates how they can be used to good effect.

INTRODUCTION

The previous article[1] in this series concentrated on the costs and benefits of using formal methods for system design. This second article focuses on the mechanics of applying these techniques in practice and is intended to be a general guide to using formal specification methods. It is not a tutorial to the application of the methods, but should give a system designer some feel for the relevance of this approach.

The message to be conveyed is that formal methods are not purely for academic interest. They can be used to back up good design practice with mathematical rigour. Although they can be used throughout a development, it is quite possible to use them in selected areas and stick to more traditional techniques for other areas. Experience has shown[2] that judicious use of formalism can bring significant benefits with minimal cost. A point worth making is that using formal methods need not be complex. This is often the case if they become an end in their own right, but real benefits can accrue through their straightforward application.

This article briefly reviews the stages involved in producing a specification, and a small case study is developed to illustrate how formal methods fit into this general pattern. Finally, the case study is critically reviewed and a route suggested by which the use of formal methods can be introduced.

SPECIFICATION

Before looking at what is involved in creating a formal specification, it is worth considering some of the more general issues involved. There are several stages by which any specification—formal or otherwise—usually proceeds. These are:

(*a*) *Capture* This is the definition of the basic elements that will comprise the final system and shows how the elements are related to each other. A familiar example of this stage is the creation of a data model to describe a software architecture. The key issue in this phase is the choice of an appropriate notation which allows the problem to be expressed as clearly as possible. As an example, the use of block diagrams to describe a very-large-scale integration (VLSI) layout is useful, but the same notation conveys little helpful information for interconnection definitions, where timing information is the key point of interest.

(*b*) *Enhancement* This is the extension of the basic model to cover all the required operation, error recovery routines and the like. It is a continuation of the above process and can be greatly aided by a well documented development method to back up the notation. The most obvious example here is the Open Systems Interconnection (OSI) reference model which acts as a guide for much of the work in the world of protocol design.

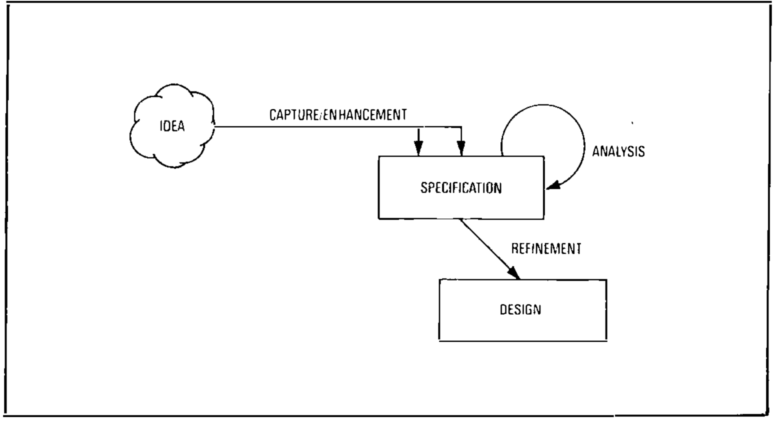
(*c*) *Analysis* Once a comprehensive model of proposed behaviour is complete, it has to be checked for validity. This analysis can take many forms but usually consists of extensive trial-and-error case studies (for example, design walkthroughs).

(*d*) *Refinement* If all the above stages are successful, a firm basis for development is created. This development typically entails either the addition of details to the initial specification, or the division of the original into several smaller pieces.

Fig. 1 shows how these phases are interrelated.

The sequence of events outlined above usu-

1—Interrelationship of stages



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† Research Department, British Telecom Engineering and Procurement

ally iterates through several cycles as the initially very abstract definition becomes increasingly concrete. Even so, it can be taken as the basis for a step-by-step guide of how to use a formal specification language.

It should be pointed out that a very narrow view has been taken (intentionally) of how an idea is implemented; a clear set of requirements has been assumed and many important aspects such as performance etc. have been ignored. These are beyond the scope of this article, which concentrates on how the proposed system behaves. It is assumed that these other factors are dealt with separately. See reference 3 for a detailed discussion of how these other factors are related.

CASE STUDY

To illustrate the use of a formal language, the translation of a set of informal requirements into a formal notation is shown. Each step in the development of the specification is accompanied by the relevant application guidelines.

In this section, the 'Z' notation[4] is used for the formal definition. It should be noted from the outset that this notation has been chosen purely to illustrate general points of application. In practice, the right language for the problem should be used; how this language is chosen is the subject of another paper[5].

Initially, an informal statement of the problem is made—the definition of a telephone directory database.

The system requirements are for a means of storing the names of telephone customers and their associated telephone numbers. It is intended that the system is implemented so that customers' details can be added or deleted as required. It should also be possible to find any given customer's telephone number.

Even this embryonic specification is open to interpretation. Before any real progress can be made, it is necessary to clarify exactly what is needed.

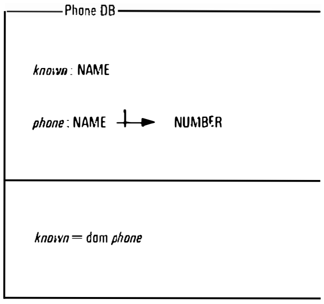
Capture

Starting from a set of informal ideas, progression is made to the stage where an explicit model has been developed which can be used to check the initial ideas. The difficult part is knowing where to start.

There are several guidelines at this stage:

- The golden rule is 'keep it simple'. This may sound like a very obvious piece of advice, but it is often overlooked. One of the prime reasons for using a formal notation to describe a system is to rationalise the proposed structure.
- The objects in the system must be written down and the relationships between them defined. These usually take the form of mappings. For instance, the definition of a telephone database systems might start with *phones*, *numbers* and some mapping between them.

All the main parts of a 'Z' definition are contained in a structure known as a *schema*; for example, Phone DB (Fig. 2). Each schema is divided into two parts: the signature (declarations) and the axioms (statements)[6].



2—Schema definition for Phone DB

The meaning of the Phone DB schema can be explained by taking each line in turn and relating it back to the original statement of requirements:

(*a*) The *names* that are known in the system are declared.

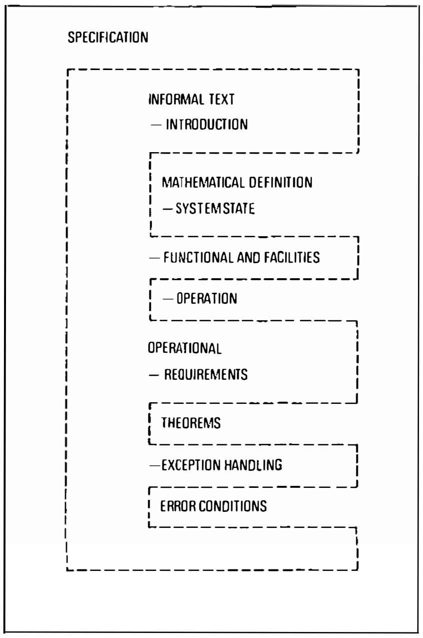
(*b*) Each *name* is related to an associated *phone.*

(*c*) State explicitly that all the *names* known should have a *phone.*

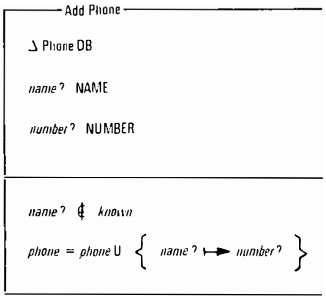
So far, a small part of the original specification has been tightened up. At the moment it is very simple. Unfortunately, it also does not say very much, and so additional information has to be added before it becomes useful.

Enhancement

At the enhancement stage, all the other parts of the specification that are required to make the final system work are included. A good way to include things that are usually overlooked or not thought of to begin with is to adopt a standard specification layout as illustrated in Fig. 3.



3—Layout of Z specification



4—Schema definition for Add Phone

More of the trial specification can be inserted into this pattern. For example, the original definition calls for some means of adding customer information into the database. A second schema—Add Phone—can be defined to cover this (Fig. 4).

Again the meaning of this schema can be given with reference to the original definition:

(*a*) The first signature states that this operation works on a Phone DB (as defined in Fig. 2). Effectively, the Phone DB schema is included here. This is an important concept in the building of complex specifications from humble origins.

(*b*) A new *name* may be added to the database. It must be of the correct type. A question mark after any variable indicates an input.

(*c*) A new *number* may be added in the same way.

(*d*) The *name* must not be already known.

(*e*) The *phone* relationship is updated by the new *name/number* pair. The BEFORE and AFTER states of *phone* are distinguished by the addition of a prime to the latter.

It is at this stage that some benefit begins to be derived from the use of formal notation. Not only have some previously very loose requirements been tightened up, but they have also been put into a form that can be analysed.

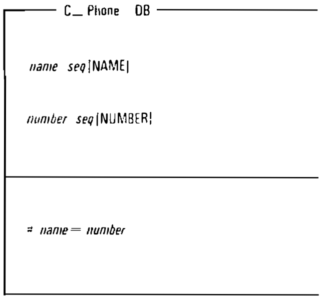
Analysis

Now to the application of mathematics—proving what has been said is correct. The first thing to note at this point is that it is necessary to select the right items to prove. The notations are certainly open to analysis, but a considerable amount of time could be spent manipulating irrelevant parts of the specification.

The general rule is to prove the obvious. It is usually here that the mistake lies. If the example is extended with a Find Phone operation, it should be shown that a Find Phone does not alter the database. This should be fairly straightforward and would normally be explicit in the definition: *phone′* = *phone*. As the specification is extended, it should be possible to show that important properties are maintained. (For instance, if a Delete Phone operation was added, it should show that ADD followed by DELETE returns the database back to where it started.)

Refinement

Once a good specification has been derived, it might be necessary for it to be developed. This entails choosing more concrete or detailed forms of what is already specified and showing that it is a valid development of the original (Fig. 5).



5—Schema for C_Phone DB

The specification must now be put into a form which more closely models the computing constructs which are going to be used for implementation. In the above schema, the names and numbers of the abstract specification and their relationship now appear as lists. This is the start of the refinement process—see reference 7 for a complete guide to this step.

EVALUATION OF THE CASE STUDY

The process of formally defining the system has now been completed. It is at this point that the validity of the end result should be critically examined. Several questions need to be answered:

(*a*) Who benefits from this approach to specification?

(*b*) At what stage are the key benefits to be found?

The first question is straightforward. It is unlikely that the average customer is going to relate to a 'Z' specification, or any other formal definition for that matter. The person who benefits from the formal approach is the systems designer who now has a means of expressing requirements in a precise format.

The second question is more subjective. Over a number of case studies[8], formal languages have been found to be very useful for design capture and enhancement. It is very difficult to write anything down until it is well understood.

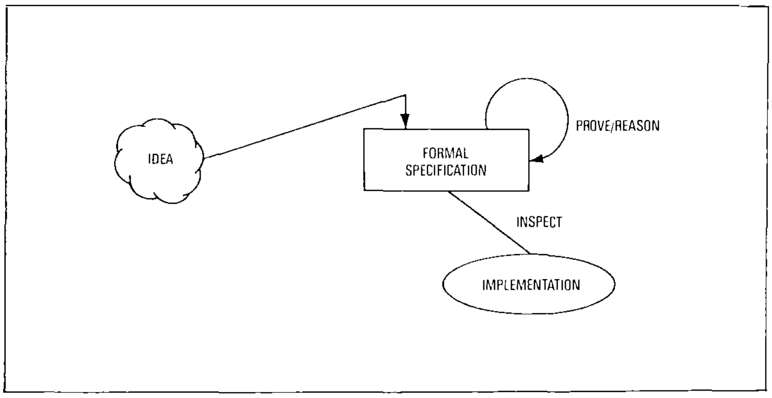
Analysis of a specification usually proves of less value because it is tedious to prove even the obvious properties of a specification. Rather than prove each aspect of system behaviour, it is common practice to informally inspect for errors. This usually unearths as many inconsistencies as formal analysis.

In general, it is too tedious and complex to carry out the refinement step. It is very demanding and the answer being sought must be known in advance anyway. To carry out fully this part of the formal development process requires a significant amount of specialist expertise.

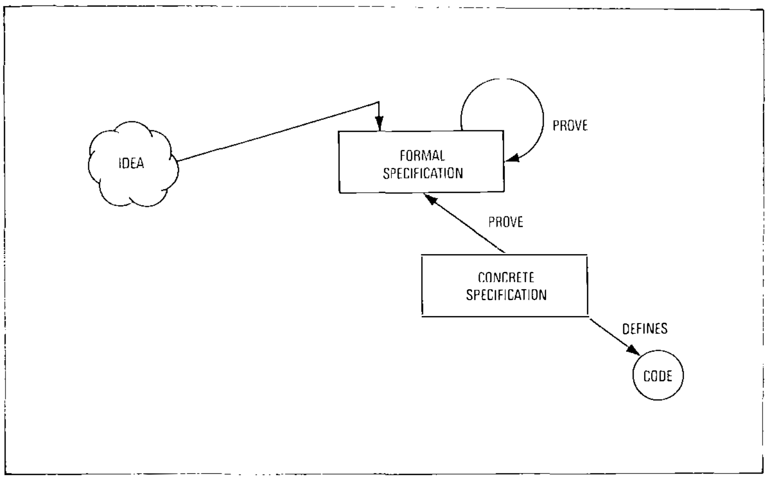
The complete picture of using formal methods in software development shown in Fig. 6(*a*) can be modified in the light of these comments to reflect an evolutionary, as opposed to a revolutionary, path to their introduction. The stages in the formal development process which have been found to consume most time for least benefit can be removed.

The revised picture is shown in Fig. 6(*b*) with the main problems of proof and refinement removed. In many cases, the value judgements inherent in engineering would lead to the latter course.

6—Formal methods for software development



(*a*) Formal development process



(*b*) Modified development process

THE WIDER CONTEXT

Having discussed how well formal notations tackle the problem they claim to deal with, it is worth broadening the issue a little.

Firstly, this is the situation at present—the current situation may be changed by a more mathematical basis to the teaching of computer science or by good support tools. In any case, it will be a while before the *status quo* changes significantly, and the type of tools required to solve some of the practical problems of formal methods will be a quantum leap from the average compiler.

On the subject of tools, it is interesting to note that much of this article has been devoted to writing down a number of rules and procedures for applying mathematical techniques to system design. If these rules and procedures could be captured, there is the basis of a support tool. A likely next step in the evolution of formal methods would be the application of artificial intelligence techniques to prototype such tools.

A second point on the broader issue of system design concerns the areas not covered by formal methods.

Looking at all aspects of turning ideas into reality, there is much more than just behaviour to consider[3]. Even if a good behavioural model is found, it might be unrealistic to implement because of, for instance, excessive memory requirements. The important point being made here is that one should always bear in mind the context and the scope of any tool (mental or otherwise) to get the best use out of it. A number of factors have to be balanced throughout any design[3] and the techniques described here pertain to only one aspect.

CONCLUSIONS

Formal Methods are no panacea, neither should they be a closed book to a system designer. They can be useful if used in the right way, within scope and within the right context.

Support tools which encapsulate the guidelines outlined here could greatly ease their introduction, but there is still no substitute for good design.

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[2] Norris, M. T., and James, P. Z—A Debrief Report. NCC Publications ISBN 0 85012 583 9, Jun. 1986.

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[5] Norris, M. T. The application of formal methods in system design. *Br. Telecom Technol. J.*, Oct. 1985, **3**(4), p. 53.

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All-Optical Regenerator

This short article is based on a press release issued by British Telecom last October announcing an experiment demonstrating the world's first all-optical regenerator for optical communications.

INTRODUCTION

British Telecom Research Laboratories at Martlesham Heath has successfully demonstrated the world's first all-optical light regenerator for use in optical communications. The regenerator, which is still in the experimental stage, both amplifies and retimes the light pulses directly without converting them from light to electricity, as in conventional repeaters.

At present, regenerators in long-distance optical links are installed every 30 km or more, and in the undersea systems which will soon span the world's oceans, they are spaced every 50 km or more. When developed commercially, all-optical regenerators should mean considerable savings in the cost of optical communications links, especially for undersea systems. Apart from being cheaper and simpler to produce, their power requirements will also be reduced. Naturally, the exploitation of this technology enables British Telecom (BT) to increase efficiency and achieve operational savings, which, in turn, benefit customers by enabling prices to be kept down.

OPERATING PRINCIPLES

The all-optical regenerator was developed by two BT research engineers, Rod Webb and John Devlin. Its key component is a microlaser which under certain conditions can behave like an optical logic switch. An optical clock signal is fed to the laser to hold the switch state just in the OFF condition. When a pulse of light from the incoming fibre arrives at the laser, it has sufficient optical energy to switch on the laser, but only when the optical clock signal is also present. This triggers the laser to generate a more powerful burst of light in synchronism with the clock which is then injected into the outgoing fibre.

BT's all-optical regenerator differs from previously demonstrated optical amplifiers in two important respects:

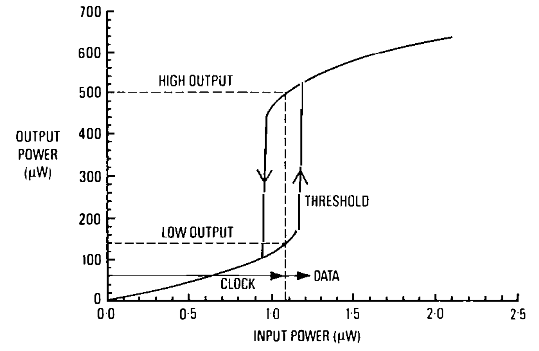
(*a*) bistable operation leads to a signal output level which is relatively constant over a range of input levels, and

(*b*) the signal is retimed by an optical clock.

The all-optical regenerator has been operated at 140 million pulses a second. Its inventors are now working to improve this performance and achieve higher rates by ensuring that all the components in the equipment are working at their most effective operating conditions.

The all-optical regenerator functions as a decision gate which retimes and restores the levels of an optical data stream with no intermediate electronic stages. It is based on the principle that a Fabry-Perot semiconductor laser has nonlinear output-power/input-power characteristics because its effective refractive index varies with optical power level. At some wavelengths this nonlinearity leads to bistability (Fig. 1).

1—Bistable amplifier characteristic (theoretical)



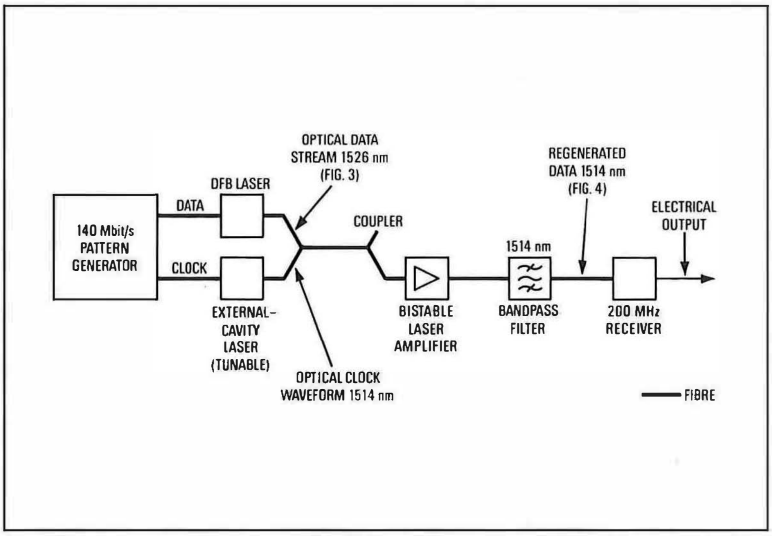
To form a regenerator, an optical clock waveform consisting of a train of pulses with peak power just below the bistable threshold is combined with the data stream and coupled into the amplifier. When the data is LOW, a slightly amplified clock pulse appears at the output. When the data is HIGH, the additional power is sufficient to exceed the threshold and the output jumps to a higher level, which is insensitive to the data power, and reverts to LOW only at the end of the clock pulse. The output is the regenerated data in return-to-zero form, retimed by the clock.

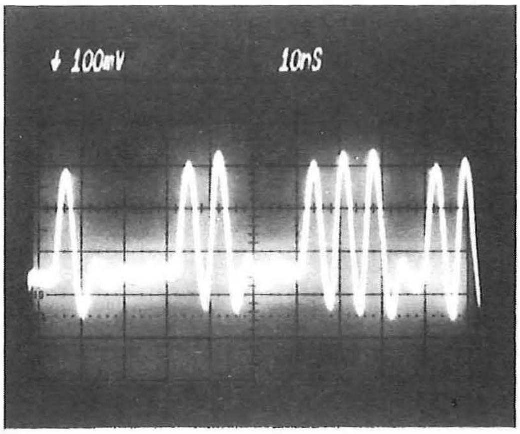
The output is at the same wavelength as the clock. However, the input data can be separated by multiples of the amplifier mode spacing which, in turn, is determined by the length of the laser cavity.

EXPERIMENT

The amplifier in the experimental system (Fig. 2) was a double-channel planar buried-heterostructure laser fabricated at BT's research laboratories with facet reflectivity reduced to 3%. The wavelength and mean power of the clock waveform were set to 1514 nm and 6 μW in the amplifier input fibre, just below the bistable threshold. Small clock pulses appeared at the output.

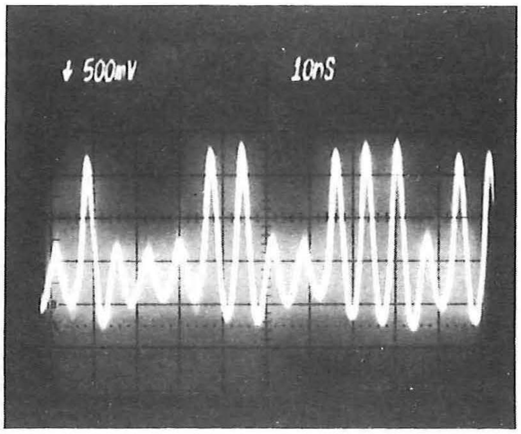
2—Experimental all-optical regenerator





Note: Risetimes limited by receivers

3—Input data stream at 1526 nm



Note: Risetimes limited by receivers

4—Regenerated data at 1514 nm

Data input was provided from a distributed feedback (DFB) laser. As continuous power from the DFB laser was gradually increased, a threshold was reached at which the output pulses abruptly jumped to a higher level.

When the DFB laser was modulated with a 140 Mbit/s return-to-zero pulse pattern, producing an optical data stream at 1526 nm (Fig. 3), the regenerated pattern appeared at 1514 nm with a mean power in the output fibre of 20 μW (Fig. 4). Error rates of 3×10^{-8} were obtained with a $2^{10}-1$ bit non-return-to-zero pseudo-random data stream of mean power 3 μW.

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(Founded as the Institution of Post Office Electrical Engineers in 1906)

General Secretary: Mr. J. Bateman, NMS3, Room 304, Williams National House, 11–13 Holborn Viaduct, London EC1A 2AT; Telephone: 01–356 9088.
(Membership and other enquiries should be directed to the appropriate Local-Centre Secretary as listed on p. 251 of the October 1986 issue of the *Journal*.)

LOCAL-CENTRE SECRETARIES—CHANGES OF ADDRESS ETC.

The telephone number for Mr. L. J. Hobson (London Centre) is now 01–728 8810.

The telephone number for Mr. J. R. Dymott, the local contact for the Associate Section in the South West, is now (0202) 206497.

IBTE CENTRAL LIBRARY

The books listed below have been added to the IBTE library. Copies of the 1982 edition of the library catalogue are available, on loan, from The Librarian, IBTE, Room GJ, 2–12 Gresham Street, London EC2V 7AG. An abbreviated catalogue was bound in with the *Supplement* included with the October 1986 issue of the *Journal*. A Library requisition form was also printed in the *Supplement*.

5434 *Elements of Relativity Theory*. Professor Lawden.

This book introduces the fundamental ideas of special relativity theory and is written so that it can be understood easily by readers whose mathematical knowledge extends no further than some elementary algebra. The physical principles and concepts involved in the theory are clearly described and mathematical treatment of the subject is kept to a minimum. Basic concepts are explained in detail to give a thorough understanding of relativity theory from which it will be possible to progress to a deeper study of the subject. This is an excellent introduction to relativity theory for those wishing to provide themselves with a firm foundation on which to base further study, or for those who wish to have enough knowledge of the theory to apply it to a range of problems.

5435 *Introduction to Artificial Intelligence*. Philip C. Jackson.

For anyone interested in the nature of thought, this book will inspire visions of what computer technology might produce tomorrow. This comprehensive survey of artificial intelligence attempts to provide answers to the following questions: Can computers think? Can they use reason to develop their own concepts, solve complex problems, play games, understand languages?

Easy-to-read coverage is given of problem solving methods, Turing machines, heuristic search theory, pattern perception, parallel processing systems and artificial intelligence achievements. This second enlarged edition contains additional material from the decade 1974–1985. The book is ideal for both the layman and the student of computer science.

5436 *Mathematical Foundations for Communication Engineering: Volume 1, Determinate Theory of Signals and Waves*. Professor Kenneth W. Cattermole.

The communications engineer is faced with a great variety of mathematical based theory: analysis of continuous and discrete signals; radiation and wave propagation; statistical detection; traffic flow and performance analysis; digital signal processing; coding for error control; cryptography. This book provides a mathematical foundation for these and many other topics. The common factor is the analysis of patterns in time and space by means of Fourier transform and its derivatives. The rigorous mathematical development is interspersed with examples drawn from many fields of communication engineering.

5437 *Computer-Aided Design and Manufacture*. Besant and Lui.

Computers are being used extensively in the engineering industry for both computer-aided design (CAD) and manufacture (CAM). Much of the industrial design is performed within the drawing office by design and production engineers and draughtspersons. Many organisations have introduced CAD techniques into the drawing office in the form of automatic draughting systems or computer graphics systems. This book aims to introduce the subject of computing as an aid to design and manufacture, and to take the reader through from the basics of computers to their application in real engineering design and manufacture. It provides a description of both the hardware and software of CAD/CAM systems, together with a practical discussion of their use in engineering. Subjects covered are computer graphics, engineering analysis, microcomputer-based CAD/CAM systems, use of computers in machine tools, robots and flexible manufacturing systems.

5438 *Telecommunications Technology*. R. L. Brewster.

Telecommunications is going through a significant stage of evolution where the analogue network is being replaced by digital transmission, step-by-step switching is being replaced by electronic exchanges and data networks are being used to communicate with computers. This book bridges the gap between traditional telephony and modern digital communications technology. Subjects covered are the telephone network, traffic theory, transmission of telephone signals, information theory, data transmission, pulse-code modulation, data networks, optical-fibre transmission, radio communication and cellular radio telephones.

5439 *The Intelligent Universe*. Fred Hoyle.

This major work represents a fundamental challenge to established thinking on the origins and nature of the universe. Fred Hoyle has entered the 'creation and evolution' debate with a work of extraordinary and far-reaching importance. In a remarkable sweep across the sciences, he assembles the current theories, examines them according to the evidence and gives judgement. The following theories are challenged: life was started by random chance; Shakespeare could be written by chance by monkeys; Darwin's theory of evolution; life originated on Earth. Fred Hoyle does not merely refute popular doctrine; in its place he presents a startling new perspective on life itself and on the past, present and future of the universe.

5440 *Fifth Generation Computers*. Peter Bishop.

This book attempts to bridge the gap between academics and professionals engaged in the research and development of fifth-generation computers and the rest of the information technology (IT) community. It gives a resumé of the developments of present-day computers, and an overview of the key concepts of artificial intelligence. The book also describes the intended overall structure of fifth-generation computer systems, the enabling hardware and software technologies which are needed to construct them, and their intended applications.

IBTE LOCAL-CENTRE PROGRAMMES, 1986–87

Readers should note that there are many amendments to the Local-Centre programmes published in the October 1986 issue. Unless otherwise stated, members must obtain prior permission from the Local-Centre Secretary to bring guests.

Anglian Coastal Centre

11 February 1987:

Computer Graphics by F. G. Cole, Head of Computer Graphics, Engineering Technical Support Services, British Telecom Inland Communications. Meeting will be held in LTB5, Essex University, Colchester, commencing at 14.00 hours.

11 March 1987:

Local Lines—The Way Ahead by I. G. Dufour, British Telecom Inland Communications. Meeting will be held in the Assembly Rooms, Norwich, commencing at 14.00 hours.

8 April 1987:

Taking Technology to the Market by Mr. M. Bett, Managing Director, British Telecom Inland Communications. Meeting will be held at the Guildhall, Cambridge, commencing at 14.00 hours.

20 May 1987:

Speaker from the Post Office, to be advised.

Bletchley Centre

12 February 1987:

The Changing Role of the Engineer in British Telecom by Mr. J. Young, Territory Engineer, Central Territory. Meeting will be held in the Jennie Lee Theatre, Bletchley, commencing at 14.15 hours.

11 March 1987:

Myths and Legends in Software Engineering by Mr. C. Jackson, British Telecom Research Laboratories. Meeting will be held in the Ballroom, Bletchley Park, commencing at 14.15 hours.

8 April 1987:

Taking Technology to the Market by Mr. M. Bett, Managing Director, British Telecom Inland Communications. Meeting will be held at the Guildhall, Cambridge, commencing at 14.00 hours.

East Midlands Centre

Unless otherwise stated, all meetings will commence at 14.00 hours.

11 February 1987:

Integrated Circuit Technology and Failure Causes by R. G. Taylor, British Telecom Materials and Components Centre, Birmingham. This will be an all-day visit to the Materials and Components Centre, with a factory tour in the morning and the lecture in the afternoon.

11 March 1987:

The East Midlands District in the Market-Place by P. D. Taylor, Director of Marketing, East Midlands District. Meeting will be held at Nottingham University.

29 April 1987:

Whatever Happened to the Candlestick? by Dr. I. S. Groves, Technology Applications Department, British Telecom Engineering and Procurement. Meeting will be held at Leicester University.

Lancashire and Cumbria Centre

The following two lectures will be held in Lecture Theatre H155, Lancashire Polytechnic, Preston, and will commence at 14.00 hours.

18 February 1987:

Cellular Radio by Mr. P. Hodson, Cellnet.

18 March 1987:

Optical Character Recognition by Mr. H. Bennett, The Post Office.

Liverpool Centre

Unless stated otherwise, meetings will be held at District Manager's Office, Imperial Buildings, Exchange Street East, Liverpool, commencing at 14.00 hours.

19 February 1987:

Towards Zero Defects by H. Wilson, Quality Manager, IBM.

18 March 1987:

Regulation of Telecommunications by Professor B. V. Carsberg, Director General of Telecommunications, Office of Telecommunications. Meeting will be held at UMIST, Manchester, commencing at 14.00 hours.

30 April 1987:

The Future of the Local Exchange Network by Dr. C. Brown, General Manager, Network Planning and Digital Exchange, British Telecom Inland Communications.

London Centre

Guests of members and Associate Section members and their guests are welcome to attend. Meetings will be held at the Assembly Rooms, 2nd Floor, Fleet Building, 40 Shoe Lane, London EC4A 3DD, and will commence at 17.00 hours with light refreshments being available from 16.30 hours. For security reasons, members and their guests must use the Shoe Lane entrance and be prepared to show a pass card.

17 February 1987:

Corporate Strategy by Angus Walker, Director, British Telecom Corporate Strategy Department.

24 March 1987:

Optical Fibres in the Local Network by John Tippler, Director, Network, and Kevin Shergold, General Manager, Local Line Services, British Telecom Inland Communications.

23 April 1987:

An Inside View of Japan Inc. by Dr. Alec Livingstone, Corporate Information Technology Manager, British Telecom Corporate Services Department.

14 May 1987:

Computer Graphics by F. G. Cole, Head of Computer Graphics, Engineering Technical Support Services, British Telecom Inland Communications. This lecture will be preceded by the Annual General Meeting of the IBTE Council, starting at 16.30 hours.

Manchester Centre

Meetings will be held in the Renolds Buildings, UMIST, Manchester, commencing at 14.00 hours.

11 February 1987:

Dealing with BT's Major Customers by Dr. S. O'Hara, Director, Business Network Services, British Telecom Business Services.

18 March 1987:

Regulation of Telecommunications by Professor B. V. Carsberg, Director General of Telecommunications, Office of Telecommunications.

15 April 1987:

The Future of the Socket on the Wall: The I.420 Interface and Beyond by M. F. J. De Lapeyre, Technology Applications Department, British Telecom Engineering and Procurement.

Martlesham Heath Centre

Meetings will be held in the John Bray Lecture Theatre at the British Telecom Research Laboratories, Martlesham Heath, commencing at 16.00 hours.

25 February 1987:

EFTPOS: Paying a Bit at a Time by P. G. Marlow-Mann, Tallis Systems, British Telecom Business Services.

12 March 1987:

Data Encryption and Security by S. C. Serpell, Public Data Networks, British Telecom Business Services.

25 March 1987:

The Future of the Socket on the Wall: The I.420 Interface and Beyond by M. F. J. De Lapeyre, Technology Applications Department, British Telecom Engineering and Procurement.

8 April 1987:

Technology in the International Network by M. Read, Head of Special Engineering and Interconnect, British Telecom International.

Mid Anglia Centre

Unless otherwise stated, meetings will be held at the Mumford Theatre, Cambridge. All lectures commence at 14.00 hours.

25 February 1987:

The Wireless Society. Does it Lack Moral Fibre? by Dr. J. E. Thompson, Deputy Director, Technology Applications Department, British Telecom Engineering and Procurement.

18 March 1987:

Hardware Techniques for the 90s by Dr. B. A. Boxall, Head of Advanced Hardware Techniques Section.

8 April 1987:

Taking Technology to the Market by M. Bett, Managing Director, British Telecom Inland Communications. Meeting will be held at the Guildhall, Cambridge. Joint meeting.

North and West Midlands Centre

16 February 1987:

Network Evolution by R. M. Culshaw. Meeting will be held at S & SC, Devon Road, West Park, Wolverhampton, commencing at 13.45 hours.

9 March 1987:

Address by M. Bett, Managing Director, British Telecom Inland Communications. Meeting will be held at the Staff Lounge Conference Room, British Telecom Technical College, Stone, commencing at 16.00 hours.

North Downs and Weald Centre

18 February 1987:

The District Materials Centre, Aylesford by Mr E. Bates, North Downs and Weald District.

Northern Ireland Centre

Unless otherwise stated, meetings will be held at the YMCA Minor Hall, Belfast, commencing at 15.30 hours.

18 February 1987:

Marketing and BTNI by Mr. A. Thompson, District Marketing Manager, British Telecom Northern Ireland.

11 March 1987:

AXE 10 System Y by D. Colbeck, Thorn Ericsson Telecommunications Ltd., and R. Pine, British Telecom Inland Communications.

8 April 1987:

Tomorrow's External Plant by I. G. Morgan, Head of External Plant Division, British Telecom Inland Communications.

North East Centre

25 March 1987:

Title to be advised. Mr. M. Townsend, District Engineer, Sheffield and Lincoln District. Meeting will be held at Tempest Anderson Hall, York, commencing at 14.00 hours.

Severnside Centre

Unless otherwise stated, meetings will be held at Nova House, Bristol, commencing at 14.15 hours.

4 March 1987:

Progress in Postal Engineering by K. H. C. Phillips, Post Office Research.

The following meeting, originally planned 1 April 1987, will be held later in the year:

Severnside's Materials Warehouse—A Step into the Future by J. Taylor, Materials Manager, Severnside District. Meeting will be held at The Crest Hotel, Gloucester.

Solent District

Details of the time and venue for meetings will be announced nearer the event, and can be obtained from the Local-Centre Secretary, Mr. G. R. F. Nunes (Tel. 0703–734257).

25 February 1987:

Quality Assurance within BT by Mr. P. Gillam, British Telecom.

May 1987:

Expert Systems. Proposed Lecture.

South Downs Centre

Meetings will be held in the Lecture Theatre, Central Library, Worthing, commencing at 14.00 hours.

17 February 1987:

Electronic Funds Transfer at Point of Sale by Mr. A. Kerrison, British Telecom Business Services.

17 March 1987:

'Just in Time'—The New Materials Management Strategy by Mr. D. Hillier, South Downs District.

Westward Centre

11 February 1987:

Myths and Legends in Software Engineering by Mr. L. A. Jackson, Research Department, British Telecom Engineering and Procurement.

12 March 1987:

Operation and Control of Digital Exchanges by Mr. K. Richardson, British Telecom.

British Telecom Press Releases

British Telecom's First AXE 10 Digital Local Exchange In Service

In November last year, British Telcom (BT) announced a further milestone in its £1billion-a-year modernisation programme—the bringing into service of the first AXE 10 digital electronic local telephone exchange. The exchange, installed to meet growth in demand for telephone service in Sevenoaks and district, Kent, was supplied by Thorn Ericsson Telecommunications Ltd.

Announcing the new exchange, Mr. Clive Foxell, BT's Managing Director of Engineering and Procurement, said: 'This underlines a major technical achievement for us in introducing a second exchange technology into our network, interworking without difficulty with our System X exchanges—and all without any interruption to customers' calls or their use of our service.

'This achievement has involved both BT and Thorn Ericsson in a major programme of engineering work adapting the AXE 10 system to British requirements.'

Mr. Foxell continued: 'With an additional exchange system now available to us, we can accelerate our modernisation programme to bring the benefits of an improved telephone service to customers sooner than ever.'

'We are currently bringing, on average, one new digital System X exchange into service every working day. With AXE 10 exchanges added to our resources, we expect this rate to increase. All customers connected to digital exchanges will benefit from significant improvement in the range and quality of telephone service. Digital operation gives customers faster call set-up and connection, and clearer speech.'

The Sevenoaks unit is designed to provide telephone service initially to about 1500 customers; it is expected that these will be connected progressively over several months. In addition, its improved telephone service is extended beyond the immediate Sevenoaks area through two remote concentrator centres, at Tonbridge and West Malling. Between them, these will provide service initially to a further 2000 customers. Extensions are planned for the exchange and the remote centres under which the combined system will grow to provide an ultimate total of nearly 40 000 lines before the end of the century.

The Sevenoaks exchange is the first of 26 local AXE units ordered by BT in March 1985. The next to come into service will be Birmingham South, which will be ready this spring.

World's First International Optical-Fibre Undersea Link Opens

The world's first international optical-fibre undersea cable, running between the UK and Belgium, was formally opened on 29 October 1986 with a two-way videoconference between London and Ostend. Known as *UK–Belgium No. 5*, the cable was laid by British Telecom International (BTI) earlier this year using its cable ship *CS Alert*. The system cost more than £10M, including a £7·47M contract with the supplier, STC. The 12 cables already in use across the North Sea have a total capacity of just over 23 000 telephone circuits; the new cable will add more than 11 500 circuits.

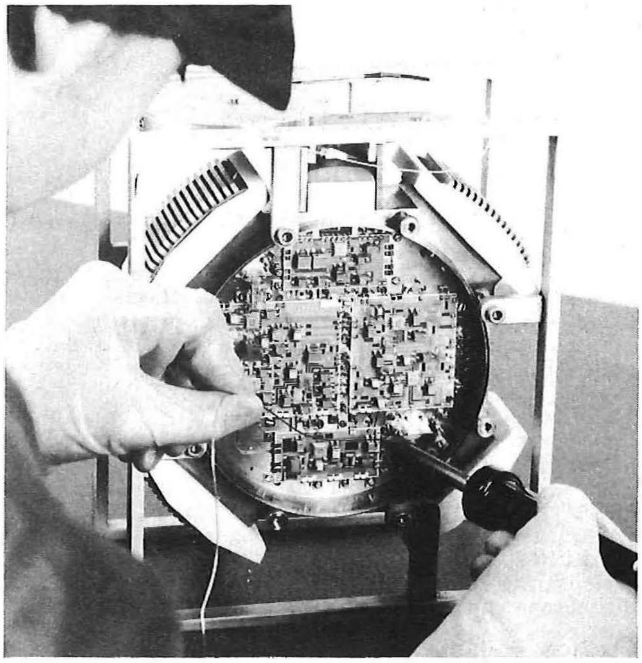
At the opening ceremony, Mr. Anthony Booth, Managing Director of BTI, and Mr. Brian Knight, Managing Director of STC Submarine Sytems, in London, were linked to Ostend by videoconference carried on the cable. Taking part in the link-up at the Belgium end were Mrs. N. Smit-Kroes, Minister of Transport and Public Works in the Netherlands, Mrs. P. D'Hondt van Opdenbosch, Secretary of State for Communications in Belgium, and Mr. H. Wirz, Head of International Network Strategy, Space Communications/Submarine Systems Division, of the Deutsche Bundespost, West Germany.

The cable ship *CS Alert* completed laying the main 80 km section of the cable in only five days. This section was buried in the sea bed by using BTI's plough to protect the cable from possible damage by trawlers and ships' anchors in one of the busiest stretches of water in the world. The shore ends of the cable were laid by the Dutch cable ship *DG Bast*. Cable laid in shallow waters near the shore was buried deep in the sea bed by using BTI's submersible Trencher by another cable ship, *CS Monarch*.

The optical-fibre cable enables BTI and other co-owners to offer a range of enhanced digital services, including videoconferencing and high-speed data communications facilities.

The first undersea communications cable between England and the European mainland (France) was laid in 1853. The cable consisted of four copper wires insulated with gutta-percha, a type of natural rubber product, and provided a total of four telegraph lines.

UK–Belgium No. 5 forms another important part of BT's plans for digital submarine cables. The TAT-8 transatlantic digital cable is planned to be in service in 1988, and customers are already signing up for leased circuit services. Soon, there will be digital cable networks across the Atlantic, fanning out over Europe. Another step forward in BT's plans was the anouncement, in mid-October last year, by 30 telecommunications organisations of their interest in participating in the TAT-9 transatlantic optical-fibre cable, and forecast usage would account for the whole of its capacity.



NL1 regenerator module

British Telecom Unveils Communications Facilities Management

British Telcom (BT) has launched a comprehensive new service for managing corporate communications networks. This service enables BT to draw on its expertise in planning and operating voice and data networks, and to achieve its eventual aim of becoming thc leader in an emerging market estimated to be growing to more than £500M a year by the 1990s. This is the market for what is known as *third-party communications facilities management* (CFM).

BT's CFM division can design, install, commission, operate and manage an entire private network; this leaves customers free to pursue their own mainstream business without the burden of having to run a telecommunications operation. In addition, the division can offer any element of the complete service, and thus give customers a wide range of options.

The concept of facilities management is not new to BT, since it has managed its own networks for many years and has already won a significant share of the market for managing international private networks, such as Trans World Airlines' European data network. BT also manages a range of computer systems for its clients. The combined value of these contracts, to companies such as Lufthansa, is more than £5M a year. Now BT is extending these services to include the management of privatc voice and data networks in the UK.

BT's CFM division has embarked on a multi-million pound investment in facility management centres in the UK. Two centres have been opened: one in the City of London together with a back-up in Ipswich, with two more being established in Birmingham and Manchester this year. The division has also won its first management contract—to assist British Aerospace to manage its corporate data network.

Announcing the new CFM service, Mr. Ron Back, BT's Managing Director for Business Services, said: 'During the last few years, businesses have become much more reliant on telecommunications. This dependence will grow as companies realise the great contribution modern communications can make to business efficiency.

'But many customers find that setting up and managing their communications facilities is becoming a demanding overhead. They find it increasingly difficult to attract the right calibre of staff and then, of course, their training and retention can also be costly and time-consuming. In short, running their own telecommunications distracts companies from their main business and makes an unwelcome addition to their costs.'

Mr. Back continued: 'The range of services we are launching today can free customers to pursue the business they know best. BT's business is telecommunications. We offer our expertise in designing and building networks; we can help customers identify their needs, find the right solution and implement their network.

'Once installed, we can operate the network on their behalf. In other words, we can help customers get the best possible value for money from their investment in communications.'

The services provided by BT's CFM division include:

(*a*) *Consultancy* the provision of expert opinion and skilled advice on the best solution to meet a company's needs now and in the future;
(*b*) *Requirements analysis* determining the network configuration and the equipment required;
(*c*) *Assistance with supplier selection* procuring the most cost-effective equipment to fulfil the requirements and meet deadlines;
(*d*) *Planning* deciding where and when the equipment is to be installed;
(*e*) *Project management* covering installation and commissioning;
(*f*) *Operational management* running the network day by day, keeping it fully maintained, providing a customer help desk, and locating and repairing faults.

The services augment BT's wide range of management systems already announced. These include:

(*a*) *SwitchMan* a control system providing switching, patching, monitoring and test access for data networks;
(*b*) *WatchMan* minicomputer-based performance-monitoring equipment for data networks which alerts managers to problems as they occur, enabling them to take immediate remedial action;
(*c*) *LinesMan* a traffic analysis, cost analysis and directory system for private telephone networks of up to 256 interconnected PABXs;
(*d*) *GuardsMan* for securing and monitoring dial-up data networks to prevent unauthorised access, and offering a wide range of protocol conversions.

Other network management systems are planned to augment the CFM portfolio, and will be announced this year.

Transatlantic Cable Boost for British Telecom Digital Services

Planning for a world-wide digital telecommunications network took a major step forward when British Telecom (BT) hosted a meeting, in October last year, of international parties interested in the proposed TAT-9 transatlantic optical-fibre cable. Representatives of 30 telecommunications organisations from 21 countries met in Britain to consider the levels of their ownership and use of the cable which is due to come into service in 1991. The conference, at the Metropole Hotel, Brighton, was hosted by British Telecom International (BTI) on behalf of the five partners who signed the initial TAT-9 agreement in Paris in May 1986: BT, AT&T Company of America, TELEGLOBE Canada, the French DGT and Telefonica of Spain.

TAT-9 will land in Britain, France, Spain, the USA and Canada. For BT, it will supplement the transatlantic capacity offered by satellites and by the first transatlantic optical-fibre cable coming into service in 1988. It will also provide a new digital connection with Spain and extensions into the Mediterranean.

Together with other links, TAT-9 will offer wholly digital connections between the Pacific basin, the US and across the Atlantic to Northern and Southern Europe.

Mr. Alan Jefferis, Chief Executive of BTI's Satellites and Lines division said: 'British Telecom and the four other initiators of the project are delighted that so many national telecommunications organisations and independent operators have shown their interest in joining the system as co-owners.

'BT can already provide digital services to many parts of the world, but cables such as TAT-9 will provide the massive volumes of capacity needed on the most heavily loaded routes. Judging by the reponse in Brighton this week, all the transatlantic capacity in the cable will be taken up from the start.'

TAT-9 will employ the latest optical-fibre technology. The transmission rate of 565 Mbit/s on each fibre is double that planned for earlier cables. Its fibres will also operate at the more efficient wavelength of 1·55 μm instead of the 1·3 μm of present cables; this will reduce the number of repeaters required. In addition, undersea multiplex branching units will provide flexibility in routing communications signals between the countries providing the landing points for the cable. When used with modern circuit multiplication equipment, the main transatlantic portion of the cable could handle up to 75 000 simultaneous telephone calls.

Engineering Trials Planned to Boost Microwave Network

British Telecom (BT) is to start engineering trials of advanced modulation equipment which could increase the capacity of its digital microwave radio network by up to a third. Four contracts worth a total of £1·5M have been awarded to GEC Telecommunications, STC Telecommunications, the Italian firm Telettra, and to NEC of Japan.

The equipment operates in the lower 6 GHz frequency band and uses a technique known as *64 QAM*—quadrature amplitude modulation. It is to be installed on three radio links and is due to start operating sometime during this summer. BT will then evaluate the performance of the equipment for general use in the network. If the equipment operates satisfactorily, its use on the microwave network would enable BT to make more efficient use of its allocation of the limited radio frequency spectrum.

The microwave network forms a major part of BT's trunk system. Together with optical fibres and coaxial cables, it forms the country's high-capacity communications highways, carrying telephone calls, computer data and television pictures between the main centres of population.

BT is converting the network to digital operation as part of its £1 billion-a-year digital modernisation programme. Digital operation brings many benefits, including clearer speech and faster call set-up. It also enables the network to carry other services—data, text, facsimile, graphics and pictures—together with speech on the same microwave, cable or fibre carrier.

BT's present methods of superimposing (or modulating) speech or data in digital form on a radio link enable the main microwave bands allocated to BT to each carry six digital channels, which operate at 140 Mbit/s and give an equivalent total band capacity of nearly 12 000 simultaneous telephone calls.

The 64 QAM equipment that will undergo trials this year will allow eight channels, equivalent to 16 000 calls, to be fitted into one band, and thereby increase its capacity by 33%. The price per channel of 140 Mbit/s 64 QAM equipment is less than two-thirds that of earlier systems.

64 QAM is the latest development in digital modulation techniques aimed at making more efficient use of the radio spectrum. The earlier digital systems used by BT employed 4-phase modulation called *quadrature phase shift keying* (QPSK), and this is used on the 11 GHz equipment. To improve efficient use of the spectrum, the 4 GHz band will use a QPSK technique where the bandwidth is deliberately restricted to less than the theoretical requirement (reduced bandwidth QPSK). This requires elegant techniques to compensate for the inevitable distortions caused by the reduced bandwidth.

An alternative is to modulate the carrier in both phase and amplitude; this is generally termed *quadrature amplitude modulation* (QAM). In 16 QAM, the carrier can take any one of 16 discrete states and this reduces the symbol rate (which determines the amount of radio spectrum bandwidth required for transmission) to one quarter of the bit rate to be transmitted; 16 QAM will be used in the upper 6 GHz frequency band.

The 64 QAM technique again uses amplitude and phase modulation to produce 64 discrete carrier states; this reduces the transmission symbol rate to one sixth of the channel bit rate and hence reduces the required transmission bandwidth to about 23 MHz. This enables the existing, internationally recommended frequency channel plan to be re-utilised, and to produce a band utilisation somewhat better than the 1800-channel analogue systems currently used in the band.

The 64 QAM systems are more demanding than the earlier systems in terms of sensitivity to transmission impairments, such as noise, symbol distortion and interface; therefore, powerful countermeasures against multipath fading effects are necessary. The general use of space diversity and complex transversal adaptive equalisers will enable 64 QAM systems to achieve the required performance standards within BT's network.

The 64 QAM system also exhibits a greater sensitivity to interference from radio channels at the same frequency on adjoining routes in the nodes of the network. This can be offset by use of orthogonal polarisation for the most prominent source of this co-channel interference, giving an extra 30 dB or more of discrimination.

BT has carried out theoretical studies, and field trials have shown that overall there is no technical penalty involved in adopting 64 QAM for the lower 6 GHz band. It is therefore being tried out on three 3+1 systems (three working plus one stand-by) operating from a node at Chester to radio stations in Holyhead, Liverpool and Manchester, respectively. Four systems have been selected from competitive tendering to obtain, in addition, a compatibility trial between the equipment of two manufacturers on one of the routes, each using a separate polarisation of the same antenna.

Product News

MerlinFax AD100

British Telecom's new facsimilie machine, MerlinFax AD100, offers all the features of MerlinFax SF100 except memory and group dialling. MerlinFax AD100 provides simple and effective facsimile communication and, when the need arises, can be upgraded to the full SF100 specification by the addition of a memory package.

MerlinFax AD100 operates to CCITT Group 3 standards and is compatible with older Group 2 machines. It has a number memory for automatic dialling with single-button selection for any one of up to 20 stations and simple two-digit abbreviated dialling for a further 80 numbers.

The terminal has a 16-step grey scale so that clear transmission of half tones is provided. This means that photographic originals can be sent and received with good quality reproduction by MerlinFax AD100. Add to these the resolution and contrast controls, white line skip to reduce sending times by passing over blank spaces and transmission at 9600 bit/s, and it is obvious that MerlinFax AD100 is designed to provide high-quality fast facsimile communication.

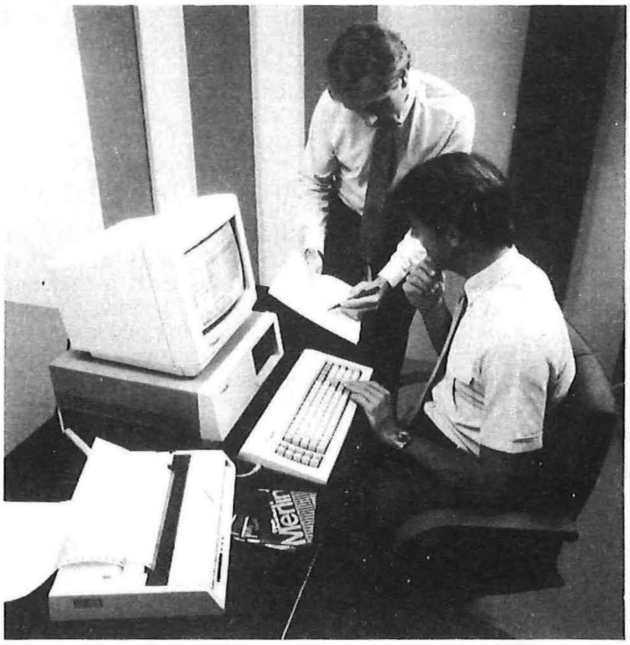
Other features include automatic timer so that documents can be sent automatically at any pre-selected time, polling to initiate document transmission from remote locations, transmission verification to indicate successful sending of documents and automatic printed heading on each received page giving date, time, sending identity and page number to identify plainly every document received.

Product News

New Call Management Systems from British Telecom

British Telecom (BT) has introduced new call management systems—the CM9000 and CM6000 series.

The CM9000 range has software which has been designed and developed entirely by British Telecom (BT) and which will enable its business customers to improve their efficiency and profitability by a more effective use of their telecommunications system. Today's managers are becoming more and more aware that efficient use of the telephone system can increase effectiveness and improve turnover. They are also aware of the need in modern business practice to be able to identify and control costs. The CM9000 range has unique features which enable managers to do this easily. Three systems in the range provide capacity for different applications for up to one million call records. Each system offers a variety of reports and is capable of concurrently running 80 different reports simultaneously. The CM9000 produces reports in WordStar compatible format for easy incorporation into other documents. The system can also 'learn' call patterns so that attention can be drawn immediately to any unusual calls not fitting the normal call pattern.


CM9000-type call management system


CM6000-type call management system

The CM9000 systems are designed to operate with most of BT's telephone systems such as Monarch, Regent, DX and BTex. BT has ensured that the CM9000 is flexible and particularly easy to use. Reports can be presented in graph or table form and comprehensive menu screens make the selection of options easy. The 'help' information enables inexperienced users to operate the system, but the system is protected from unauthorised users by a password security system.

The CM6000 series of call management systems is developed specifically for small companies and businesses that need to identify and justify calls by customer account code. The CM6000 has a V24 interface which enables it to link up with most systems, but it has been specifically designed to be used with BT's telephone systems supporting up to 32 extensions; for example, Octara, Septara, and Pentara. The two models in the CM6000 range can produce call reports in a concise, easy to read form from an integral printer. They can record up to 1800 call records and produce two types of report:

(*a*) summary totals detailing the number of calls, and their duration and cost; and

(*b*) details of individual calls.

Cheetah Plus

The design of British Telecom's (BT's) new Telex terminal, Cheetah Plus, has been based on experience gained from over 44 000 Cheetah machines in service. Cheetah Plus brings together a wide range of proven features in a modern design of terminal.

The new features offered by Cheetah Plus include password protection, so that use of the easy-to-operate terminal can be restricted to authorised personnel. The memory capacity has been increased, and further expansion is available from the 3·5 inch integral disc drive option. The modern styling of Cheetah Plus makes it suitable for any office location.

Its simple operation, which is based on a visual display unit, means that anyone can readily operate Cheetah Plus, and the new larger screen provides more help information to the user. Text editing allows word perfect preparation of messages off-line while other messages are being received or sent. Three levels of memory capacity provide a large number of messages to the average Telex user. The storage capacity also means that messages can be prepared in advance and sent automatically later; this allows the user to keep the line free to receive incoming calls during the working day. Automatic time and date insertion ensures a clear indication of when the message was sent.

British Telecommunications Engineering

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2. The Author Index shows articles under each author's name.

3. The page numbers in each part (April, July, October and January) of Volumes 1–5 are given in the following table.

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