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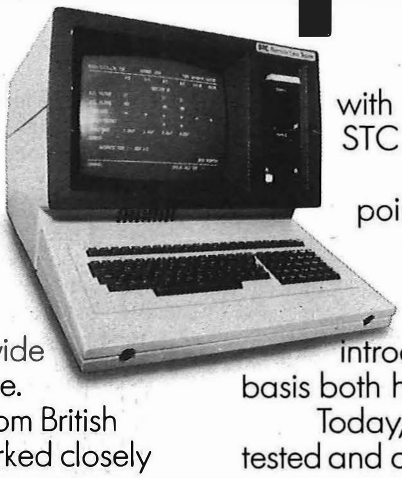


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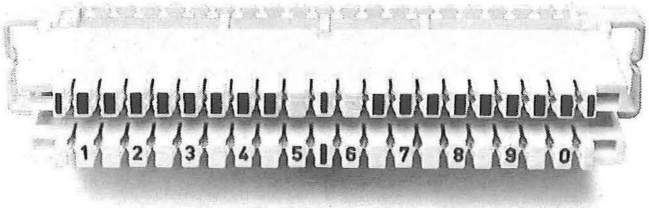

British Telecommunications Engineering

EDITORIAL

The changes in the regulation of telecommunications services in the UK have meant that British Telecom has had to reappraise the way it operates and serves its customers. British Telecom has undergone considerable internal reorganisation to meet the needs imposed by the change from a monopoly to a competitive environment, and the creation of National Networks is one example of this. The article on p. 2 of this issue of the *Journal* considers the factors influencing these changes and describes some of the ways in which National Networks is reacting to market forces.

Other significant changes are also taking place in telecommunications in the UK. In November 1983, the Government announced the award of 11 franchises for the first pilot cable TV projects, and British Telecom is playing a major role as a member of five of the eleven consortia that have been granted licences. The article on p. 6 of this issue of the *Journal* briefly describes the history of British Telecom's long involvement in cable systems and the two distribution techniques now being offered by British Telecom—the VHF coaxial system (tree and branch) and the switched-star system. British Telecom's VHF coaxial system, at present qualifying for only a 12-year licence, can be readily enhanced to provide the full range of interactive services and thus qualify for the 20-year licence initially available only to the switched-star systems. Licences are also being granted to existing television relay companies to permit them to extend their present services and to bring them into line with those provided by the new franchise holders.

National Networks

Keynote Address to the Institution of British Telecommunications Engineers

R. E. G. BACK, C.ENG., M.I.E.E.†

UDC 621.395.74 : 681.327.8 : 621.394.7

This address was given by Mr. R. E. G. Back, Managing Director of British Telecom National Networks, to the London Centre of the Institution of British Telecommunications Engineers on 26 September 1983. In his address, Mr Back discussed the reasons behind the decision to set up National Networks and goes on to describe how National Networks is meeting the challenge of competition.

INTRODUCTION

The formation of National Networks was just one of the steps that had to be taken in the long march to change the old GPO into a telecommunications company able to compete effectively in the marketplace. As I shall attempt to show, the forces that make this a logical step are not solely political and, like it or not, there is an inevitability about the changes which are taking place in our industry worldwide, which we should welcome rather than resist if we are to be true to our heritage. Certainly, in the past, we have adapted to changes in technology, market forces etc., but they are all now occurring simultaneously, and in an unprecedented manner giving rise to radical change.

CREATION OF NATIONAL NETWORKS

The reasons that convinced British Telecom (BT) to set up National Networks are, I hope, well understood, but I will restate them—because they are as true and as relevant now as they were in Spring 1982 when the BT Board took the first decisions.

External Factors

Firstly, and most importantly, were the factors external to BT where developments in technology, customers and competition bring about fundemental changes to the tasks to be done. Let us look at each of them individually.

Technology

Technology now provides the capability to deliver many new services which customers require. Indeed, there is a great deal of truth in the statement by our present Director of Research that technology has now made everything possible, all that is needed is for the requirement to be defined and the necessary funds made available. Equally important, technology is reducing the cost barriers to entry into the marketplace, making it easier for specialised new competitors to achieve a profitable critical mass, and we can expect an upsurge of entrepreneurs entering the communications market with highly focussed, high-technology services. As these factors widen the range of technical choice, BT will need to respond by offering more highly focussed products and services to meet the more disaggregated market needs.

Customers

Customers are being forced by their own imperatives to rely more and more on communications networks for their total integrated needs—voice, data, text, facsimile etc. Their businesses are being shaped around the communications facilities and their reliance on their working effectively is so crucial to them that they are placing increasing demands for improved and enhanced services. At present, two quite separate trends can be seen as customers wrestle with their communications problems and opportunities. The majority are reacting to the increasing choice and complexity by emphasising their basic business expertise (I make cars not networks) and withdrawing from the specialist communications area—looking to the supplier or specialist consultant to chart the way forward. Others are recognising that there may be an opportunity to reduce costs and to tailor systems closely to their needs by acting as their own systems integrator using multiple sources for equipment supply.

Competition

Competition in long-distance communications arrived for BT with Mercury, which has already announced investment of £200M and, although constrained by the problems of its build-up phase, can be a powerful competitor. But that is only the tip of the iceberg, there are the early moves on CATV, the cellular radio licences, the Government's intention to allow resale and the ever-present possibility of satellite services. As an aside, I must say I have not understood why satellite costs in Europe are so high when compared with the USA, where costs appear to be lower for both earth stations and satellite transponders. This can be only a short-term phenomenom and we must expect circuit costs in Europe using this medium to fall and become a factor in the future. We must, therefore, assume that, as in the USA, highly-focussed network competition will be capable of winning a substantial share of BT's most profitable segments by 1990.

As a consequence of the changes I have outlined, we must move from supplying a relatively few general services up and down the country to competing in at least four specific market segments—trunk switched services, local switched services, plus national and local specialised services—each of which has its own characteristics and in each of which the competition is likely to be fierce. The interactions between segments, particularly between switched and specialised services, are particularly fluid as new technology is implemented in the network and, as a consequence, we shall increasingly be operating in two quite different arenas—a nationally oriented network services business and a set of geographical local communication services businesses.

Internal Factors

The second and quite different factor leading to the setting up of National Networks is internal to BT, where it has been accepted that inland telecommunications cannot continue to be run in the traditional monolithic form. In the changed environment in which we will have to operate, it will be essential to take and implement decisions much faster than has proved possible before, and this will be feasible only in

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† Managing Director, British Telecom National Networks

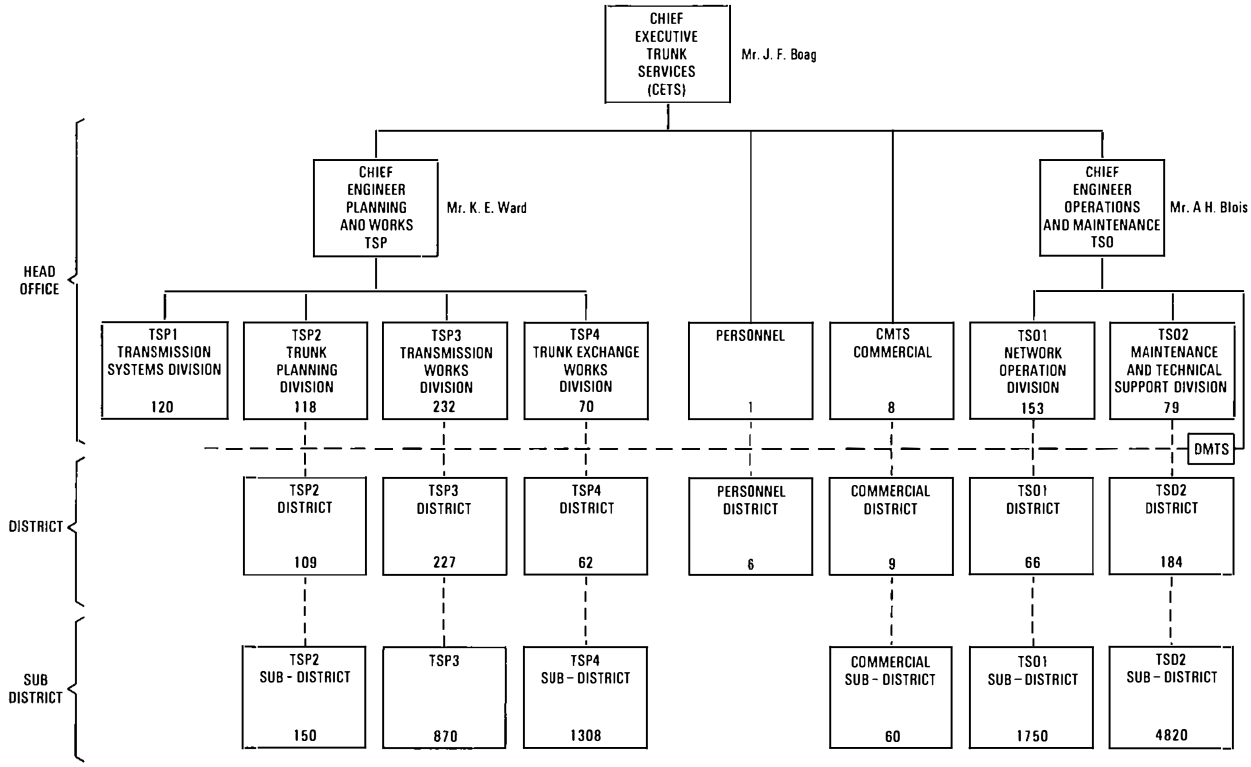


FIG. 1—Trunk Services organisation

smaller more manageable units based on the new market segments. Furthermore, those working in smaller units more readily identify with the commercial success of the enterprise in which they are involved; there is greater concern for the customer and a better perception of his needs.

These then were the factors which were the principal motivators for setting up National Networks with business responsibility for the trunk service and long-distance specialised services. We were also given account management responsibility for major BT customers. With few exceptions, there is a close correlation between the size of account and the use of long-distance communications facilities.

STRUCTURE OF NATIONAL NETWORKS

To meet its responsibilities, National Networks has two separate businesses, each under the control of a Chief Executive. Trunk Services has business responsibility for the STD services, whilst the Specialised Services unit has responsibility for a whole range of services, including Telex, Packet Switching and long-distance private circuits, and analogue and digital (including wideband) circuits. Each unit has its own commercial/finance arm, but as Head of National Networks, I have the direct support of a Commercial Director with a small team charged with the development of new management and financial reporting systems and for commercial advice.

Trunk Services

The organisation and setting up of Trunk Services in Areas and Regions has been a long drawn-out negotiation, but regrettable though it may be, it was not unexpected. We were, after all, proposing to change a part of our organisation which had not materially altered for 50 years or so. But, with the die now cast, the important thing is to get on with the implementation, so that all parties can concentrate on their proper job—service to the customer.

With a relatively small staff, Trunk Services will be organised vertically; that is, all planning and works will be integrated into one structure from Headquarters to Area level, and similarly for operations and maintenance, as well as the commercial and personnel arms. (See Fig. 1.) In this way, we expect to create a responsive organisation able to take on the major technical and commercial tasks of the next few years—particularly that of changing the trunk network from analogue to digital technology. I expect the single management of the network to ease the problems of the transfer to digital, and to enable us to react quickly to any unexpected delays in particular places and to business opportunities as they arise.

Specialised Services

Turning now to Specialised Services, the present organisation is centred on two major arms—engineering under the Chief Engineer for Specialised Services, and marketing under the Director of Marketing. There is also a finance/commercial arm. (See Fig. 2.) The marketing/sales department has specialist sales and network support units at many

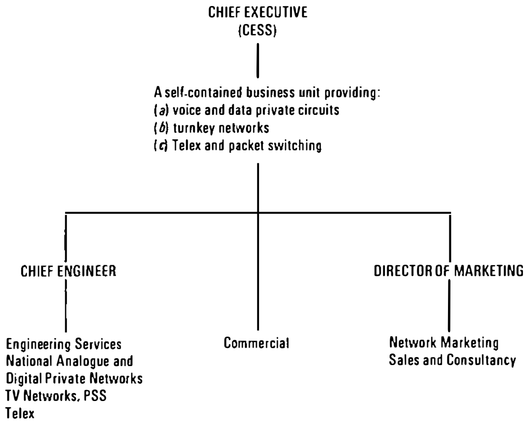


FIG. 2—Specialised Services organisation

Regional headquarters, where they are in close touch with similar Local Communications Services units. The Major Account Managers now report to the Director of Marketing, via the Head of Sales, though they, of course, have a corporate responsibility and represent BT as a whole.

This organisation and staff in it have achieved much in the past year in bringing forward new products and selling them vigorously to customers, and nothing should detract from these successes. Indeed, the highest praise has been accorded them in the press where the competition is alleged to have been dismayed by our progress. All has not been plain sailing however, and we have been able to learn a number of lessons already.

The first is that BT has no perception yet of the effort, both in terms of quantity and quality, it has to put into marketing and selling in a competitive market. Products, no matter how good, do not sell themselves. BT, in its sales network, has not, so far, advanced beyond the point of advertising its wares and taking orders: that will not work as competition bites.

Good marketing and selling alone do not shift products unless they themselves are good, and well supported in terms of documentation, speed of provision and backed by a good maintenance service. Long-term success must be based on service and, to provide that in depth, all sections of the business with a part to play must be linked into the selling process.

We have learned much about product launch—not solely when the engineering side is ready, or can be pushed into saying when they will be! Proper pre-planning of the marketing thrust based on the assurance that the product will be available, supported by rapid rectification procedures if anything should go wrong, as well as proper maintenance documentation to the field, must all be co-ordinated.

Overriding all other aspects in importance to the long-term health of the Business is the need to understand customer's requirements and to seek to help him solve his communications problems in running his business. It is a mistake to base your approach to customers on products—particularly when those products overlap in capability and facilities.

For these reasons, after one short hectic and relatively successful year, we are already moving to a new organisation for Specialised Services which will tackle the problems I have outlined. Under this reorganisation, the sales and marketing units will be organised into business sectors (for example, finance, manufacturing etc.) so that the people working in those sectors can become knowledgeable about the business they are serving (see Fig. 3). In this way, sales and marketing staff will be much closer to their customers and be better able to help solve communications and related problems and be aware of the 'add-on' facilities which the particular market sector requires. Backing the sales team will be product units responsible for the success of their product or group of products. It is the product unit which will worry about the quality of its product, its cost and price, the maintenance procedures and organisation—everything in fact which makes one product sell and another languish on the shelves.

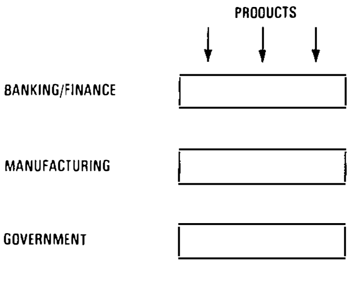


FIG. 3—Sector Marketing

In addition to strengthening our market and sales units over the past year, a process which we shall have to continue, we have devoted a great deal of attention to two other elements of our organisation—the finance and commercial arms. Faced with a competitive situation, we must have adequate information on our costs broken down into sufficient detail to be relevant to individual services. The previous method of treating BT as a single profit centre concealed, not only from higher management but also from those managing individual products or services, the true profitability of services. Certainly, we in National Networks have been surprised to find that some long-standing services which we now supply are making quite heavy losses, and we have to consider whether we can turn them into profitable ventures or cease to provide them.

Despite our efforts over the past year, we still lack reliable cost information on which to base sensible business decisions and we, like other units in BT, must improve our financial reporting systems rapidly and radically.

Similarly, as we enter the competitive arenas, we find that our commercial procedures are amateurish and we have to improve these quickly. For example, we must have procedures for assembling tenders which take account of our changed legal/regulatory position, assess the risks involved, the cost implications and the strategic issues, and apply audit procedures which ensure that the tender which is submitted is consistent with BT's objectives and standards.

NATIONAL NETWORKS AT WORK

In the remainder of the lecture, I will take one or two existing or planned products or services from National Networks and use these to show how the formation of National Networks and our changing perspective of the role of the unit, together with the onset of competition, has affected our reactions.

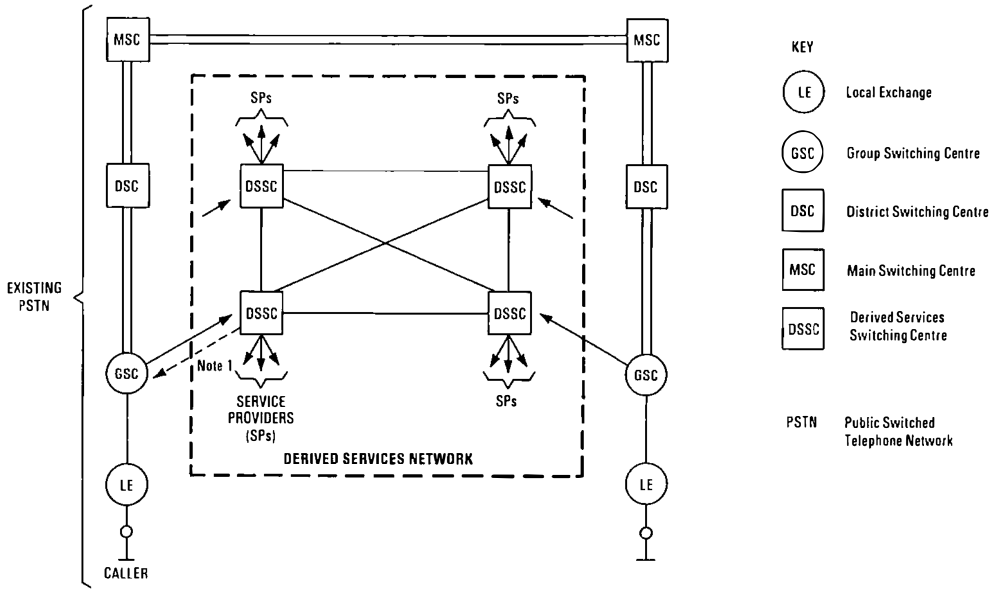
Network Modernisation

The central element in National Network's competitive armoury is, of course, the trunk network; both the PSTN and the transmission network on which so many other services are carried. If customers become dissatisfied with the service which that network can provide, they soon will have alternatives to which they can transfer. It is therefore essential that both the existing analogue network and the digital network that will replace it are designed, provided and operated to the highest standards, and that the transfer from analogue to digital is achieved without serious customer inconvenience. Recognising the importance of modernising the network, and the economic advantages that it gives, National Network Trunk Services have accepted the challenge to bring forward the completion of modernisation in the belief that our unified management structure makes the achievement of an earlier date more practicable.

Derived Services Network

Trunk Services will soon be bringing forward a new network—the derived services network (DSN)—to meet a specialist market need (see Fig. 4). A number of users such as the mail-order houses, AA, RAC, etc. require services based upon access to specially allocated universal codes which are connected to one or more of the customers' offices; the caller is charged a special rate (for example, freefone or local), with the service provider billed for the actual cost of the call.

Services of this type can be provided by System X exchanges with their capability to examine many digits, but in the present network, with its acute shortage of national



Note 1: Occasional low usage connections can be routed to SPs via the PSTN

FIG. 4—Derived Services Network interface with the public switched telephone network

number groups, such services are not directly practicable. By providing eight derived service switching centres using recovered Strowger switches associated with register-translators (RT14), together with equipment for billing and measurement purposes, we plan to offer the service in early 1985 and to continue to offer it until System X exchanges with the appropriate facilities are able to take over. The DSN thus takes advantage of a niche in the marketplace and depends for its success upon recognition of the opportunity and speedy design and implementation of the solution.

National Private Circuit Digital Network

Our major competitor—Mercury—has made digital private circuits for business customers its number one marketing thrust, but has not had it all its own way. The press has rightly been commenting frequently on the speed and precision of BT's (National Network's) response. Central to this response is the national private circuit digital network (NPCDN), which supports our KiloStream and MegaStream services. NPCDN consists essentially of dedicated digital trunk links provided between cross-connection sites in major towns and shorter links to digital multiplexors in local telephone exchanges. Widespread coverage and high-quality service, including short provision times, were judged to be essential.

The factors that have contributed to the success of the KiloStream and MegaStream services are:

(*a*) an early appreciation that the service would be popular with business customers,

(*b*) the decision that the potential market justified the pre-provision of main links and cross-connection points,

(*c*) major revision of the priorities given to the provision of digital links for NPCDN compared with other uses,

(*d*) ruthless pressure on suppliers (to which they responded very well),

(*e*) a major marketing and selling effort, and

(*f*) correct pricing.

The going has not been entirely smooth. We have encountered problems in service, particularly those caused by short breaks in transmission, and short error bursts. We are still urgently investigating complaints, but the causes so far identified are:

(*a*) faulty components on high-level data links,

(*b*) unsoldered joints on frames and in customers' premises, and

(*c*) working-party faults.

What sorts out the good and successful from the indifferent suppliers is not so much the problems encountered, but the speed and determination with which they are solved. We intend to be a successful competitor.

CONCLUSION

In this lecture I have set out the reasons for forming National Networks as a separate unit within BT, described our organisation and, by some limited examples, tried to illustrate the different ways we are reacting to market forces. We have made mistakes and doubtless will do so again, but as perceived by the customer there can be no doubt that we have made a good start on the right road. It is important to remember that our past market share of 100% means that in a competitive environment we must lose some jobs that we have regarded as ours by right, but the market is an expanding one and may be further stimulated by competition. It is firmly our intention to be a major force in the new markets opening up to us as we already are in the existing areas.

Biography

Ronald Back joined the BPO in 1942 as a Youth-in-Training. After working on various aspects of microwave radio systems and the provision of satellite earth stations at Goonhilly, he was appointed Deputy Director in Network Planning responsible for transmission planning and submarine cable systems. In 1975 he moved into the Service Department, and in 1979 became Senior Director responsible for Networks. This was followed in 1982 by appointment as Assistant Managing Director, and in September 1983 as Managing Director, National Networks. In November 1983 he was appointed to the Board of BT. Mr Back is also President of the Institution of British Telecommunications Engineers.

Broadband Cable Systems

W. G. SIMPSON, B.SC., C.ENG., M.I.E.E.†

UDC 621.315.2 : 621.397.743 : 621.396.74

A change in the political climate has cleared the way for cable TV systems to become broadband integrated communications networks capable of providing a wide range of services in the future. This article reviews the past role of British Telecom (then part of the Post Office) in the provision of radio and television relay systems, and describes the developments by British Telecom of cable systems to exploit the new business opportunities.

INTRODUCTION

British Telecom (BT) has long been aware of the opportunity its ubiquitous network affords for the provision of services other than telephony. The first initiative to exploit the network for other services was taken just prior to the outbreak of the Second World War. At that time, radio relay networks were common in towns and cities. They usually provided a few programmes over *ad hoc* networks, by using separate pairs of wires for each. Customers were connected to the network in parallel and the only apparatus required was a loudspeaker and a selector switch. At a time when radio receivers required long aerials and were battery powered, this arrangement was attractive and, since the service was also inexpensive, it was popular. The Post Office, as BT then was, planned to provide a similar service by transmitting radio programmes at carrier frequencies over the telephone network, thus eliminating the need for a separate network of cables. To this end, a Local Lines and Wire Broadcasting Branch was set up within the Engineer-in-Chief's Office to develop a suitable system. In the event, the development was overtaken by the war and, when this ended, the commercial climate had completely changed. Radio receivers were more sensitive (reducing the aerial requirement), were increasingly mains powered, and were relatively less expensive. As a consequence, the attractions of radio relay services were much reduced. A few existing systems lingered on for some years, but no new ones were provided and the Post Office did not resume the development.

TELEVISION RELAY

The next opportunity for exploiting local networks for services other than telephony occurred with the introduction of television relay systems. The prime reason for the development of these was the problem of low off-air signal strengths in some places. The relay systems overcame this by the erection of large aerial arrays on masts located in favourable positions. The common aerial and cable network merely replaced the individual aerials, hence the mnemonic *CATV* (common (or communal) aerial television). Apart from the signal strength argument, CATV was not very attractive in the UK because, for many systems, normal receivers had to be used. The cost of the cable system had, therefore, to be compared with that of an aerial. The elimination of large numbers of unsightly aerials was an unquantifiable benefit, but it did not influence individual customers unduly. The major advantage of CATV—the ability to provide programmes which were not available off-air---could not be exploited in the UK because of the licensing conditions. Television relay systems prospered in the UK in the 1950s, but as signal strengths were improved in black spots by the use of small fill-in transmitters, the number of customers declined and CATV ceased to be a profitable field for investment.

THE WIRED-CITY CONCEPT

Elsewhere in the world, there were no constraints on the programmes that cable systems could carry. Also, in some places, there were opportunities for increasing the number of programmes distributed by the reception of distant stations. Because of these advantages, CATV grew rapidly and prospered, particularly in North America. In the 1960s, the spread of cable networks prompted futurists to coin the term *the wired city*. They envisaged the development of comprehensive networks, with cables carrying many services other than entertainment television. The implications for the providers of telephone services were obvious—they had to become involved in the television relay business to protect their vital interests. BT, therefore, decided it would compete with the established relay companies in the provision of cable systems, even though at the time it appeared commercially unrewarding in the UK.

THE NEW TOWN EXPERIENCE

BT realised that the only advantage of CATV in the UK was the elimination of unsightly aerials. It concentrated its attention, therefore, on the new towns which were springing up throughout the country. The authorities responsible for these urban developments set considerable store on environmental considerations and usually forbade the erection of outdoor aerials, so providing a fertile field for cable systems. A particular advantage for BT in concentrating on new towns was that it had to provide telephone networks anyway, and the costs of cable installation could, therefore, be shared between the telephone and the television cables.

In open competition, BT was selected to provide broadband cable systems in a number of new towns, starting with Washington, in County Durham, in 1966. Other new towns in which BT now provides systems are Irvine, in Scotland, and Brackla, in Wales, together with the new city of Milton Keynes, in England. Isolated systems have also been provided in new housing estates in some other locations.

Because the ban on outdoor aerials applied only in the new towns, and in the absence of any other incentive for customers to pay for a cable service, the growth of CATV in the UK as a whole fell to a low level during the 1970s. But for the changes in the legislative climate described later, the relay systems would probably have followed the radio systems into eventual extinction. BT's systems have, however, continued to grow in step with the building programmes in the new towns. Although still only a relatively small provider of systems, BT has been responsible for most of the

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† Director, Local Line Services, British Telecom Local Communications Services

limited new provision in recent years.

The broadband cable system provided in Washington initially was a conventional VHF coaxial cable system and has been described in previous issues of the *Journal*. The broadband cables were installed in the same ducts as the telephone cables and made as much use as possible of common joint boxes, equipment housings and lead-ins. In the late-1960s, however, all such VHF systems were made virtually obsolescent by the change from the 405-line picture standard to 625 lines, accompanied by a change to the UHF frequency band for off-air transmission. These changes could have readily been accommodated by BT's broadband cable systems by down converting the UHF channels to spare VHF channels at the head-end of the system. This solution was thwarted by the TV receiver manufacturers changing over to UHF-only sets after a brief period in which they manufactured dual-standard VHF/UHF sets. The only way UHF-only sets could be accommodated on a VHF system and be acceptable was when a small minority of sets were UHF-only, but it was clearly unsatisfactory if all sets were of this type, which would ultimately be the case. BT's response was to develop what has now become a classic ***hybrid*** solution (see Fig. 1). In this hybrid system, signals continue to be transmitted at VHF frequencies over the major part of the network, but are up-converted near the customer's premises and the final distribution is at UHF frequencies, compatible with the receivers. The advantage of the hybrid system was that it avoided the very high losses that would have been the penalty for transmission at the UHF frequencies over the whole route from the head-end to the customer.

The hybrid system has been described in previous issues of the *Journal*[1]. It was first installed in the new city of Milton Keynes, but the systems in the other new towns have now been converted to the hybrid type.

An inconvenience posed by the change of line standard was the necessity for relay systems to transmit both old and new standards until such time as there were no more 405-line recievers in service.

The experience gained from the new town broadband networks, particularly with the hybrid system, has proved invaluable in the design of the systems for the future which are described later. It has given confidence in the location of complicated translation equipment in the network in telephone-style cabinets. It has also emphasised the need for the utmost flexibility so that changes, such as that in line standards, can be accommodated. Inevitably, further changes will occur in the future; indeed, some are already casting their shadows.

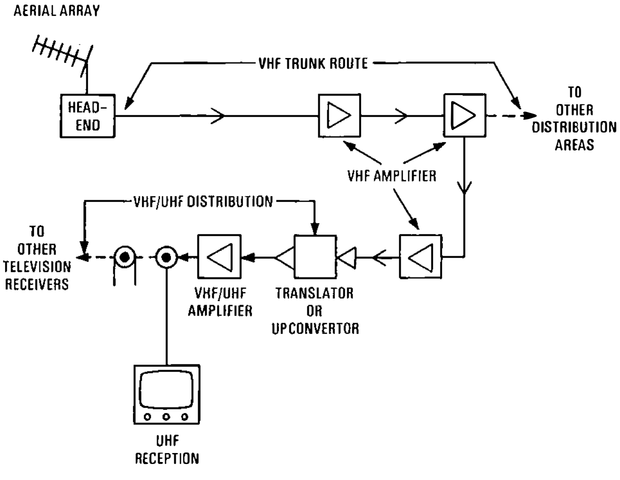


FIG. 1—Hybrid UHF/VHF cable system

CHANGE IN THE POLITICAL CLIMATE

It has been seen that the growth of CATV in the UK has been inhibited by the constraint that systems could provide only programmes that were receivable off-air. In 1981, however, the Information Technology Advisory Panel (ITAP) was appointed to advise the Government on matters relating to Information Technology. In February 1982, the ITAP reported that there were powerful economic and industrial arguments for encouraging the growth of cable systems in the UK, but expressed the view that the necessary finance for this would not be forthcoming until there was a change in Government policy that would enable cable systems to offer a wide variety of programmes and services. The Government response to the ITAP report was to establish an inquiry under the chairmanship of Lord Hunt to:

> 'take as its frame of reference the Governments wish to secure the benefits for the United Kingdom which cable technology can offer and its willingness to consider an expansion of cable systems which would permit cable to carry a wider range of entertainment and other services ...'

The report of this inquiry was presented to the Government in October 1982. It was generally favourable to removing the constraints on cable systems and concluded that:

> 'they and public service broadcasting could co-exist without unneccessary inhibition on the development of the former and without damage to the essentials of the latter'.

After the receipt of the two reports mentioned above, the Government published a White Paper in April 1983 setting out its proposals for the future of cable systems in the UK. For the immediate future, it proposed to invite applications for the installation and operation of cable systems each serving up to 100 000 homes. It proposed to issue pilot licenses for 10 to 12 systems that appeared likely to offer the most positive contribution to the application of advanced technology and which would provide both a comprehensive range of programme services and the capability for interactive services.

Among the services it anticipated would be within the capability of the new systems were:

(*a*) about 30 video channels, some of which would be suitable for direct broadcasting satellite (DBS) programmes,
(*b*) audio channels,
(*c*) at least one return video channel, and
(*d*) two-way data channels, some of which would have a signalling rate of 80 kbit/s.

The White Paper did not prescribe any particular type of system or technology, but it made it mandatory for all underground ducts to be laid in star configuration to facilitate the future provision of switched-star systems.

Subsequent to approval of the White Paper by Parliament, 37 applications were received for licenses to provide and operate new cable systems. BT was associated with the consortia making 11 of these applications. In the event 5 of the 11 applications were successful. BT will be providing the cable networks and systems in Aberdeen, Belfast, Coventry, Liverpool, and Westminster. In three of these areas, it will provide advanced switched-star systems. In the other areas, radial VHF systems suitable for upgrading to switched systems will be provided. The reasoning behind the design of these systems is discussed in the following paragraphs, and the two systems are briefly described.

TOPOLOGIES FOR THE SYSTEMS OF THE FUTURE

All CATV systems have to meet a basic requirement. They must be capable of connecting a customer's TV set to one of a number of centrally distributed programme channels. This means that a selector switch controlled by the customer must be interposed between the customer's set and the system centre. Within this constraint, system designers are

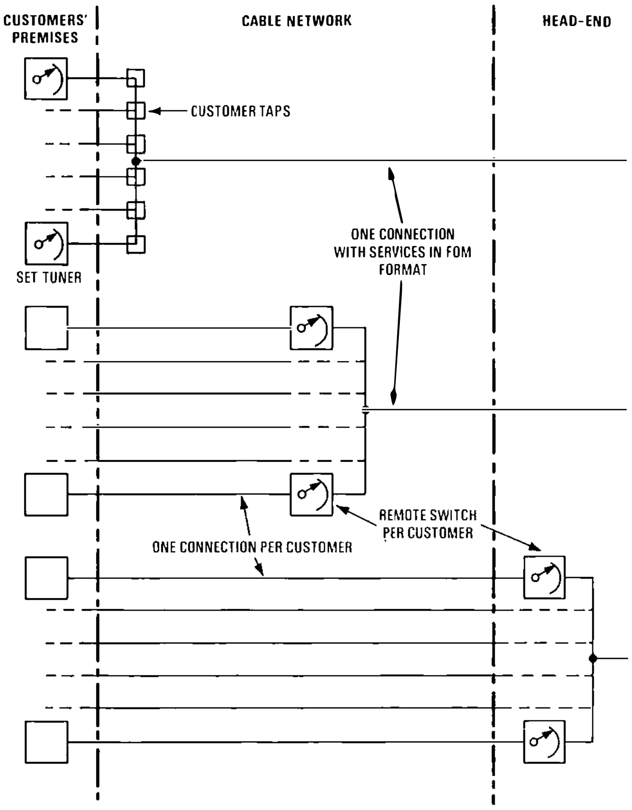


FIG. 2—Alternative switch positions

free to position the switch point where they wish. (The control for the switch must, however, be within reach of the customer.) Fig. 2 illustrates various locations for the switch.

At one extreme, the switch point may be in the customer's home. Normal off-air reception is in this category. For this, the switch is the tuner that normally forms part of the TV set. It selects one of many programme channels received by the aerial. Conventional CATV systems are also in this category. In coaxial cable systems, the switch may be the set tuner or an additional set-top converter; in multi-pair systems, it is a space switch.

At the other extreme, the switch may be at the centre of the system, in a similar position to the exchange in a local telephone network. Individual connections then have to be provided for each customer to the system centre. The German Bundespost's experimental BIGFON[2] system is of this type, the customer's connections being made with optical fibres.

Between these two extremes, the switch point may be anywhere in the network between customers and the centre. In telephone network terms, it could be at a distribution point (DP), at a pillar or at a cabinet.

Various factors affect the choice of the position of the switch.

(*a*) Individual customer connections are required between the customers and the switch when the switch point is not in the customer's home.

(*b*) Switches located in the network require housings and some common equipment. The nearer the switches are to the customers, the fewer the customers served by each housing and the greater the number of housings required.

(*c*) A control system must be provided between a customer and a switch remote from his home. A customer's switch may be part of his TV set, whereas a remote switch is an additional component to be paid for. (This applies, however, only when the number of channels distributed is within the capacity of the set tuner. For the large numbers of channels to be distributed in the future, this is unlikely to be the case and an additional customer switch will be required.)

(*d*) Services other than simple CATV systems are more readily provided in network-switched systems; these make it possible to provide connections from the centre to individual customers if required.

(*e*) Connection of premium services, such as pay-TV, can be more securely barred to customers who should not receive them when the switch point is in the network, rather than in the customer's home.

For cable systems providing only CATV type services, the dominant factor is the extra cost of the individual customer connections required when the switch is in the network. For this type of service, therefore, customer switching is the most economic solution, even for systems providing large numbers of channels.

In the new climate, however, such systems are not acceptable as a long-term solution. The systems now to be provided are intended to form the foundations of a fully-integrated network which will satisfy the communication needs into the twenty-first century. BT believes that the future lies with network switched systems and that only these, or cable networks that can readily be converted to network-switched systems, should be provided from now on. The question is, therefore, where should the network switch be positioned, not whether there should be one.

The basic trade-off is between the costs of individual customer connections and the shared cost of common equipment at the switch point. Typical results are indicated by Fig. 3. This has been drawn using current costs for cables and equipment, and for a normal urban customer density. Only costs which vary with the numbers of customers served by one switch point have been taken into account. The curves of Fig. 3 show that the lowest cost per customer served results when switch points serve between 150–300 customers. The corresponding average connection length is between 100–200 m. Centre switching, which could involve many thousands of individual customer connections of an average length of the order of 2 km, would be prohibitively expensive at current plant costs. In the longer-term future, however, the costs of opto-electronic devices and optical fibres may fall sufficiently for this option to be reconsidered. BT's switched-star cable system, which is described later, is based on switch points serving up to 300 customers. It is believed to be the most cost-effective system for providing the full range of cable services envisaged for the future.

BT appreciates, however, that a lower-cost customer-switched system will satisfy the immediate, largely CATV, needs of customers. The acceptance of cable systems will undoubtedly be very price sensitive initially. The introduction of systems capable of providing the full range of services,

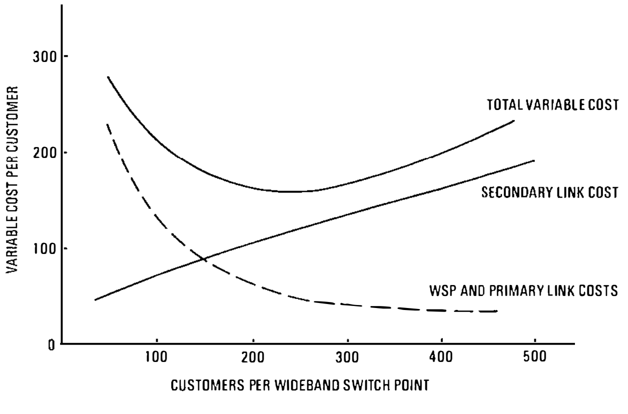


FIG. 3—Switch point size-optimisation curves

for some of which there is little demand at present, could well be counter-productive in that it could inhibit initial growth and discourage investment. BT has considered it commercially expedient, therefore, to develop the alternative customer-switched VHF system described in a later paragraph. BT remains convinced that all cable systems must ultimately be of the network-switched type, and the cable plan of its customer-switched system will facilitate the introduction of network switching in the future. To this end, the final distribution to customers is radial; that is, individual customers connections are connected to the equivalent of a telephone DP instead of being branched from a frontage cable as is the normal practice with customer-switched CATV systems. To minimise the cost penalty of this, the radial distribution centres, which are embryo switching points, serve up to only 20 customers each. This is less than the optimum for network-switched systems at present. In the future, however, it is expected that the balance of advantages will favour smaller switches.

TECHNICAL OPTIONS

There are two basic technologies involved in cable systems: transmission and switching. The options on transmission can in turn be considered under the headings of media and modulation methods.

Transmission Media

The choice lies between coaxial cables and optical-fibre cables (excluding microwaves, which may have a role in some applications). Coaxial cables have less bandwidth than optical fibres, but this is compensated for by the availability of efficient and cost-effective frequency-division multiplexing (FDM) techniques for exploiting the bandwidth they have. At the high frequencies that must be used to provide the 30 or more video channels required by future cable systems, however, coaxial cables require line amplifiers to be spaced relatively close together. By comparison, optical fibres have the significant advantages of small size and low attenuation, avoiding the need for line amplifiers. Unfortunately, the linearity of present optical devices limits the number of video channels that can be provided per fibre. A further disadvantage is that the devices are relatively costly.

The modular topology of BT's network-switched cable system allows the media for each part to be chosen separately, taking into account the relative strengths and weaknesses of the alternatives. For the customer-to-switch-point connection, the bandwidth requirement is modest and well within the capacity of coaxial cables without amplification. If optical fibres are used, optical transmitters and receivers have to be provided on a customer basis and the high cost of these makes this alternative uneconomic. For switch points serving larger numbers of customers (for example, for centre switching), the small size of optical fibres would be an overwhelming advantage, but overall economics rule out this possibility at present.

In the links between the switch points and the network centre, matters are much more evenly balanced. On the one hand, coaxial cable systems with sufficient capacity are fully developed, with all the necessary amplifiers, splitters etc. readily available. On the other hand, in this part of the network, cables are taking up valuable duct space in already congested routes; this gives optical fibres a significant advantage. The limited number of channels it is possible to provide per fibre is of lesser importance because links to the switch point will be provided in pace with the demand for the non-CATV services. It will be possible, therefore, to meet growth in the future by applying advanced technology to exploit the fibres more fully, and thus avoid the need for new fibres. When the prospects for the future are reviewed, it is considered that the best medium for the switch-point-to-centre links in a switched network is optical fibre.

Modulation Methods

Bandwidth considerations, and the use of amplitude modulation (AM) for both the off-air signals and in receivers, makes frequency-division multiplexing (FDM) the most attractive option. An exception to this is that it is convenient to provide frequency modulation (FM) VHF radio channels throughout the network in their off-air form and frequency. The use of digital time-division multiplexing (TDM) would be prodigal of bandwidth and could be contemplated only in a wholly optical-fibre network. At present, the high cost of analogue-to-digital (A/D) and digital-to-analogue (D/A) converters for use at the high frequencies involved is also an inhibiting factor.

Switching Methods

The choice is between:

Frequency Switches

Frequency switches select a required signal from a number of signals presented in FDM form on a single input connection. The switches use electrical tuning techniques and may take the form of a continuously-variable tuned circuit or a number of pre-tuned circuits. This can involve frequency convertion to an intermediate frequency or to baseband. The most common example of a frequency switch is the tuner that forms part of TV receivers. An element of frequency selection must be used when a number of input signals are received in FDM over a single path. Frequency switches are, therefore, the obvious choice for customer switching (for set-top converters as well as the in-set tuner) and may feature in switches in the network.

Space Switches

Space switches establish exclusive paths between input and output; for example, between a customer's connection and a link to the system centre. The switches may have mechanical contacts or may use solid-state techniques, and they can take the form of crosspoint matrices. Links can be multipled over several inputs so that a number of customers can gain access simultaneously to the same link. Space switches are transparent; that is, the input and output signals take the same form. In the present state-of-the-art, space switches using solid-state techniques in crosspoint matrices appear the most promising devices for within-network switching.

Time-Division Switches

Time-division switches require inputs and outputs to be in digital form. If they are inserted in analogue networks they must be preceded and followed by A/D and D/A converters, respectively. Their use is, therefore, likely to be economic only in largely digital networks.

Optical Switches

It is possible to envisage switches through which the signals remain in the form of light. In the long term such switches may become attractive for use in wholly fibre networks, but they do not, as yet, exist in a commercially viable form.

BRITISH TELECOM'S SWITCHED-STAR SYSTEM

General Outline

The general arrangement of the system, which has been described in a previous issue of the *Journal*[3], is illustrated in Fig. 4. It is network switched at switch points having capacities of up to 300 customers. The head-end-to-switch-point links (the super-primary and primary networks) are provided by optical-fibre cables, each fibre carrying four video channels or the equivalent in other services. No amplification is needed in these links. The switch-point-to-customer connections (the secondary network) are provided

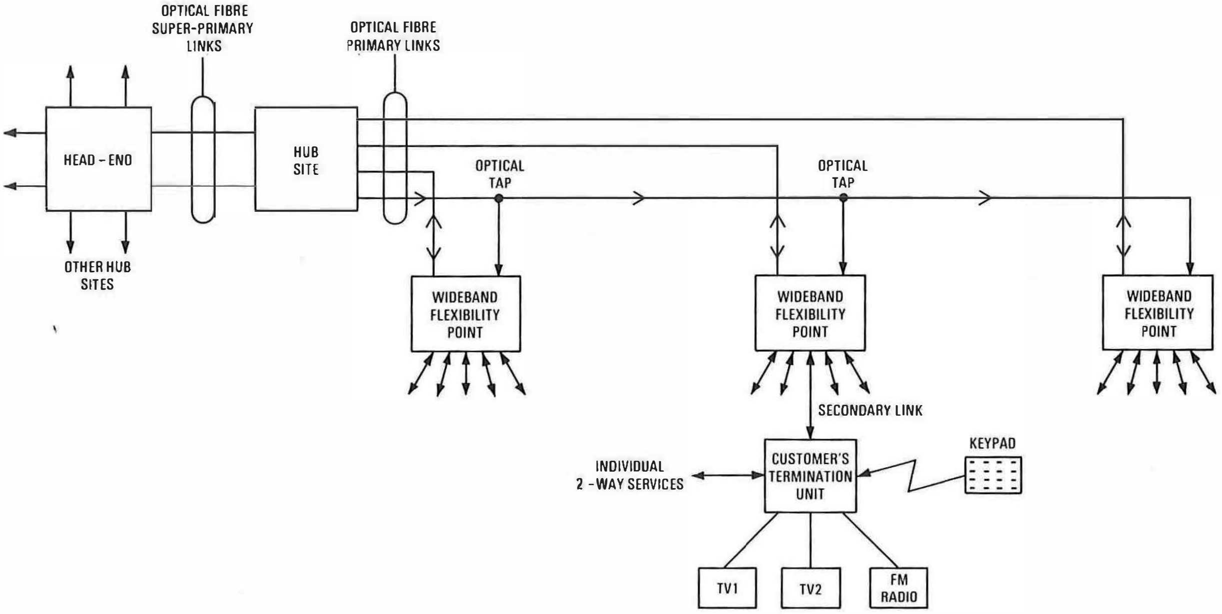


FIG. 4—Switched-star network topology

at present by micro coaxial cables. A single coaxial pair carries all the services required by one customer in FDM form. The customer equipment consists of a small hand-held keypad with an infra-red link to a set-top unit. The two downstream video channels carried by the cable are connected to standard UHF receivers, or to a videocassette recorder (VCR), by selecting the appropriate channels on the receivers or VCR. The set-top unit contains the frequency converter to raise the network channels into the UHF band and controls the remote switch by using the data capacity of the link. As well as the video channels, the secondary link also carries FM radio transmissions at off-air frequencies and format so that standard receivers can be connected directly to the system.

Physical Features

The system matches, wherever possible, the features of the telephone network it parallels, and uses the same cable routes, ducts and jointing chambers, where space is available. The head-end is normally a telephone exchange. The small size of multi-fibre cables of the primary links avoids congesting the ducts near the exchange. The switch points are housed in street cabinets similar to those used in the telephone network, but are more numerous. The secondary connections are provided by using multi-coaxial pair cables in the range 5, 10, 20 and 30 pairs. The diameter of the 30 pair cable is 35 mm. Final distribution to customers follow the telephone practice for the locality served. Where this distribution is overhead, both the telephone and the cable-system connections are made with a single composite drop-wire. Where underground connections are provided, the cables are placed in 50 mm ducts.

The Remote Switch

The arrangement of the equipment at a switch point is illustrated in Fig. 5. The design of the switch is crucial to the whole concept. The basic module is a 32 × 64 crosspoint space switch. The contacts are solid-state FET devices. Switching is carried out at video baseband frequency; this provides a convenient interface that allows maximum flexibility between the different parts of the system. Each customer requires two outputs, and the basic module serves 30 customers from its 64 outputs. Modules are provided in stages to match the growth in the number of customers. About half of the 32 switch inputs are multipled between switches and are connected to primary links for the distribution of broadcast services. Others are connected to dedicated primary links. The remainder are connected to two secondary switches which give access to other services, such as Prestel adapters and videotex display generators. The customer switch outputs include frequency changers to raise the video signal to the frequency required for the customer links. They also include the launch amplifiers. Each switch module is associated with a microprocessor that scans the secondary links for information sent from the customers' units. This processor is able to operate the video crosspoints, and can switch those channels which make up the basic service without reference to other processors.

As well as the microprocessor in the customers' switch modules, there is a larger processor at each switch point. This keeps track of everything the switch-module processors do and interfaces with the head-end computers. The switch-point processor holds customer class-of-service data and

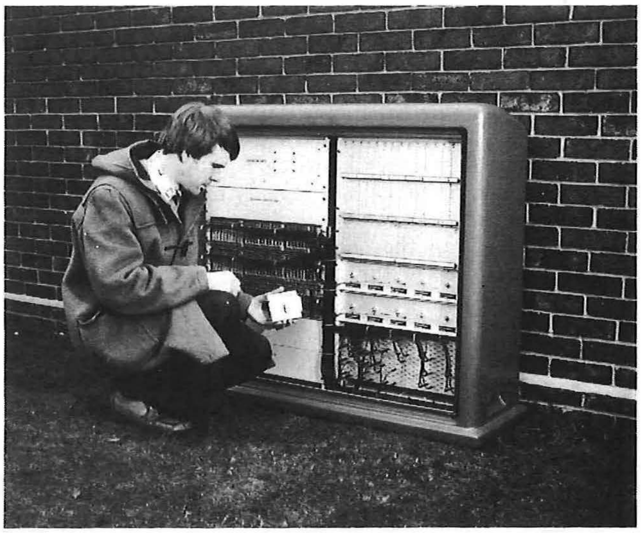


FIG. 5—Wideband switch point

controls their access to other than the basic services.

Return video paths can be provided from any customer by hard wiring within the switch point. The only limitation on the number provided at a switch point is the availability of free secondary links to the centre, and these can be provided in response to customer demand.

Primary Links

Four FM video channels are multiplexed over each fibre. The optical transmitters use broad-spectrum laser sources. The fibres carrying the broadcast services serve up to three switch points in a branching arrangement by using optical splitters.

Facilities

The basic capacity of the system is as follows.

(*a*) Up to 30 video channels are provided to each switch point from the head-end, of which any two can be switched simultaneously to any customer. Some of the channels are suitable for DBS services. Switching is under the control of the customer, but selection of any channel can be barred to a customer depending upon the class of service to which he is entitled. Within the switch point, channels can be switched to local video sources.

(*b*) An upstream video channel can be provided from any customer, which may be hard wired to a primary link. The primary links can be reinforced, if necessary, to provide a number of upstream paths. Local video connections can also be established if required.

(*c*) The off-air frequency spectrum between 88 MHz and 108 MHz, covering the nationally broadcast FM radio channels, is provided.

(*d*) Low data rate services are provided to the head-end for all customers.

The system has been designed to provide great flexibility, and the uses to which the facilities are put can be varied in accordance with circumstances.

Services

The system operator, and through him the customer, decides the uses to which the above facilities are put. Among the possibilities are:

(*a*) off-air TV, including imported programmes and DBS channels,
(*b*) subscription TV,
(*c*) pay-per-view,
(*d*) video library services,
(*e*) interactive videotex, a service similar to Prestel,
(*f*) photovideotex, and
(*g*) low-speed telemetry including alarms.

Management Facilities

The widespread use of microprocessors in the system, linked together by data links of ample capacity, provides a powerful tool for system management. Among the facilities provided are:

(*a*) for the customer, detailed billing;

(*b*) for the programme provider, revenue information, voting results and viewing statistics;

(*c*) for the system operator, remote connect/disconnect facility, generation of bills, statistics on viewing by service, fault monitoring; and

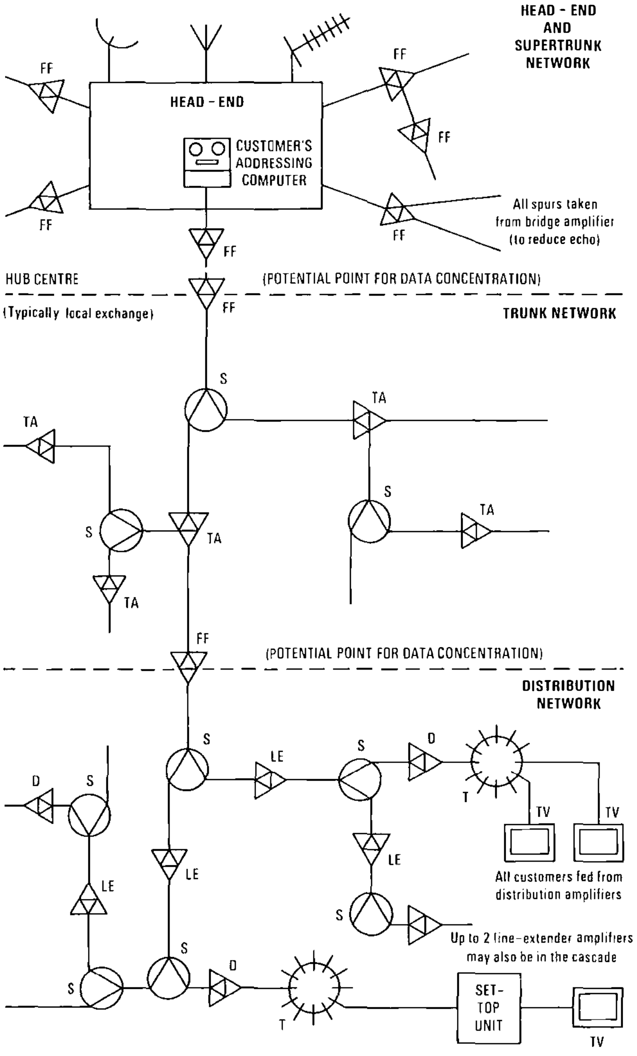
(*d*) for the cable network provider, transmission system statistics on error rates and faults and system computer performance statistics.

BRITISH TELECOM'S VHF COAXIAL CABLE SYSTEM

General outline

The system is basically a customer-switched system with the customers connected to a VHF highway from the head-end by a tree-and-branch coaxial cable network. It differs from conventional CATV systems, however, in that the final distribution to customers is made by individual radial connections to distribution points. The distribution points are the potential switching points for a network-switched system. To facilitate further future enhancement to a network-switched system, the cable network is structured to provide clear interfaces at which data can be collected and processed, and at which transmission capacity can be readily augmented to cater for development.

The topology of the network is illustrated in Fig. 6. The hub centre is normally at a telephone exchange, but more than one may be located at the same exchange. The head-end may be located at one of the exchanges covered by the system or may be at a separate site.



D : Distribution amplifier
FF : Feed-forward amplifier
LE : Line-extender amplifier
S : Splitter
T : Distribution point (potential point for network switch)
TA : Trunk amplifier
TV : Customers' television

FIG. 6—VHF coaxial cable system topology

Transmission throughout the cable network is at VHF frequencies. Each customer is provided with a set-top switch unit, which is controlled by a hand-held infra-red unit. The switch is a frequency tuner that selects the required VHF channel and up-converts it to a pre-determined UHF channel to which the TV receiver has to be tuned. In addition, another frequency converter in the set-top unit block converts four VHF channels to four channels in the UHF band. These can be accessed directly by using the within-set tuner and by the tuner in a VCR. The direct access channels are spaced at double the normal spacing to allow for the lack of discrimination in normal set tuners.

Physical Features

As for the switched-star system, the VHF coaxial cable system makes the maximum use possible of existing telephone plant, such as ducts. Again, the final distribution to customers homes matches that of the telephone network. The cable network will make use of hardware developed for, and proved in, the telephone network, such as the range of reopenable cap-ended joints.

Frequency Allocations in the VHF Highway

The main frequency allocations are shown in Fig. 7. Apart from the band allocations shown in Fig. 7, there are numerous spot frequency allocations for system administration and control purposes. The return-path capability is provided by bypassing each downstream amplifier. The bypass may itself be amplified for transmission in the upstream direction.

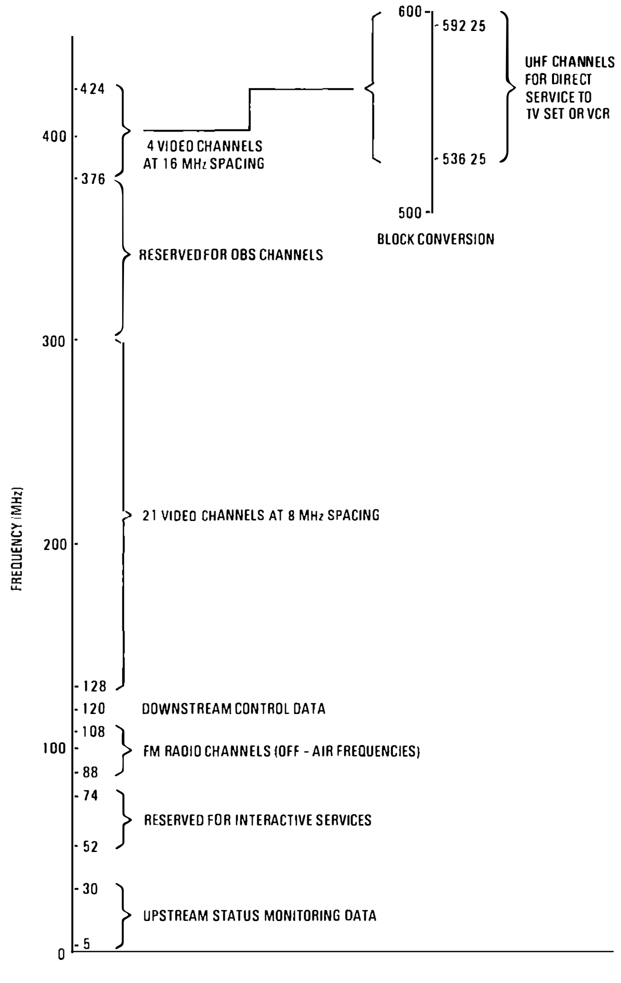


FIG. 7—Frequency allocation of VHF coaxial cable system

Interactive Services

For interactive services, an exclusive bothway data connection must be established between each customer and the head-end. In VHF coaxial cable systems, this is done by using both downstream and upstream paths of the VHF highway in a TDM system. Each customer's set-top unit has a unique address code to which it can respond. The head-end is able to poll every address code cyclically, passing data to and receiving data from each customer in turn. Typically, a customer's set-top unit would be interrogated every 20 s. The information sent may be *enabling* instructions required for the subscription television service described later. The information returned can be alarm signals, voting decisions, audience monitoring and simple home shopping.

Premium Services

Although it is not so flexible as the switched-star system, the VHF coaxial cable system does allow the provision of subscription-TV channels. These are transmitted over channels in the normal VHF spectrum, but are barred to non-subscribing customers by one of two methods:

(*a*) a frequency trap may be provided in the customers' service lead to reject the subscription channels, or

(*b*) the signal may be transmitted in an encrypted form that can be decoded only by the set-top units of subscribing customers.

Pay-as-you-view TV is also possible. For this, the set-top units of customers receiving such a channel signals the fact, via the return data path, when it is polled by the head-end. The data is then processed at the head-end and the appropriate bill generated.

The use of decoding set-top units allows the censoring of subscription and pay channels. Information on programme category rating, similar to the ratings used for films, is transmitted to the customer's unit from the head-end during the polling cycle. This makes the reception of the channels subject to control by a 'parental lock'.

Future Enhancements

One of the major difficulties in the efficient utilisation of bandwidth for interactive services on traditionally-configured tree-and-branch networks is the effect of separate noise sources being added together at the head-end. In effect, each terminal transmitting upstream has to compete with the amplified interference from all the other equipment in the network. The structured architecture adopted for BT's VHF coaxial cable system allows the return path to be interrupted at defined signal level points and so permits cheaper and more effective interactive products to be employed. Therefore, rather than providing each customer with a high-performance modem, the equipment needs to work only to a local concentration and processing point where return-channel concentrators gather together the signals for onward transmission to the head-end.

The service facilities that may be offered include software downloading for personal computing, videotex, home shopping and home banking. The primary concentration and processing point will be at a network switch, serving about 20 customers and, as indicated earlier, located at the final distribution point.

SYSTEM STANDARDS, INTERFERENCE, IMMUNITY AND SAFETY

Both the systems described above have been designed to conform to British and International standards for transmission, where they exist.

Particular care is being taken in the cabling into and within customers' homes to ensure that noise pick-up does not exceed the BSI standard. In the VHF coaxial cable system, two pilot frequencies are available to detect and locate leaks. The optical-fibre links in the switched-star system are inherently free from radiation and pick-up.

The cable networks are adequately protected against mains contacts from customers' faulty receivers. Protection is given in the switched-star system by an isolating transformer and capacitors, and by isolating capacitors in the VHF coaxial cable system.

CONCLUSIONS

It is the customer who will eventually determine the future of cable systems, whether they whither and die as radio and television relay systems did in the past, or expand and prosper to become the basis of a ubiquitous integrated network providing all the communication needs of the future. The customer's response can be influenced by

(*a*) making systems as cost effective as possible, particularly in the early years, so that high penetrations are achieved and the costs spread over as many customers as possible, and

(*b*) increasing the attractiveness of the systems by making a wide range of services available to meet the expanding needs of customers.

In developing its switched-star and VHF coaxial cable systems, BT has made a significant step towards the ultimate success of cable systems, an integrated communications network of the future.

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[3] Ritchie, W. K. Multi-Service Cable-Television Distribution Systems. *Br. Telecommun. Eng.*, Jan. 1983, **1**, p. 205.

Biography

Geoff Simpson has held a variety of posts since joining the British Post Office (BPO) in 1941 as a Youth-in-Training. As an Assistant Engineer in 1949 he worked on the development of carrier and coaxial line systems. When he became a Senior Executive Engineer in 1959, he joined the Research Department at Dollis Hill and worked on 3 kHz channelling equipment for submarine cables, and carrier systems for deloaded audio cables. He has been a BPO delegate to CEPT, CCITT and CCIR and is Vice Chairman of CMTT, the joint CCITT/CCIR study group on long-distance television and sound programme transmission. He has been Deputy Director of Network Planning Department and Director of Transmission Department; he is currently Director of Local Lines Services.

Book Reviews

Noise (second edition). F. R. Connor. Edward Arnold Ltd. viii+135pp. 78 ills. £4·50.

Modulation (second edition). F. R. Connor. Edward Arnold Ltd. viii+133pp. 87 ills. £4·50.

Signals (second edition). F. R. Connor. Edward Arnold Ltd. viii+126pp. 89 ills. £4·50.

These three volumes, dealing separately with noise, modulation and signals, are new editions of books first published in 1972. Each has been revised and extended by the increased use of appendices.

The volume on noise begins with a survey of the various types of electrical noise found in communication systems, and this is followed by a description of some of the mathematical ideas concerning random variables. Circuit noise, noise factor, and noise temperature are considered in the chapters which follow, and the book ends with a comparative study of some important communication systems. The volume on modulation has the first part of the book devoted mainly to analogue methods employed in present-day systems, such as amplitude modulation and frequency modulation. Some consideration is then given to phase modulation and the various types of pulse modulation in current use, such as pulse-code modulation. The book ends with a chapter devoted to the alternative problem of demodulation at the receiver, and the treatment covers the important methods used at present. The volume on signals has the early chapters devoted to an analysis of the various types of signals and a study of their particular characteristics. Subsequent chapters deal with the transmission of signals and the signal techniques employed in various applications. The book ends with an introduction to the important subject of information theory, which deals with the general problem of the transmission of information in any communication system.

These books are aimed at students studying degree-level courses and practising engineers who wish to obtain a basic understanding of the subjects; and this is reflected in the level of mathematics used, and the depth of treatment of the subjects.

The worked examples, which are a feature of these books, are carefully selected to clarify and extend the main text and should be particularly valuable to students preparing for examinations. They also illustrate the wide range of practical situations to which the basic concepts can be applied. On the other hand, the concise presentation and slimness of the volumes make them suitable for the engineer who wishes to obtain an appreciation of a subject quickly. The numerous appendices help in this respect by keeping the main text clear while providing the detail for the reader who wishes to pursue a subject; the listed references will also aid further study.

Although a great deal of material has been covered by each book, the overall balance between text, mathematics and illustrations makes them easy to digest, either as a whole or in individual chapters; and all of these books should be of value to their intended readers.

J. M. Alexander

Electronic Mail: The Communications Medium for the 1980s

J. MORRIS, B.SC., M.SC.†

UDC 621.397.12 : 681.327.1

This article, the first of two, generally introduces the subject of electronic mail, outlines its strategic importance to telecommunications administrations, and discusses likely developments for the future. The second article, to be published in a later issue of this Journal, will concentrate on the technical aspects and the facilities provided by the Telecom Gold service.

INTRODUCTION

The intriguing statement—the end of written communications as you know it today—was featured in a recent advertising campaign to promote British Telecom's (BT's) electronic-mail service and Telecom Gold, a new company set up by BT to market a comprehensive range of automated office services.

But the statement reflects much more than just another promotional campaign: it captures the new era for BT brought about by the advent of competition, by the reshaping of its organisation, and by the emergence of new strategic markets.

The 1980s heralded a new era in communications, both in the UK and worldwide—an era that is modernising the ways in which people communicate and function at work, and in business generally. In a nutshell, it is the era of electronic mail.

Although the 1980s may be the era of electronic mail, the concept itself has been well known and has functioned in numerous forms for years: Telex, facsimile, and message switching are all part of everyday life. However, the convergence of traditional activities—data processing, communications and office services—linked with new technology, has begun to realise the vast potential of the communications and information services.

Electronic mail is now emerging as a key feature in many services, products and systems: message switches with mail facilities; in-house mailbox packages running on mainframes; communicating terminals, local networks and clustered systems; value-added services from traditional bureau suppliers; and major public services such as Teletex and Telecom Gold. Electronic mail in all its forms is being recognised by a cross section of service providers, system suppliers, and PTTs* alike as an integral facility that will enhance their product offerings and provide the basis for communicating and processing information.

AUTOMATED OFFICE AND INFORMATION SERVICES

Entry into the automated office and information services market can be approached from many directions. The strength of a PTT lies mainly in its communicating heritage and it is the skills derived from this heritage that form the primary platform for expansion. This can manifest itself in a whole range of facilities which, in general, can be grouped into two key areas:

(*a*) communicating terminals and more sophisticated in-house systems; and

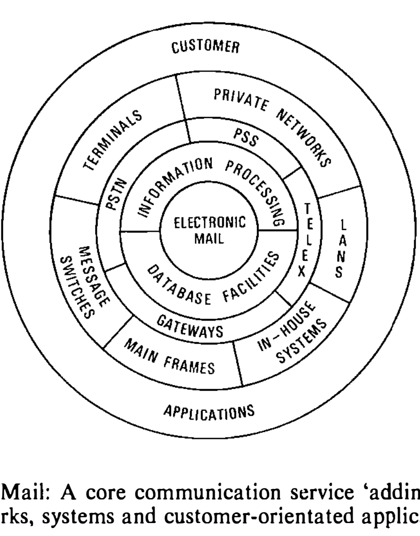
(*b*) centralised communications, gateways and information processing services.

Equally important, it will be the more traditional forms of communications revenue which could well be affected by the impact of such sophisticated communicating office products and systems. Therefore, the need to stimulate growth in network usage through the introduction of new communication and information-based services now has to feature as an integral part of strategic planning in PTTs. Hence, the concept of 'adding value' to the network is one that is crucial to a PTT offering any form of mail service.

ELECTRONIC MAIL

Electronic mail is now recognised as the major facility that will form the keystone of office automation. It will be an integral facility within many product ranges; more importantly, it will provide the 'core' medium for centralised communication and information services. This core will also provide the framework for integrating communications with an extensive range of supporting facilities. Many such facilities are emerging, and cover:

(*a*) electronic filing and retrieval mechanisms,
(*b*) public noticeboards and directories,
(*c*) database management and information processing facilities,
(*d*) gateways to third-party databases,
(*e*) network interconnection, both national and international,



Electronic Mail: A core communication service 'adding value' to networks, systems and customer-orientated applications

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† Managing Director, Telecom Gold
* PTTs—Posts, Telegraphs and Telephone Administrations

(*f*) interconnection with other competitive services, and
(*g*) expanding connectivity through support of a wide range of stand-alone terminals, systems and local networks.

By integrating these facilities in numerous ways for individual markets, a comprehensive range of applications can be accommodated. By combining communications with such applications, the real needs of an organisation or market sector can be addressed.

INTERNATIONAL COMMUNICATIONS

The significance of international communications as an integral part of an electronic-mail application is also emerging with key locations of interest lying on the Far East–Middle East–UK–USA axis. International communications in its traditional form may well take on a new dimension with the growth of integrated applications based on electronic mail. As organisations, or their business functions, become internationally orientated, the range of applications can develop on an international scale. Hence, with the expansion of electronic mail, the concept of the global customer account will emerge.

This new concept may well have far-reaching effects for the PTT organisations in each country. International telecommunications is managed through the various regulatory and control bodies, with each PTT operating within its own geographical domain. The idea of the global account using electronic mail based on interlinked systems spread throughout the world overrides any limitations imposed by geographical boundaries. This could well have major implications for the way in which such services are marketed, operated and developed. Although this concept is not new to the international timesharing business, the emergence of electronic-mail services operated by PTTs adds a further dimension to the concept, one which will have a major impact on global communication.

The products and services now emerging for this market are likely to have relatively short life cycles, with competition linked to continually improving technology, which will force a rapid pace of enhancement. Traditionally, PTT organisations are not geared to develop and sustain this rate of enhancement. To turn around a monopoly organisation takes time; therefore, steps have to be taken to stimulate change and provide footholds in the market place whilst the organisation is reshaped.

TELECOM GOLD

BT has been completely restructured over the past two years. One small but significant part of this reorganisation included the creation of Telecom Gold, a new and independent company, which was set up as a spearhead into the automated office and value-added systems markets.

Telecom Gold offers a comprehensive range of centralised services, with electronic mail (in the form of mailboxes) providing the core service. This core is complemented by electronic filing, public and private noticeboards, forms processing, database management services, and gateways to other BT facilities—Telex, Radiopaging and Telemessage—which combine to bring a broad range of integrated services to the business community.

Interconnection with similar mail services operated by Canada, the USA, Australia, Hong Kong and the Netherlands provides the basis for an interconnected service, which is expanding rapidly as more countries install equivalent systems.

This novel approach to the market is also reflected in the acquisition by BT of the electronic-mail service itself. The major development of electronic mailbox technology has been in North America. A team of independent consultants was engaged to conduct an exhaustive search of this market to find the software package most suitable to the needs of the UK. Specific criteria were: user friendliness; the range of services offered; and the potential for network and product integration. Overall, the package had to be commercially acceptable and proven in the US market.

A customer receives training on the Telecom Gold Service from a Customer Support Executive

Of all the services reviewed, the software package marketed by ITT Dialcom Inc. was chosen by BT as the basis for its premier electronic-mail service in the UK.

Progress since the electronic-mail service and Telecom Gold were launched on 22 March 1982 has been remarkable: financial targets have been achieved and the tremendous growth experienced has confirmed the potential for electronic mail, both on a national and international basis.

FUTURE EXPANSION

The next two years should see a rapid expansion internationally of electronic mail. Interconnection to Radiopaging, Telex, Telemessaging and database management services are likely to be expanded to provide more sophisticated facilities, and the interconnection with Teletex introduced.

Expansion into customers' premises with communications hardware to connect customer systems and networks to this central communication mail gateway is the next logical phase to exploit the concept of integrated communications.

Biography

John Morris has been involved with BT's new Dialcom Electronic Mail since its inception in 1981 during his previous role as Business Development Manager for BT. Aged 37, he has spent 19 years with BT, his first position being that of an Engineering Apprentice. Having gained a B.Sc(Hons.) in Electrical Engineering and awarded an M.Sc. by the Warwick Business School, John Morris moved into management services and in 1974 joined the Central Audit Unit of the Post Office. In 1978 he became personal assistant to the Managing Director of National Girobank. With the splitting of BT from Posts and Girobank in 1980/81, he rejoined BT to work with McKinsey & Co., Management Consultants, on how best to reorganise the business to meet competition.

The Larne–Portpatrick Submarine Cable System: The Use of Recovered Equipment

R. G. GREENFIELD, B.SC., C.ENG., M.I.E.R.E.†

UDC 621.315.28

This article describes the provision of a submarine cable system to carry inland trunk traffic between the UK mainland and Northern Ireland. The project is unusual in that much of the cable used for this link had previously been in service under the North Sea carrying traffic between the UK and the Netherlands.

INTRODUCTION

It is not very often that the gamekeeper gets a chance to turn poacher, but this is exactly what happened during 1983 when members of various groups in British Telecom (BT) found themselves in the role of contractor to BT's National Networks. The project was for the provision of a new submarine telephone cable linking the UK mainland to Northern Ireland, and was required because the Trunk Services Planning Division were concerned about the lack of route diversity. The drawback was that, because of the limited further requirement for analogue equipment and an understandable reluctance to invest large sums of money in such technology at this time, a low-cost system was required. However, because of their inaccessibility when in service, submarine cable systems are required to have high reliability, and the quality required to achieve this is not compatible with low cost. The provision of a system within the budgetary constraints therefore represented quite a challenge. The solution finally proposed by British Telecom International's (BTI's) Submarine Cable and Microwave Division was novel and, although not an entirely unique concept in submarine-cable history, it was certainly a very unusual one. The proposal was to provide the cable system almost entirely from recovered plant and for the recovery, re-installation and testing to be carried out entirely by BT staff.

The system would carry 480 × 4 kHz circuits between the existing submarine cable repeater station at Portpatrick, near Stranraer, to the main network centre at Larne, Co Antrim. The cable would be a single coaxial 0·935 inch diameter (over the dielectric) wire-armoured type, of which roughly 26 nautical miles (NM) would be required to link the landing points. Transmission would be by normal frequency-division multiplexing, the top line frequency of the low-band direction of transmission being 2296 kHz and that of the high-band direction 4776 kHz. Because of the cable loss at these frequencies, three suitable submersible amplifiers, or repeaters, spaced roughly 7·5 NM apart would also be required.

In addition to these items, a total of 2·8 NM of 0·935 inch diameter coaxial land cable, in new dedicated duct, would be needed to link the landing points to the respective repeater stations. Finally, and by no means of the least importance, terminal transmission equipment and repeater power-feeding equipment would be required in the terminal stations themselves.

The project plan was formulated in the early months of 1982; financial authority for the project was granted on 22 April 1982 and a provisional target ready-for-service (RFS) date of 31 May 1983 was agreed upon.

All that remained was to implement the project.

OBTAINING THE PLANT

Sea Cable

The supply of the sea cable was probably the most speculative part of the whole project. As already indicated, some 26 NM of armoured cable was required to link the proposed landing points at Drains Bay (Larne) and Port Mora (Portpatrick). Of this length, something like 2 NM needed to be double-armoured, or double-armoured-and-screened, cable for use in the shallow water immediately adjacent to the beach. This shallow-water section is known as the *shore-end*.

Fortunately, sufficient double-armoured cable existed in BTI's cable depots to enable the longer Scottish shore-end to be constructed (1·350 NM) and the Northern Ireland shore-end to be partially completed. The Netherlands PTT also held a section of shore-end cable of which they wished to dispose, and this was sufficient to complete the second shore-end (0·673 NM).

The remaining section of single-armoured main sea cable had to be found from another source, however, since the depletion of stand-by stocks of main sea cable by such large amounts could not be tolerated, even if enough cable had existed to meet the 24 NM requirement.

The problem was solved by using a submarine cable in the North Sea which, since being put into service in 1968, had been plagued by faults caused by trawler activity. This was the Covehithe–Katwijk B 480-circuit system, which linked the UK and the Netherlands, and which was taken out of service in 1981 when its persistently bad fault record made it uneconomic to maintain in traffic.

Submarine telephone cable, unless exposed to an abnormally harsh environment such as severe tidal scouring or electrolytic corrosion, generally has a very long and useful life, far in excess of the planned system life of 25 years. Indeed, there are instances of nineteenth century telegraph cable being recovered in pristine condition. This is particularly true when cable has a covering of seabed material, which prevents the water flowing over the cable, and which limits the supply of oxygen for the corrosion process as a result. These are just the conditions that are often found in the North Sea, where the action of sand waves can bury cables. It was therefore proposed to obtain the required 24 NM of cable by recovering the Covehithe–Katwijk B system.

This system, which was 103·5 NM in length (between landing points) and which contained 14 submerged repeaters at an average spacing of 7·2 NM, was owned jointly by BTI and the Netherlands PTT; BTI, as a result of agreements reached after the cable was taken out of service, owned the western half to a point between repeaters R7 and R8 and the Netherlands PTT owned the eastern portion. The Covehithe shore-end, which was known to be heavily buried by sand and therefore inaccessible for recovery, was ignored; this meant that there existed an available 47·5 NM of

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† International Lines, British Telecom International

wholly BTI-owned cable from which 24 NM of usable cable needed to be recovered.

It was felt that this would present no problems since there appeared to be twice as much available cable as that required; but in this context the sand waves on the sea bottom become a double-edged sword. Although for cable preservation it is beneficial to have a light covering of sand, if the cable becomes heavily buried, it becomes impossible to pull the cable free without its breaking strain being exceeded. In these circumstances, the cable would part during recovery and the section would be lost. As there is some sand wave movement in certain parts of the southern North Sea, there was no way of knowing which parts of the cable would be sanded-in without prior inspection of the route. One favourable factor, however, was the knowledge that sand waves are more prevalent in the eastern half of the southern North Sea and that this would therefore tend to affect that section of the system belonging to the Netherlands, rather than BTI's section.

Land Cable

The submerged section of a submarine cable system usually terminates in purpose-built manholes constructed above the high-water mark on the beach, or on a sea front or promenade, where this is available. This manhole provides facilities for cable anchorage and jointing, and permits the sea cable and land section to be installed separately. In a few cases, where the repeater station is situated on, or very close to, the sea front, the required length of land cable can be kept short; unfortunately, the restricted choice of landing points at Larne and Portpatrick, and the inland positions of the repeater stations, precluded this.

Once again the problem was one of supply, at short notice, of a quantity of specialised cable of which only limited stocks were held. Purchase of new cable was an obvious option, but cable manufacturers with full order books cannot be expected to divert effort from major projects and to tool up for the production of a limited quantity of cable within a very short timescale. Luckily, Standard Telephone and Cables plc (STC) at Southampton had a small quantity of surplus land cable from another project that conformed to normal BT specifications in all essential respects. In the event, STC were able to supply 1·65 NM of this cable.

The remaining 1·15 NM of cable was found from various sources. BTI's cable depots at Torquay and Goonhilly contributed from their stocks on the understanding that they would be replenished with new cable at the earliest opportunity. Land and earth cable was recovered from the Covehithe–Katwijk B land route at Covehithe, to make up the balance.

Repeaters

Three submersible repeaters were required for the Larne–Portpatrick system, at a spacing of about 7·5 NM, and it was felt that the best way of providing these was to use stand-by repeaters from stock. Unfortunately, since stocks of the required T-type repeaters were not plentiful, it was recognised that a recovered repeater from the Covehithe–Katwijk B system would also have to be used.

Of the seven available repeaters from this system, one, T14, had been laid as a result of a repair in 1980 and had, therefore, used up only a small portion of its planned working life prior to the removal of traffic from the system in 1981. In addition to the recovered T14, two stock repeaters, T77 and T63, would be used to make up the complement for the Larne–Portpatrick system. Two other recently laid repeaters, T88 and T89, would also be recovered to replace T77 and T63 in store and thus ensure that the stand-by stocks were not depleted to an unacceptably low level. Any additional repeaters that could be recovered from the Covehithe–Katwijk B system would be regarded as a welcome bonus.

Terminal Equipment

It is common practice among telecommunications administrations to purchase a spare set of submarine terminal equipment for each type of system in service. These spare terminals are owned jointly by the administrations investing in the systems concerned and each one contributes toward the costs of their upkeep and storage. In the event of a catastrophe on one of the systems, the administration concerned with that system can take up an option to buy out the interests of the other administrations and use the equipment to restore service.

Naturally, it is very rare for this option to be exercised, although the prudence of this kind of contingency planning has been demonstrated over the years. In most cases, however, the spare terminal is never used, and the growth of traffic and system capacity in the North Sea during the past 20 years has meant that, if a spare terminal is not used within, say, the first 10 years of its life, then the number of circuits lost as a result of a catastrophe would tend to be small relative to the size of the network as a whole, and would probably not warrant priority restoration.

This was the case with the North Sea 480-circuit spare terminals purchased by the then Post Office in 1970 and installed at Blythburgh repeater station, Suffolk. Here, two complete terminals, one for the A-end and one for the B-end of a system were installed to the normal rigorous standards that would have been applied to a working submarine cable system. Although not kept permanently powered, the equipment was regularly energised, checked and maintained by local Telephone Area staff. This terminal equipment was, therefore, the obvious choice when terminal and power-feeding equipment for the Larne–Portpatrick system was being sought (see Fig. 1).

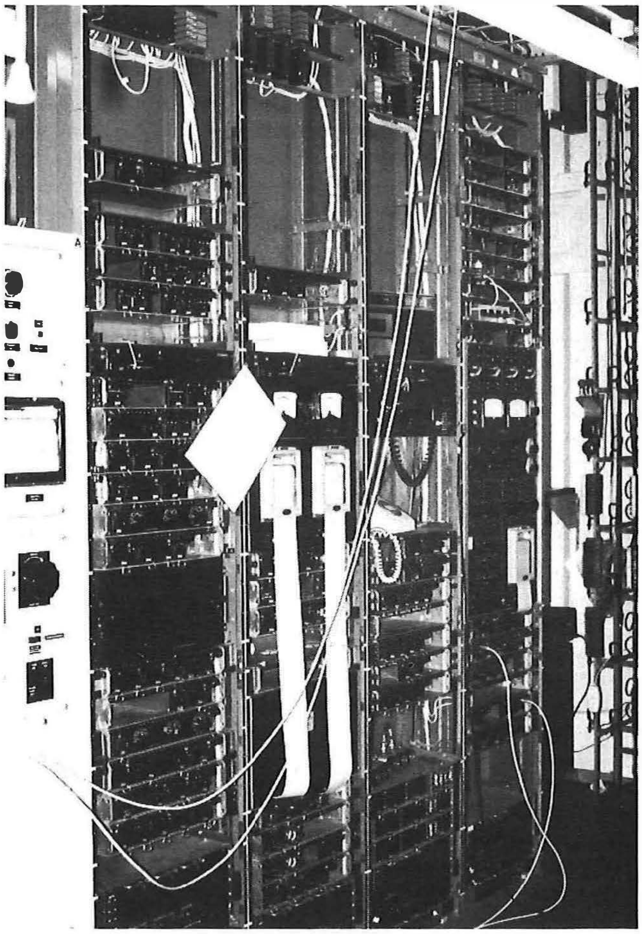

FIG. 1—Terminal transmission equipment at Portpatrick

The facilities offered by these terminals were:

(*a*) An A-type transmission rack designed to shape, equalise and transmit the low-band signal (308–2296 kHz) to line; and to receive the high-band signal (2788–4776 kHz) from the line and shape, demodulate and equalise it to recover the baseband signal.

(*b*) A B-type transmission rack designed to shape, equalise, modulate and transmit the high-band signal to line; and to receive the low-band signal from the line, shape and equalise it prior to demultiplexing.

(*c*) Two ancillary racks, whose function was the generation and monitoring of system pilot frequencies, and the generation of the system carrier of 5084 kHz used to modulate and demodulate the high-band signals.

(*d*) Two engineering order wire racks, whose function was to provide up to four speech channels for engineering communication between terminals.

All of the above equipment, known collectively as *terminal transmission equipment* (TTE), was designed to operate from a −24 V DC power supply.

In addition to the TTE, the spare terminal equipment included two unduplicated power-feeding equipments (PFE) capable of feeding a constant current of 150 mA to submerged repeaters, up to a maximum voltage of 1300 V. This equipment was designed to operate from a 240 V AC power supply and, whilst perfectly adequate to power the system, it was considered to be a little over-rated for use on a submarine cable requiring only 120 V. It also had the drawback of being mains operated, and use of this equipment alone would have required the provision of no-break mains supplies at both terminal stations.

Once again, the defunct Covehithe–Katwijk B system provided the solution. The Covehithe PFE comprised duplicated power units, each of which were capable of producing the required constant-current output at a maximum voltage of 500 V; it also operated from a −24 V DC power supply. It was therefore decided to employ this equipment at the Portpatrick terminal (see Fig. 2), and to use one of the unduplicated mains-powered spare PFEs at Larne where it could be operated from a long-break mains supply. In the event of a mains failure, the Portpatrick terminal would have two PFE units, each of which was capable of powering the system. A high degree of system security could thus be obtained for a minimal financial outlay.

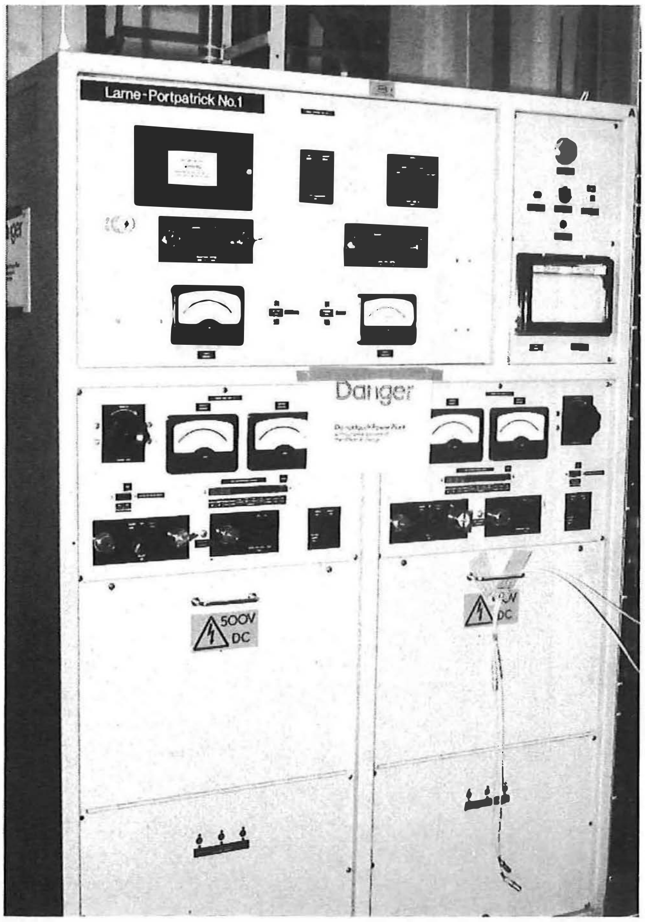

FIG. 2—Power-feeding equipment at Portpatrick

To enable the submerged repeaters to be tested and checked when in service, a spare submerged-repeater monitoring equipment (SRME) from Winterton repeater station in Norfolk was included in the package for installation at Portpatrick.

Finally, multiplexing equipment in the form of supergroup translating equipment (STE) had to be found. This equipment had to perform the conversion of the eight basic supergroups (312–552 kHz), which form the traffic load for a 480-circuit system, to the baseband signal (312–2292 kHz). On the receive side, the STE's function was to recover the eight individual supergroups from that same baseband signal.

Four shelves of STE were available at Covehithe and these were pressed into service at Portpatrick. At Larne, BT Northern Ireland hoped to fulfil the STE requirement by adding to a batch of equipment already on order. In the event, however, this equipment could not be available in time, and spare equipment was made available by the Wales and the Marches Telecommunications Board instead.

PROJECT IMPLEMENTATION

As outlined in the introduction to this article, the planning phase of this project was completed by April 1982, when authority was received for the work to go ahead. From this point on, the project entered an organisational and implementation phase.

The summer of 1982 was taken up with site visits, and negotiating wayleaves and consents from local landowners in the case of the land cable planners, and from various Government departments in the case of BTI/Marine Services. At the same time, arrangements were being made for the shipment of the terminal equipment from Blythburgh, Winterton and Covehithe to Larne and Portpatrick. By the end of August 1982 all of this equipment was on site.

By this time the project co-ordination and system engineering group had written the draft installation instructions, to enable staff in the local Telephone Area to install the terminal equipment. A site visit in mid-September finalised the details.

September also saw the first meeting of the project coordination team, in London. Periodic meetings of the various interested parties in a project such as this are absolutely vital to ensure that the various contributions dovetail correctly. Here, problems were discussed and various target dates were confirmed for project activities as follows.

The provision of duct for the land cable would take place during January/February 1983, and the installation of the land cable and power-feed earth would follow immediately after. Terminal equipment would be installed, by local Telephone Area staff, also during the first two months of 1983. The system engineering group would then test the equipment in March 1983.

Because of the 'marginal costing' nature of the marine element of the project, it was agreed that the work of recovering and laying the cable would be carried out by either *CS IRIS* or *CS MONARCH*, on an interruptable basis, at a convenient quiet spell in their work schedules. At this time, *CS IRIS* was still serving in the Falkland Islands, but a tentative date of February 1983 for the recovery and laying operations was set.

During the period up to Christmas 1982, the project picked up speed and the various BT divisions continued with their individual tasks. The land cable group designed the power-feeding earth-electrode systems, continued with the production of ductwork planning documentation to enable the local area works groups to let the civil engineering contracts, and to finalise their wayleave negotiations. Recovery of a quantity of land cable at Covehithe took place in December 1982.

BTI/Marine Services negotiated the purchase of shore-end cable from the Netherlands PTT and its transport to Southampton, along with shore-end cable from the BTI Depot at Dalmuir, near Glasgow. They also produced a memorandum giving a detailed plan of how the marine work would be carried out.

The system engineers completed the terminal installation memoranda and, with the aid of BT/Procurement Executive, negotiated a contract with STC for 1·65 NM of new land cable. They also carried out detailed studies of the predicted noise performance of the system to decide the tolerance that could be permitted in the spacing of the repeaters in the event of unexpected changes in the amount of submerged plant available. Production of terminal equipment testing and system commissioning manuals was also begun. Testing of spare land cable at BTI's depots at Goonhilly and Torquay took place during this period, and orders were placed for maintenance test equipment for use when the system was in service.

On the 15 December 1982 the second meeting of the project co-ordination team was held and the year ended with the project on schedule and the pieces beginning to fall into place. Some uncertainty still remained over the availability of a cableship, however, and a deferment of the marine operations until April 1983 began to be considered.

In the New Year, the first phase of installation began in earnest. In January and February 1983, duct was installed for the land cable, from the repeater stations to the landing points. The installation of the terminal equipment was also completed and the land cable, including that purchased from STC, was shipped to the respective Telecommunications Engineering Centres at Ballymena and Stranraer.

The system engineers thoroughly tested the terminal equipment during March 1983, and left the equipment on a continuous confidence trial while they waited for the recovery and installation of the submerged plant. Land cable and power-feeding earth-electrode systems were installed by the land cable group at the end of March 1983 and jointed by mid-April.

At the third and final meeting of the project co-ordination team on 24 March 1983, it became clear that, because of the non-availability of a cableship until mid-May, the recovery operations would not commence before then and regrettably a commensurate two month deferment of the RFS date for the system would be inevitable.

At this point, although installation work was suspended pending the availability of *CS IRIS*, the system engineers took advantage of the break to add the finishing touches to the necessary system documentation such as commissioning and laying instructions, and various contingency plans were discussed among the parties.

Finally, at a meeting on 12 May, it was determined that *CS IRIS* would be in a position to commence recovery of the Covehithe–Katwijk B system on 24 May 1983.

Accordingly, by 31 May 1983, after a week during which great skill in ship and cable handling was demonstrated by the officers and crew of *CS IRIS*, over 30 NM of cable and five repeaters had been recovered and tested. Such was the success of the operation that 20 NM of the cable was recovered in only four separate sections. This considerably simplified the parallel operation of re-jointing it, together with repeaters (see Fig. 3) for its new application, under the supervision of the system engineers.

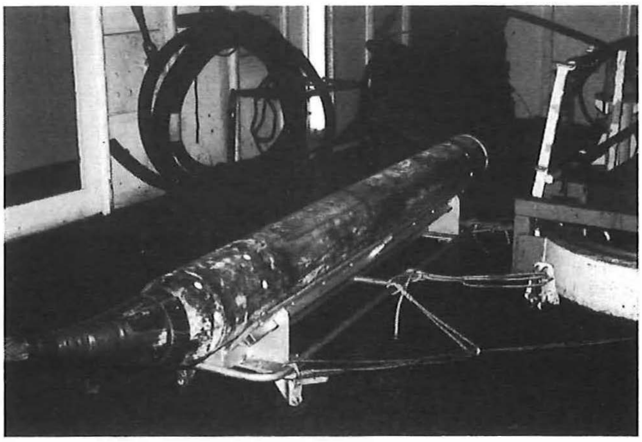

FIG. 3—Recovered repeater T14 on board *CS IRIS*, having been jointed into the new system

FIG. 4—*CS IRIS* laying the Drains Bay shore-end cable

Loading of the shore-end cable took place at Southampton on 15–17 June 1983, and *CS IRIS* sailed to carry out cable laying on 18 June 1983. The shore-end at Portpatrick was laid on 20 June with the Larne shore-end and main sea-cable lays taking place on 21–22 June (see Fig. 4). The system was powered for the first time from Portpatrick at 0740 hours BST on 22 June 1983 and, after carrying out preliminary tests, the system engineers gave *CS IRIS* clearance to leave the cable ground at 1100 hours.

Commissioning tests commenced on 27 June 1983 and were completed, with no serious problems arising, by 27 July 1983. A one-week stability test commenced at 1400 hours on 28 July and, after this was completed successfully, the system was made available for service on 5 August 1983.

TECHNICAL ASPECTS

General System Description

The coaxial cable, together with three 2-way repeaters, was installed between Larne, Co Antrim and Portpatrick, Wigtownshire in June 1983.

In all, 25·731 NM of 0·935 inch wire-armoured sea cable and 2·816 NM of screened land cable, making a total cable length of 28·547 NM, were used.

Standard repeater station terminal equipment was used to assemble the telephone channels into groups, supergroups and hence hypergroups.

Twelve telephone channels are translated to form a group 60–108 kHz.

Five groups are translated to form a supergroup 312–552 kHz.

Eight supergroups are translated to form the basic hypergroup 312–2292 kHz. This hypergroup forms the input to the submarine cable system terminal equipment.

Spacing between supergroups is a minimum of 8 kHz and the mean power level in a channel is assumed to be −13 dBm0.

The basic hypergroup 312–2292 kHz is used directly for one direction of transmission over the submarine system. This is designated as the *low band.*

In the opposite direction of transmission, the basic hypergroup is translated by means of the 5084 kHz system carrier into the frequency band 2792–4772 kHz. This is designated as the *high band.* At the receive terminal, the high band is demodulated with the system carrier to recover the basic hypergroup.

Fig. 5 shows a diagrammatic representation of the system frequency spectrum.

The A-terminal of this system is Larne. This terminal transmits the low band and receives the high band. It also feeds positive voltage to the cable centre conductor, to power the repeaters.

The B-terminal is Portpatrick. This terminal transmits the high band and receives the low band. It feeds negative voltage to the cable.

Terminal Equipment

The terminal equipment provides the following facilities:

(*a*) A frequency comparison pilot of 60 kHz can be multiplied up to 300 kHz and transmitted from the A-terminal. This 300 kHz pilot is received at the B-terminal and is divided down to 60 kHz, to enable the master oscillator frequencies of the two terminal stations to be compared and synchronised.

(*b*) The overall level stability of the system is assessed by continuously monitoring the system pilots, which are located one at each end of the basic hypergroup spectrum. The pilots are transmitted in both directions, combined with traffic, from the terminal transmission equipment input at each terminal to the output of the terminal equipment at the distant terminal. The pilot frequencies are:

A–B Direction	308 kHz	2296 kHz
B–A Direction	2788 kHz	4776 kHz

(*c*) Seasonal changes in cable attenuation as a result of variations in sea temperature can be compensated for by adjustment of switches on the temperature equaliser units. These units enable combinations of flat and cable-shaped attenuation to be added to or removed from the terminal transmission paths.

(*d*) Cable repairs, even in relatively shallow water, necessitate additional cable being put into the system. The terminal transmission equipment is fitted with cable simulation networks, which can be strapped out as the length of the system increases. In the case of the Larne–Portpatrick system, these networks can compensate for 1 NM of repair cable inserted during the life of the system.

(*e*) A separate engineering order wire (EOW) rack is provided at each terminal to allow communication between repeater stations. The equipment provides up to four audio channels of 2 kHz bandwidth, and translates them up to the frequency band 804–812 kHz prior to input to the terminal transmission equipment and hence the submarine cable. At the receive terminal, this frequency band is demodulated and the audio channels are recovered.

Submersible Repeaters

The submerged repeaters used in this system have a single three-stage negative-feedback amplifier employing transistors of proven reliability and long life. A two-stage transistorised supervisory amplifier is also provided within each repeater. Equaliser networks are provided at the input and output of each repeater amplifier to assist in matching the insertion-gain characteristic to the cable-loss characteristic. The gain of each repeater is 42 dB at the system top traffic frequency of 4772kHz.

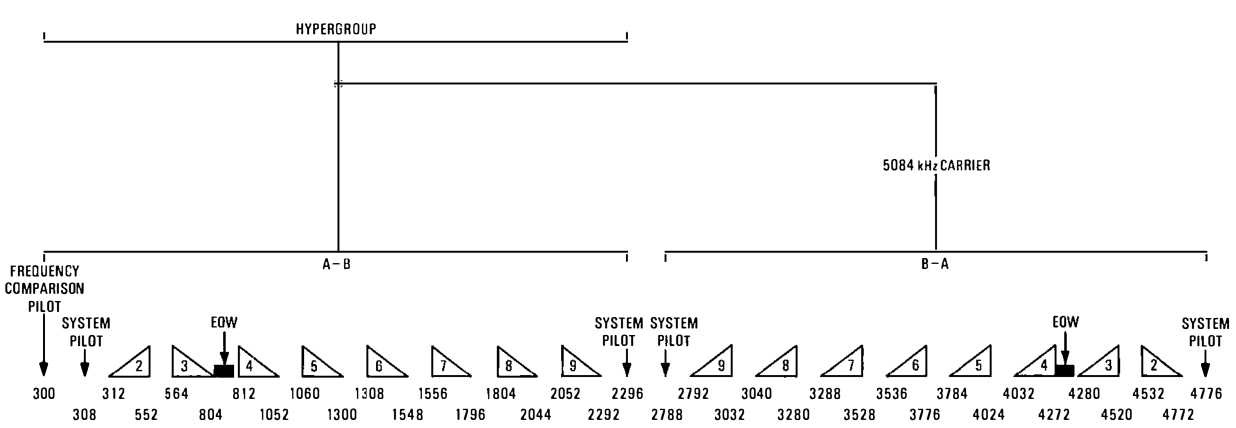

FIG. 5—System frequency spectrum

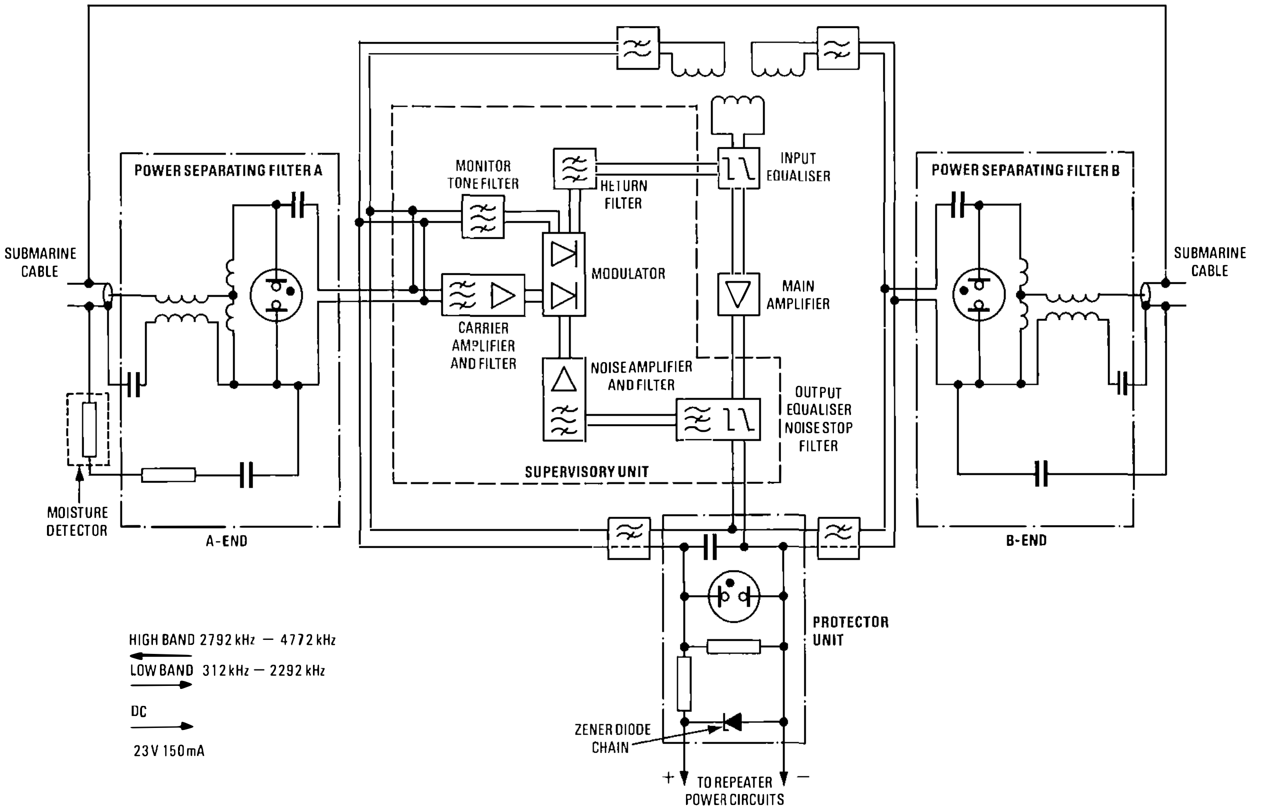

FIG. 6—Functional diagram of a submerged repeater

Fig. 6 shows a block diagram of a submersible repeater of the type used in this system.

Submersible-Repeater Monitoring Equipment

Because of the inaccessibility of the repeaters, it is useful to be able to assess their performance from the terminal stations while in service. To do this, repeater monitoring equipment has been installed at the B-terminal, Portpatrick, and this can be used to make measurements of the loop gain and noise performance of each repeater without traffic being affected. The individual repeaters are distinguished from each other on a time basis by the use of pulsed and continuous carrier signals. These measurements can be recorded and can be carried out either automatically or manually.

Power-Feeding Equipment

The repeaters are supplied with power from each end of the coaxial cable by a constant direct current flowing along the centre conductor and returning via the power-feeding earth electrodes and the sea. The system line current is 150 mA.

The PFE is powered from the nominal 24 V station battery supply at Portpatrick; at Larne it is operated from the 240 V AC mains supply via a rectifier. The equipment consists essentially of a static inverter operating at 1000 Hz, a step-up transformer and a rectifier. Control circuitry using saturable reactors is used to maintain the output current within close tolerances and tripping alarms initiate automatic shutdown in the event of dangerous over-voltage and over-current conditions. This is vital, since electrical storms, lightning strikes and cable damage can all precipitate current and voltage surges from which the repeaters must be protected.

Fig. 7 shows a block diagram of the main elements of the PFE.

Fig. 8 shows the regulation characteristics of two equipments sharing the load. The 'droop' characteristics of the

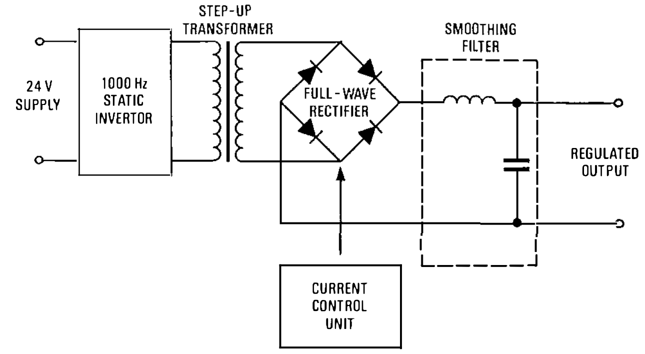

FIG. 7—Main elements of power-feeding equipment

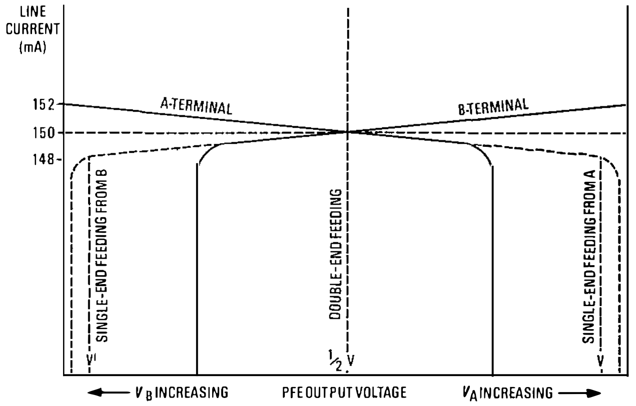

FIG. 8—Power-feeding equipment droop characteristics

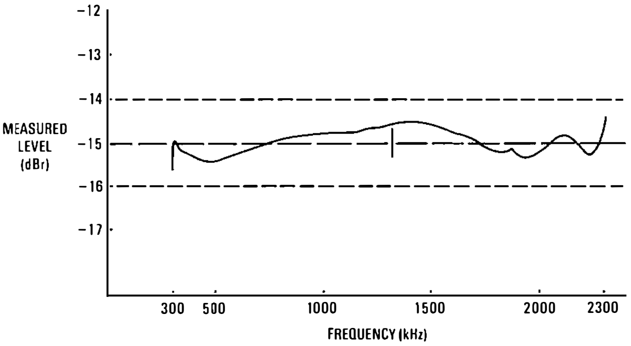

FIG. 9—System attenuation/frequency response (A–B direction)

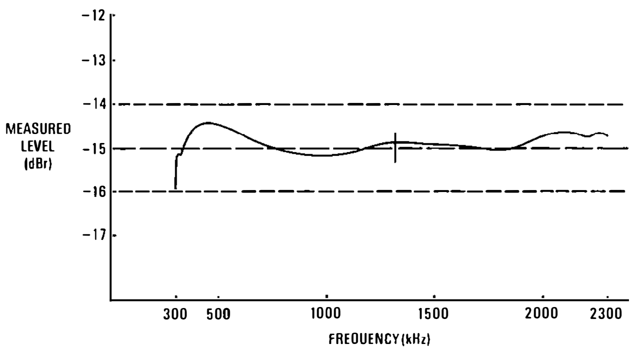

FIG. 10—System attenuation/frequency response (B–A direction)

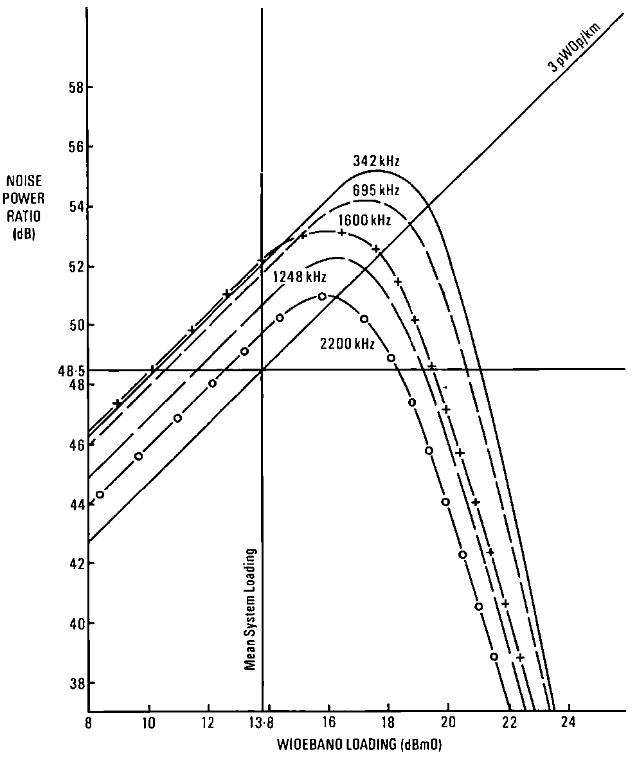

FIG. 11—System white noise loading response (A–B direction)

curves enables the equipments to operate together without one PFE being driven OFF by the other.

System Performance

The two most interesting performance characteristics of a submarine cable system are generally taken to be:

(*a*) the system attenuation/frequency responses for the two directions of transmission, and

(*b*) the noise-power ratio/wideband loading characteristics.

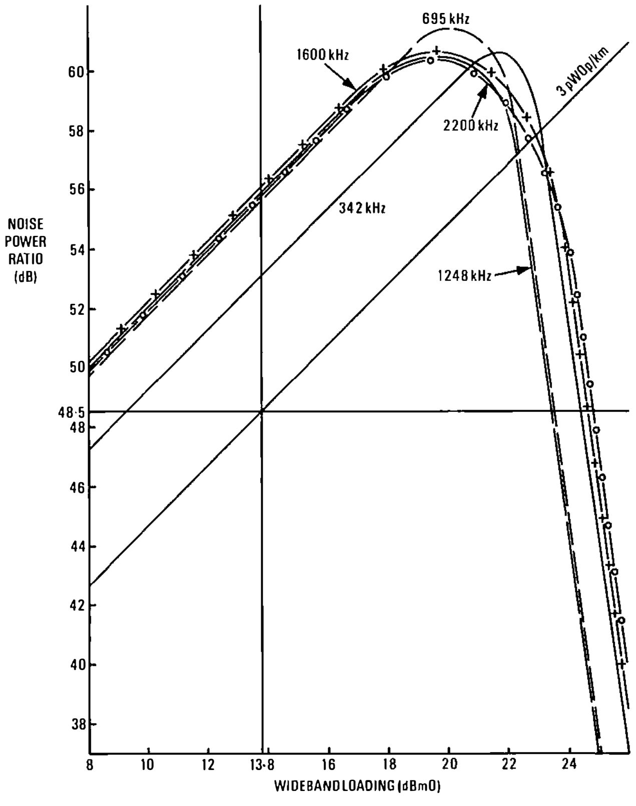

FIG. 12—System white noise loading response (B–A direction)

Figs. 9 and 10 show that the attenuation/frequency responses, following equalisation, clearly meet the specified spread limit of ± 1 dB relative to the −15 dBr point.

Figs. 11 and 12 show the variation of noise-power ratio with wideband loading. The required limit here was that the noise contributed by the submarine system should not be greater than the equivalent of 3 pW/km plus 140 pW noise allowance for the terminal equipment. This limit is represented by the 45° line, and at the mean system loading of $+13{\cdot}8$ dBm0 $(-13 + 10 \log_{10} 480)$ it is met with comfortable margins in both directions of transmission.

CONCLUSIONS

It has been demonstrated that, given the right circumstances, recovered plant can be used to provide high-quality submarine-cable telephony circuits with a life expectancy approaching that obtained with new equipment.

The benefits to BT have been great, in terms of experience gained, job satisfaction to all who were involved, and costs which were several million pounds less than for a newly-purchased system.

Biography

Bob Greenfield is an Executive Engineer in the submarine cable projects group of BTI. When he graduated from Queen Mary College, University of London, he joined the Submarine Cable Division of BT in May 1974. After three years in the long-term planning duty, he transferred to the terminal equipment and commissioning group. Since September 1982 he has continued to work in the submarine cable projects group, but with responsibility for submersible plant and laying operations.

A Digital Speech Voltmeter—The SV6

R. CARSON†

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For over 50 years, engineers have measured speech levels with instruments which need skill to use and which do not give closely repeatable results. This article gives a brief history of speech-level meters and describes the SV6, a digital instrument that overcomes many of the difficulties associated with earlier approaches.

INTRODUCTION

A speech voltmeter is an instrument for measuring an electrical signal that has speech-like properties. The Speech Voltmeter No. 6 (SV6) can measure continuous or interrupted speech signals over a wide range of levels with high accuracy and repeatability. It measures the active level, defined as *the RMS level of the speech signal while present*, and can also indicate long-term (average) level, duration of measurement, and speech activity (which is the relationship between the active and long-term levels).

The term *speech voltmeter* is used because the device is essentially a true-RMS voltmeter which can cope with the non-continuous nature of speech signals. It does this by deciding when speech is present and by using that time period for calculating the level of the speech signal.

This article discusses some other instruments for speech-level measurement, and illustrates how speech voltmeters in particular have developed, before going on to describe the SV6 in detail.

SPEECH LEVEL MEASUREMENT

In analogue transmission, it is important to know the signal level being transmitted, so that active devices can be set up to operate most effectively. To make the most efficient use of digital transmission methods, it is often essential to know, and to control closely, the analogue signal level at the analogue-to-digital interface.

In subjective experiments to determine the reference equivalent (the predecessor of the modern loudness rating) of a circuit, for example, a subject speaks at a steady, known level over a standard type of connection. A second subject compares the level heard in this condition with that heard when using the unknown connection and, by the adjustment of an attenuator, balances the two for equal loudness. For the results to be valid, the talker must maintain a constant level of speech. This was one of the first uses of speech voltmeters, both to measure the absolute level of the speech and as a feedback indicator to help the talker keep his or her speech level constant.

METHODS OF MEASURING SPEECH LEVELS

Speech levels cannot be measured satisfactorily with a simple (sine-wave calibrated) AC voltmeter because:

(*a*) speech signals do not have a precisely defined form factor (RMS/average ratio), which can be applied as a correction to the reading; and

(*b*) normal speech is neither continuous, nor predictably discontinuous.

The first consideration implies that a true-RMS-reading meter is needed; it is not so easy to deal with the second. Approaches to solving the problem differ and depend on the application.

Peak-Reading Meters

In Europe, for applications where (as in broadcasting) the requirement is to ensure that the peaks of the signal (whether speech or music) do not exceed a given value, peak-reading meters are popular. Examples of these are the BBC Peak Program Meter (PPM)[1] and the German U71[2]. These meters respond very quickly as the signal level rises, but only slowly as it falls. They use peak rectifier circuits in which the output voltage is directly proportional to the peaks of the input voltage.

The performance requirements for tape-recorder input-level meters are similar, (many of them, although described as *peak reading*, do not conform to the PPM specification) and many readers will be familiar with their use. In modern domestic equipment some type of fluorescent or other non-mechanical display is often used in place of the traditional meter movement. It is not difficult to adjust the input level of music or speech to prevent overmodulation, that is, a certain indication is never exceeded, but the movement of the indicator makes it difficult to put an exact value on the input level.

The PPM works well as the indicating element in a feedback control system that includes a human element, but not as a measuring device. It has the further disadvantage that it indicates the peaks of the waveform, not the power level, and so does not necessarily relate to the subjective loudness of the signal. (One side-effect of this can be observed in the loudness of radio and television commercials—there is no suspension of the laws of physics that allows the transmitted signal to be modulated more than 100% during commercials.)

Since the peaks of a music or (particularly) speech waveform constitute only a very small proportion of the total signal, they are not the most reliable statistic on which to base signal-level measurement. A measuring device that takes account of all parts of the waveform, in general, indicates a more widely useful quantity.

VU Meter

In the USA, a meter that measures *volume units*[3] is widely used, for both broadcasting and telephone communication measurements. This type of meter has also appeared on tape recorders. It does not have the slow decay rate of the PPM, and so the movement of its needle is more jerky and tiring to the eye. The rectifier has the following relationship:

$$V_{\text{out}} = k(V_{\text{in}})^{1\cdot 2},$$

where k is a constant.

This rectifier law is based on the performance of copper-oxide disc rectifiers, even though the original proponents of the standard agreed that square-law rectification was desirable. It was claimed that the effect of the smaller exponent was negligible.

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† Research Department, British Telecom Development and Procurement

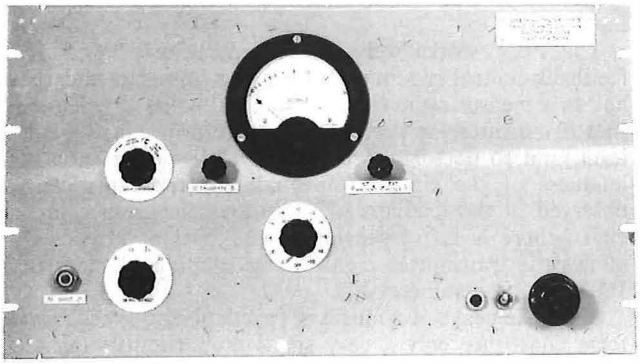
The standard method of taking a reading on speech is to observe the meter for 10 s, ignore the one or two highest deflections, and read the remaining (more typical) maximum deflections as the signal level. Obviously, there is some scope for operator interpretation, and readings cannot usually be repeated with any great accuracy.

Speech Voltmeters

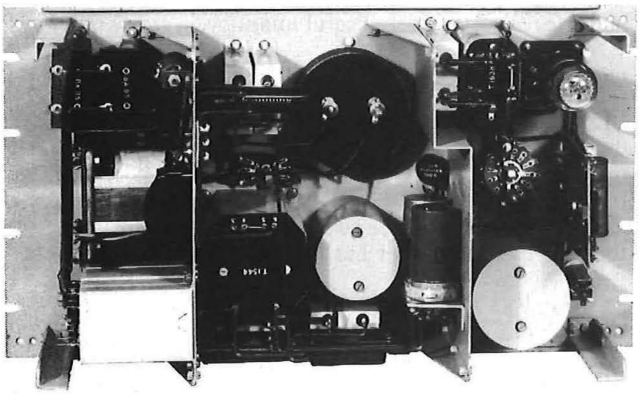
Measuring instruments called *speech voltmeters* have been in use for almost half-a-century, but have not enjoyed the widespread acceptance and popular acclaim which that lifespan might seem to imply. This is partly because they are not very easy to use, and partly because, with the earlier types, a team of specially trained observers was needed.

The simplest type of speech voltmeter is a true-RMS meter with defined dynamic behaviour. Examples of this are the SFERT Volume Indicator[4] and the ARAEN Volume Meter[5], which is identical to the British Post Office Speech Voltmeter No. 3 (SV3)[6], see Figs. 1 and 2. (The SV1 was used in the 1930s[7], and the SV2, although not called that at the time, was a portable speech voltmeter made for war-time use; only two of those were ever constructed.) These meters each consist of a calibrated amplifier, followed by a square-law rectifier, feeding a moving-coil meter. They are all read by the *CCITT method*[8]; the required level is that which is just exceeded, on average, once every 3 s. Obviously this method, too, depends on the skill of the operator. It has been shown[9] that a significant proportion of readings from a single observer will be up to 1·5 dB in error, and that between several trained observers, readings can consistently differ by up to 4 dB. With untrained observers, the differences are more than doubled. Measurements can be made only on continuous speech, not on short phrases or speech with large silent periods.

The SV4[10] was designed in the late-1940s to overcome some of the lack of precision in reading the SV3. It was essentially an SV3, but instead of a meter, it had a circuit whose electrical output was analogous to the movement of a meter needle. This circuit fed a number of counters, which recorded the imaginary needle's passage over various scale points. The characteristics of the meter could be varied. It was only a laboratory tool, since it required repeated replaying of the speech sample. It occupied three 7-foot equipment racks, and the power supply for the valve heaters had a capacity of 55 A at 6·3 V.



(*a*) Front Panel



(*b*) Interior

FIG. 1—Speech Voltmeter No. 3

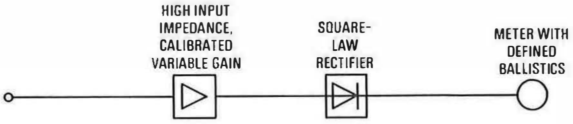


FIG. 2—Block diagram of the SV3 (1947)

Experience and experiment led to the SV4A[11] (see Fig. 3) with fixed characteristics. With the technology then available, it was not easy to duplicate the CCITT reading method exactly, but a method was devised to give consistent, repeatable results, even on fragmentary speech. Although smaller than the SV4, the SV4A was still large and heavy. This lack of portability, and the careful setting up required, made the SV4A unsuitable for anything other than laboratory use.

A different approach was taken in the next stage of development, resulting in the SV5[12]. This consisted of a calibrated amplifier followed by a linear rectifier, feeding a linear integrator. The integrator output was read by a valve voltmeter. Integration periods of 1 s or 10 s could be chosen. The final meter reading was steady and did not require operator interpretation. However, since the quantity measured was the mean modulus of the signal, a form factor correction had to be applied to give a value related to the power of the signal. The form factor was subject to some uncertainty, and had to be different for telephone or high-quality speech.

Adding a square-law circuit between the rectifier and the integrator overcame the inconvenience of using a correction factor and created the SV5A[13] (see Fig. 4). Skill was still required in selecting the most appropriate integration period and the right moment to start the measurement. Also, if the input attenuator was not correctly set, the measurement had to be repeated. (The attenuator of the SV3 could be adjusted as measurement proceeded and the meter gave immediate

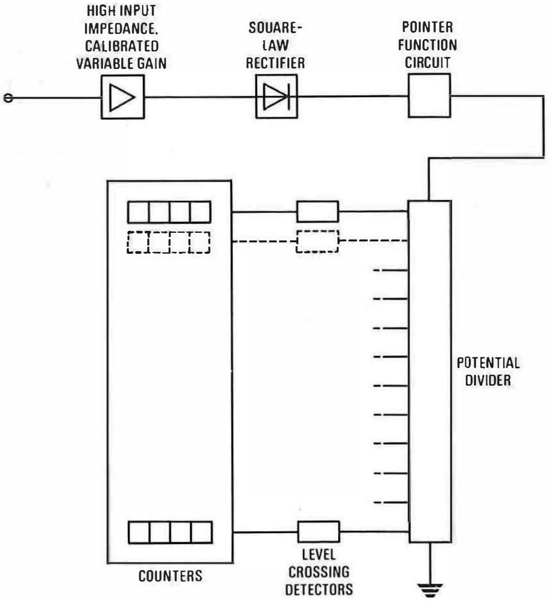


FIG. 3—Block diagram of the SV4A (1952)

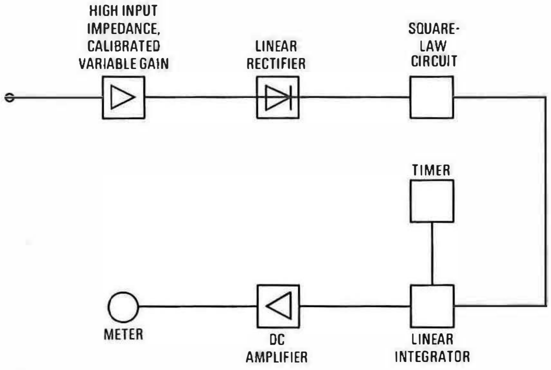


FIG. 4—Block diagram of the SV5A (1960)

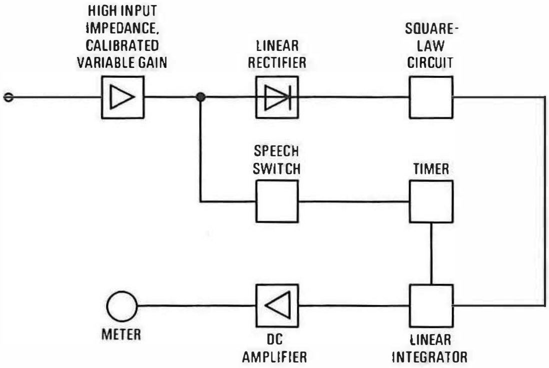


FIG. 5—Block diagram of the SV5B (1961)

visual feedback.) The results were consistent, but since the operator had to set the correct input attenuation in advance, and be sure that speech would continue throughout the integration period, it was not suitable for use on live speech.

In the SV5B[14] (see Fig. 5), a speech detector is fed from the input amplifier, and this controls a timer. The timer is enabled by a front-panel control, but permitted to run only while speech is deemed to be present. This makes the choice of the starting instant less critical and allows the SV5B to measure fragmented speech with good repeatability. The speech detector includes rectification, smoothing and hang-over, which bridges brief periods of silence in speech. The timer period is fixed at 10 s, but because of the speech detector, the total measuring period is usually longer.

The SV5B still requires the operator to select the correct input attenuation, but it gives consistent results, on all types of speech, which do not need observer interpretation. The original valve version was described (by comparison with earlier equipment) as being reasonably portable, although it weighed 65 kg. Fig. 6 shows two of the instruments in use in rack-mounted form. Note that a meter and its associated power supplies fill most of each end bay of the rack. The SV5B was used by Research Branch (now British Telecom Research Laboratories (BTRL)) from 1960 until about 1973, when the SV5B MkII[15] (see Fig. 7), using semiconductors, became available. Besides being smaller and capable of being carried in one hand, the SV5B MkII could emulate the SV3 (this was not difficult to arrange, since the SV3 and SV5 use the same type of meter movement), to allow measurements to be made according to CCITT recommendations. This facility was needed because the original thermionic valve operated SV3s were becoming unserviceable, and nothing had been developed since that had received official international approval.

FIG. 6—Two rack-mounted SV5Bs

Although it was seen at the time of its introduction as merely an interim development (pending the development of a digital speech voltmeter), the SV5B MkII has remained a standard laboratory tool for about 10 years. BTRL has manufactured the quantities required for its own use. British Telecom Factories Division have also produced small quantities in standard and modified form for use outside BTRL, both in the UK and abroad.

However, the greatest strength of the SV5B also leads to its greatest operational weakness. It makes consistent measurements because it takes account of whether the speech signal is active. So there must be a threshold level above which speech is deemed to be present. This cannot be too low or the circuit noise will be treated as speech; it cannot be too high or some of the quieter parts of the speech itself will be lost. Since it will be useful to be able to measure speech signals at various different levels, an absolute threshold is impractical. This problem can easily be solved by using a threshold which is a fixed level (say 15 dB) below the level of the speech—but this leads to the unfortunate conclusion that the speech level can be measured only if it is already known.

This is why the user of the SV5B has to guess the speech

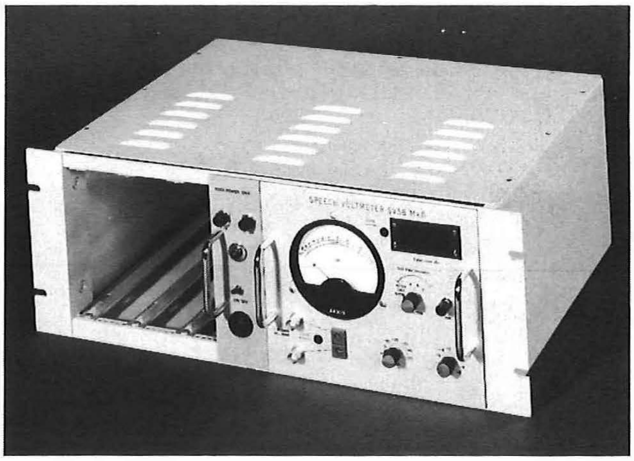


FIG. 7—Speech Voltmeter No. 5B MkII

level (in effect the threshold level) and keep repeating the measurement, using a different sensitivity of the meter, until the true value is found; that is, when the final integrated speech level is 15 dB above the chosen threshold level. This need to repeat the measurement means that tape-recorded speech can be measured with good accuracy (at the cost of some tedium for the operator), but live speech cannot.

The level of 15 dB was adopted as a reasonable value, which ensures that the threshold is above the noise and other non-speech signals[14].

Digital Speech Voltmeters

A number of ways have been tried to drag speech voltmeters into the digital age, and make them easier to use. One approach is gradually and continuously to adjust the threshold during measurement, and display a constantly updated reading. A prototype meter using this principle has been built[16] and is known unofficially as the *SV5C*. Another concept is to simulate a number of speech voltmeters in parallel, each set to a different threshold, and obtain the final result by interpolation. This has been implemented on a minicomputer, but that type of speech-level meter is rather too expensive for most potential users, as well as being rather bulky to carry around.

The microprocessor has been used increasingly in research work from about 1976 onwards. A modular computer system, based on the Motorola 6800 device, was designed and constructed by the speech transmission assessment group, for subjective experiment control and data capture and processing. One of the modules was a prototype speech voltmeter, using the 'multiple SV5B in parallel' method. It showed the results on a simple light-emitting-diode display, and various values (speech voltage, duration of measurement, mean power, etc.) could be selected by a rotary switch. It could be remotely controlled by another computer if required, by using standard interface modules.

Several examples of this design (now called the *SV6*) were made once the concept had been proved. The new meter was used side by side with the SV5B for some time, and confidence in its capability was built up. Over a relatively restricted range of speech levels its measurements had good repeatability and corresponded well with those of the SV5B. It was decided to produce a small quantity of units, both for use within BTRL and to test the likely market, but for various reasons, it was not practical to produce the prototype model as it stood.

The modular microprocessor system used a racking practice that was becoming obsolescent, and that was not recommended for new work. Once the decision to change mechanical parts was taken, other changes followed. The prototype's 12 bit analogue-to-digital converter (ADC) limited the useful range of the unit, and so a 15 bit converter was substituted. The front panel was completely re-designed to use press-buttons instead of a rotary switch, and incorporate a liquid-crystal display (LCD), which had full alphanumeric capabilities. The instrument became a separate, dedicated package that was no longer just a plug-in modular part of another system (Figs. 8 and 9).

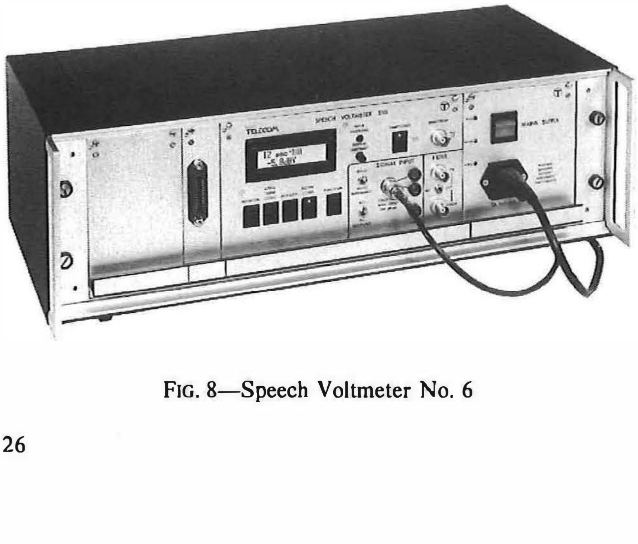


FIG. 8—Speech Voltmeter No. 6

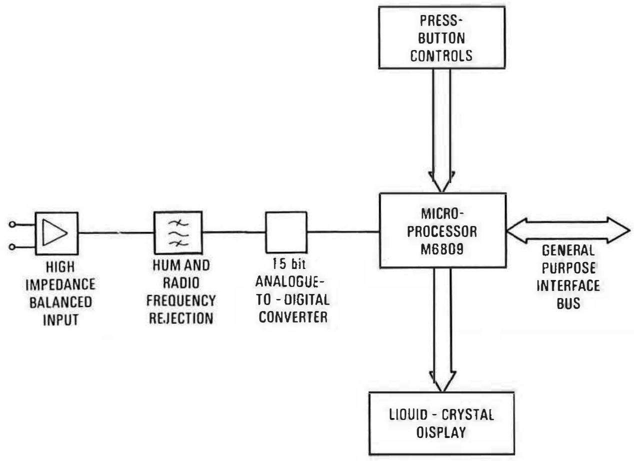


FIG. 9—Block diagram of the SV6 (1983)

The first production batch of 50 units has now been assembled (by Malden Electronics Ltd., London). Lively interest has been shown in the SV6 by other administrations and organisations, and all of the instruments produced have already been sold or allocated to end-users within BT.

SPEECH VOLTMETER No.6

The SV6 performs the function of the SV5B, in measuring the level of speech signals while they are active. Not only can the SV6 do this in real time, and over a wide range of levels without adjustment, but it also has other features and facilities that make it more versatile and easier to use.

Facilities

The SV6 can be used to measure the following:

(*a*) active level (RMS level while speech is present),
(*b*) long-term level (RMS level for whole measuring period),
(*c*) duration of measurement, and
(*d*) activity (fraction of the measuring period for which speech is present).

Each of these results can be displayed by pressing the appropriate front-panel button (see Fig. 10).

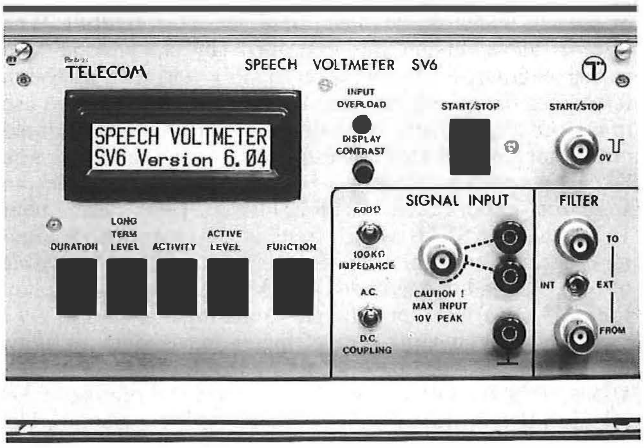


FIG. 10—Front Panel of the SV6

Unlike the SV5B, the measuring period is not fixed, and can be up to several hours if desired. It can also be much shorter, but, for repeatability, measurements should cover at least 3–5 s of active speech.

The user can choose to start or stop a measurement, at any suitable time, by pressing the button marked STOP/START. As soon as one measurement is complete, another can be started, and the results of the previous measurement (any of the four mentioned above) can be read out, while the current one proceeds. The values appear on an alphanumeric display.

While a measurement continues, the elapsed time is shown, and an indication of instantaneous signal level is given in the form of a bar-graph display. These displays are not affected by interrogation of the previous results. When the measurement is stopped, the value of the currently displayed result is updated and, if any error conditions were detected during the measurement, an error code is displayed to help identify the problem.

The levels may be shown as dBV (0 dBV = 1 V), as dBm in either 600 Ω or 900 Ω circuits (0 dBm = 1 mW), or as decibels referred to any convenient test level (shown as dB REL). The reference level can be set or reset after any continuous tone has been measured—this could be from a standard oscillator or a calibration tone on a tape recording. The activity may be shown as a percentage or a fraction.

Further versatility is provided by making the SV6 controllable from a computer via a standard bus. The standard used conforms electrically and mechanically to IEEE†-488 (1978), commonly called the *general purpose interface bus* (GPIB).

The meter has a filter that is intended to reject mains hum and tape hiss, while it retains the frequencies (between 200 Hz and 5 kHz) of greatest importance in telephony. A switch allows either an external filter or a wire link to be substituted, when measurements in different bandwidths are required. A special feature of the meter is the provision of a menu of commands and extra facilities. This menu may be read by repeated presses of the front-panel button marked FUNCTION. Any menu item can be selected by pressing the START/STOP button while that item is being displayed. To exit from the menu mode, any one of the display buttons is pressed. The advantage of this method is that new menu items can be incorporated in the instrument's program to extend its capabilities, without any other physical changes. The current menu contains the following features:

(*a*) *Reset Meter* This allows the meter to be returned to the state it was in when first powered-up, with all features in a standard condition.

(*b*) *Reference Level* The SV6 can store the value of long-term level from the last measurement. This is the datum used when the level is displayed as dB REL. The reference can be displayed without being altered.

(*c*) *Partial Reset* This is similar to the full reset, but without destroying the stored reference level.

(*d*) *Auto-Repeat* This facility makes the SV6 continually repeat a short measurement and display the result (long-term level only); this dispenses with the tedious process of starting and stopping the meter when checking the instrument's calibration and offset adjustment.

(*e*) *Overload* An error is shown if the ADC input was overloaded for more than 1% of the measuring period, and this item allows the exact percentage to be checked.

(*f*) *Interface Bus* Various interface parameters are set by internal switches. These can be examined and temporarily altered by the remaining menu items. The instrument can also be set to ignore commands from the controlling computer.

Remote Control

All the basic functions of the front panel, together with some extra ones, are accessible through the interface bus. The controlling computer can send a short message to be displayed on the LCD of the SV6. The front panel controls can be partially or completely disabled to prevent unintended changes being made. The current bar-graph level can be read, and the error code from the last measurement checked. On request, each result can be sent individually from the SV6 to the controller, or they can be transmitted as a complete list, complete with mnemonics for identification. The meter can be completely reset, and the last overload count can be interrogated. The status of the SV6 (running or not, etc.) can be queried. There is also a special facility to interrogate intermediate variables used in the calculation procedures. This last facility is intended only for in-house use in further refinement of the instrument's program.

Future Developments

If the input signal is continuous, the meter functions as a true-RMS voltmeter, and the active level equals the long-term level. It could be used as a psophometer with appropriate filtering, although it would also need external amplification if low levels are to be measured. If the internal program is modified to remove the application of hangover (see later), it could be used to give quick and accurate level measurement of such signals as interrupted tones. This, along with other facilities yet to be developed, could be offered as a new menu item. Existing users could have the latest version of the instrument simply by plugging in a new set of two or three dual-in-line memory packages.(See Fig. 11.)

OPERATION OF THE SV6

First, a brief review is given of the principles used in the SV5B. It has two main parts: an RMS voltmeter and a speech timer. The input signal is squared and accumulated on a storage capacitor, and the amount of charge is shown by the front-panel meter. The input signal is also rectified and filtered to extract the envelope. If the resulting value is above a threshold level, the timer is allowed to run (see Fig. 12). The SV5B uses a 2-section RC filter, each section having a time-constant of 30 ms. The threshold is that level just exceeded by the envelope signal of a sine wave whose RMS level is 15 dB below the expected active level of the input signal. Since the threshold signal is derived from the mean *absolute* level of the signal, and this is being compared with the *RMS* signal level, the threshold DC level must actually be 15·91 dB below the expected active level. (The

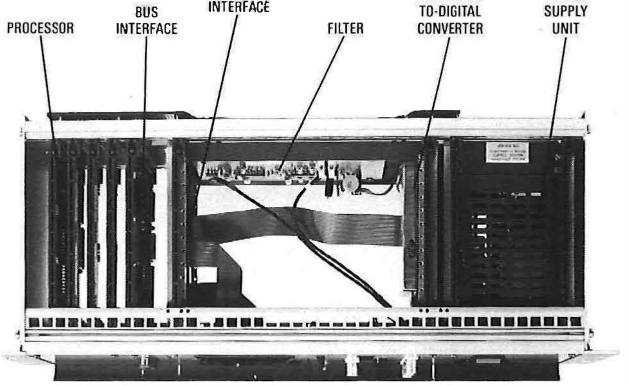


FIG. 11—Interior of the SV6

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† IEEE—Institute of Electrical and Electronics Engineers Inc.

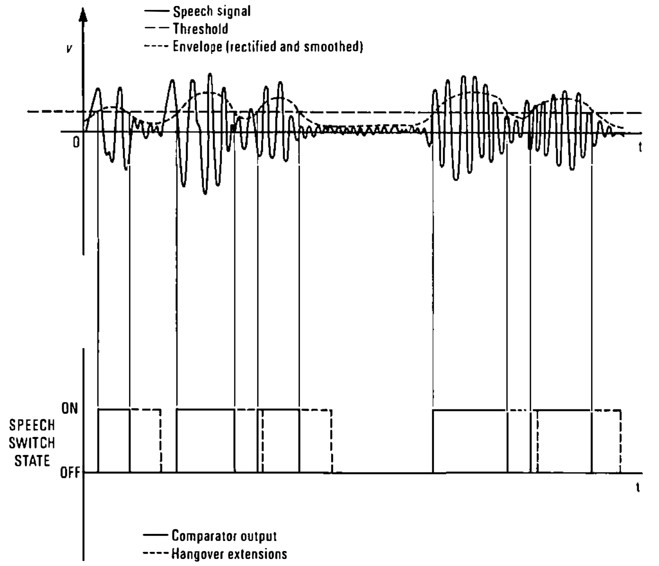

FIG. 12—Derivation of active time in the SV5B

RMS/mean ratio of a rectified sine wave is 0·91 dB.)

A speech voltmeter must exclude from its measurements long pauses, such as those between sentences, but must include short silences which form part of the structure of the speech. For example, in the word 'actor' as usually pronounced, a silence of about 200 ms occurs between the 'c' and the 't'. A listener perceives this, and even longer silences, as continuous speech. The method used to mimic this effect is to apply a hangover to the timer so that speech is still counted as active for 200 ms after it has fallen below the threshold. The filter characteristics, threshold level and hangover time cannot be chosen independently, since their effects interact[14].

When the timer has counted 10 s of active speech, measurement is stopped and the meter is frozen. The threshold used is always 15·91 dB below 0 dBV on the meter scale. If the meter needle comes to rest within 1 dB of that scale indication, the input attenuator was correctly set and the speech timer operated on the right threshold. If the needle stops outside that small range, the speech timer operated incorrectly since it was using the wrong threshold, and the measurement must be repeated with a different value of input attenuation.

The Digital Approach—The SV6

Since each of the several thresholds being used simultaneously in the SV6 would result in different 10 s portions of active speech being sampled, it must be made to measure over any arbitrary time period. Thus, although the SV6 uses the same principles as the SV5B during its measurements, its results cannot be exactly compatible because it is difficult to ensure that a precisely identical segment of speech has been measured. This slight incompatibility is outweighed by the greater versatility of the SV6.

The new instrument is almost completely digital in operation. However, the bandpass filter and the input buffer (which provides overload protection for the expensive ADC module) are straightforward analogue circuits using operational amplifiers. The ADC samples the input signal regularly, and provides a digital code upon which all subsequent operations are performed. The resolution of the ADC is 14 bits magnitude. All bits are used in accumulating the sum of the squares of the samples, but only 11 bits are used in calculating the envelope. (This part of the program is largely unchanged from the version used with the previous 12 bit ADC.)

The instrument is controlled by a microprocessor, in this case a Motorola 6809. The program, originally written in assembly language, is now mainly in PL/9. This high-level language for the 6809 permits the writing of programs that are easily read and updated, and produce fast-executing and compact code when compiled. Certain critical parts of the program remain in assembly language. The most important of these is the sampling routine.

Sampling

The input signal must be sampled at a fixed rate for the results to be meaningful, but Nyquist sampling is not required because no information about the frequency content of the signal is needed. The aim is not to store enough information to permit reconstruction of the speech signal, but rather to gather some statistics about the speech. If an unrepresentative selection of samples were taken, the results would be in error. This could occur when a periodic signal with a frequency close to the sampling rate is measured. In practice, the probability of errors of this type is low and can be reduced by the use of a higher sampling frequency and a longer measurement period. If repeatability of within 0·5 dB is required for measurements containing at least 3 s of active speech, the minimum sampling frequency is about 250 Hz.

The sampling routine is activated by timer-controlled interrupts. The remainder of the program (which responds to button presses, updates the display, etc.) runs as a continual background task. It is normal for interface bus signals to interrupt an instrument's internal program, but clearly this could not be permitted here. The sampling routine includes a procedure that checks for interface activity, so that timing is not affected. The final choice of sampling rate is governed by how fast the processor runs, and how much processing must be done in the sampling routine. Some slack time must also be allowed for the background tasks.

Two distinct operations are performed on the samples. Firstly, the total energy is measured by squaring and accumulating the samples; this enables the program later to determine the long-term mean level (decibel equivalent of RMS voltage) by dividing energy by total time. Secondly, the envelope of the signal is extracted by simple second-order exponential filtering, by using the following formulae:

$$P_{\text{current}} = M \times X + (1 - M) \times P_{\text{previous}}, \text{ and}$$

$$Q_{\text{current}} = M \times P_{\text{current}} + (1 - M) \times Q_{\text{previous}},$$

where X is the rectified input sample, M a constant, P an intermediate value, and Q the filtered output which is used to determine whether or not the speech is active at any moment. The sampling rate is determined by the following formula:

$$M = 1 - e^{-1/0.03f},$$

where 0·03 is the required 30 ms time constant and f is the sampling rate in hertz.

In the present design, the processor can sample at a rate exceeding 700 Hz and still have time to perform all the necessary calculations per sample. A slightly lower rate is chosen in practice to permit the background routines to operate at a reasonable speed. The filtering arithmetic is easier if M is a number composed of fractional powers of 2 between 1/2 and 1/256. Some possible values and their corresponding sampling rates are shown in Table 1.

The remainder of the sampling algorithm is concerned with recording the number of times that the envelope exceeds each of 11 threshold levels spaced at 6 dB intervals. The lowest threshold used by the program is equivalent to 4 units of the ADC, or about 2·44 mV. The lower the threshold, the greater is the proportion of time that the envelope exceeds it, and therefore the lower the active power (computed by

TABLE 1

Possible Sampling Rates

Value of M	Binary Fraction	Sampling Rate (Hz)
1/32	.00001000	1049
1/32+1/256	.00001001	931
1/32+1/128	.00001010	837
1/32+1/128+1/256	.00001011	759
1/32+1/64	.00001100	694*
1/32+1/64+1/256	.00001101	640
1/32+1/64+1/128	.00001110	593
1/32+1/64+1/128+1/256	.00001111	552

*This value was chosen

dividing the total energy by the active time recorded for that threshold).

The program maintains an activity count corresponding to each threshold; it also applies 200 ms of hangover to prolong the activity indication for any threshold that has recently been exceeded.

The envelope value is computed at each sample and then compared with each threshold in turn from the top downwards. Where there is unexpired hangover, but the threshold exceeds the envelope, activity is incremented and hangover decremented; where the envelope equals or exceeds the threshold, activity is incremented and hangover set to maximum.

Thus, at the end of the measurement, the following quantities have been accumulated:

(*a*) number of samples (proportional to time);

(*b*) sum of squared samples (proportional to voltage squared, or energy); and

(*c*) an activity count for each threshold (proportional to the time that speech is deemed to be present by application of that threshold), see Fig. 13.

Processing The Results

After sampling has finished, the program calculates the long-term mean level and the active level of the speech samples. Mean level is simply the decibel equivalent of energy divided by total time, but active level (speech voltage) is more difficult to evaluate. The sampling subroutine has provided activity counts for each of the 11 trial thresholds used, so that 11 trial active levels can be calculated, as indicated in Fig. 14.

The true active level is defined as the one that exceeds the threshold used for its derivation by 15·9 dB, so the program interpolates between the two closest values, where one trial activity differs by less than 15·9 dB from its threshold and the other by more. The interpolation is done, after all quantities have been converted to decibels, by successive halving of the interval until a sufficient degree of accuracy has been obtained. The active level having been determined, the program estimates the activity for the signal by using the formula:

activity(%) =
100 antilog [(mean level (dB) − active level (dB)) / 10].

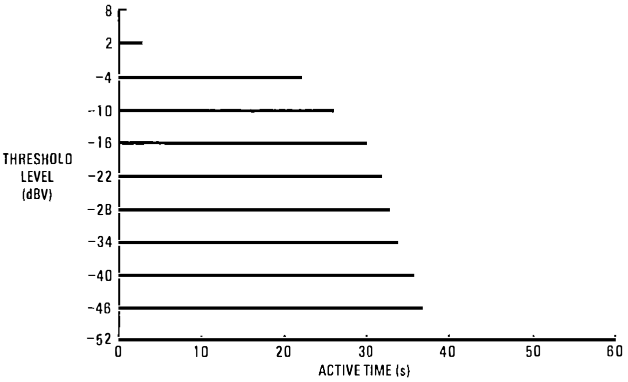

FIG. 13—Typical activity counts for each threshold

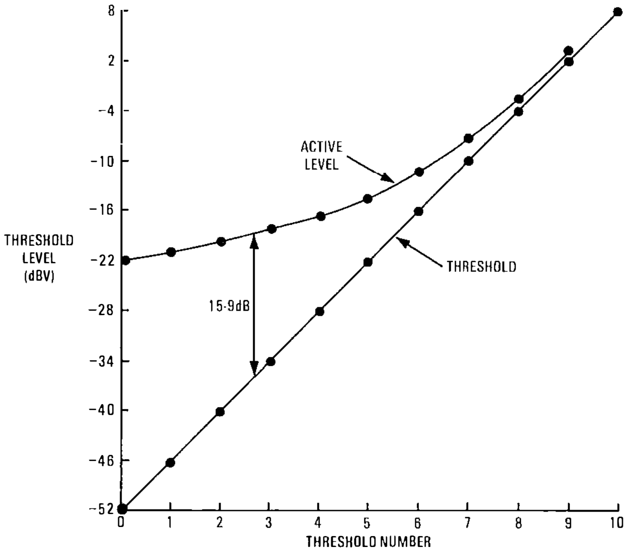

FIG. 14—Relationship between trial active levels and thresholds

Dynamic Range

The dynamic range of the instrument depends, to a large extent, on the signal being measured. A 15 bit ADC is fitted, but in determination of the thresholds for the active level, the present algorithm uses only 12 bit arithmetic, based on the most significant bits from the ADC; 1 sign bit plus 11 bits magnitude provides a 66 dB range. The relative accuracy increases with increasing signal level. The maximum input level is ±10 V; the largest sine wave that can be accommodated without overload is therefore 7·07 V RMS or 16·99 dBV. At the other end of the range, the accuracy diminishes rapidly below a sine wave level of −54 dBV. Speech signals have a peak/mean ratio of some 15 dB; the largest speech signal that can be handled is therefore around +5 dBV. The level of the lowest threshold is about −52 dBV; the smallest speech signals must be around 15·9 dB above this; that is, about −36 dBV. The theoretical dynamic range for speech is therefore about 41 dB. In practice, a dynamic range of about 40 dB (−35 to +5 dBV) is observed; below the lower end of this range, the instrument is not usually able to estimate the active level reliably, although it will still give an indication of sine-wave mean level down to about −54 dBV, and long-term level for speech or noise at still lower levels. In order to achieve the maximum accuracy, it is best to operate the speech voltmeter at as high a level as possible, and measure active levels in the range 0 to +5 dBV.

CONCLUSIONS

The SV6 provides a simple, accurate and repeatable means of measuring speech levels. Unlike previous methods, it requires no operator interpretation, adjustment or calculation, and can be used on live speech.

It will measure speech levels from +5 dBV to −35 dBV, for durations of up to several hours, in balanced or unbalanced circuits. It will also measure continuous signals as a true-RMS voltmeter, and could be adapted for use as a psophometer or for other special purposes, by combinations of hardware and software additions.

The SV6 is supplied in an instrument case, but can also be mounted on a standard 19 inch rack. The equipment includes a filter to reject unwanted low-frequency signals such as hum, and unwanted high-frequency signals such as tape hiss.

Fifty instruments have been made and are in service. Negotiations are in progress to grant a licence for the commercial manufacture of further quantities—the indications are that demand will be strong as considerable international interest has been shown through the CCITT.

Acknowledgements

The author wishes to express his thanks to Graham Trott, who designed the laboratory prototype; to Brian Surtees for assistance with mathematics and statistics; and to David Shumake and Kevin Catto, who built the production prototype.

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Biography

Rowland Carson is an Executive Engineer in the Telephone Systems and Performance Division of BTRL at Martlesham Heath. Born in Ballymoney, Northern Ireland, and educated at Dalriada Grammar School, he started work at BT's Dollis Hill Research Station in 1964 as a Scientific Assistant and has worked on colour television transmission, PCM multiplexing and assessment of speech transmission performance. He holds an HNC and Endorsments.

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Power Systems and Reliability

Part 1—Present-Day Systems

K. E. BANFIELD, B.SC.†

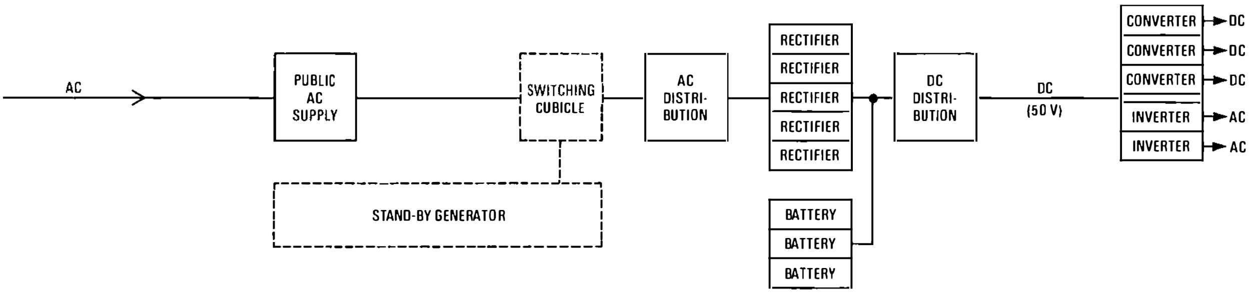
UDC 621.311.4.004.6

The reliability of power systems for telecommunications equipment depends upon the availability of the public mains supply, the provision of a stand-by generator and battery, and the power conversion architecture. Part 1 of this article discusses the reliability aspects of each section of a modern power system. It describes how traditional problems have been overcome by the use of small replaceable power units and sealed batteries to produce custom-built power supplies with any desired input, output and reliability to form variants of British Telecom's Power System 2000 family. Part 2, to be published in a later issue of the Journal, will discuss the reasons and methods for full integration of the power system into the switching architecture.

INTRODUCTION

Power systems for telecommunications applications generally conform to the basic configuration shown in Fig. 1. Some applications do not require a stand-by generator. If battery stand-by is not required, the rectifier/converter combination is replaced by a power unit, which converts the AC supply voltage to the working voltage of the equipment in one stage. Most modern power-conversion units use switch-mode techniques operating above 20 kHz, while the trend in batteries is towards the use of sealed lead-acid chemistry.

For no-break systems, the battery maintains service until the AC supply is restored or the stand-by generator starts. The battery also allows time for manual intervention to repair or restart the generator, or for repair of one or more rectifiers in the DC power subsystem, without the DC supply being interrupted.



SYSTEM DESCRIPTION	$\frac{1}{\text{MTBF of system}}$	= $\frac{\text{generator fail-to-start probability}}{\text{MTBF of AC supply and battery}}$	+ $\frac{\text{generator operating probability}}{\text{MTBF of generator}}$	+ $\frac{1}{\text{MTBF of switch cubicle}}$	+ $\frac{1}{\text{MTBF of AC distribution and battery}}$	+ $\frac{1}{\text{MTBF of rectifiers and battery}}$	+ $\frac{1}{\text{MTBF of DC distribution}}$	TARGET VALUE FOR 50 V SUPPLY	TARGET EQUIPMENT RELIABILITY
1-hour battery, multiple rectifiers, stand-by generator	$\frac{1}{\text{MTBF (urban)}}$	= $\frac{0{\cdot}005}{8\ 2}$	+ $\frac{10^{-5}}{0{\cdot}1}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10^4}$	+ $\frac{1}{1000+}$	+ $\frac{1}{10^4}$	$\frac{1}{700+}$	$\left(\frac{1}{100}\right)$
5-hour battery, multiple rectifiers, stand-by generator	$\frac{1}{\text{MTBF (rural)}}$	= $\frac{0{\cdot}005}{6{\cdot}0}$	+ $\frac{10^{-5}}{0{\cdot}1}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10^4}$	+ $\frac{1}{1000+}$	+ $\frac{1}{10^4}$	$\frac{1}{200+}$	$\left(\frac{1}{50}\right)$
24-hour battery single rectifier, no generator	$\frac{1}{\text{MTBF (rural)}}$	= $\frac{1}{120}$	+ $\frac{10^{-5}}{0{\cdot}1}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10^4}$	+ $\frac{1}{200+}$	+ $\frac{1}{10^4}$	$\frac{1}{100+}$	$\left(\frac{1}{50}\right)$
CUSTOMER DIRECT DIALLING IN									
15-minute battery, single rectifier, stand-by generator	$\frac{1}{\text{MTBF (rural)}}$	= $\frac{0{\cdot}005}{4}$	+ $\frac{10^{-5}}{0{\cdot}1}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10}$	+ $\frac{1}{10^4}$	$\frac{1}{10}$	$\left(\frac{1}{10}\right)$
6-hour battery, single rectifier, no generator	$\frac{1}{\text{MTBF (urban)}}$	= $\frac{1}{170}$	+ $\frac{10^{-5}}{0{\cdot}1}$	+ $\frac{1}{10^4}$	+ $\frac{1}{10^4}$	+ $\frac{1}{20}$	+ $\frac{1}{10^4}$	$\frac{1}{20}$	$\left(\frac{1}{10}\right)$

MTBF figures are in years

FIG. 1—Block diagram of a power system and examples of reliability

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† Energy, Transport and Accommodation Department, British Telecom Local Communications Services

Reliability

British Telecom's (BT's) requirements for the reliability of −50 V DC power supplies for telephone exchanges range from a mean-time-between-failures (MTBF) of 200 years for small rural exchanges to 700 years for key centres. (In the 1970s, the targets were 100 and 500 years, respectively[1].) The public switched telephone network requires no-break power supplies that can be repaired immediately to give virtually 100% availability.

For customer installations, security is often specified by non-mathematical means; for example, whether a no-break supply is required, or whether a long-term battery or generator is required to fulfil direct-dialling-in rules.

The reliability of a power system depends on: the probability and duration of AC supply failure; the probability of the stand-by generator failing to start or failing when in service; and the probability of failure of the rectifier/battery subsystem, AC/DC distribution and converters. The total failure rate is the sum of the failure rates for each subsection. (In Fig. 1, failure rates are shown as inverse MTBF values; this is valid where constant failure rates apply.)

The overall reliability of the system can be enhanced by providing a second AC supply, additional redundant generators, rectifiers or converters, or a larger battery. All of these alternatives increase the probability of the AC supply being restored, or the faulty units being repaired, before the battery stand-by time is exceeded. The key parameter is the mean-time-to-repair (MTTR) a faulty unit, and its value has been extremely difficult to assess in the past because of the difficulties of fault-finding on large traditional power equipment.

Power System 2000

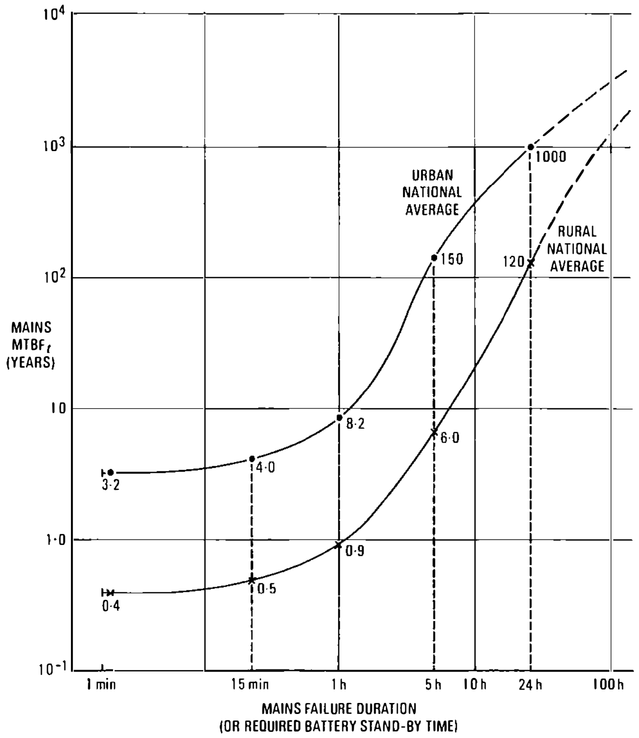
By using smaller power units that can easily be replaced, the parameter MTTR can be considered as the mean-time-to-replace a faulty unit, which is much easier to assess. The concept of using a flexible combination of small replaceable power units to build customised power systems of any desired reliability has led to the development of the modular building-block system known as *Power System 2000*. This flexible approach also permits power systems to be designed for any particular application.

MAINS RELIABILITY

Fig. 2 shows typical national AC-mains-failure statistics. It should be noted that the values shown are national averages grouped into rural and urban categories. Local values may be between or beyond these limits. The dominant factor contributing to the higher reliability of urban supplies is that they are generally laid underground, where they are comparatively immune from environmental effects. Supply disruptions due to industrial disputes are not random and cannot be included in these statistics; however, such disruptions can be anticipated and nullified by stand-by generator operation. No accurate seasonal variation can be determined from existing data.

The mains-reliability statistics shown in Fig. 2 are considered to be typical for this country, though large yearly variations must be anticipated. For instance, during the winter of 1981/82 severe weather conditions caused extended AC mains failures, which led to over 100 telephone exchange outages through complete battery discharge. For that year, the MTBF for rural failures in excess of 24 hours equated to only 17 years, compared with the average of 120 years.

The provision of additional mains supplies to improve security is economically feasible in only very few locations, such as in city centres.



MTBF$_t$: Mean time between failures for failures in excess of time t

FIG. 2—Mains-failure statistics

STAND-BY GENERATORS

Stand-by generators, with start-up times between 0 and 80 s, are normally used to prevent long-term equipment outage due to failure of the mains supply, or for no-break systems as an alternative to long-term battery stand-by.

Generator Failure Modes

The operational MTBF of the generator during normal running is large compared with the total running time when the generator is used in a stand-by mode and, therefore, negligibly affects system reliability. If the generator is used continuously, or for extended periods of stand-by, the operational MTBF of the generator may become important.

The frequent mode of failure is the generator failing to start. This failure mode is caused by random problems such as starter-motor failure, or switching cubicle mis-operation. This factor can be incorporated in the system reliability calculations as a probability of failure to start when called upon to do so. The probability is assessed to be 0·005 or 1-in-200. The factor 200 can be used as a direct multiplier for mains MTBF (from Fig. 2), as shown in Fig. 3.

Generator Mean-Time-To-Repair

For no-break systems incorporating both battery and stand-by generator, the battery is also considered as a back-up for the failed generator, allowing the opportunity for manual intervention to repair and start the unit. Since travel time and fault-finding time is indeterminate, it is difficult to establish a statistically meaningful MTTR figure for generator repair. However, one indicative statistic has emerged: 90% of failed generators are repaired and restarted within 5 hours. This factor, which can greatly improve the system MTBF, has not been included in Fig. 3.

Multiple Generators

At present, multiple generators are installed only in BT's largest centres when necessitated by high power levels. The generators are not configured in a true redundant

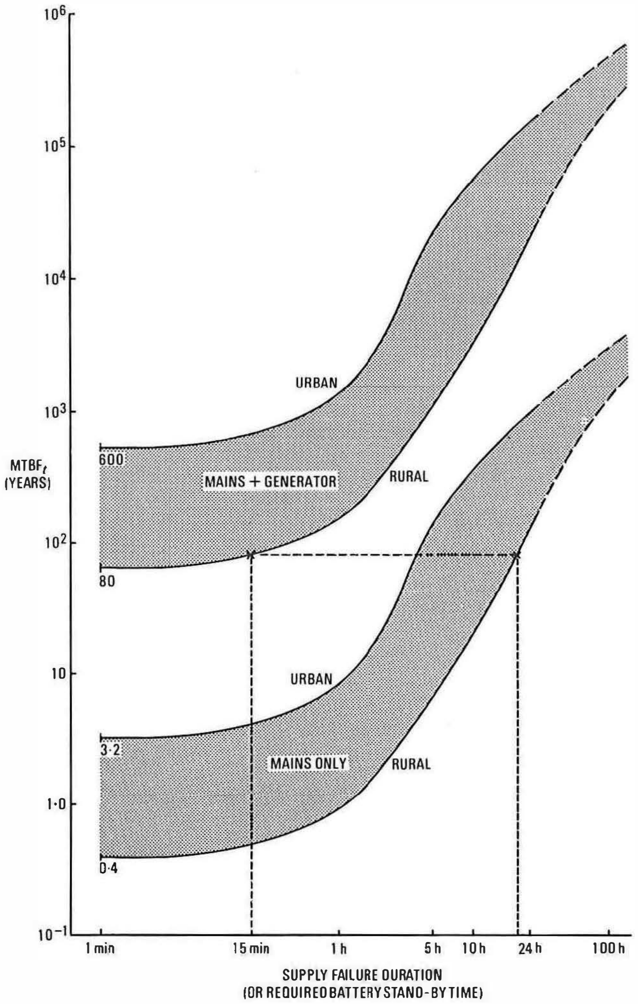


FIG. 3—MTBF$_t$ for mains only and for mains with stand-by generator

arrangement; instead, they feed separate load sections so that, when a generator fails to start, exchange services are only partially degraded. For AC-operated equipment such as air-conditioning and chilling plant, for which higher reliability targets are set, multiple generators are not necessary.

Small Generators

Small mobile or portable generators can be used for temporary replacement, either during planned maintenance, or upon the catastrophic failure of an installed generator.

For Power System 2000, low-powered generators can be used. High-frequency (400 Hz) output generators are compatible with switch-mode power supplies and could offer size and weight advantages in the future. When enclosed in noise-reducing cabinets, generators can be acceptably quiet in near-office environments.

AC SWITCHGEAR AND DISTRIBUTION

Generally, AC switchgear and distribution items are sufficiently reliable so as not to degrade the system. Faults occurring at the interface with active circuit elements are normally included in the failure rate of that element; for example, generator control-cubicle faults in generator statistics, and distribution faults in rectifier failure rates.

BATTERIES

Battery MTBF

Batteries have two failure modes. The first is the random fault, such as an open-circuit inter-cell connector. This type of fault has an MTBF well in excess of 1000 years and is therefore not a critical system parameter. However, dormant faults in batteries present special difficulties to system designers. Identification of this type of fault generally requires a test discharge of the battery.

The second failure mode is the non-random condition full discharge. While discharging during a failure of the AC supply, the battery acts as a short-duration redundant unit. The net reliability is defined as the *MTBF for AC supply failures of duration in excess of time t*, where *t* is the battery stand-by time. If the stand-by generator fails to start, the battery allows time for repair. For rectifier/battery systems, the battery can be considered as a time-dependent redundant module to permit faulty rectifiers to be repaired without disruption of the output. However, the battery cannot cover faults on discharge paths through converters, inverters and the DC distribution beyond the battery. These areas, especially if they are accessible to accidental contact, can become reliability weak points.

Battery MTTR

The battery recharge time is equivalent to the MTTR for a repairable system, in which the battery is a redundant module. The probability of a second mains failure during the battery recharge interval is the ratio of that time interval to the mains MTBF for any given mains failure time. The net probability of a second mains failure duration exceeding the partially recharged battery reserve is always negligible. It is therefore unnecessary to seek extra-rapid battery recharge.

Battery Economics

For higher-reliability no-break applications, the choice between a stand-by generator or a large battery can be analysed for cost effectiveness. For example, as shown in Fig. 3, a desired reliability for a system having a particular power rating in a rural part of the country can be achieved by using either a 20-hour battery, or a 15-minute battery and a stand-by generator. The use of a long-term battery is normally the cheaper solution; furthermore, redundant rectifiers may not be required in the DC system to make it adequately reliable (see Rectifier section). However, a stand-by generator can cover a mains failure over a period of days if adequate fuel reserves are provided or transported in; but a battery is certain to fail if the duration of the mains failure exceeds the battery stand-by time at the prevailing load, unless a replacement battery or mobile generator can be taken to site. Local decisions must depend upon local conditions; for example, to meet direct-dialling-in requirements, a 6-hour battery or a 15-minute battery and stand-by generator must be installed. The 6-hour battery is invariably the cheaper solution, but its reliability is lower and in rural areas may be inadequate.

BT Batteries

Traditional Planté batteries are used in most BT and customer installations. For the office-compatible Power System 2000, only sealed batteries are used; special battery stands and accommodation with high ventilation rates are no longer required and, instead, the sealed batteries are housed in cabinets, which normally match the equipment cabinet.

The sealed batteries preferred by BT are the oxygen-recombination type rather than the excess-electrolyte gel type[2]. The former emits minimal amounts of hydrogen, whereas the latter gradually consumes the excess electrolyte as emissions of hydrogen and oxygen.

In the recombination-type cell, the plates are separated by a fibreglass mat, or similar material. The electrolyte is

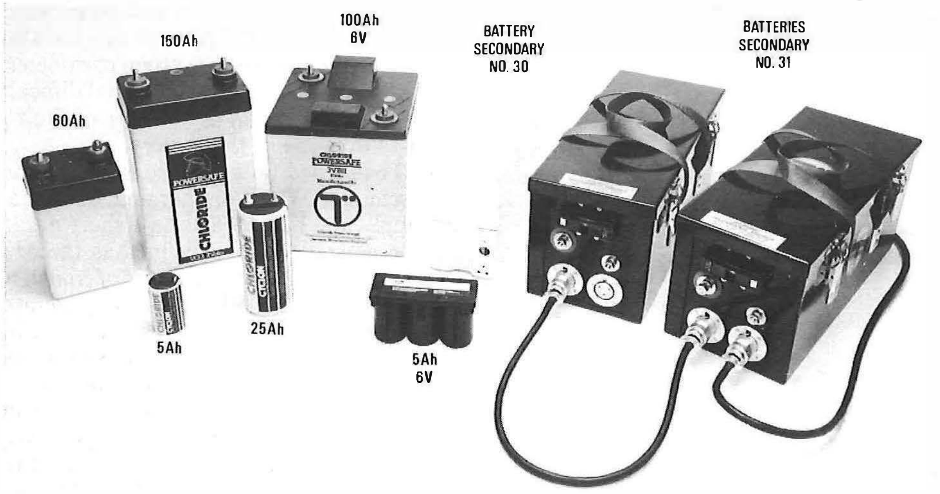


FIG. 4—Sealed lead-acid cells and batteries

absorbed onto this mat, so that the electrolyte is unspillable, and the cell can be operated in any orientation.

For Power System 2000, cell capacities of 5, 25, 60, 100, and 150 A h are available (see Fig. 4); the 100 A h size is configured as a 3-cell 6 V monobloc. The cells have a relatively long life in service on trickle charge, typically 10 years; this compares with 4–6 years for gel-type cells. The cells can deliver at least 50% of their energy in one hour. Comparable figures for gel-type cells are only half of this value.

RECTIFIERS/POWER UNITS

Reliability

Good rectifier reliability has traditionally been achieved through simplicity of design. Rectifier MTBFs well in excess of 20 years are attained with basic copper-and-iron circuits and simple electronic control. Switch-mode techniques, with benefits in size and weight, are now standard; a unit MTBF of between 10 and 20 years is attainable with these more complex designs. For systems without stand-by batteries, parallel redundant power units have been used to give higher security.

For customer installations and small rural telephone exchanges, a single rectifier with battery back-up has been adequate to meet security targets. The provision of a long-duration battery permits the rectifier to be repaired *in situ* or replaced by a small portable unit. For example, 90% of rectifier failures can be corrected by repair or replacement before a 24-hour battery becomes discharged. Therefore, only one-in-ten rectifier failures results in system failure. If the rectifier MTBF is 20 years, then the combined MTBF for the rectifier and battery is 20 × 10 = 200 years. Mathematically, this is equivalent to

$$\text{System MTBF} = \text{rectifier MTBF} \times \exp\left(\frac{\text{battery stand-by time}}{\text{rectifier MTTR}}\right),$$

where the rectifier MTTR is 10 years.

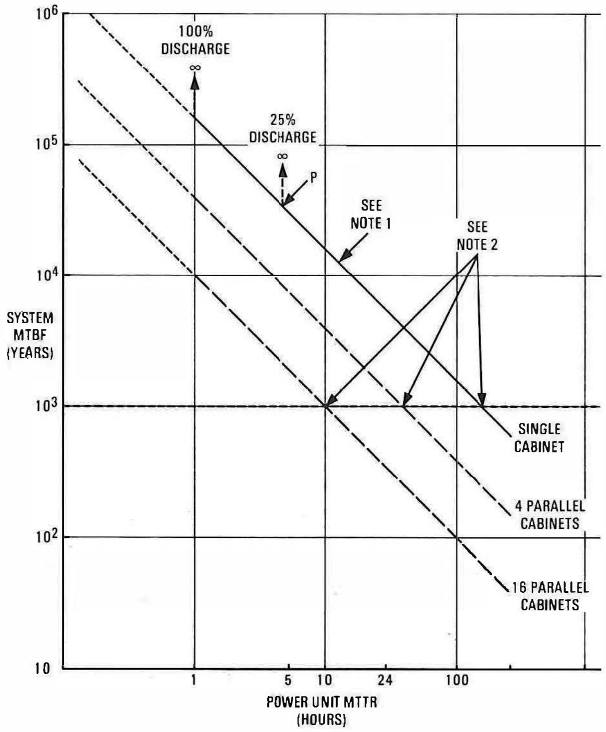
Most telephone centres have multiple redundant rectifiers combined with a 1-hour battery. Traditional rectifiers have been physically large, requiring *in situ* repairs since portable replacements have not been feasible. Design deficiencies, and human error during the design, maintenance and repair of these rectifiers, have meant that the rectifier system MTBF has been well below 1000 years compared to the theoretical value of 10 000 years. Outages caused by genuine component failure have been minimal.

Present-day rectifiers are smaller and more manageable. They can be used in multiple redundant configurations ($n + 1$) with no maintenance. Repair is by replacement, with access to live distribution areas minimised.

The general reliability formula for $n + 1$ rectifiers is

$$\text{system MTBF} = \frac{\text{unit MTBF}}{(n+1)} \times \frac{\text{unit MTBF}}{n \times \text{unit MTTR}} \times \frac{1}{\text{number of cabinets}}$$

Fig. 5 shows an example of the formula for 4 + 1 rectifiers in a single cabinet for variable rectifier MTTR. If these cabinets are paralleled, as for System X^2, the overall system reliability is inversely proportional to the number of cabinets in parallel.



Note 1: The general reliability formula for $n + 1$ power units is

$$\text{system MTBF} = \frac{\text{unit MTBF}}{(n+1)} \times \frac{\text{unit MTBF}}{n \times \text{unit MTTR}} \times \frac{1}{\text{number of cabinets}}.$$

The graphs plotted are for 4 + 1 power units ($n = 4$) and power unit MTBF = 20 years. At point P, where power unit MTTR = 5 hours, the system MTBF = 35 000 years.

Note 2: For parallel System X racks with a system MTBF of 1000 years, the maximum number of cabinets × MTTR = 160.

FIG. 5—Example of the reliability of systems with multiple redundant power units

Security is enhanced if the battery is considered as a short-term redundant module. If the maximum time to replace a rectifier module is less than the battery reserve time under assisted discharge, system reliability is very high. For the example shown in Fig. 5, the probability of two rectifiers failing simultaneously is very small; yet the battery would give five hours stand-by while discharging at 25% of the full load (three of the required four rectifiers still operating). In a manned exchange, or wherever rectifiers can be replaced within five hours, the rectifier/battery subsystem need never fail.

BT Rectifiers

The latest family of standard BT rectifiers and power units (see Fig. 6) uses switch-mode power-conversion techniques[2]. Power rating is between 100 and 1500 W, with a choice of output voltages between 5 and 80 V. The rectifiers can generally be connected in series or in parallel to give any reasonable voltage or current output. Where total rectifier capacity exceeds 5 kW, it is necessary to condition the rectifier current input so as not to exceed harmonic limits stipulated by the Electricity Council; this facility is optional with the largest rectifiers. Many power units have been developed by numerous project groups within BT; these are being rationalised into a smaller range with single and multiple outputs at various voltages and powers.

DC DISTRIBUTION

The DC distribution system should be treated in the same manner as a 240 V AC supply; that is, human contact should be prevented. Then, if cable ratings and fuse discriminations are correctly dimensioned, the reliability of the DC distribution system should be an order of magnitude greater than any active element in the power system. Present policy is to shorten DC distribution paths by distributing rectifiers and batteries towards their point of use.

Power System 2000 cabinets are intended to stand *en suite* with their equipment cabinets; all DC distribution facilities can then be contained within the cabinets.

(*a*) No. 168 (*b*) No. 160

FIG. 6—Rectifiers

CONVERTERS

Second-stage power-conversion units—converters for DC output, and inverters for AC output—use switch-mode techniques in most new equipment. The units are generally configured either individually, so that failure results in outage of that part of the equipment, or as a 1 + 1 system, with either unit being capable of sustaining the entire section load. Subsystem MTBFs of 10 years are typical.

BT Converters

As with power units, numerous DC converters, often with similar specifications, have been developed by BT project groups (see Fig. 7); these can be rationalised into 2 main up-to-date categories, namely System X and UXD5 converters. For Power System 2000, certain proprietary converters are used to complement the existing range.

INVERTERS

Inverters are often configured in 1 + 1 systems, as are converters. They have also been configured in larger *n* + *x* systems, to increase the power rating and to improve security of the AC output. For multiple redundant schemes, the general reliability formula for *n* + 1 rectifiers given above applies. Typical inverters are shown in Fig. 8.

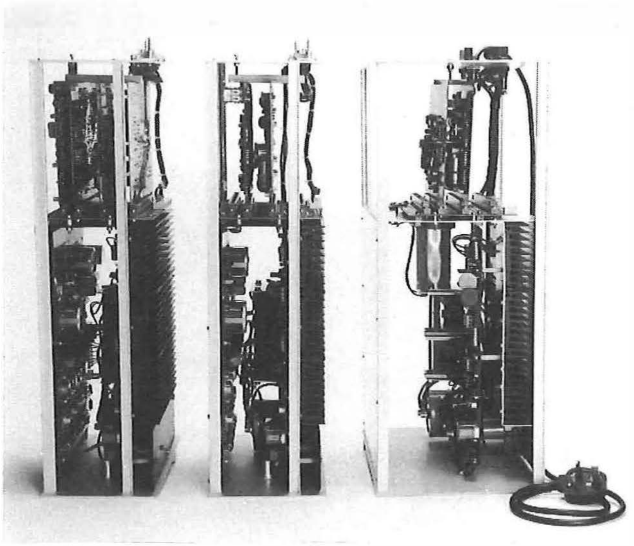
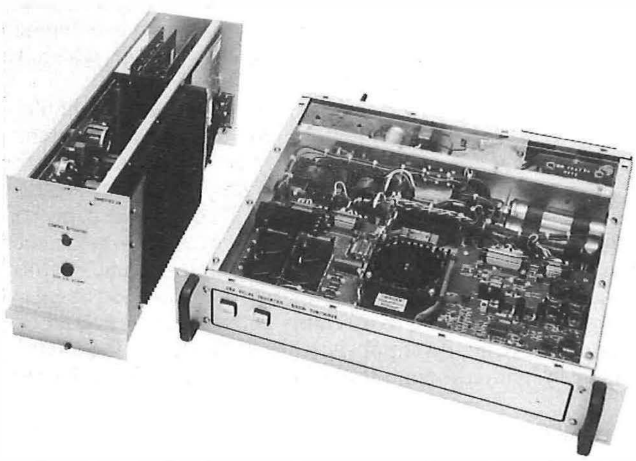
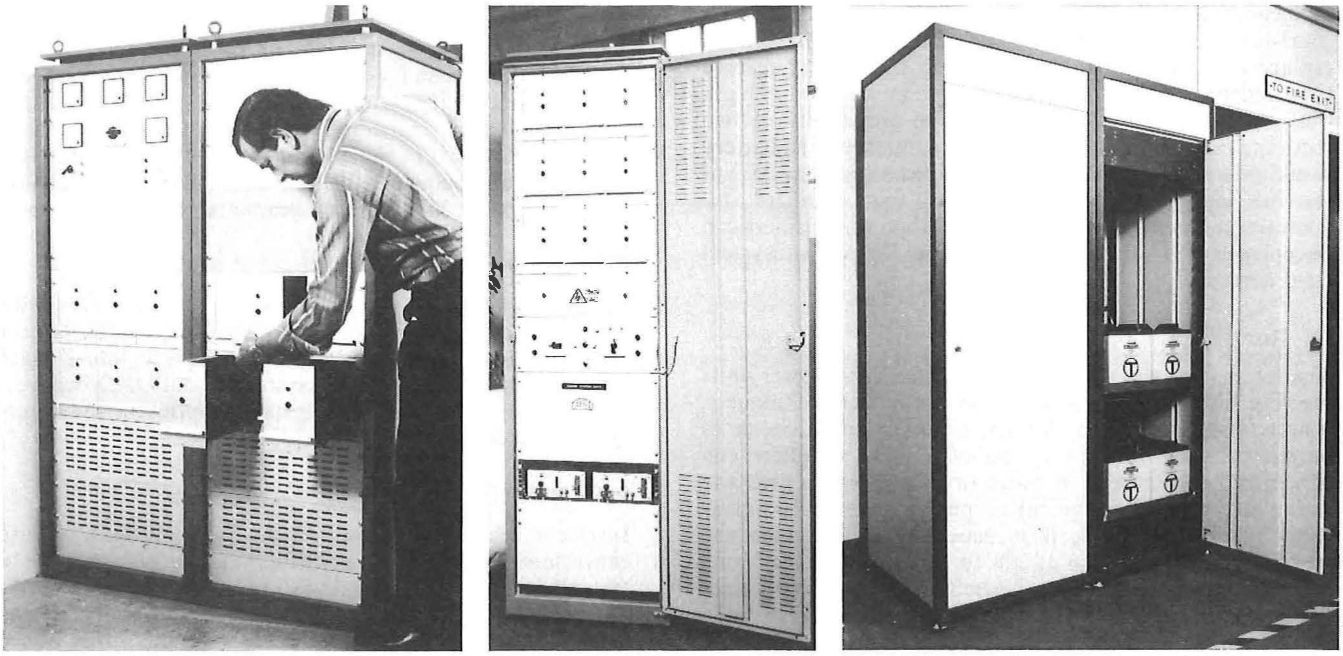


FIG. 7—DC–DC converters



(*a*) No. 2A (*b*) No. 2D

FIG. 8—Inverters No. 2



(*a*) No. 2007—inverters for radio station

(*b*) No. 2006a—uninterruptable power supply for SPC telegraph exchange

(*c*) No. 2008g—DC stand-by for Monarch

FIG. 9—Examples of Power System 2000

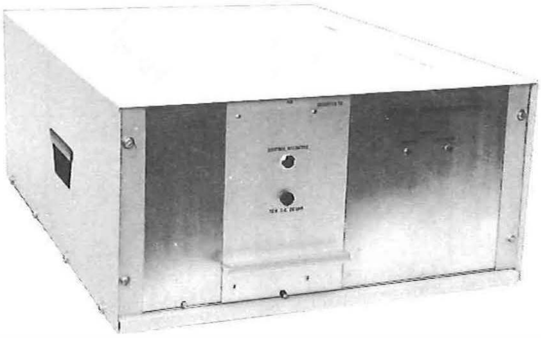


FIG. 10—Power System 2006c—500 V A uninterruptable power supply

One of the first applications for $n + 2$ replaceable units was Inverter System No. 1 developed in 1975/6 for the experimental packet switching system. A system MTBF of 200 years was required and this was achieved by assembling a 7 + 2 system of 860 W inverters. Subsequent development has led to the first modular switch-mode inverter, which was developed especially for BT[3].

The standard inverter combines, in a single module, a DC-to-AC inverter and a static AC change-over switch. A 500 V A module is operated singly or in parallel with other identical units to feed a 240 V single-phase load. No common-control equipment is required. The module converts a 50 V DC input to 240 V 50 Hz AC by switch-mode techniques. Alternatively, it can divert a mains/stand-by 240 V supply to the output, so as to maintain an uninterrupted AC supply to the load. Switching between the inverter and external AC mains supply is at the discretion of the module's logic system, although the priority is selectable by the user.

POWER SYSTEM 2000

The quest for higher reliability and better maintainability in power systems has led logically to the concept of a flexible combination of small units. The basic switch-mode building blocks for Power System 2000 are standard BT approved rectifiers, batteries, inverters, converters, and power units, ensuring good maintainability in the future by replacement with identical or compatible units.

A particular system is configured by selecting appropriate units, adding ancillary switchgear and environmental controls, and packaging into cabinets or shelves. The systems can be attractively packaged in standard 19 inch rack practice (IEC 297) or any telecommunications/computer matched cabinets to form variants of the Power System 2000 family.

For some applications, there may be a capital cost penalty over traditional power systems. However, the improved security, maintainability and compatibility, and the simplified and shortened installation, often reduces the whole-life cost.

Some examples of systems are shown in Figs. 9 and 10.

ACKNOWLEDGEMENTS

The author would like to thank all those people who have supplied information for this article, particularly Mr. J. A. O'Connor, BT Power Division, for information on batteries.

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Biography

Kenneth Banfield is an Executive Engineer in BT's Telecommunications Power Division. He joined BT in 1971 after graduating in Physics at the University of Birmingham. He has worked on various power aspects and, since 1978, specialised in power electronics (switch-mode power conversion). He has worked on the development of inverters, rectifiers and converters for modern power systems. He represents BT on the British Standards Institution Power Electronics Sub-Committee, and at various national and international conferences.

Resources Management

K. KNIGHT†

INTRODUCTION

Early in 1983, a group of General Managers from British Telecom (BT) attended a presentation on a copyright training programme produced by Development Dimensions International (DDI) of Pittsburgh, USA, called *Resources Management*; the presentation was organised by the British Telecom Management College (BTMC) in conjunction with DDI. As a result, Bradford Telephone Area decided to try out the training programme. Trade union representatives in Bradford were informed at an early stage of what was intended and further informed throughout the programme.

OBJECTIVES

The Resources Management programme has two basic objectives: to improve efficiency in the way resources are used, so that productivity is increased and measureable results are produced in eight weeks; and to develop a climate of awareness and receptiveness that would continue to encourage efficiency.

STRATEGY

The starting point of the Resources Management programme is to give participants a practical framework that enables them to look for inefficiency; this framework is termed the *input/output concept*, and is illustrated in Fig. 1. It is readily seen that improved productivity arises from either

(*a*) more wanted output for the same input (that is, by increasing goods and/or services and keeping the resources constant), or

(*b*) the same wanted output for less input (that is, by maintaining the same level of goods and/or services and using less resources).

Possible causes of resource losses are considered within eight areas: materials, energy, labour, money, equipment, tools, buildings/accomodation, and unwanted output. Subsequently, individuals identify specific resource losses in their own working areas and decide on projects to reduce these, and so improve productivity.

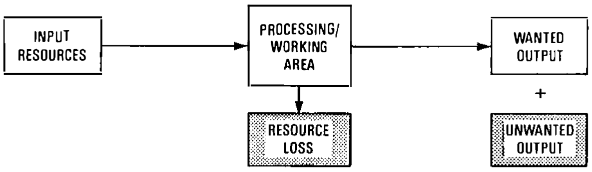

FIG. 1—The input/output concept

THE RESOURCES MANAGEMENT SYSTEM

The Resources Management programme involves three groups of people working together under the co-ordination of an administrator, as shown in Fig. 2

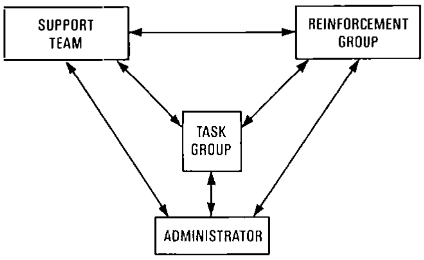

FIG. 2—The Resources Management system

Administrator

The administrator(s) organises all events, trains the others involved and generally progresses the programme from start to finish. A company's own staff are used as administrators.

Task Group

The task group is the focus of the Resources Management programme. It comprises the people who directly improve the management of resources and hence productivity, and normally has 12, 15 or 18 members.

Reinforcement Group

The managers of the staff in the task group, each having three staff in the task group, form the reinforcement group. Their role is to assist their staff in selecting an appropriate project, and to give advice and encouragement during its implementation.

Support Team

Managers and specialists from at least the same level of the organisation as the reinforcement group form the support team. They provide a broader company view, and are primarily responsible for verifying and costing the results of projects. Each member of the support team supports the three task-group members of a particular reinforcement-group manager. Members should not normally have staff in the task group, but should certainly not act as support for their own staff.

PRELIMINARY TRAINING

An instructor from DDI trained six BT staff, one each from Bradford and Gloucester Telephone Areas and four from BTMC, in an administrators' workshop. This was an intensive one-week residential course held at Bexhill at the end of April 1983. As a result, DDI accredited all six staff as administrators for Resources Management. Subsequently, the BTMC staff were assigned, two to each Telephone Area, to help with training and to gain first-hand experience of the Resources Management programme.

AREA TRAINING

In Bradford Telephone Area, 15 staff (level 1) were selected

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† Bradford Telephone Area, British Telecom

for the task group; these comprised Assistant Executive Engineers, Telecommunications Superintendants, Executive Officers and Higher Clerical Officers from most divisions in the Area. Their five supervisors (level-2 staff) formed the reinforcement group and another five level-2 staff the support team.

The programme started in May with a three-day reinforcement workshop for the ten members of the reinforcement group and support team. This covered not only the training that the task group were to receive, but also the additional training for the reinforcement and support roles. The format included slide and video presentations, and role playing.

Task-group training followed with three training sessions, each of half a day held at weekly intervals. Between sessions, members of the task group had to meet individually with their manager in the reinforcement group and then their support team member. This arrangement enabled assistance to be given to the members of the task group, as necessary, to identify and select a project for making more efficient use of resources within their own working environment.

PROJECT IMPLEMENTATION

The members of the task group were then totally responsible for carrying through their project during the remainder of the programme. They fitted this work in with their normal work, including regular consultations with their reinforcement and support managers. The programme normally lasts about eight weeks from the start of the task-group training to the completion of the project. However, because the Bradford programme ran into the main summer leave period, it was extended by over a month. Even so, the time allowed for the programme was considered to be tight by many participants. At the end of the programme, projects were verified and costings agreed by the members of the support team.

PROJECTS

Most projects were neither large nor innovatory. In fact, one of the strengths of Resources Management is that it enables projects that might not have been pursued after the initial idea to be carried through. In addition, it caters for small individual projects, the combined benefits of which can be significant.

Projects implemented in Bradford Telephone Area included:

(*a*) arranging the external painting of buildings directly with contractors,

(*b*) avoiding the unnecessary filing of records,

(*c*) reducing the number of separate holdings of small stores,

(*d*) replacing 15 cwt vehicles with 6 cwt vehicles,

(*e*) purchasing building materials in bulk rather than in individual lots,

(*f*) changing from daily to weekly time sheets,

(*g*) discontinuing the duplication of records,

(*h*) reducing the periodicity of some traffic-meter readings,

(*i*) redeploying unused effort, and

(*j*) speeding up provision of service.

RECOGNITION

The programme culminated in a *recognition meeting* held at the beginning of September. The managers in the reinforcement group presented details of individual projects and announced annual savings for their three task-group members. When the total savings were known, the General Manager, in the presence of the Area Board and trade union representatives, thanked everyone for their efforts, and individually congratulated members of the task group on their performance.

RESULTS

The programme in Bradford Telephone Area achieved first-year savings of £40 000. Most projects had continuing benefits and many savings will increase in future years. Some members were considering further projects. As to be expected, participants did not find it easy to fit in the extra work required of the programme with their normal workloads. Also, parts of the training package, which is still in an American format, came in for some criticism.

However, there was general acclaim for the opportunity to work with peers from across the organisation, and to share ideas and problems. The system of team working, involving management support, was considered a strong point of Resources Management. So too was the structured approach with a set, albeit demanding, timescale. Not surprisingly, the members of the task group were pleased with the successful results of their projects.

CONCLUSION

Bradford Telephone Area intends to build on what has already been achieved and is undertaking a further Resources Management programmme. The timing will avoid the problems caused during a period of high annual leave.

The BTMC has signed a licence for using Resources Management within BT and will be pleased to supply further information and any assistance necessary.

ACKNOWLEDGMENTS

The author thanks David Tidswell and Ray Lawrance from BTMC Horwood House and Bexhill, respectively, for their help with the training in Bradford.

Biography

Ken Knight is with the Bradford Telephone Area. He joined the then General Post Office in 1962 as an open-competition Telecommunications Traffic Superintendent in the Manchester Telephone Area. In 1965 he transferred to North West Region Headquarters and then back to Manchester Central Area in 1969. He moved to Bradford Telephone Area in 1970 on his promotion to Senior Telecommunications Superintendent. After a period of being responsible for the management of automanual centres and then the forecasting, planning and designing of automatic telephone exchanges, he became the Service Manager responsible for handling customers' service problems and accounts disputes. He has been trained and accredited by DDI as an administrator for their Resources Management programme.

A Hundred Years of Royal Mail Parcels

H. R. HENLY, C.ENG., M.I.E.R.E.†

UDC 656.882(091)

In 1983, the Post Office celebrated the centenary of the parcel post service. This article, based on the Christmas Lecture given by the Institution of British Telecommunications Engineers, in December 1983, briefly traces the history of the service and describes some of the innovations that have been introduced over the past 100 years.

INTRODUCTION

The Royal Mail Parcels Service currently handles around 180 million parcels per year, delivering to commercial and private addresses throughout the British Isles. Although the service is recognised as starting in 1883, in fact parcels were being delivered by the Post Office long before that time. This article traces the history of the service and looks *en-route* at the development of some of its many facets.

EARLY BEGINNINGS

The Royal Mail has a very ancient lineage. In the *Old Testament* you may read that 'the posts went with letters from the King'. In this country, at least from the time of King John, a special service of messengers was maintained, both at home and beyond the seas, for the conveyance of the King's despatches and of the private correspondence of the Court.

The *Chronicles of Croyland*, from the time of King Edward in 1480, contain instructions for the organisation of relays of horses for carrying the King's despatches (see Fig. 1).

The first 'Master of the Posts', Sir Brian Tuke, was appointed by Henry VIII as long ago as 1512 and was paid £66 12s 6d a year to see that horses were kept available for persons travelling on the King's business.

In the sixteenth century, private persons were allowed to send their letters by the King's post, but they had to settle the fee by bargaining with the messenger. Such was the origin of the *Royal Mail*, but it carried only letters.

Proposals were made in 1635 for a public service, and by the end of the reign of Charles I the Post Office had taken shape. Fig. 2 shows part of the Royal Proclamation of Charles I, 1635, which established the public postal service and fixed postage rates. The Civil War caused much confusion of the postal services. Little is known of the service during this period, when the title *Royal Mail* would have been highly inappropriate. Nevertheless, a service existed and an Act of Parliament of Charles II, 1660, settled postage rates and produced the first Post Office Charter (see Fig. 3).

The first known parcel service in the UK was started in 1651 by a Londoner, William Dockwra. The charge was 1d for parcels up to 1 lb (0·5 kg) in weight and up to £10 in value. Parcels were collected and delivered within the area of the City of London, Westminster, Southwark, Rotherhithe, Wapping, Ratcliffe, Limehouse, Stepney, Poplar and Blackwall. One of Dockwra's advertisements is shown in Fig. 4. Dockwra was probably responsible for the first use of postmarks, examples of which are shown in Fig. 5. This service competed all too well with the Post Office and a number of legal actions were brought against Dockwra. The service came to an end in November 1682, only to be taken over by the Post Office almost immediately, and parcels

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† Engineering Department, The Post Office

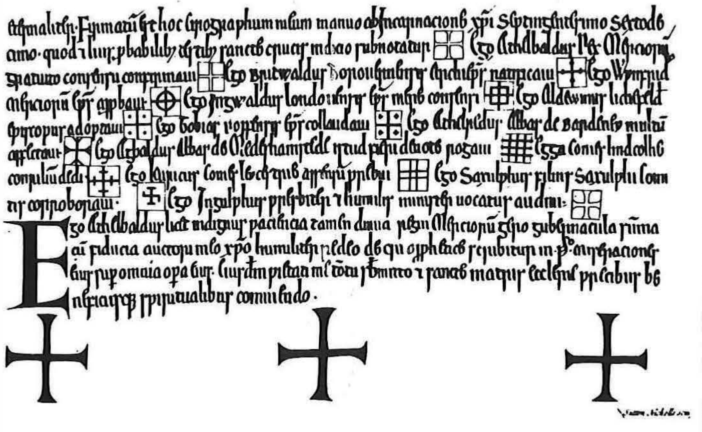


FIG. 1—Extract from the *Chronicles of Croyland*, 1482

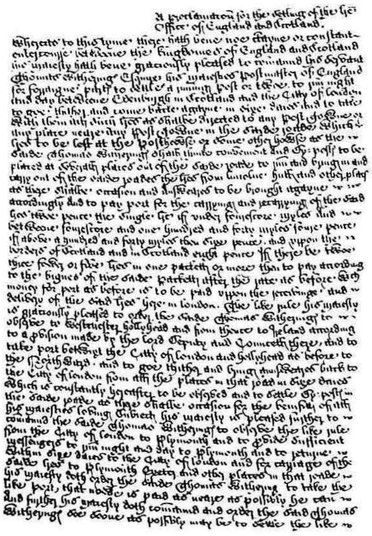
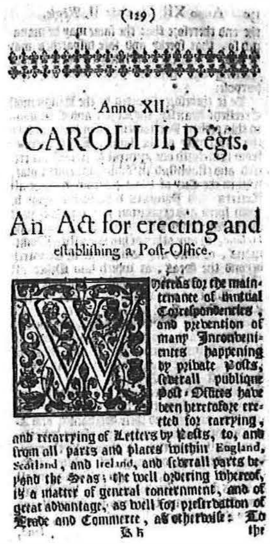


FIG. 2—Royal Proclamation of Charles I establishing the public postal service in 1635



(129)

Anno XII.

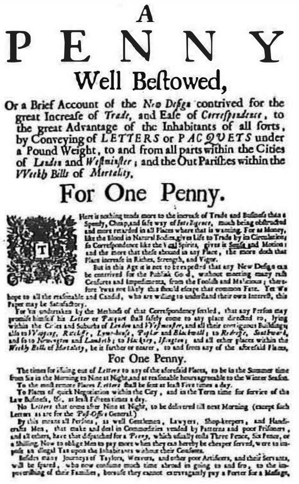
CAROLI II. Regis.

An Act for erecting and eſtabliſhing a Poſt-Office.

Whereas for the maintenance of mutual Correſpondencies, and prevention of many Inconveniencies happening by private Poſts, ſeverall publique Poſt-Offices have been heretofore erected for carrying, and recarrying of Letters by Poſts, to, and from all parts and places within England, Scotland, and Ireland, and ſeverall parts beyond the Seas; the well ordering whereof, is a matter of general concernment, and of great advantage, as well for preſervation of Trade and Commerce, as otherwiſe: To the

Kk

FIG. 3—The Royal Charter of Charles II



A
PENNY
Well Beſtowed,
Or a Brief Account of the *New Deſign* contrived for the great Increaſe of *Trade*, and Eaſe of *Correſpondence*, to the great Advantage of the Inhabitants of all ſorts, by Conveying of *LETTERS* or *PACQUETS* under a Pound Weight, to and from all parts within the Cities of *London* and *Weſtminſter*; and the Out Pariſhes within the *Weekly Bills* of *Mortality*,

For One Penny.

FIG. 4—Dockwra's penny post advertisement 1680–1681

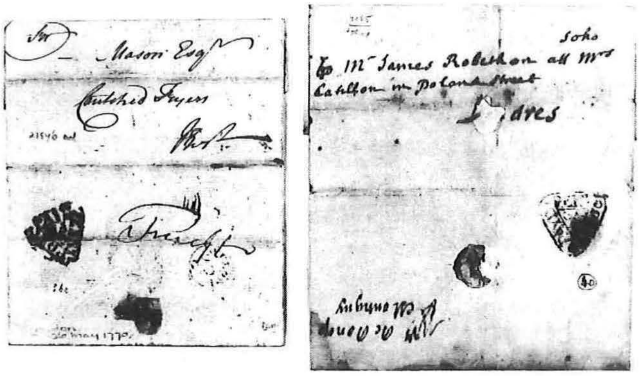


FIG. 5—Dockwra's penny postmarks

CAUTION.

BY the Acts 9 Queen Anne, and 41 Geo. III. the Practice of collecting Letters and Packets, and sending and conveying them by Stage-Coaches, Carts, Waggons, *Ships*, *Vessels*, *Boats*, *Barges*, and other Conveyances, instead of by the Post, is declared to be Illegal, and the Penalty for every offence is £5, and One Hundred Pounds for every Week, one Half to be paid to any Person who shall give Information of the same.

All Persons are therefore warned against the Commission of these Offences.

By Command of the Post Master General,

F. FREELING,
Secretary.

FIG. 6—Cautionary Leaflet issued by the Postmaster General invoking the Act of Queen Anne.

continued to be carried. About that time, during the war with France, some very curious parcels were entrusted to the Post Office for conveyance to the continent; for example, 'Two servant maids, going as laundresses to my Lord Ambassador Methuen; fifteen couples of hounds to the King of the Romans with a free pass'. However, these were casual assignments and no systematic parcel service existed.

Dockwra's service continued under the Post Office as a penny post and, by 1702, it handled over 1 million parcels and letters per year. In 1794 the fee was increased to 2d (approximately 1p), and disappeared only with the postal reforms of 1840.

Before the end of her reign, Elizabeth I had proclaimed a monopoly for the Post Office over the carriage of letters, except where a letter accompanied a parcel. Fig. 6 shows a cautionary leaflet produced by the Postmaster General enforcing this monopoly. From 1794, parcels were treated as large pieces of mail and charged for as heavy letters.

Another interesting and little known fact is that from 1691 until 1823 the Post Office had not one but two Postmasters General. This novel bisection of the office was almost certainly for political reasons—one Whig and one Tory. The Post Office had no monopoly on the carriage of parcels and private companies continued to carry parcels by carriers, wagons and stage coaches. By the 1820s, there were several large companies in London and the larger cities operating nationwide parcel services, and there is strong evidence that they were using adhesive labels to denote the pre-payment of charges long before Rowland Hill introduced the Penny Black. Unfortunately, few of these labels have survived.

(*a*) Sir Henry Fawcett, Postmaster General 1880–1884

(*b*) Frederick Baines, CB., organiser of the Parcel Post

FIG. 7—The grand architects of the Parcel service

When the railways came in the late-1820s, the conveyance of parcels was an important part of their business. As the rail network expanded, so did the volume of parcels carried by them and, by the 1850s, the railway companies had effectively cornered the parcel business. The postal reformer, Henry Cole, in 1839, wanted to establish a uniform parcel post, and Rowland Hill suggested in 1842 that the Post Office should operate a parcel service. These proposals were voiced many times in the Post Office and in Parliament, but the railway companies and Pickfords were a powerful opposition lobby and the proposal was effectively shelved for 44 years.

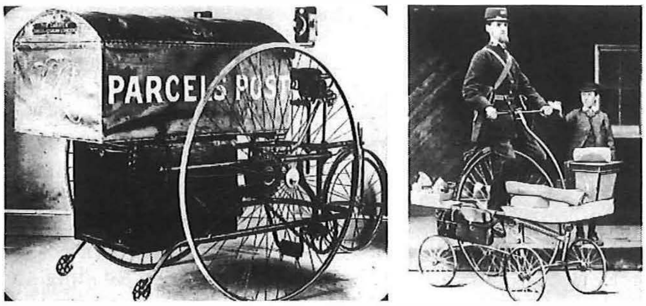
In 1837, another private postal service, which included parcels, was formed in London and operated by The London Parcels Delivery Company. Its advertisement offered same-day delivery within Greater London with charges varying from 3d for a 3 lb parcel to 1/- (5p) for a 56 lb parcel. There were surcharges for the outer London area and a 6d surcharge for each 28 lb above 56 lb up to a maximum of 112 lb (50 kg).

However, by the 1860s, the Post Office was being forced to reconsider its position on parcels, and Frederick Hill, at that time an Assistant Secretary to the Post Office and younger brother of the then retired Rowland Hill, was undoubtedly a prime mover towards the start of a parcel service. A Book Post was started against much opposition, mainly from the railways, and this was used to press the case for a parcels service. It was a popular service—and not only for books as the following anecdote reveals: A woman called upon to pay a surcharge on a pair of trousers sent by Book Post quoted the Post Office Guide ruling that 'anything which is open at both ends may go by Book Post'.

Frederick Hill realised the business advantages of a parcel service and argued that other European countries, notably Prussia, already had a parcel post service, saying 'England, instead of being notably in the van is in the rear'.

In fact, Britain was overtaken by her North American colony of New Brunswick, which introduced the first parcel service in the British Empire on 1 February 1859.

The birth of the General Postal Union in 1874 (now known as the *Universal Postal Union*), due mainly to the



(*a*) A parcel mail tricycle, circa 1883

(*b*) A centre cycle nicknamed the *hen and chickens*, circa 1883

FIG. 8—Early parcel carrying vehicles in use in London

The first Parcel delivered in the United Kingdom by Parcels Post.

Miss Geraldine Mawe,
2 Belsize Park
Gardens,
Hampstead

F. E. Baines.

PARCELS POST.
Hampstead Green, 200, Haverstock Hill
(LONDON. N.W.)
(For Postage Stamps and Date Stamp)

FIG. 10—The first parcel delivered in the UK by parcel post

efforts of the Prussian Postmaster General, led to more discussions of a parcel service, and to a convention for the exchange of parcels between the countries of Europe, Great Britain and her Empire and many other countries in the world. Britain and Ireland, it was noted, could not sign the convention because they did not have a parcel service, and they were given until 1882 to bring the convention into effect.

THE PARCEL SERVICE

The man who made the breakthrough in the problems that had prevented the setting up of a parcel service was Sir Henry Fawcett (Fig. 7(*a*)) who, in spite of being blind since childhood, had risen to the position of Postmaster General. He gave the task of overcoming all the difficulties to his Inspector General of Mails, Frederick Baines (Fig. 7(*b*)). Baines' greatest success was in reaching agreement with the railway companies who were demanding 50% of the postage collected on all parcels. They finally agreed to settle for 51% of the postage on items carried by rail.

In April 1883, Fawcett announced in Parliament that an agreement had been reached and that 'no effort shall be wanting on the part of the Post Office to bring a scheme for a parcels post into operation with the least possible delay'. Whilst the Post Office Parcels Act was being drafted, Baines proceeded with a detailed plan of campaign.

Baines and the Postmaster General were faced with a daunting task. Nearly 1000 Head and Branch Post Offices had to be adapted or rebuilt and arrangements made for collection and delivery to more than 15 000 postal districts. Existing offices had to be adapted for the new task and new premises acquired.

Fig. 8 shows two of the parcel carriers used in London for carrying parcels. The first is a tricycle, whilst the second (Fig. 8(*b*)) was known as the *hen and chickens* owing to its arrangement of one large and four small wheels.

A marquee was erected in Glasgow to house the parcel-sorting operation (Fig. 9). Baines foresaw that new buildings would be required in London for parcel handling. An institution known as *The Middlesex House of Correction*, or as *Clerkenwell Jail* and as *Cold Bath Fields Prison*, in Clerkenwell, was taken over. The main sorting area was set up in the treadmill house. This later became today's Mount Pleasant Post Office, one of the largest sorting offices in the world. Baines' planning extended to minute detail on a wide range of problems. Drawings exist for parcel baskets and for the design of horse-drawn carts; all of which were prepared for the opening of the service.

The Royal Mail Parcel Service started on 1 August 1883.

Fig. 10 shows the label of the first parcel, sent appropriately by the chief architect of the service—Frederick Baines. It was delivered by the Post Office to 2 Belsize Park Gardens, Hampstead. All in all, 1883 was indeed a busy year for the Post Office.

By 1885, the Post Office was handling 26·5 million parcels per annum. An article in Caskells' magazine describes a visit paid to the parcel post department in St. Martin's-Le-Grand where some of the more curious items that were sent by parcel post were shown: a box containing two live snakes;

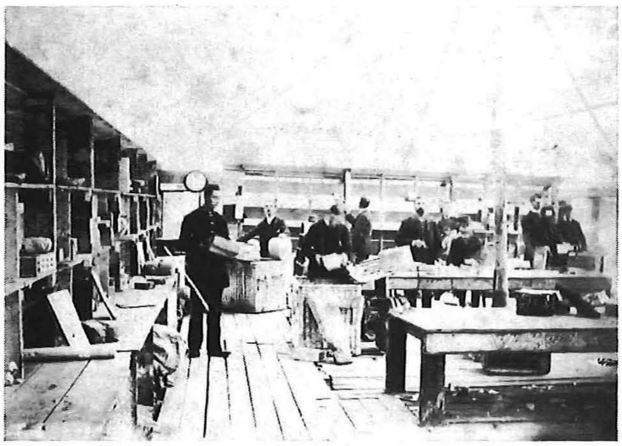


FIG. 9—The marquee erected at Glasgow to house the parcel-sorting operation

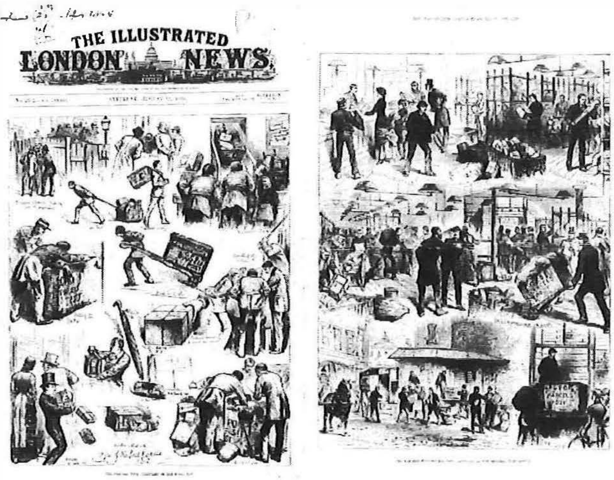
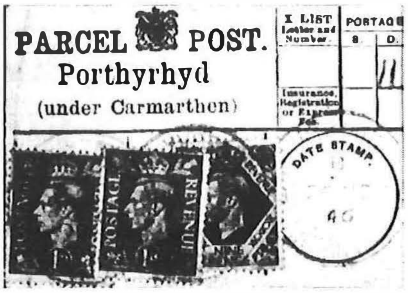


FIG. 11—Parcel handling on the first day as seen through the eyes of the *Illustrated London News*

FIG. 12—How we work our postman in the country. A sketch from *Nature* showing the variety of parcel post



PARCEL POST.
Porthyrhyd
(under Carmarthen)

FIG. 13—The last parcel label recovered at Porthyryd in 1946

a tin box full of live leeches; a collection of curling irons, garters, socks and ice cream—all together on a warm day. Just before Primrose Day 1886, 10 000 packets of primroses were sent from the country to London, and nine bundles of firewood!

Fig. 11, from the *Illustrated London News*, depicts parcel handling on the first days of the service, whilst Fig. 12 shows the great variety of items sent by parcel post. It is interesting to note that there is still the same variety today. To coincide with the inauguration of the parcel service, labels, designed to take the necessary stamps to pre-pay the postage, were issued to all offices. These labels had an area reserved for the date stamp of the office receiving the parcel, the object of the label being to enable the stamps to be cancelled on a flat surface before application to the irregular surface of the parcel. This procedure worked well for private parcels, but business houses dealing with large quantities of parcels could not be bothered with such a cumbersome procedure and they stuck the stamps directly on the parcel. It was also used as a means of accounting for parcels sent by rail. The use of the label for this purpose was abandoned at the outbreak of war in 1914 and the issue of labels then ceased. Remaining stocks of labels continued to be used up to the late-1920s, and one label from Porthyrhyd has been found dated 1946 (see Fig. 13).

In 1885, the foreign and colonial parcel post was introduced initially to India, Egypt and Gibraltar, while 1898 saw the introduction of pre-payment of customs charges for parcels addressed to foreign countries.

In 1883, five contractors were appointed to operate horse-drawn mail carts (see Fig. 14) in the major towns and cities, and attention was directed to the design of suitable vehicles for parcel carrying in order to provide some independence from the railways.

Horse-drawn parcel coaches were introduced in 1887 in a bid to cut costs and further reduce dependence on the railways on the long-haul routes. By 1890, the night coach was operating from London to Oxford, Colchester, Watford and Chatham. Highway robbery was not uncommon and the coaches carried armed guards. The last run of the Brighton–London coach was in June 1905, after which it was replaced by a motor vehicle (see Fig. 15).

The first horse-less van—steam propelled—was used on parcel carriage between London and Redhill in 1897. In 1898, a Daimler van was introduced between Reading and Newbury and three motor parcel vans were introduced in 1903 for the London, Liverpool and Manchester parcel service. In the field of transport, the British Post Office led the World. Figs. 16 and 17 show two early vehicles, whilst Fig. 18 depicts the first rural post car, which was introduced at Sittingbourne, Kent in 1910.

In 1928, an experimental electric van, the Electro-mobile (see Fig. 19) was put into service.

By 1930, air transport had developed considerably and flying boats were used on the service to India, and carried Royal Mail parcels. Nowadays, a large proportion of mail, including parcels, is carried by air on both internal and international routes.

Some very interesting developments in a different form of transport took place in the middle of the last century. In 1870, the pneumatic despatch railway was opened to carry letters and parcels between Euston Station and the General Post Office in the City. It consisted of a cast-iron-lined brick tunnel of roughly horse-shoe shape about 4·5 ft wide. Steam-driven suction fans sited at Holborn drew air out of the tunnel which had to be kept air-tight by elaborate seals of rubber or leather—which were eaten by rats. This railway was the successor of earlier experimental systems, including one between Euston and the North Western District Office. Fig. 20 shows a carriage and the mouth of the tube.

The system fell into disuse after only eight or ten years. Twenty years later, a scheme was proposed to reopen it after it had been converted to electric power, but nothing came of it. Part of the tunnel is now used to carry telephone cables. Only two of the carriages have survived, one is in the London Museum and the other at The Bruce Castle Museum. Ironically, in recent years, similar schemes have been under investigation both in America and Germany.

In 1909, the design of the Post Office Railway was initiated, but the First World War and its aftermath delayed the project and the railway was finally opened for service in 1927. It is a 610 mm (2 ft) gauge electric railway some 20 m beneath the streets of London, and links seven principal offices and two main-line rail terminii. This underground railway crosses some 10 km of East, Central and West London and thus avoids the weather and traffic conditions

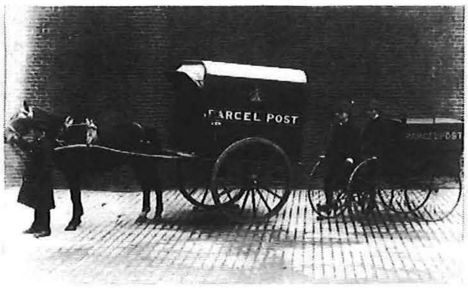


FIG. 14—A horse-drawn mail cart shown here with a twin-driven cycle parcel post carrier, circa 1887

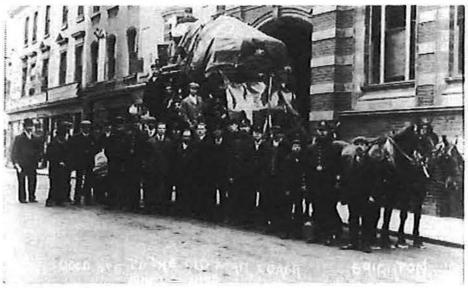


FIG. 15—The last run of the Brighton to London parcel mail coach; it was replaced by a motor vehicle in 1905

FIG. 16—The first McNamara experimental motor mail van (capacity 7 cwt); it was fitted with an adapted horse-van body and operated on the London mail contract in 1905

FIG. 17—Royal Mail parcel coach, London to Brighton at Friar's Oak, 1905

FIG. 18—The first rural post car at Sittingbourne, Kent, 1910

FIG. 19—One of the two Electro-mobile battery electric vans 1928

that disrupt transport on the surface. Apart from minor modifications, its design remains basically unchanged today. Each two-car train (Fig. 21) can carry 40 parcel bags or 110 letter bags at a maximum speed of 55 km/h. Currently carrying some 12 million bags per year, the railway still makes a valuable contribution to the Post Office's transport system.

Returning to the present, the Post Office has continued to develop its own transport and now has the largest fleet in the country, using large articulated vehicles and domestic air transport for its long-haul routes.

From the outset, a large proportion of the parcel volume carried has been from commercial customers; for example, mail order companies. Since October 1969, when the Post Office ceased to be a Government department and became a nationalised corporation, it has adopted an increasingly commercial attitude. The Post Office operates in a highly competitive environment where conventional parcels are concerned and now handles more parcels than all other carriers put together—about 180 million each year—and aims to deliver in the UK within three days. There are 23 000 Post Offices in the UK, which serve as acceptance points. In addition to the traditional parcel service, there is an overnight contract service for next-day delivery—the *Nightrider*—in the Greater London Area and this makes use of a distinctive label.

Contract services for local delivery are also operated. These require the minimum of packing and, as with the Nightrider service, the limits on size and weight are relaxed.

Datapost was introduced in 1970 and is still growing rapidly in importance. It is a highly-reliable overnight door-to-door conveyance service for important packages using air and road transport (see Fig. 22).

MECHANISATION

Now let us turn briefly to that part of the parcel service concerned with mechanisation. Clearly, in a business which is very labour intensive (with 122 000 operational staff working on letters and parcels) and one which involves a high degree of arduous manual work, the Post Office must look continuously at how technology can be harnessed to keep the business competitive and efficient.

Conveyors are the arteries of the mechanised offices. The earliest conveyors were installed in 1902 for the Post Office Savings Bank and in 1910 in the newly completed King Edward Building, London, to handle letter bags. In 1925, the Manchester Parcel Office was opened. This used two rising conveyors to bring parcels from the loading platform to the first floor and discharged them into trolley baskets. From these baskets the parcels were sorted manually into a nest of 12 chutes giving access, by conveyors, to the secondary sorting positions, known as *roads*, on the floor below.

In 1927–28, the Inland Parcel Office at Mount Pleasant was opened. In this installation, parcels were brought from the loading bay by two conveyors and discharged on to a long storage glacis. They were manually sorted via multiple hoppers on to seven distributing conveyors. Unfortunately, this installation, which was, at the time, one of the largest and best equipped mechanised offices in the world, was destroyed by bombing in 1944. Parcel offices at Birmingham, London South East, Liverpool, Newcastle, Bristol and Nottingham were all mechanised in the 1930s, and the first

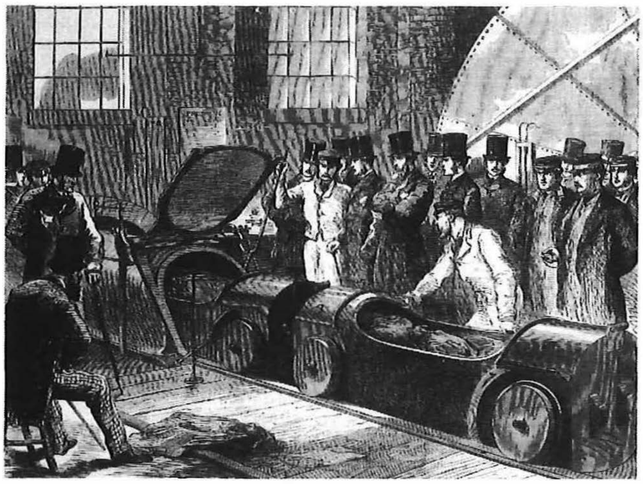


FIG. 20—First despatch of mail bags through the pneumatic tube from the North Western District Office, Eversholt St., to Euston Station, 1863

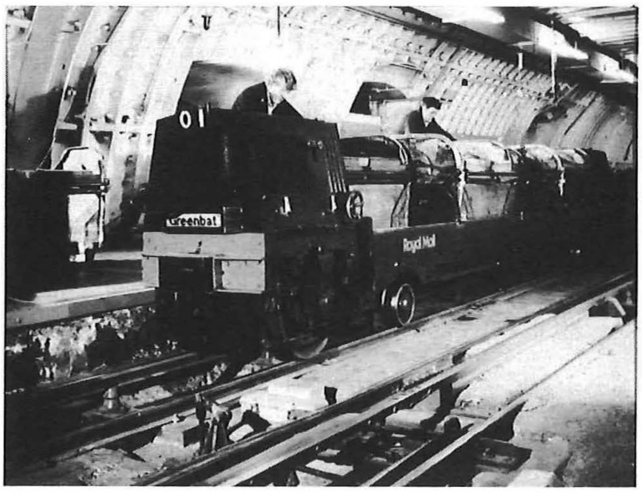


FIG. 21—The Post Office Railway

FIG. 22—Datapost by air

twin-band riser was installed at Crewe in 1932. All of these installations were still in use in the 1950s.

To eliminate the physical effort entailed in manually sorting parcels to a number of receptacles, the Post Office began experiments in 1937 at Paddington Sorting Office with a Sovex parcel-sorting machine. After reading the address, the operator placed the parcel on a trapdoor and pressed a button corresponding to the required destination. The trapdoor opened and dropped the parcel into one of a continuously moving chain of hoppers. An electromechanical control system ensured that at an appropriate point the hinged bottom of the hopper was opened and the parcel dropped onto a cross-conveyor, which carried it to a secondary sorting position.

Development was resumed after the war and machines were installed at Leeds and London Western District Office. Overhead chain conveyors were first used by the Post Office at Leamington Spa in 1955 for the transport of parcel and letter bags within a sorting office. Since then, close to 30 km of chain conveyor have been installed at various offices.

FIG. 23—Proposed location of PCOs under the parcel post plan

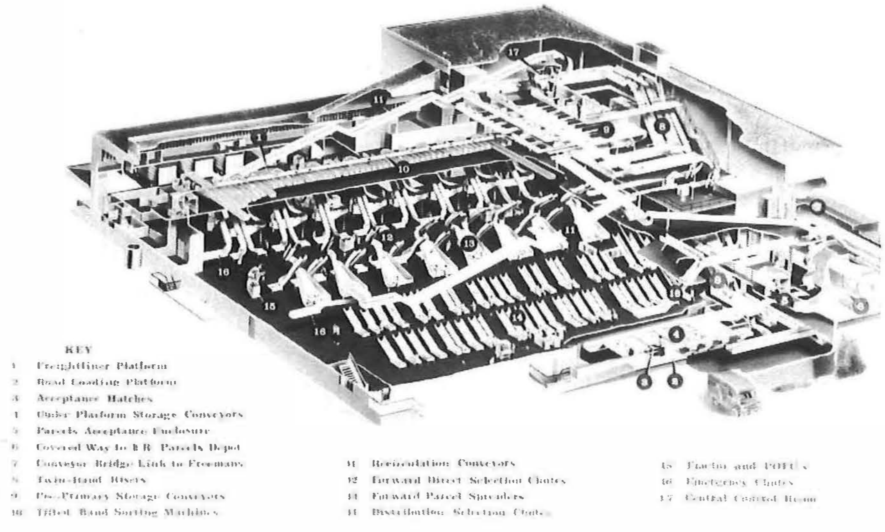


FIG. 24—An exploded view of Peterborough PCO

FIG. 25—A tilted-belt parcel-sorting machine seen from the operator's position

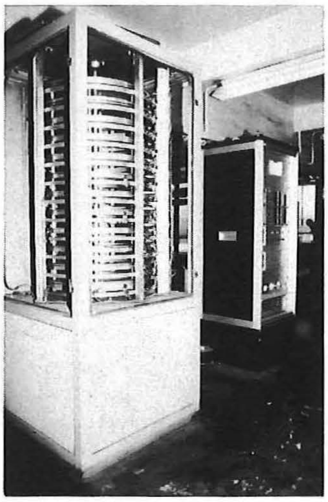


FIG. 26—A new microprocessor-based parcel-sorting-machine controller alongside an earlier electromechanical pin-wheel controller at Sheffield PCO

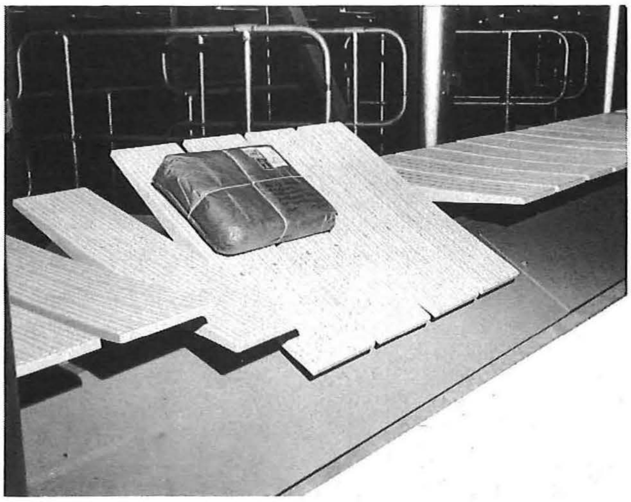


FIG. 27—The tilting-slat parcel-sorting machine at Redhill PCO

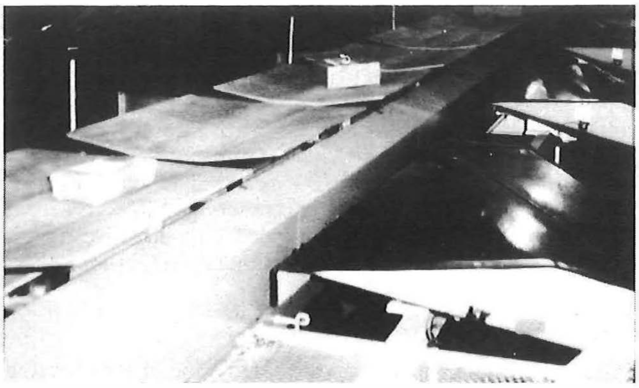


FIG. 28—The tilting-tray parcel-sorting machine at Watford PCO

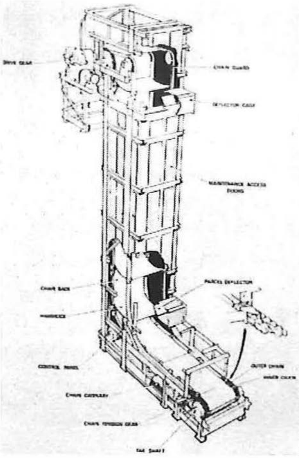


FIG. 29—The Langton riser

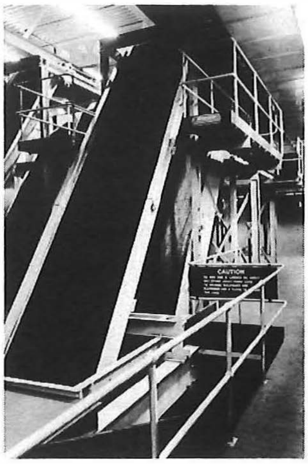


FIG. 30—The twin-band riser

The early-1970s saw the introduction of the parcel-post plan in which parcel sorting was to be concentrated at 27 Parcel Concentration Offices (PCOs). These offices would be sited so as to optimise transport of parcels between them. Fig. 23 shows the location of the offices concerned.

Fig. 24 shows a cut-away view of the PCO at Peterborough, which is a medium-sized office. The first impression gained on entering such an office is that of walking into a machine. It comprises a number of sorting machines connected together by a system of conveyors and chutes. This office uses the tilted-belt sorting machine shown in Fig. 25.

The tilted-belt machine, originally developed by the Australian Post Office in 1950, was redeveloped by the British Post Office and three machines were installed at Worcester in 1962. The machine comprises a conveyor belt tilted at 37° to the horizontal and, at right angles to the lower edge of the belt, a side wall containing a number of discharge doors. The belt initially runs horizontally to form an induction section. Parcels loaded at the induction section travel down the belt in contact with the side wall. The operator, after reading the address, presses an appropriate key on a keyboard to select the destination. The control unit times the movement of the parcel down the belt and, when it reaches the appropriate discharge point, the door is opened and the parcel slides from the belt into a chute. In this way, a parcel can be routed to one of a number of destinations. As a result of the success of the first machines, it was adopted as the standard and between 1962 and 1981 over 100 were installed in the UK. The number of destinations provided varied between 20 and 50, according to the office.

The control system for the tilted-belt parcel-sorting machine was originally electromechanical, but this has been superseded by electronic and, more recently, by microprocessor-based systems. The latest microprocessor-control system now in use in the Sheffield and Birmingham PCOs is shown in Fig. 26, together with an electromechanical pin-wheel controller that it replaced.

In recent years, the need has arisen to handle larger and heavier parcels and for faster and more flexible sorting machines. Consequently, a tilting-slat machine was installed at Redhill Parcel Office for operational and engineering assessment in 1980. This is shown in Fig. 27. It comprises a line of slats carried on a driven chain. Each slat is 175 mm wide and can be tilted to either side. Parcels are carried by a number of slats according to its length and the slats are tilted sequentially to discharge the parcel into the destination chute. This machine can handle up to 5000 parcels an hour and utilisation is high because it can be fed by 4 induction stations.

Another high-speed machine is the tilting-tray sorting machine which has been installed at Glasgow and Watford.

FIG. 31—Mail all-purpose trailer equipment (MATE)

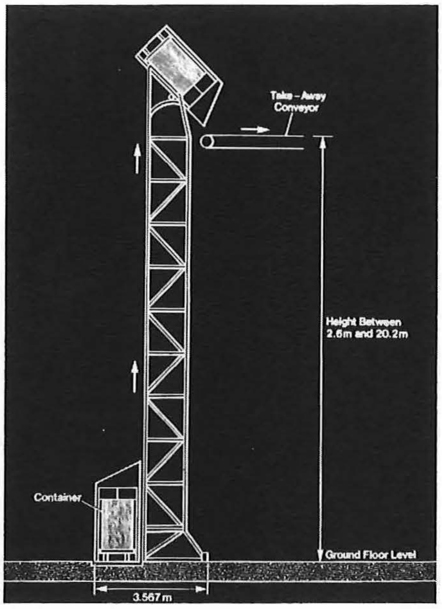


FIG. 32—The high-speed lift-and-tip machine

FIG. 33—An experimental automatic container filler on trial at Cardiff PCO

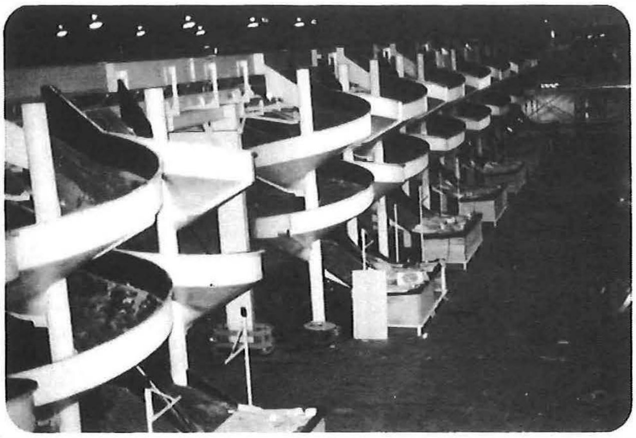


FIG. 34—The safe-glide spiral chute at Glasgow PCO

Fig. 28 shows the installation at Watford. The trays, of an appropriate size for an average parcel, are attached to a chain, which is in a continuous loop. This has the advantage of being very flexible as regards layout, and throughputs as high as 10 000 parcels per hour can be achieved. It can handle large items by allocating two trays, and a large number of selections (for example, 500) can be made.

Considerable developments have been made over the past 30 years in the use of containers and uplift systems. Systems such as the Langton riser (Fig. 29) and the twin-band riser (Fig. 30) were developed in the 1960s for the uplift of loose parcels and bags. Nowadays, most parcels transported between sorting offices are carried in containers called *MATES* (mail all-purpose trailer equipment), shown in Fig. 31, or in pallet retention units (PRUs).

Until recently, MATES were automatically emptied only by rotary tippers and the contents then uplifted by a slow-rise belt conveyor. A recent development is the high-speed lift-and-tip machine (see Fig. 32) now installed at Redhill and Glasgow. This elevates the MATE containers to a high level, discharges the parcels and then returns to ground level.

Packing containers by hand is an arduous and expensive task. Currently, methods of automatically filling containers at the discharge chutes of the parcel-sorting machine are under development. Fig. 33 shows an experimental container filler on trial at Cardiff PCO.

Chutes are widely used to carry parcels under gravity from the sorting machine to a lower level for further sorting or packing into containers. Until recently, chutes were designed by empirical methods and their performance was unpredictable. Parcels could attain high speeds with consequent parcel damage. Computer-aided research has enabled the Post Office to design a spiral chute (the safe-glide) in which the speed and the path travelled by the parcel is controlled. Regardless of the size or weight of the parcel, it always emerges at the bottom of the chute at only 3 m/s. Fig. 34 shows safe-glide chutes installed at Glasgow PCO.

The safe-glide chute has also been installed at Redhill, Leeds, Glasgow and Watford and has proved so successful that it is now being sold to foreign postal administrations.

What of the future? Already new technology is being examined with a view to improving the efficiency of the handling and sorting operations. Currently, the application of bar-codes to parcel sorting is being considered. If all parcels had a machine-readable code as part of the address, they could be automatically sorted thus fully utilising the capacity of the latest parcel sorting machines. The bar-code also yields valuable quality-of-service information. Dependent upon the application, the bar-code can be read by using either a laser scanner mounted across a conveyor, or by means of hand-held light-pens.

CONCLUSION

The above abbreviated history of the Royal Mail Parcels Service has of necessity omitted a great deal of information. The aim has been twofold: to trace the history of the service, and to show the considerable innovative genius which has been responsible for the rapid developments that have taken place mainly in the past 100 years. The challenges to ingenuity are still there as the parcel service enters its second century, both in making the service cost effective and in attracting new business from the general freight market.

ACKNOWLEDGEMENTS

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COST 201—A Procedure for the Optimisation of Telecommunication Networks

D. GREENOP, M.SC.,† and R. CAMPBELL, B.SC.*

UDC 621.39 : 681.327.8

The optimal planning of a telecommunication network is a complex and difficult task. Ten European countries have participated in the COST 201 project with the purpose of designing a mathematical procedure for the optimisation of national switched and transmission trunk networks. This article gives a general description of the methods of solution used in the procedure.

INTRODUCTION

This article summarises the results of four years of British Telecom's (BT's) collaboration in a joint European project on telecommunication network optimisation. The project, known as *COST 201*, was carried out under the auspices of the COST‡ organisation. Ten countries participated in the project and each contributed a full-time researcher.

All the participating administrations were interested in methods for designing the most economic national network that would satisfy a given grade of service. Such a network should also be suitably protected to ensure a specified minimum standard of service when it is disrupted either by equipment failure or sudden increases in demand. COST 201 has developed a computer-based optimisation procedure that can be used to plan and evaluate such a network.

Currently, BT has an assortment of manual and computer-based methods for network planning. Today's business requirements demand that planning methods should respond quickly to changes in demand on the network through either the introduction of new services or fluctuations in economic activity. There are also pressures to reduce both the planning lead times and planning effort.

To meet these requirements, planners are making greater use of computer-based planning methods. The advantages of such methods include the possibility of handling complex mathematical techniques in the planning of the network, the ability to access and manipulate network information more easily, and the quick response to the provisions of new services.

The COST 201 procedure has been developed as a medium-to-long-term planning tool for producing optimal network designs. The advantages of the procedure over other planning programs available in BT include its ability to handle large networks (600 nodes), to integrate the optimisation of the switched and transmission networks and to include network protection methods.

This article describes the design philosophy of the procedure, the network model adopted and the component modules inside the procedure. Finally, brief details of tests carried out on a realistic network are given.

OPTIMISATION METHODS

COST 201 has applied mathematical optimisation methods to the economic planning of networks. The methods used are typical of those applied to many other operational research problems.

The greatest difficulty encountered in the optimisation process is that of mathematically modelling the physical system in question. In practice, the problem is likely to be extremely complex with many factors affecting the behaviour of the system. The first step is always to produce a simplification or model of the practical situation.

The next step is the establishment of mathematical functions that usually carry out either the minimisation or maximisation of some quantity. This function is known as the *objective function*. In most cases, several quantities are involved in the objective function, some of which are variables, while others are constraints. It is necessary to keep the objective function as simple as possible by making certain assumptions about the behaviour of some variables; this is known as *reduction*. Similarly, some constraints may be disregarded; this is known as *relaxation*.

In this project, the global objective function has been reduced into simpler functions handled by different parts of the procedure. In each case, the function refers to the minimisation of cost, subject to differing quality-of-service constraints.

Fig. 1 illustrates the shape of a typical objective function. The procedure developed searches for the global minimum. However, as illustrated, it is possible that local minima may be found.

A problem associated with the use of many objective functions is that, when the procedure is run as a whole, the combined effect may be to miss the global optimal solution.

Tests made with the whole COST 201 procedure indicate that the feasible region is wide and that the global minimum is very flat. This is to be expected given the size of the problem handled. It also suggests that several networks are acceptable as solutions.

TERMINOLOGY

Network planning and network optimisation, in particular,

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† National Network Strategy Unit, British Telecom National Networks

* Local Network Strategy Department, British Telecom Local Communications Services

‡ COST is a committee for European Co-operation in Scientific and Technical Research. It was originally set up by the European Economic Community (EEC) for research into subjects, such as meteorology and pollution, that were too expensive or too wide ranging for individual countries to undertake in isolation. Participation in projects is open to all 19 European countries, and not just those that are members of the EEC.

Representatives of the governments of each EEC country form the Committee of Senior Officials (CSO), which decides on areas in which research should be carried out. It also determines which countries are interested in collaboration in each particular field, and prepares the legal agreements necessary to initiate a project. The UK is represented on the CSO by the Department of Trade and Industry.

For each major area of research, a technical committee is set up to determine projects that need to be tackled and to advise the CSO. The Technical Committee—Telecommunications is responsible for all the projects in telecommunications and has a representative from British Telecom.

All COST projects in telecommunications are coded *COST 2XX*. Apart from COST 201, British Telecom is also participating in COST 202 on digital local networks, COST 203 on component reliability, COST 205 on radio propagation above 10 GHz, COST 208 on optical-fibre systems and COST 211 on video redundancy techniques.

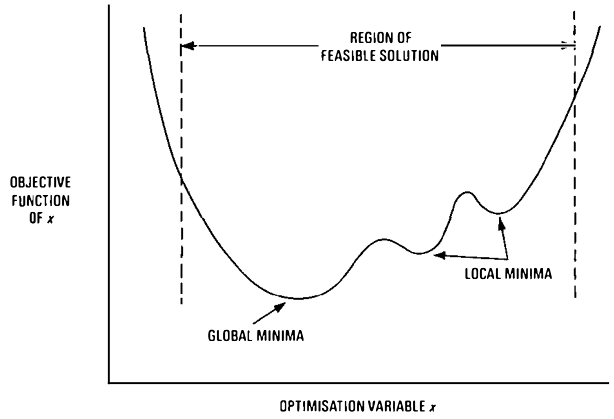


FIG. 1—Example of an objective function

use terminology and concepts derived from fields such as graph theory, traffic theory and mathematical programming. To assist the reader, some of the frequently used terms in this article are explained. For further information on network planning terminology, the reader is directed to a book produced in the early stages of the project[1].

A telecommunication network can be described in terms of theoretical graph concepts. The COST 201 procedure uses two graphs, one each for the switched and transmission networks. A graph is constructed from *edges* and *nodes*; in the switched network the edges are identified as trunk groups and the nodes as switching centres. For the transmission network, the edges are transmission media and the nodes transmission centres. A graph normally has *flow* on it; for the network graphs, this flow is traffic in the switched network and circuit demands in the transmission network. Simplified definitions of terms used in this article are as follows:

Network model This refers to an abstraction of the real network into a network upon which the algorithms work.

Algorithm This is a mathematical method, usually heuristic, which performs some function on the network model. An algorithm need not be an exact mathematical function, but rather an approximated solution method.

Program This refers to the computer software used to realise the algorithms on the network model.

Procedure This refers to the collection of algorithms and programs.

Target network This is the set of input data that specifies a network to be optimised.

Traffic relation This refers to the traffic between any two switching nodes.

Grade of service This is the probability that a call is lost in the network.

Final-choice blocking or grade of service This is the grade of service offered to traffic on its final trunk group routeing.

End-to-end blocking or grade of service This is the overall grade of service between originating and destination switching nodes, independent of routeing paths and the number of trunk groups involved.

Quality of service This is a subjective measure of the quality of the network that reflects the behaviour of the network in failure or overload condition.

PROJECT SPECIFICATION

The problem to be studied was how to minimise the total network cost under the constraint of meeting certain network quality-of-service criteria. Fig. 2 illustrates the interrelationship between the different parts of the problem. The left-hand side of the figure represents the optimisation of the traffic routeing in the switched network, and the right-hand side the circuit routeing in the transmission network. The network optimisation takes place between the opposing poles of quality of service and cost.

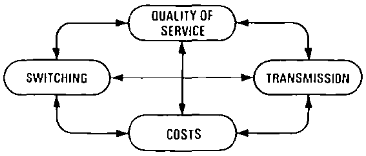


FIG. 2—Interrelationship between parts of the procedure

The planning process covers a range of activities spanning different time-scales and degrees of details. Fig. 3 illustrates some typical aspects of the planning process. This project aims at providing a procedure for use in the medium-term, long-term and strategic planning horizons of phases 4 to 7.

The project started with the definition of an outline specification that the algorithms should be capable of meeting; the most significant aspects of this specification are:

(*a*) to be capable of working on large networks of the order of 600 switching nodes,

(*b*) to be able to run on such a network in approximately 6 to 8 hours on a computer,

(*c*) to include network protection methods,

(*d*) to be able to evaluate the quality of service and cost of a network,

(*e*) to use end-to-end blocking in the switched network,

(*f*) to be able to treat a mixed technology environment,

(*g*) to include switched and transmission circuit modularities,

(*h*) to be capable of both hierarchical and non-hierarchical routeings in the switched network,

(*i*) to integrate into one procedure both switched and transmission networks,

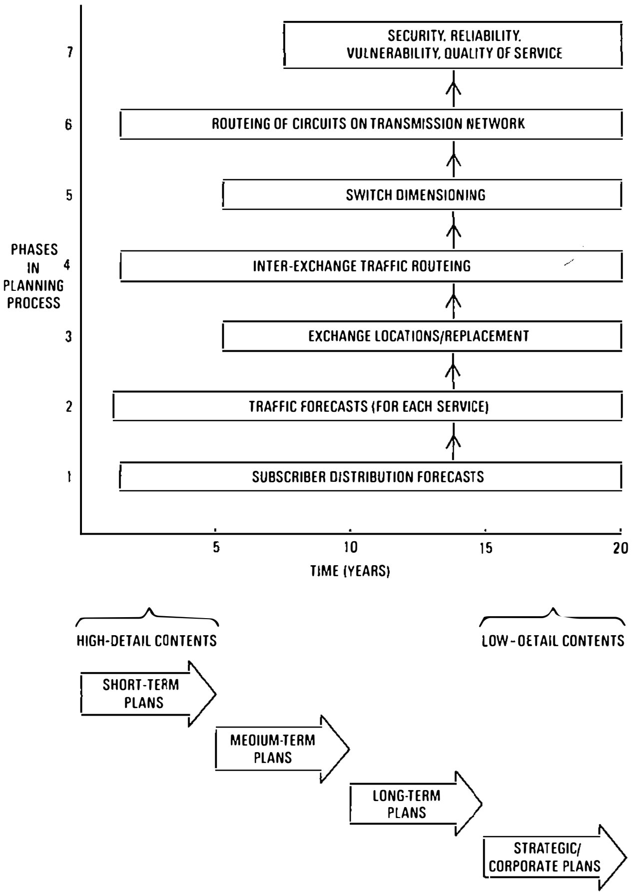


FIG. 3—The planning process

(*j*) to be capable of optimising a target network 10 to 15 years hence, and

(*k*) to include, if required, the existing transmission network, and to be capable of routeing on transmission systems with capacity constraints.

From this specification, it was decided to emphasise the need to have a procedure that would work on large networks. This put a constraint on both the level of detail that could be included in the network model and the complexity of the algorithms.

Certain problems were immediately obvious, including how to find good methods for calculating end-to-end blockings and for organising the large amounts of data needed to test the algorithms. Previous work had been carried out in this field, but on networks considerably smaller than that intended for this procedure.

NETWORK MODEL

The model adopted for the algorithm to work on consists of two graphs, the switched network graph and the transmission network graph. The important difference between these graphs is the flow that is routed upon them. On the switched network graph, traffic is routed and the edges represent trunk groups that are dimensioned with circuits adequate to carry this flow. The edges on the transmission network graph represent transmission sections, and the flow routed on them is a circuit demand constructed from trunk groups, switched leased circuits and non-switched circuits. Figs. 4 and 5 illustrate these concepts.

In the transmission network, the lowest level of detail is the transmission section, which can be either analogue or digital. As it is possible to have both types of edges between nodes, and in the same system, a further level of detail called a ***transmission medium*** is introduced. For example, in the example shown in Fig. 6, sections g and f may be run in the same duct. The use of transmission media enables a maximum limit to be put on the capacity of a system. In this case, it could be the size of the duct space or the number of coaxial pairs.

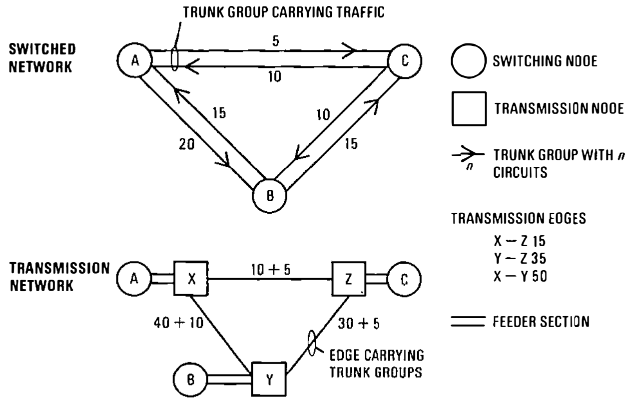


FIG. 4—Network model

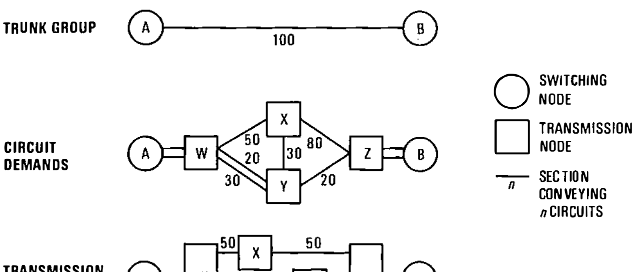


FIG. 5—Edge representation

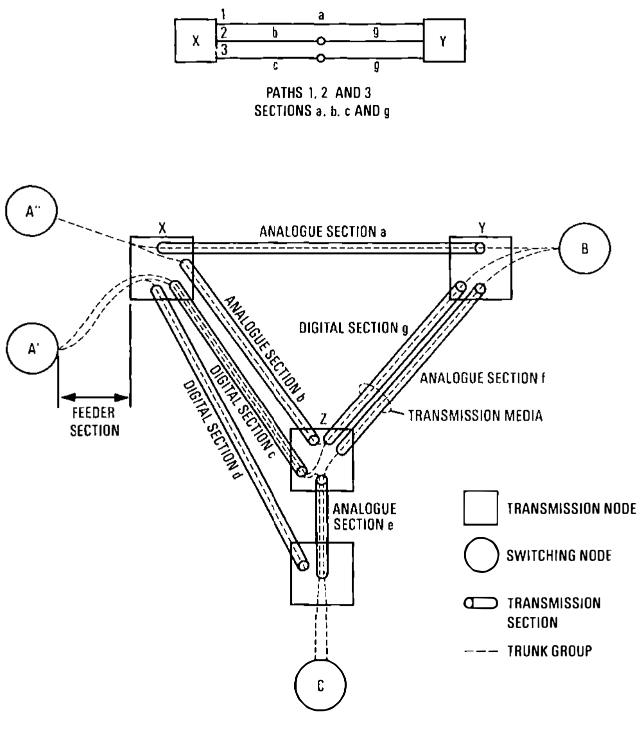
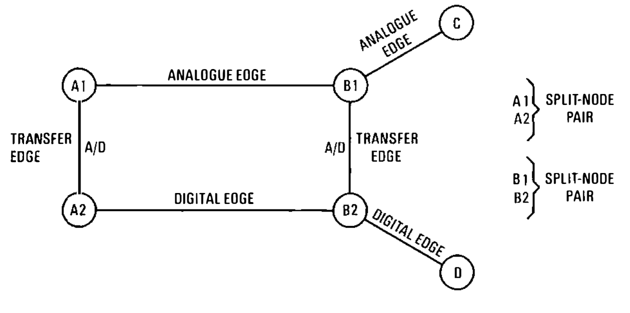


FIG. 6—Transmission network model

The two graphs are also connected at the nodes. Associated with each switching node is a transmission node. The connection is via a feeder section, which is not considered in the model. There are free transmission nodes, which do not have an associated switching node, and it is possible to have more than one switching node associated with each transmission node.

At each transmission node it is possible to change transmission sections and, in particular, to change section technology. For this, a transfer edge is introduced at a node. Unless otherwise specified in the input data, there is complete flexibility at a transmission node. The existence of this transfer edge splits the node into two, producing a multigraph (see Fig. 7).

In this model, it is not possible to handle transmission hierarchies. Instead, the flows are modularised at the base building-block sizes; for example, 2 Mbit/s for digital and group level for analogue systems. To include more detail would have increased the size and complexity of the algorithms.



A/D: Analogue-to-digital conversion

FIG. 7—Split transmission node with transfer edge

EDGE COST FUNCTIONS

Two principal sets of cost functions are used. For the switched network, the costs used for a trunk group are simply

$$nmcL + nmt,$$

where n is the number of modules,
m is the module size,
c is the cost per circuit per kilometre analogue or digital,
L is the length between switching nodes, and
t is the terminal circuit costs.

In addition, there is a cost per erlang for transit switching at a node.

The cost function for an edge for the transmission network is shown in Fig. 8. There are two components to the cost function: the fixed cost representing the cost of a new system, and marginal costs based upon the cost of circuit increment. Cost for a circuit demand routed in the transmission network is

$$\sum_{i=1}^{e} n_i m_i c_i d_i \text{ for existing plant, and}$$

$$\sum_{i=1}^{e} n_i m_i c_i d_i + \sum_{i=1}^{e} f_i \text{ for new plant,}$$

where d is the route distance between transmission nodes,
e is the number of edges in the circuit demand, and
f is the fixed cost of an edge.

A transmission medium can have two cost functions, one for each technique.

The switched network is optimised by using approximate costs and distances, while the transmission network is optimised by using accurate transmission costs and lengths. The procedure can be iterated by giving back to the switched network the real costs of trunk group routeings on the transmission network. Alternatively, a penalty trunk group cost, reflecting transmission utilisation, can be given to the switched procedure. The true total costs of the network are derived from the sum of the switched node costs and the transmission costs.

PROCEDURE DESIGN

The first approach to procedure design was to formulate a global optimisation algorithm that would dimension both the switched and transmission networks. Complexity studies showed that this would be difficult to solve for large networks. Therefore, the traditional approach of decomposition into two separate optimisation procedures was adopted. The two parts are known respectively as the *switched network optimisation procedure (SNOP)* and the *transmission network optimisation procedure (TNOP)*. A key design criterion for the SNOP was to use an end-to-end blocking in dimensioning the network. The arguments for using this approach were

(*a*) that the customers' expectation of service quality is matched in the design of the network, and

(*b*) that, when a meshed network is designed on a conventional final-choice basis, it is not clear what the end-to-end grade of service is.

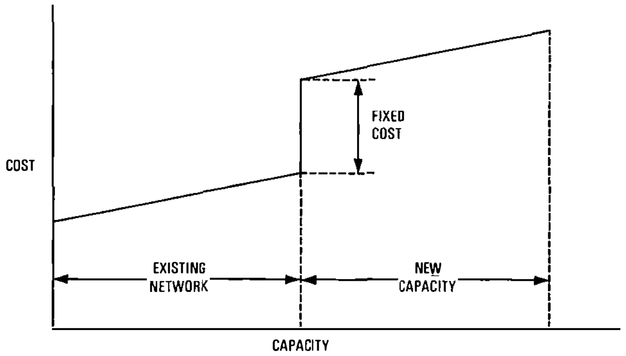


FIG. 8—Cost function on an edge

Three possible algorithms using end-to-end blocking in the network were investigated. The first used an extended Pratt's 'final trunk group procedure'[2] algorithm, modified for recursive calculation of end-to-end blocking. The second was based upon an algorithm developed by Berry[3] for the calculation of end-to-end blocking; and the third used a method developed by Blaauw[4], which decomposed the network into two parts, the high-usage trunk group and backbone or final-choice trunk group. A comparison was made on a small network between the Blaauw and Berry methods, and on the basis of computer time requirement the Blaauw method was adopted.

There were few studies available on transmission network optimisation with protection methods, and so TNOP was designed from first principles. Five constituent parts to the procedure were identified:

(*a*) network structure optimisation;

(*b*) circuit routeing optimisation, which diversely routes the circuit demand on the transmission network;

(*c*) a failure model for determining the requirements for protecting transmission media;

(*d*) stand-by optimisation, which routes the protection requirement on the transmission network; and

(*e*) overdimensioning optimisation of circuit demand.

Each of the protection methods would be balanced against the others to achieve an optimal mix of protection. Further studies showed that, as it was difficult to make cost functions for balancing the protection methods, this approach was not feasible. The overdimensioning function was transferred to the SNOP part of the procedure as it was appropriate to the switched network.

To determine an optimal network structure, the need for a front-end algorithm was recognised. This would select from a maximum transmission network an available network capable of carrying the circuit demand and stand-by protection. The conceptual organisation of the procedure is shown in Fig. 9.

With the overall design principles established, the two

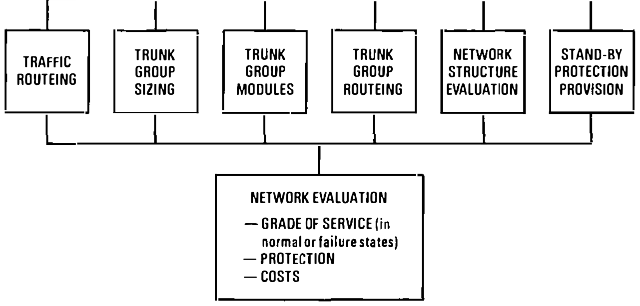


FIG. 9—Concepts of COST 201 procedure

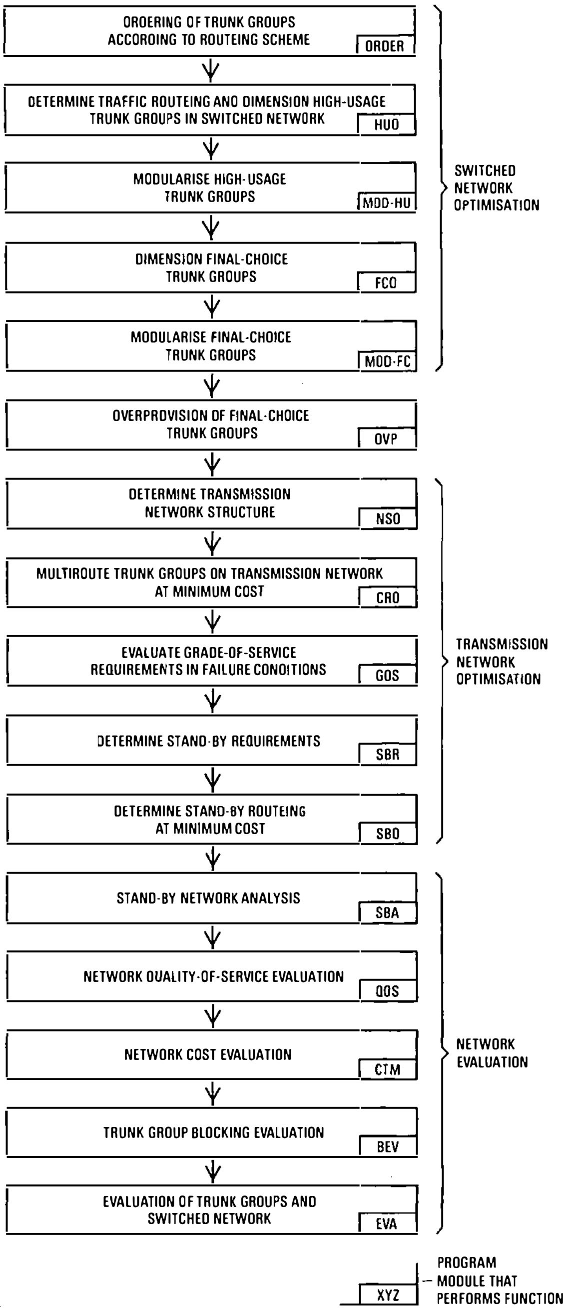


FIG. 10—Global description of COST 201 procedure

subprocedures were developed by further decomposition into individual program modules performing specific functions (see Fig. 10). The two parts of the procedure, SNOP and TNOP, are now described separately.

DESCRIPTION OF SWITCHED NETWORK OPTIMISATION PROCEDURE (SNOP)

The main features of SNOP can be summarised as follows:

(*a*) the minimisation of the switched network costs, including the costs of trunk groups and switching equipment;

(*b*) the inclusion of constraints for the end-to-end blocking or, if chosen, the use of final-choice blocking;

(*c*) thresholds on the minimum levels of trunk group provision;

(*d*) modular engineering (that is, each trunk group may be dimensioned as a multiple of a prescribed size of circuit module, depending on either the end switches or the type of transmission plant used);

(*e*) the option to combine trunk groups between common-node pairs (that is, pseudo-bidirectionably); and

(*f*) the handling of non-hierarchical routeings.

The problem to be solved by SNOP is to minimise the costs of both the trunk group routeing and transit switching, while the end-to-end blocking is kept below a maximum value. The optimisation problem can be represented mathematically as:

$$\underset{\substack{n_t \in N \\ s \subset S}}{\text{minimise}} \left[\sum_{t \in T(s)} c_t n_t + \sum_{i=1}^{SN} c_i A_i \right],$$

and subject to $$B_r < B_r^{\max} \; \forall_r ,$$

where A_i is the transit traffic,
c_i is the cost per erlang,
n_t is the number of modules,
c_t is the cost per module,
t is the trunk group,
$T(s)$ is the set of all trunk groups in the routeing scheme,
s is the actual routeing scheme,
S is the input routeing scheme,
N is the maximum set of trunks,
SN is the number of switching nodes, and
r is the traffic relation.

To solve this problem the following input data are necessary:

(*a*) a traffic matrix containing all originating–terminating offered traffic flows;

(*b*) an input maximum routeing scheme giving all routeing possibilities;

(*c*) circuit module sizes for all trunk groups;

(*d*) costs per circuit module for routeing each trunk group, transit switching costs per erlang and the terminal circuit costs; and

(*e*) descriptions of permanently switched circuits.

The most important data produced by SNOP are

(*a*) a trunk group information file containing information on the size, blocking, offered traffic and trunk group costs;

(*b*) a reduced routeing scheme;

(*c*) the end-to-end blocking values for all traffic relations; and

(*d*) the total switched network costs.

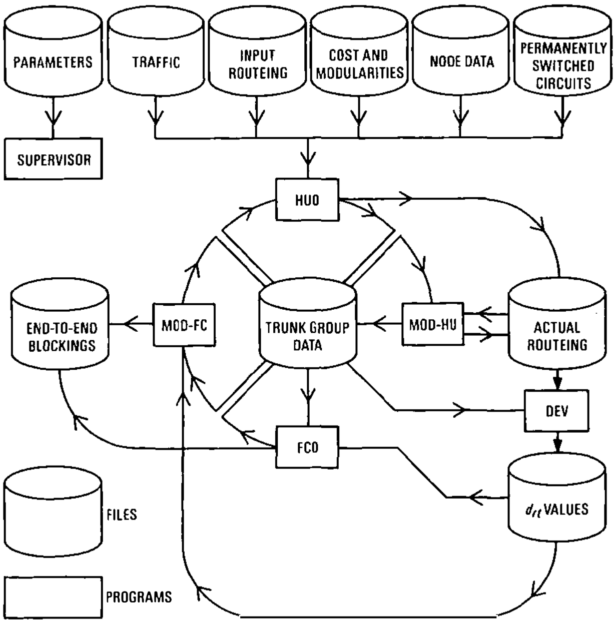


FIG. 11—SNOP file organisation

The file structure of SNOP is illustrated in Fig. 11. The important feature of this organisation is the use of a common file, TGDATA, for the transfer of data through the SNOP modules. This file holds data on each individual trunk group, and includes trunk group circuits, costs, circuit module sizes and blockings.

The SNOP procedure is decomposed into two parts: the high-usage optimisation part, involving modules HUO and MOD-HU, and the final-choice optimisation part with modules FCO and MOD-FC. In addition, modules are provided for other functions involved, either in the optimisation procedure, or for evaluation of the results.

One advantage of this modular design approach is that it is possible to run subsets of the full modular sequence to provide, for example, no circuit modularisation of trunk group by excluding modules MOD-HU and MOD-FC. The run order of the modules is dependent upon the decomposition of the procedure into high-usage and final-choice parts. In order to perform the final-choice optimisation, a feasible routeing scheme, and knowledge of the high-usage trunk group blockings and the traffic offered to final-choice trunk groups are needed. To achieve this, the module HUO is run in an initialisation mode by using a dimensioning method developed by Rapp^5.

With this achieved, the final-choice optimisation module FCO can be run and the procedure iterated back to the high-usage optimisation module HUO for dimensioning of the high-usage trunk groups using the Pratt's technique.

The function of each SNOP module is described along with the routeing rules used in the switched network.

Routeing Rules in SNOP

For switched network optimisation, an important input is the set of rules for the routeing of traffic relations. As the ability to handle both hierarchical and non-hierarchical networks was a principal design criterion of the procedure, a flexible method for specifying these rules had to be adopted. The important characteristics of the method developed can be described as follows.

In Fig. 12, an example of a routeing for traffic relation I to J is shown; the bold lines represent final-choice trunk groups. From each exchange I, there is up to a maximum of six possible outgoing trunk groups for each traffic relation (I, J). Except where the endpoint of the trunk group is the destination exchange J, there can be up to six possible choices from each intermediate exchange. The six possible outgoing trunk groups constitute a multiple overflow system with a clearly defined final trunk group. The restriction on this scheme is that the resulting network must be cycle free, and that a trunk group must be either high usage or final choice for all traffic relations.

The maximum routeing scheme for every switching-node pair is given as input to the procedure in the file MAXROUT. The module HUO then selects a feasible routeing scheme from this and places the result in the file MINROUT.

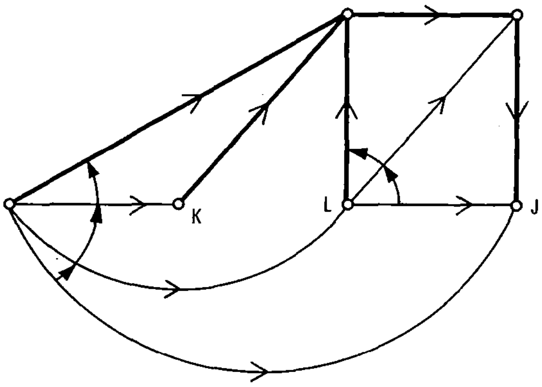


FIG. 12—Example of traffic routeing

Module ORDER (Ordering of Trunk Groups)

The module ORDER orders the trunk groups of non-hierarchical networks. In the later optimisation modules, it is necessary to know the sequence of overflows for each traffic relation. This module orders the trunk groups so that it is possible to route the traffic according to the input routeing scheme given in the MAXROUT file. It may be impossible to order the trunk groups because of the routeing scheme, in which case the network is probably too non-hierarchical and adjustments have to be made to the input routeing scheme.

Module HUO (High Usage Optimisation)

The high-usage trunk group optimisation module HUO can be used either in an initialisation role or as a final dimensioning algorithm for high-usage trunk groups. Two distinct methods are used, the Rapp and Pratt methods, respectively. Rapp's method does not take account of previously dimensioned trunk groups and so is used only for initialisation. Pratt's method considers the previous status of the network and can be used in an iterative mode. The solution from Pratt is also more accurate.

Rapp's method is based on an approximation of the marginal occupancy of a trunk group. When a high-usage trunk group t is being studied, the cost of a circuit on this trunk group is compared with the sum of the costs of two circuits joining the end points of the trunk group to the transit node K belonging to the alternative route. Fig. 13(*a*) illustrates this.

If we let

$$\varepsilon = \frac{c_t}{c_{\mathrm{I,K}} + c_{\mathrm{K,J}}},$$

then the marginal occupancy is taken to be

$$H = \varepsilon\{1 - 0{\cdot}3(1 - \varepsilon^2)\}.$$

In the simple Rapp's method, no account is made of the transit switching costs at the transit node. A modified Rapp's method was produced to overcome this deficiency.

Pratt's method considers a traffic flow from I to destination L offered to trunk group t, see Fig. 13(*b*).

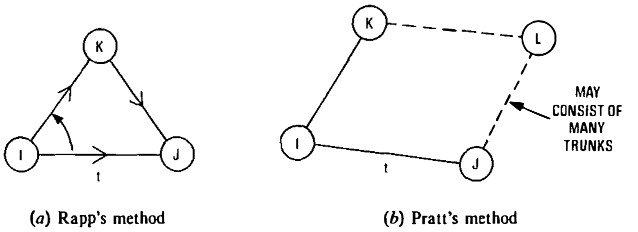
The first-choice route is I–J–L and the second-choice route is I–K–L.

The trunk group t (I–J) is optimally sized when the cost of one erlang on the route I–J–L is equal to the cost of one erlang using the route I–K–L.

The marginal occupancy can be expressed as

$$\frac{c_t}{COST1 - COST2},$$

where *COST1* is the cost of one erlang using route I–K–L, and *COST2* the cost of one erlang on route J–L. The cost of transit switching is included in the route costs.



(*a*) Rapp's method (*b*) Pratt's method

FIG. 13—Methods of comparing trunk group costs

Module MOD-HU (Modularisation of High-Usage Trunk Groups)

After module HUO has been run, all high-usage trunk groups are dimensioned in an optimal way. However, the sizes of the trunk groups are not modular. Module MOD-HU converts the size of the trunk groups to modular quantities.

As the capability of a trunk group to carry traffic is related to the size of the trunk group, any change in the number of circuits necessitates a change to the traffic streams.

The solution developed examines each trunk group, and a decision is made between rounding up or down to the adjacent circuit module size. As the rounding starts with a nearly optimal size, any change to the trunk group size produces a sub-optimal solution. The choice is made on the basis of the type of rounding that causes the least change from the optimal solution.

To speed the modularisation process, an option exists to use predetermined thresholds.

This module is also able, if necessary, to modularise all trunk groups and introduce bidirectionality.

Module FCO (Final-Choice Trunk Group Optimisation)

This module solves the second part of the SNOP procedure by optimising the final-choice trunk groups. The problem can be expressed with final-choice trunk group blockings as independent variables:

$$\underset{N_t \in \boldsymbol{FC}}{\text{minimise}} \sum_{t \in \boldsymbol{FC}} c_t N_t(b_t),$$

$$\text{subject to} \quad \sum_{t \in \boldsymbol{FC}_r} d_{rt} b_t \leq B_r^{\max} \; \forall_r ,$$

where c_t is the cost per circuit,
N_t is the number of circuits,
b_t is the blocking,
$\boldsymbol{FC}$ is the set of final-choice trunk groups,
$\boldsymbol{FC}_r$ is the set of final-choice trunk groups used by a relation,
d_{rt} is the end-to-end blocking coefficient, and
r is the traffic relation.

To simplify the optimisation, linear constraints are used to assess the blocking for each traffic relation. The coefficients d_{rt} of the blockings in the constraint are determined by applying a recursive formula. This formula is a development of that produced by Blaauw[4] for hierarchical networks. The calculation of the blocking coefficients is carried out in a subprogram called *DEV*.

The solution is too complex because of the size of the problem. Therefore, a number of simplifying techniques such as relaxation are used on the set of constraints, so that only a subset is considered at each iteration. It is also necessary to transform the problem into its dual and, in this way, a simplified optimisation problem is obtained. For the optimisation, a conjugate gradient search method developed by Fletcher and Reeves[6] is used.

Module MOD-FC (Modularisation of Final-Choice Trunk Groups)

This module transforms the sizes of all final-choice trunk groups into modular sizes, while maintaining the end-to-end blocking of each traffic relation in the network. A heuristic iterative approach is used and this consists of three main steps.

Firstly, the size of a final-choice trunk group is rounded down to the next module below. A check is then made on the blockings for each traffic relation. For those traffic relations that do not meet the blocking constraint, a list is made of the trunk groups involved and the list is searched to find the important bottlenecks in the network. Finally, the bottleneck trunk groups are identified and their size increased by one circuit module. This is repeated until all traffic relations satisfy the blocking constraint.

Module OVP (Trunk Group Overprovision)

The module OVP provides overprovision of trunk groups to cater for the additional traffic demands in the network that can arise because of network overload conditions. The reason for overprovisioning is that it puts a degree of resilience in the network and, as such, is part of the protection strategy for securing the network under failure conditions. Two methods are used to handle overprovision, the first uses an abnormal-traffic matrix to provide traffic values higher than that usually expected. The second applies a simple factor to increase the sizes of the trunk groups.

The module OVP can be used either individually in the SNOP procedure or, if the abnormal-traffic matrix is used, in conjunction with other SNOP modules. If this method of protection is not required, then this module can be omitted from the run sequence.

Evaluation Modules for SNOP

Three evaluation modules are used within the SNOP part of the procedure. The first is module BEV for the calculation of the blockings of each traffic relation. This produces a histogram of the network blockings. Module TEV performs a similar function for the traffic flows in the network, and module EVA provides a print-out of trunk group information, transit switching capacities at nodes, and switched network costs.

These evaluation modules are able to run after each of the optimisation modules and so give an indication of the procedure's performance.

DESCRIPTION OF TRANSMISSION NETWORK OPTIMISATION (TNOP)

The object of this part of the overall procedure is to dimension in an optimal way both the circuit routeing in the transmission network and the stand-by network. The problem is complicated by having to consider together two protective measures: multirouteing of circuit demands, and stand-by protection of transmission media. Moreover, the procedure must guarantee that the end-to-end blocking of traffic relations upset by a network failure is not worse than a particular blocking value. For this reason TNOP is more complicated than the simple optimisation of circuit demands on the transmission network; it has also to evaluate the effects of network failure on the traffic carried on the switched network.

To treat failures in the transmission network, a failure model is treated in module SBR. This model assumes that only one transmission media is in failure at any time in the network.

Before any routeing optimisation is carried out, the structure of the transmission network is examined; this allows the planner to input a maximum transmission network which can contain many planning options. This maximum network is reduced to an available network by deleting new transmission edges and capacities that are not likely to be needed to route the circuit demands.

Finally, the results of the optimisation procedure are examined by three evaluation modules: one to measure the quality of service of the network in failure condition, another to provide details of the stand-by routeings and the third to analyse the network costs. This last module, CTM, also acts as the feedback module for iterations between SNOP and TNOP. In order to decrease TNOP's complexity, the procedure has been decomposed into modules as shown in Fig. 14.

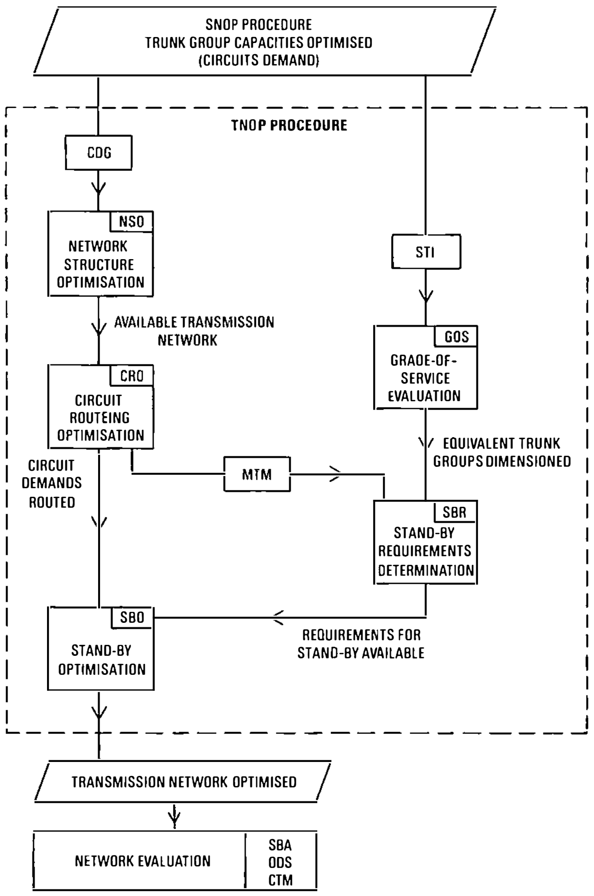


FIG. 14—Key TNOP modules

TNOP File Structure and Data Requirements

Unlike SNOP there is no common file running through the TNOP procedure. Instead, each module produces a set of output files, which are used by later modules. One problem of decomposing the procedure into modules is that a large amount of data needs to be transferred. The amount of data in TNOP is determined by the requirement to handle both transmission and quality of service data. Fig. 15 illustrates the data flows and files used by TNOP.

TNOP requires as input the following data:

(*a*) description of the maximum transmission network, which includes existing and planned capacities;

(*b*) marginal and fixed costs for each transmission edge in the network, which reflect the type of system used;

(*c*) the minimum degree of the transmission nodes and transfer capacity at the nodes; and

(*d*) details of any demands for non-switched leased circuits.

The output of TNOP is a fully dimensioned transmission network with multirouteing and stand-by protection.

The modules CDG (circuit demand generator), STI (SNOP to TNOP interface module) and MTM (media to trunk group mapping module) are data handling routines. The remaining modules are now described.

Module NSO (Network Structure Optimisation)

The module NSO determines the optimal structure of the transmission network necessary to carry the trunk group demand from SNOP. To avoid duplication of algorithms, the module CRO (circuit routeing optimisation) is used to produce a feasible routeing for the NSO module. There are two separate phases to the network structure optimisation. First, module CRO makes an initial routeing on the maximal network. The second phase, known as the *reduction phase*, tests each transmission edge to see whether it should be kept (fixed) or deleted from the network.

Whether an edge is deleted or fixed will depend on the network structure constraints and an estimation of the cost of the two solutions. There are two network structure constraints that cannot be violated when an edge is being deleted; namely, the minimum node degree for each node and the connectivity between the ends of an edge when it is tested. When estimating the cost of deleting an edge, module NSO contains the option either to reroute the trunk groups individually or to reroute only the load between the ends of the edge. During the rerouteing process no violations of capacity limits are allowed and the transmultiplexing costs and circuit modularity are taken into account.

After module NSO has run, the network has sufficient capacity to accommodate both the circuit demands and the stand-by network. If necessary, module NSO can be iterated to reduce further the capacity of the network. It will not, however, add new edges to the network; all edges to be examined must be in the input data.

Module CRO (Circuit Routeing Optimisation)

The purpose of this module is to find the optimal routeing of trunk groups and leased circuits in the transmission network. To increase the resilience of the network against failure, trunk groups are diversely routed on more than one transmission path. The module also observes capacity constraints on the transmission media and leaves sufficient capacity on the media for stand-by circuits if required.

The problem that module CRO has to solve is how to optimise a multicommodity flow under capacity constraints. To achieve a solution for large networks, an iterative solution method has been chosen. The method is to handle the capacity constraints by using Lagrangean relaxation, and then to decompose the problem into several single-commodity minimum cost flow subproblems. A feasible solution is obtained by iterations where the Lagrange multipliers are changed by a subgradient technique. The implication of this is that, if a capacity constraint is violated on an iteration, then, on the next iteration, the edge is given a higher cost function, hence forcing a different path for some of the demands. However, this is not always sufficient to produce a feasible solution. Therefore, a penalty cost is also added to the edge when the capacity approaches the edge maximum.

The shape of the cost function used on an edge is shown in Fig. 16. This cost function controls the multirouteing of a circuit demand, and is shaped by two input parameters α and γ. When the flow on an edge exceeds γN, the marginal cost increases by αL, where N is the size of the demand and L the length of the edge. With these cost functions, the circuit demand is routed on disjoint paths when this can be done at lower additional costs.

The optimisation method used to treat these convex piecewise-linear cost functions is a shortest augmenting path technique with a label-correcting algorithm to route each circuit demand.

Module GOS (Grade of Service Evaluation)

When a failure occurs in the transmission network, it is necessary to examine the grade of service of each traffic relation affected by the failure. This would take a long time to calculate for all traffic routes in a large network. To overcome this, a simplified heuristic method is used in which each traffic route is substituted by an equivalent trunk group. The task of this module is to compute the end-to-end blockings in the no-failure condition and, from these, derive the capacities of the equivalent trunk group. The method used assumes that, when a failure occurs, the reduction in terms of equivalent circuits of the route is in the same proportion as the reduction of actual circuits of the worst trunk group used in the route. So the number of equivalent

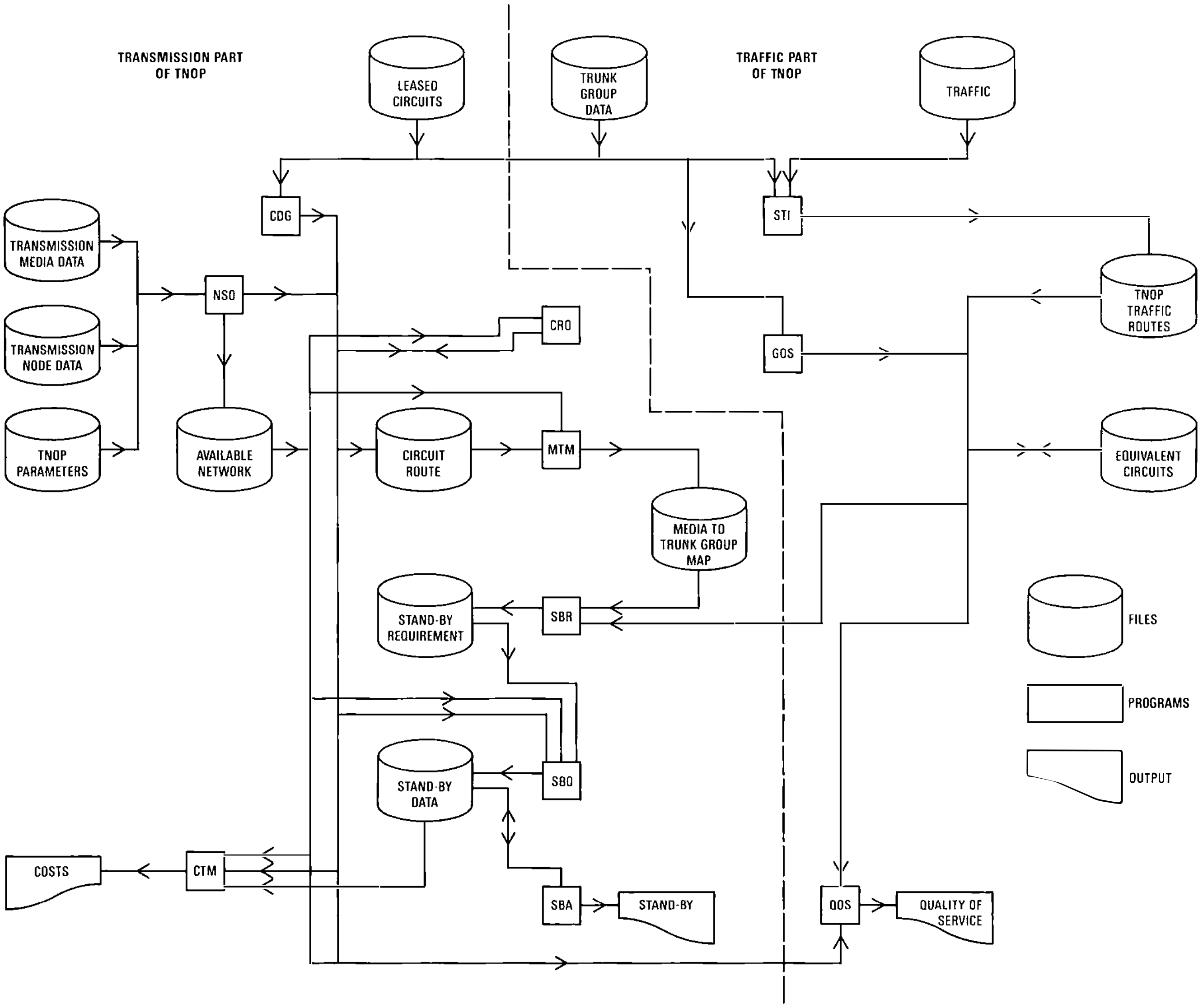


FIG. 15—Simplified TNOP data flow and files

circuits of route K in failure f is:

$$Q_{Kf} = Q_{K0} \times \min_{t \in K}\left(\frac{N_{tf}}{N_{t0}}\right),$$

where Q_{K0} is the number of equivalent circuits in non-failure condition,

N_{t0} is the capacity of trunk in no-failure condition, and

N_{tf} is the capacity of trunk group in failure condition.

The end-to-end blockings are then calculated as the loss probability of an equivalent trunk group. In the no-failure condition, the blockings are exact and, in the failure condition, the method gives a good estimation of the blockings.

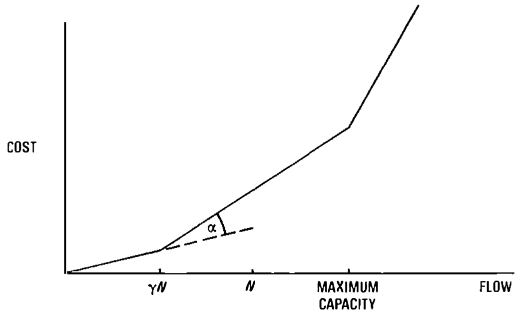


FIG. 16—Modified cost function of a transmission edge used in module CRO

Module SBR (Stand-by Requirement Calculation)

The SBR module calculates, for the failure of each transmission medium, the number of stand-by circuits necessary to protect the medium. The number of stand-by circuits provided depends upon the value of the maximal end-to-end blocking in failure condition.

The stand-by requirements are computed according to the criterion of minimising the global number of circuits ΔN_f to be protected in each failure. The module requires as input the circuit routeing of the trunk groups from module CRO and the equivalent circuits from module GOS. The method takes account of the multirouteing carried out by the module CRO in calculating the stand-by requirements.

Module SBO (Stand-by Network Optimisation)

The purpose of module SBO is to route optimally the stand-by requirements for each network failure, as determined by module SBR on the transmission network. Certain assumptions have been made to simplify the problem.

(*a*) The stand-by routeing is made on the available transmission network by using capacity reserved or left spare by the circuit routeing module CRO.

(*b*) The provision of stand-by circuits partially or totally restores the normal failed capacity between the end nodes of the failed transmission medium.

(*c*) The stand-by network is considered to be fully rearrangeable; that is, the maximum rerouteing flow between each pair of nodes depends only on the structure of the network and on the stand-by capacities of the edges.

The method adopted is to subdivide the stand-by requirement into modules and route a number of these modules (parcels) at each iteration on the network at minimum cost. This prevents the possibility of a totally unfeasible solution, through lack of capacity in parts of the network.

It is possible to specify both whether a transmission media should be protected and whether it should carry stand-by circuits.

The output of the module is a dimensioned stand-by network; a list is produced of transmission media which are either impossible to protect or are only partially protected.

TNOP Evaluation Modules

SBA (Stand-by Analysis Module)

The module SBA uses the stand-by network dimensioned by module SBO to determine the routeings of each transmission medium in failure. This information is used to examine how each medium is protected and where spare capacity still exists in the transmission network. This information is also used by modules QOS and CTM.

QOS (Quality of Service Evaluation Module)

The purpose of module QOS is to examine the final end-to-end grade of service of each traffic relation affected by a network failure. From this, the quality of service of the network in failure can be estimated.

CTM (Costing Module)

The costing module produces transmission network costs and statistics. It also acts as an intermediary between TNOP and SNOP when looping the whole procedure. In this role, it provides revised trunk group costs and modularities to be used on the next iteration of SNOP.

PROCEDURE TESTS AND ANALYSIS OF RESULTS

For testing and validation of the procedure, three networks of different sizes were used:

(*a*) *Demonstration Network* comprising 6 switching nodes, 10 transmission nodes and 21 transmission media;

(*b*) *Medium-Size Network* comprising 47 switching nodes, 77 transmission nodes and 200 transmission media; and

(*c*) *Large-Size Network* comprising 600 switching nodes, 313 transmission nodes and 501 transmission media.

The demonstration network is used to validate the algorithms because it is small enough to allow manual checking of the results. But, because of its size, no conclusions can be drawn as to the correctness of the whole procedure.

The medium-size network is modelled on a real national network. This network was used in most procedure tests as it was sufficiently large to show the properties of the procedure, while not taking too long to run on the computer.

The large-size network is also based on a national network and has been used to demonstrate that the procedure is able to run on such a network in reasonable computer time.

The results shown here are all based upon the medium-size network. As there are a number of optional run sequences for the procedure modules, a standard run option has been adopted (see Fig. 17). The results shown can be classified as

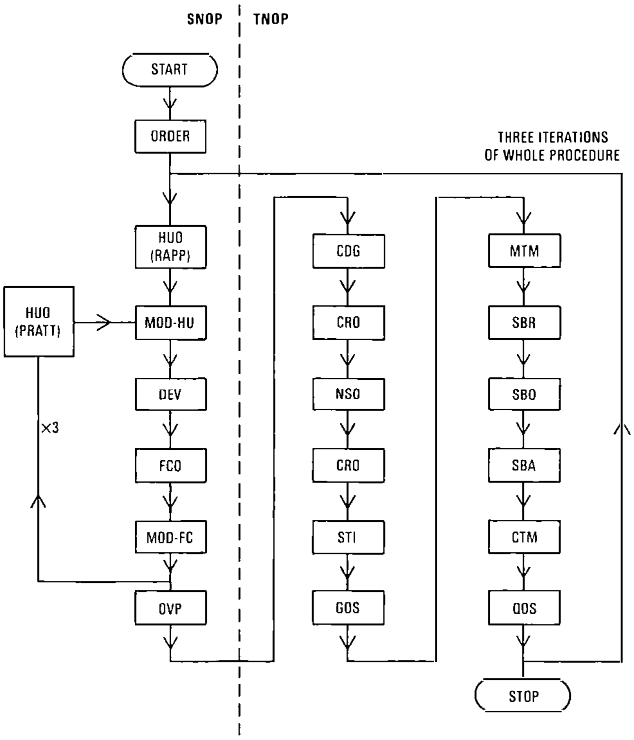


FIG. 17—Standard run of cost procedure

(*a*) properties of the SNOP procedure,

(*b*) properties of the TNOP procedure, and

(*c*) properties of the whole procedure, including iteration.

SNOP Results

From Fig. 17 it can be seen that the switched network procedure is iterated three times using Pratt's method in the HUO module on iterations 1, 2 and 3. The results of these iterations are shown in Table 1. From the results, the effect of network modularisation in modules MOD-HU and MOD-FC can be seen. Also indicated is a reduction in the number of high-usage trunk groups produced by module HUO and the increase in final-choice trunk groups. The network costs show an increase, although there is a reduction in the mean end-to-end blocking. The distribution of end-to-end blockings after each run of MOD-FC is shown in Fig. 18. From these results, it has been concluded that, with this test network, only two interations of SNOP are necessary, the use of Pratt's method yields a network saving of 1·7% and, from comparison with data not shown here, there is a saving of 1·8% in network cost when end-to-end grade of service is used rather than final-choice grade of service.

TNOP Results

A series of tests was carried out using the trunk group data produced by the standard run of SNOP. In these tests, the relationship between a number of TNOP input parameters was examined; in particular, the following:

(*a*) the relationship between multirouteing parameters and network cost and quality of service (without stand-by),

(*b*) the relationship between $\hat{B}$ (maximum allowed value of end-to-end blocking in failure condition) and the stand-by network costs, and

(*c*) the relationship between $\hat{B}$ and the network total cost.

The parameters found to have the greatest importance when searching for an optimal solution were α and γ, the multirouteing parameters in module CRO. Fig. 19 illustrates the type of solution found after a series of runs of TNOP. With the test network, a value 20 for α was used and it can

```
RANGE :    0.0       10.0      20.0      30.0      40.0      50.0
           +---------+---------+---------+---------+---------+
0.0000 - 0.0025 *******************************
0.0025 - 0.0050 *************
0.0050 - 0.0075 *******
0.0075 - 0.0100 ***********
0.0100 - 0.0125 ********
0.0125 - 0.0150 *******
0.0150 - 0.0175 ****
0.0175 - 0.0200 *
0.0200 - 0.0225 ***
0.0225 - 0.0250 **
0.0250 - 0.0275 *****
0.0275 - 0.0300 *
0.0300 - 0.0325
0.0335 - 0.0350
0.0350 - 0.0375
0.0375 - 0.0400
```

(*a*) Iteration 1

```
RANGE :    0.0       10.0      20.0      30.0      40.0      50.0
           +---------+---------+---------+---------+---------+
0.0000 - 0.0025 *****************************************
0.0025 - 0.0050 ***************
0.0050 - 0.0075 *******
0.0075 - 0.0100 **********
0.0100 - 0.0125 *****
0.0125 - 0.0150 *****
0.0150 - 0.0175 ***
0.0175 - 0.0200 *
0.0200 - 0.0225 *
0.0225 - 0.0250 *
0.0250 - 0.0275 ***
0.0275 - 0.0300 **
0.0300 - 0.0325
0.0335 - 0.0350
0.0350 - 0.0375
0.0375 - 0.0400
```

(*b*) Iteration 2

```
RANGE :    0.0       10.0      20.0      30.0      40.0      50.0
           +---------+---------+---------+---------+---------+
0.0000 - 0.0025 ***********************************
0.0025 - 0.0050 ****************
0.0050 - 0.0075 *******
0.0075 - 0.0100 ***********
0.0100 - 0.0125 *******
0.0125 - 0.0150 ******
0.0150 - 0.0175 ***
0.0175 - 0.0200 *
0.0200 - 0.0225 ***
0.0225 - 0.0250 ***
0.0250 - 0.0275 *
0.0275 - 0.0300 *
0.0300 - 0.0325
0.0335 - 0.0350
0.0350 - 0.0375
0.0375 - 0.0400
```

(*c*) Iteration 3

FIG. 18—Final distribution of end-to-end blockings after each internal iteration of SNOP

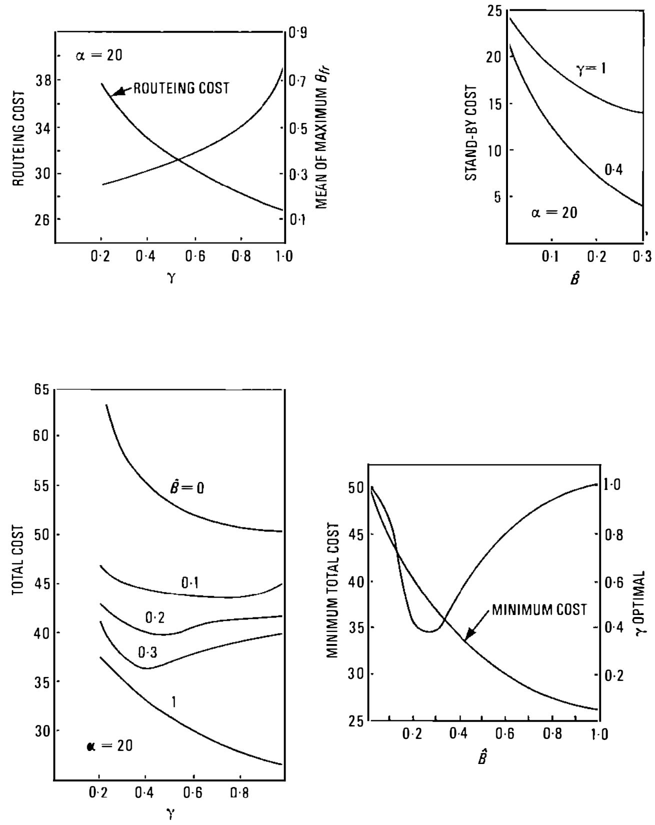


FIG. 19—Relationship between routeing costs, multirouteing parameters and blocking in failure

be seen that a value of 0·4 for γ produces an optimal network cost with a blocking in failure of 20%.

Whole Procedure Tests

At this level of testing, there are few parameters to be varied. Previous tests of modules and then SNOP and TNOP will

TABLE 1
Results of SNOP Modules After Three Iterations of SNOP

Process	HUO†	MOD-HU	FCO	MOD-FC	HUO*	MOD-HU	FCO	MOD-FC	HUO *	MOD-HU	FCO	MOD-FC	OVP
Number of Trunk Groups													
High Usage	431	199	199	199	197	166	166	166	159	153	153	153	153
Final 1	92	92	92	92	146	146	146	172	172	172	172	172	172
Final 2	23	54	54	54	0	26	26	26	7	12	12	12	12
Direct	0	29	29	29	31	35	35	35	35	36	36	36	36
Total	546	374	374	374	374	373	373	373	373	373	373	373	373
Number of Circuits													
High Usage	11 024	7 659	7 659	7 659	9 162	7 072	7 072	7 072	6 831	6 145	6 145	6 145	6 145
Final 1	10 079	14 026	12 330	13 216	11 392	13 401	11 065	12 711	12 869	15 068	12 702	14 438	16 500
Final 2	224	1 835	1 180	1 775	0	1 937	1 720	1 937	545	1 257	1 002	1 107	1 230
Direct	0	1 470	1 194	1 470	1 545	2 070	1 687	2 028	1 873	2 130	1 720	2 088	2 076
Total	21 327	24 990	22 363	24 120	22 099	24 480	21 535	23 748	22 118	24 600	21 569	23 778	26 064
Approximate Total Cost (£M)													
Transmission	14·0	15·3	14·1	14·9	14·4	15·5	14·1	15·2	14·5	15·6	14·2	15·2	15·5
Terminal	5·1	5·9	5·3	5·7	5·3	5·8	5·2	5·7	5·3	5·9	5·2	5·7	5·8
Transit	4·0	5·0	5·0	5·0	4·3	4·4	4·4	4·4	4·3	4·4	4·4	4·4	4·4
Total	23·1	26·2	24·4	25·6	24·0	25·7	23·7	25·2	24·1	25·8	23·8	25·2	25·7
Total Transit Traffic (Erlangs)	6 630	8 379	8 379	8 379	7 236	7 347	7 347	7 347	7 127	7 276	7 276	7 276	7 263
Mean End-to-End Blocking	0·010	0·003	0·027	0·009	0·011	0·003	0·027	0·007	0·014	0·003	0·029	0·008	0·005

† Rapp's method
* Pratt's method

TABLE 2
Results of Three Iterations of the Procedure

Procedure	Run 1	Run 2	Run 3
SNOP Costs (£M)			
Terminal Costs	5.8	5·9	5·8
Transit Costs	4·4	4·1	4·2
Total Switching Cost	10·2	10·0	10·0
TNOP Costs (£M)			
Circuit Routeing Costs			
Analogue	5.876	5·220	5·335
Digital	6·863	7.222	6·875
Transfer	3·902	3·797	3·408
Total Cost	16·641	16·239	15·618
Stand-by Routeing Costs			
Analogue	7·838	5·993	7·689
Digital	2·344	2.680	2.573
Transfer	3·600	3·150	3·525
Total Cost	13·782	11·823	13·787
Fixed Costs	10·296	12·182	10·713
Total Transmission Costs	40·719	40.244	40·118
Total Network Costs (SNOP and TNOP) (£M)	50·9	50.2	50·1
Mean EEB in Non-Failure	0·008	0·006	0·007
Mean of Maximum EEB in Failure (no stand-by)	0.69678	0.77735	0·70869
Mean of Maximum EEB in Failure (with stand-by)	0·15159	0·14739	0·14945
Network Failure Probability	0·000684	0·000726	0·000687

EEB: End-to-end blocking

have fixed parameters at their optimal value. The area of interest for whole procedure tests is whether the procedure works together and produces reasonable network solutions.

By using the standard run of the procedure, three iterations of SNOP and TNOP are made. The values iterated back to SNOP from TNOP are costs of trunk groups. The philosophy is to make the cost inputs to SNOP as realistic as possible.

Two types of cost can be given by the CTM module back to SNOP: the actual trunk group routeing costs in the transmission network or penalty trunk group costs, which reflect the utilisation of the transmission edges. This implies that trunk groups that are not economically routed in the transmission network are penalised. Table 2 shows the total network costs (switched and transmission) for three iterations of the whole procedure; also shown are the mean network blockings for no-failure and failure situations.

CONCLUSION

This article has given an overview of the technical development of COST 201. The procedure has been designed with the requirements of the planner in mind. However, because the results are shared among 10 countries, the level of detail in the model had to be transparent to their different requirements.

Several participating administrations, including BT, are currently evaluating the COST 201 procedure for use by their planning groups. Although the project has ended, there is continuing co-operation concerning implementation methods and exchanges of ideas on possible modifications.

Much has been learnt from the project, not only of the problems of designing complex algorithms, but also the structuring of network data and the problem of verifying the results.

For the future, it is envisaged that the procedure will be developed to suit the needs of BT. In particular, the development of integrated computer-aided planning systems (ICAPS) would provide the opportunity for the procedure to work with other planning systems on a common database.

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Biographies

David Greenop works in the Network Structures, Models and Economics Section of BT's National Network Strategy Unit. After graduating from the University of Sussex in 1975 with an honours degree in Physics and Logic, he joined the Traffic Division of BT/Portsmouth. In 1978, he obtained an M.Sc. in Telecommunications Systems from Essex University and, in 1980, joined the Network Strategy Unit as the BT representative on the COST 201 project team. He has played a key role in the designing and testing of the procedure. His particular areas of speciality are the design, modelling and forecasting of networks.

Ronald Campbell works in the Service/Network Evolution Strategy Section of BT's Local Network Strategy Department. He graduated from the Belfast College of Technology in 1968 with a B.Sc. degree in Mathematics and Physics. In the following year, he joined the Forecasting Section of the General Post Office as an open entrant, and worked on call and traffic studies in the Marketing Department. There he developed considerable expertise in the application of computer techniques to forecasting. He transferred to the trunk routeing group of Network Planning Department in 1974 and worked in the general field of routeing. Subsequently, he became involved in developing computer tools for testing and analysing the output from call loggers for destination analysis used in network modernisation and utilisation studies. Currently, he is implementing the COST 201 procedure in BT and is editing the supporting documentation.

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Significant changes to the Rules as proposed in the Secretary's letter to Members of 1 October 1983 have now come into effect.

Reference copies of the Rules updated to 1 January 1984 are now held by all Local-Centre Secretaries and Members of Council.

MEDAL AWARDS FOR LECTURES AND PAPERS PRESENTED IN THE 1982/3 SESSION

Council unanimously agreed to award Medals as follows:

Institution Senior Bronze Medals to Mr. A. R. Willis for his lecture *Speech Recognition and Synthesis*, and to Mr. E. J. Powter for his lecture on *Future Cable TV Networks*.

An Institution Field Medal to Mr. H. G. Perrett for his paper *System Enhancement of Analogue Exchanges*.

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L. Wray	55 Castle Drive, Kemsing, Sevenoaks, Kent TN15 6RW
C. Wroe	252 Woolwich Road, London SE2 0DW

Members about to retire are reminded that they, too, may secure life membership of the Institution at a once-and-for-all cost of £10·00 and so continue to enjoy the facilities provided, including a free copy of this *Journal* posted to their home address.

J. BATEMAN
Secretary

British Telecom Press Notices

LONDON'S FIRST SATELLITE EARTH STATION

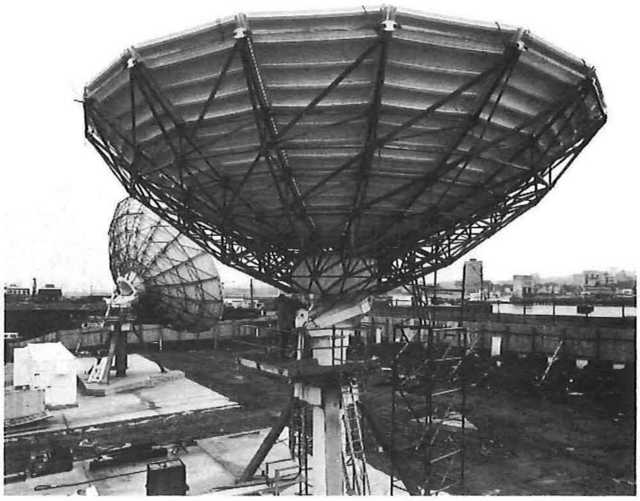
British Telecom International's (BTI's) new satellite earth station in London's docklands began service in February of this year.

The first customer is Satellite Television whose nightly programme, *Skychannel*, is being transmitted to audiences in seven European countries. In less than six months after the initial development of the site began at the new location, Pier Road, North Woolwich, BTI had its first aerial working and a second nearing completion.

Both the first and second aerials at London North Woolwich are 13 m in diameter. Prior to the operation of the first aerial, the Skychannel service was carried by a BTI terminal at Madley, Hereford. The site at Pier Road, which is close to the old King George V dock, was, until last autumn, a power cable manufacturing complex incorporating a number of Victorian buildings. BTI began clearing the site during August 1983, and the first terminal was installed the following December. The two aerials and associated equipment were supplied by Marconi Communications Systems Ltd. A third terminal will be built later this year.

Skychannel is being transmitted by BTI via the European Communications Satellite, ECS F1. Skychannel will be received by viewers in Switzerland, France, Germany, Finland, Austria and Norway as well as the UK; eventually, it will be a round-the-clock service. In addition, BTI expects to transmit four television channels via an Intelsat satellite to provide a service to UK cable networks.

An agreement with BT for use of an Intelsat satellite and the London earth station has already been reached with United Cable Programmes, the consortium that includes Rediffusion, Visionhire Cable, Rank Satellite and Cable, Plessey, and UIP TV.


The new earth station at North Woolwich

London North Woolwich is London's first earth station, and its speedy establishment means that BTI is well positioned to offer the City a full range of advanced communications services using digital transmission techniques as well as video conferencing.

UK–BELGIUM SINGLEMODE CABLE

Sir George Jefferson, Chairman of British Telecom (BT), has signed a contract for £7·25M with Standard Telephones and Cables plc (STC) for the construction of the world's first international optical-fibre undersea cable. The cable, 122 km in length, will link the UK to Belgium and will be made in Britain by the submarine-systems division of STC.

The award of this contract means that in 2 years time telephone calls, computer data and messages will travel between Britain and continental Europe as pulses of laser light along tiny strands of ultrapure glass as thin as a human hair.

The investment is being shared between 4 countries; half of it will be held by BT International and the balance by the Deutsche Bundespost of West Germany, the Belgian RTT and the Netherlands PTT.

The cable, which is capable of carrying nearly 12 000 telephone calls simultaneously, will be laid by BT's cableship, *Alert*, in the spring of 1985, and will be buried to protect it against damage caused by shipping, particularly those ships involved in trawling activities.

The new cable will benefit both STC and BT in a variety of ways. It will provide valuable design and manufacturing experience for STC, and, together with the proposed contract for the supply of its system for part of the transatlantic TAT8 cable, will help to put the company in a strong position for future exports of these systems. BT will gain useful operational experience in handling this new kind of cable, and experience of cable burying techniques.

The new cable will operate in digital form, at speeds of up to 280 Mbit/s. Digital operation means that a variety of information-technology services, as well as speech, can be carried along the same path more efficiently than present-day analogue transmission. It will also mean considerable savings in transmission costs because the system will use singlemode transmission, the technique that enables single rays of laser light to travel great distances along a fibre before regeneration by a repeater is required.

The new cable will use three submerged repeaters, each containing three bothway optical regenerators, which will be installed at approximately 30 km intervals to make the total length of the system between terminal stations 122 km.

The cable is being installed as a part of BT's huge investment programme in international links, which is currently costing £60M a year, needed to cater for the growth in modern digital-based services. The new cable will enable BT to meet demand from its business customers for advanced digital communications with other countries, and, in this context, its drive to provide these new services within the UK will be matched by its ability to provide the services internationally.

The cable will aid BT's plans to provide digital facilities between the UK and Europe by using satellite transmission. This business service, known as *SatStream*, should begin sometime this year, and digital communications via the Belgian cable should become available by the latter part of 1985.

British Telecom Press Notices

SLIMTEL

British Telecom (BT) has introduced a one-piece press-button electronic telephone, called *Slimtel*, which has a retail price of less than £30, including value added tax.Tyne Tees has been selected as the area in which the new telephone is to be introduced; initially it will be available through BT's Area offices and selected retail outlets in the North East. However, it should be available throughout the whole country by this summer.

Slimtel has been designed and developed by BT itself, and is being manufactured at BT's factory at Cwmcarn, Gwent, in South Wales. Slimtel has a number of features that have previously been available only on the more expensive telephones. This model offers:

(*a*) *Last number redial* When a button on the telephone is pressed, the telephone automatically redials the last number that was called.

(*b*) *Silent button* When pressed, this button (marked S) allows a user to have a conversation with a third party without being overheard on the telephone.

(*c*) *Ease of operation* By using a small switch a user can key in a number without having to pick up the instrument.

(*d*) *On/off switch* A simple switch on the base of the telephone opens or cuts off the line.

Slimtel offers customers value for money, and enhances BT's range of attactive new telephones for the residential market. Slimtel represents a very small part of BT's total telephone requirements; so BT will continue to purchase the main bulk of its requirement for telephones from UK industry.

Slimtel will initially be offered in only one colour—an attractive off-white; but other colours may be available later. Although it is designed to function primarily as a table-top telephone, Slimtel can be wall mounted on a matching wall bracket. The new model is connected by BT's new plug-and-socket system for use anywhere in the home. Slimtel can also be rented.

Slimtel

STAR SERVICES

Black boxes controlled by microchips will soon extend the availability of the advanced telephone services that British Telecom (BT) is to provide on its System X exchanges later this year. Customers on existing telephone exchanges will have new press-button telephone facilities, known as *Star Services*. BT have already started to introduce Star Services, and by midsummer they will be available in over 200 locations.

Customers at home, and in small businesses with direct telephone lines, will then have facilities that are in many cases better than those available to larger firms from modern office switchboards. Customers will be offered eight Star Services.

Code calling This saves users time, and errors in dialling frequently-used numbers; up to 27 (each of up to 16 digits) can be stored and called quickly by using a short code.

Repeat last call This eliminates users having to redial engaged numbers in full; a short code does the work.

Charge advice This is for people who want to know instantly how much a call has cost; at the end of a call, a recorded announcement gives the charge.

Reminder calls This service helps busy people to remember an appointment, or provides a wake-up service; a simple dialled code ensures that the caller's telephone is rung back at the chosen time.

Call diversion This saves lost business resulting from missed calls; incoming calls are automatically switched to any chosen alternative number, provided only that it can be dialled.

Call waiting This means that an incoming call can be taken while the Star Service is engaged on an outgoing call; on receiving an ALERT tone the customer can hold the existing call or switch between the calls as required.

Three-way calling This enables customers to avoid time-consuming call backs; a customer can hold one call, make another and interconnect both for a 3-way conversation.

Call barring This improves telephone security; customers can stop all incoming calls (to avoid being disturbed at night, for example) and restrict outgoing calls.

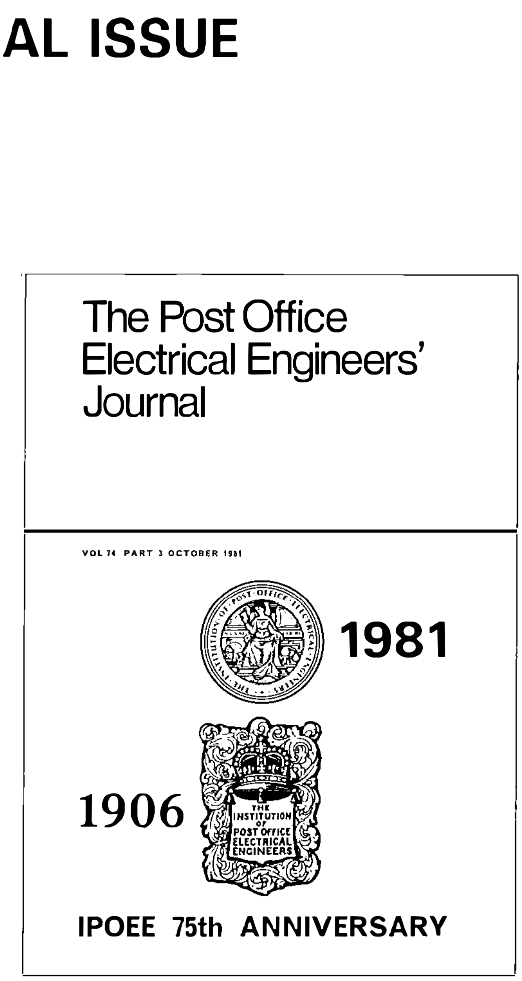
The new telephones have two extra buttons, marked with ★ and #. Customers gain access to the Star Services by pressing combinations of these and the numerical buttons. For example, to set up call diversion, the customer presses ★, 21, ★, then the number to which calls are to be diverted and then #. The exchange black box responds with its electronic guide voice to confirm that calls for the particular number are to be diverted to the number given.

Four similar services are already available in the USA, where they have proved very popular. BT's decision to offer eight Star Services from the outset reflects its confidence—confirmed by wide-ranging market research—that they will appeal strongly to British telephone users.

OCTOBER 1981 SPECIAL ISSUE

The October 1981 special issue contains articles on the following topics:

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS
TELECOMMUNICATIONS AND SOCIETY
THE INLAND NETWORK
INTERNATIONAL SERVICES
SWITCHING AND SIGNALLING
MECHANICAL AND CIVIL ENGINEERING
CUSTOMER APPARATUS
TRANSMISSION
POSTAL ENGINEERING
RESEARCH
THE FUTURE



The Post Office
Electrical Engineers'
Journal

VOL 74 PART 3 OCTOBER 1981

1981

1906

IPOEE 75th ANNIVERSARY

The October 1981 issue of the *Journal* was a special double-size issue to mark the 75th Anniversary of the Institution of Post Office Electrical Engineers. The issue reviews many of the changes that have taken place in telecommunications and postal services since 1956.

Copies of the issue are still available, price £1·40 each, including post and packaging (the cost to British Telecom and British Post Office staff is 48p).

If you wish to order copies, please complete the order form below and send it to the address shown. (Cheques and postal orders, payable to *'BTE Journal'*, should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post.

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Notes and Comments

CORRESPONDENCE

Elcom Systems Ltd.,
19 Station Approach,
Fleet,
Aldershot,
Hampshire GU13 8QY.

Dear Sir,

Once again, in your January 1984 issue, you refer to the first automatic exchange in the UK at Epsom, introduced in 1912. I can remember in the late-1950s when Epsom was reached from the London director area by dialling EH4 and asking the operator for the subscriber's number. Presumably, Epsom was then a manual exchange. Do any of your readers know when the original automatic working was discontinued, and why?

Yours faithfully,
D. Whitaker

(This reference was in the *Editorial*; would anyone care to write and comment? *Editor*)

PUBLICATION OF CORRESPONDENCE

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

Letters intended for publication should be sent to the Managing Editor, *British Telecommunications Engineering*, LCS/P5.1.1., Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

SYSTEM X REPRINTS

All copies of the book containing reprints of System X articles have now been sold.

CORRECTION

The article *The Impact of the Invention of Polyethelene on World Telecommunications*, published in the July 1983 issue of the *Journal*, contains one piece of outdated information. At the top of p. 84, the author describes Telecom Australia's method of proofing LDPE-sheathed cable against termite attack. The statement that no successful termite attack on protected cable had been seen over a 10-year period was correct at the time of the reference quoted (1973). Mr. B. M. Byrne of Telecom Australia has drawn the author's attention to a later publication[†] which concludes that nylon 11/12-protected cable should be regarded as ant and termite *resistant*, rather than ant and termite *proof*. In areas where cables are prone to this type of damage, the incidence of attacks on protected cable decreases to 5% of that experienced on unprotected cable, and this is operationally acceptable.

[†] BYRNE, B. M. Entomological Deterioration of Polymers in Underground Tropical Environments. *Proceedings of the Sixth International Congress on Metallic Corrosion*, Section 16, Sydney, Australia, Dec. 1975.

British Telecommunications Engineering

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The price to British Telecom and British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 90p (£1·40 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975; January, April and October 1976; and January 1982 issues.

Orders, by post only, should be addressed to *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG.

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Remittances for all items (except binding) should be made payable to *'BTE Journal'* and should be crossed '& Co.'

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Model-Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Copies of the syllabi and question papers are not sold by *British Telecommunications Engineering Journal*, but may be purchased from the Sales Department, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

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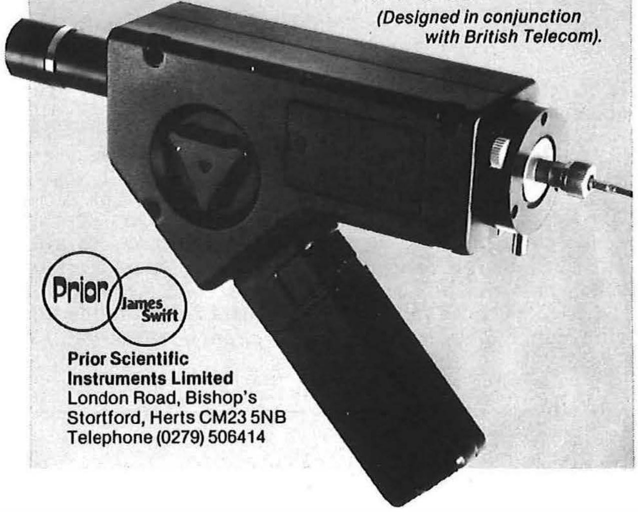

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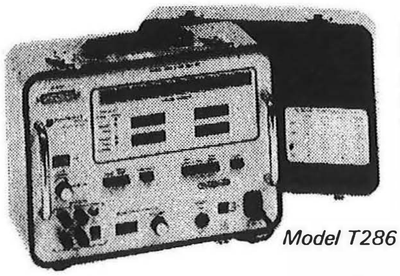
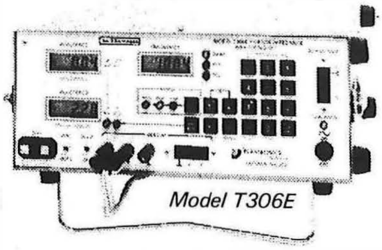


Model T286

Model T286 DTMF Test Set for evaluating performance of dual tone multifrequency (DTMF) tone systems and equipment.



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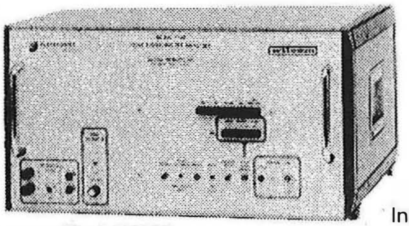
Model T306E Phasor Impedance Measuring Set measures both resistive and reactive components of impedance (R±jX) at frequencies between 20Hz and 20kHz



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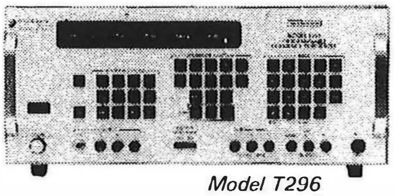
Model T180 Tone Signalling FFT Analyzer portable test set providing means to measure signals which occur as short bursts of tone. Including KP, MF and DTMF.



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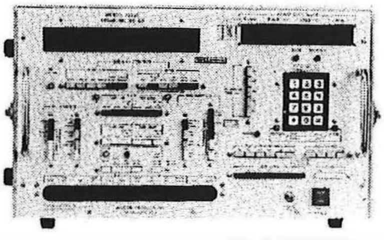

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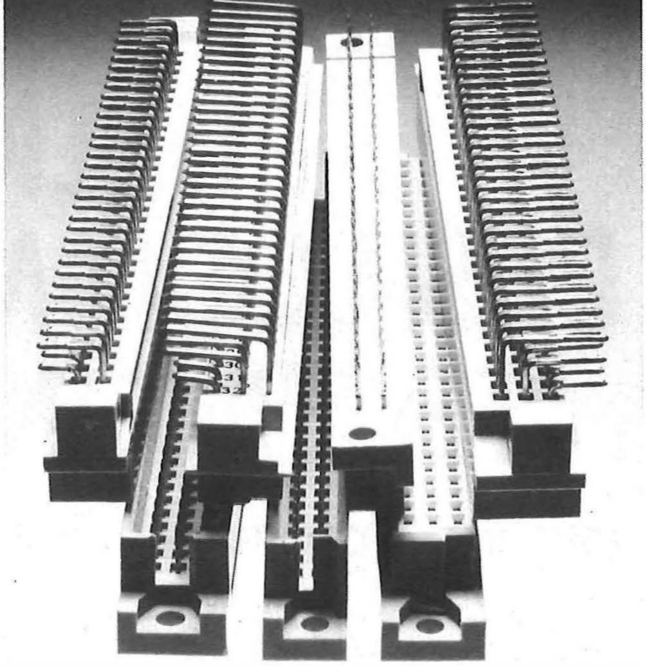

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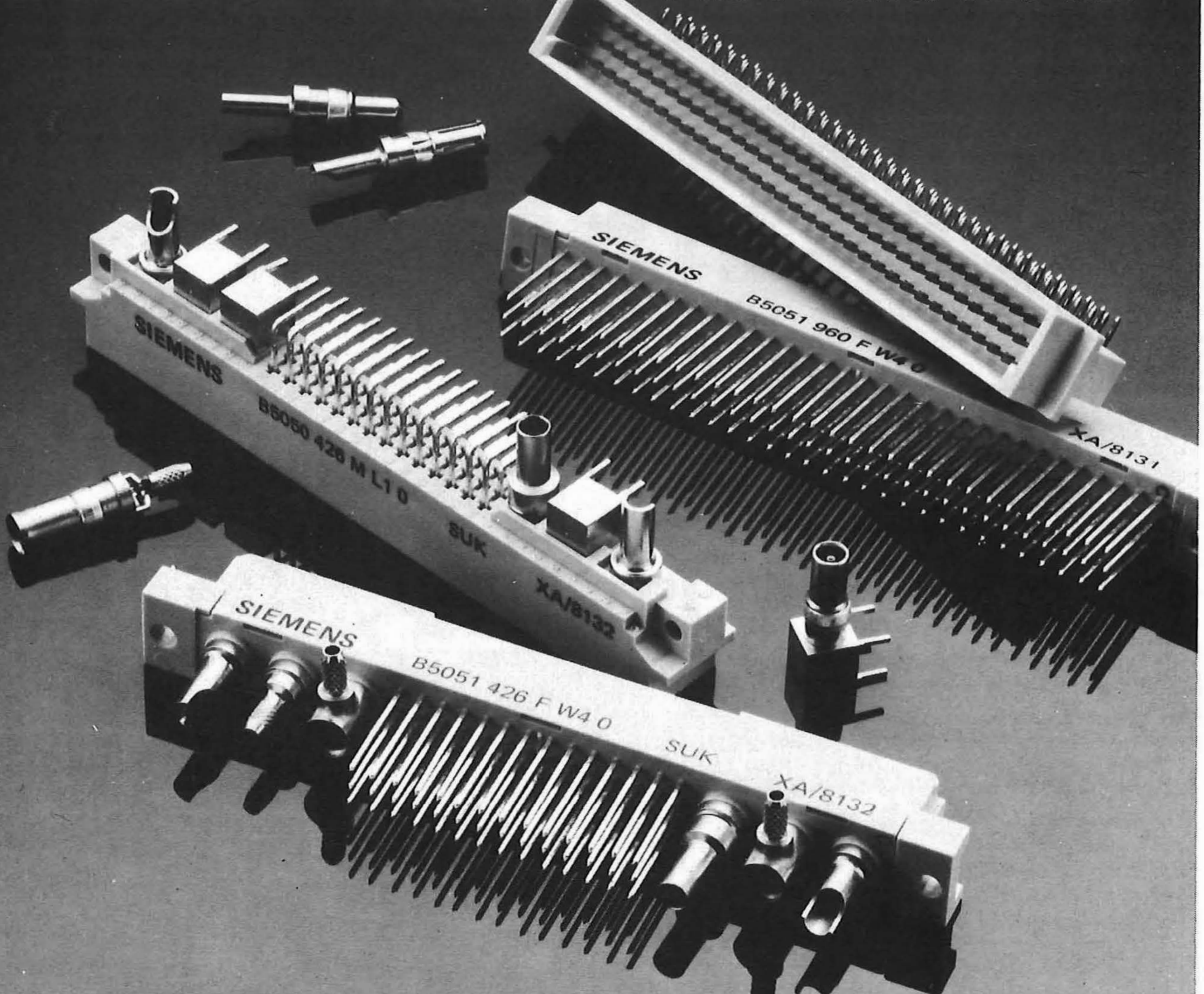

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BT 43 series

BT/Greenpar/British Standard cross reference

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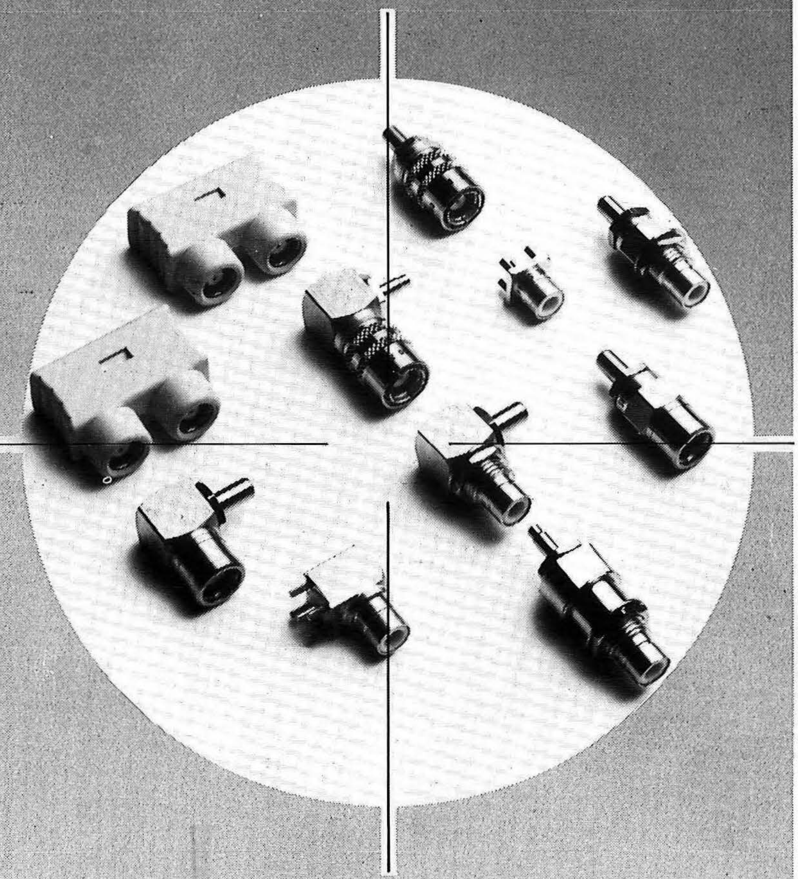
43/2A	G67241D117	06-03-1B2-Q	2002
43/3A	G67241D62	06-03-1B3-R	2003
43/4A	G67241D22	06-03-1BB-B	RG179B/U
Straight Latching Crimp Sockets			
43/1B	G67243D280	06-03-2B1-C	2001
43/2B	G67243D117	06-03-2B2-Q	2002
43/3B	G67243D62	06-03-2B3-R	2003
43/4B	G67243D22	06-03-2BB-B	RG179B/U
Right Angle Latching Crimp Sockets			
43/1C	G67244D280	08-03-2B1-C	2001
43/2C	G67244D117	08-03-2B2-Q	2002
43/3C	G67244D62	08-03-2B3-R	2003
43/4C	G67244D22	08-03-2BB-B	RG179B/U
Right Angle Crimp Sockets			
43/1D	G67242D280	08-03-1B1-C	2001
43/2D	G67242D117	08-03-1B2-Q	2002
43/3D	G67242D62	08-03-1B3-R	2003
43/4D	G67242D22	08-03-1BB-B	RG179B/U
Straight Bulkhead Crimp Plugs			
43/1A	G67245D280	07-02-1B1-C	2001
43/2A	G67245D117	07-02-1B2-Q	2002
43/3A	G67245D62	07-02-1B3-R	2003
43/4A	G67245D22	07-02-1BB-B	RG179B/U
Right Angle Bulkhead Crimp Plugs			
43/1B	G67249D280	11-02-B1-C	2001
43/2B	G67249D117	11-02-B2-Q	2002
43/3B	G67249D62	11-02-B3-R	2003
43/4B	G67249D22	11-02-BB-B	RG179B/U
Straight 5 mm Bulkhead Mount Plugs			
43/1C	G67247D280	07-02-2B1-C	2001
43/2C	G67247D117	07-02-2B2-Q	2002
43/3C	G67247D62	07-02-2B3-R	2003
43/4C	G67247D22	07-02-2BB-B	RG179B/U
Straight PCB Mounting Plug			
43/1D	G67207	13-02	
Right Angle PCB Mounting Plug			
43/1E	G67210	14-02	
U Link			
13A	G67229	33-05	

Greenpar offers a comprehensive range of miniature and r.f. connectors, cables and assemblies and has been an approved BT supplier since 1973.



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Greenpar

Greenpar Connectors Ltd.
P.O. Box 15, Harlow, Essex CM20 2ER
Telephone (0279) 39111
Telex 81404 GRNPAR