The Post Office Electrical Engineers' Journal

VOL 66 PART 4 / JANUARY 1974

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

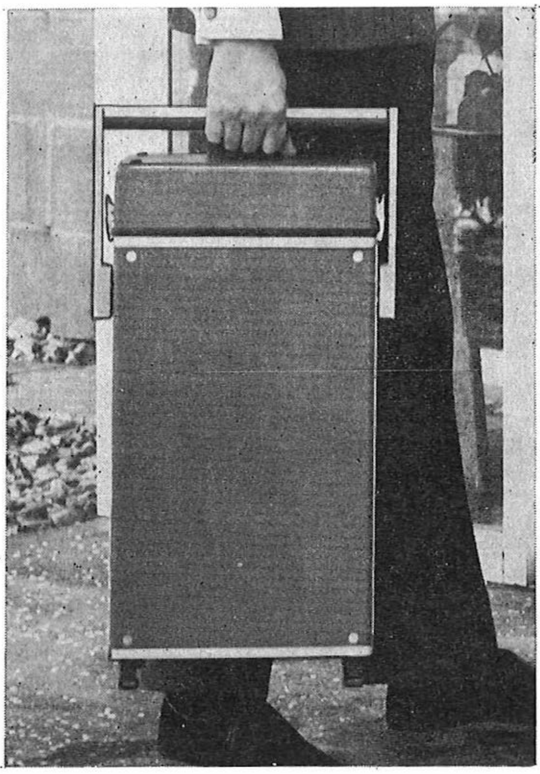
VOL 66 PART 4 JANUARY 1974

Contents

Published in April, July, October and January by the *Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG

Price 21p 31p (Including Postage and Packaging). Orders by post only.

Annual Subscription (post paid): Home and Overseas £1.24. (Canada and U.S.A., 3 dollars)



Hewlett-Packard announces a truly portable Amplitude and Delay Distortion Analyser that betters CCITT recommendations

* Transmitter and receiver combined in single, rugged, easy-to-carry case.

* Measures group delay and attenuation distortion using CC ITT approved principles.

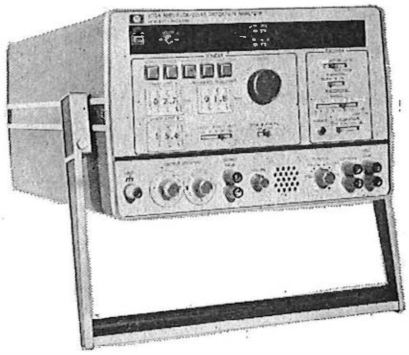
* Measuring frequency range 200 Hz to 20k Hz Reference frequency 400 Hz to 20 kHz. Synthesiser accuracy of the generator gives enhanced repeatability of results.

* Absolute level measurements from +10dBm to −50dBm from 200 Hz to 20kHz.

* Solid state digital displays. Selectable digital averaging facility to improve noise rejection.

* Facilities provided include: automatic continuous/single frequency sweep and incremental stepping; X-Y recorder outputs.

* Options: loudspeaker; telephone facility; dc loop holding; flexible tone blocking.



For full details on this portable, practical instrument, which sets new standards of accuracy in this field, please contact Hewlett-Packard Ltd., 224 Bath Road, Slough, Bucks., SL1 4DS. Tel: Slough 33341.

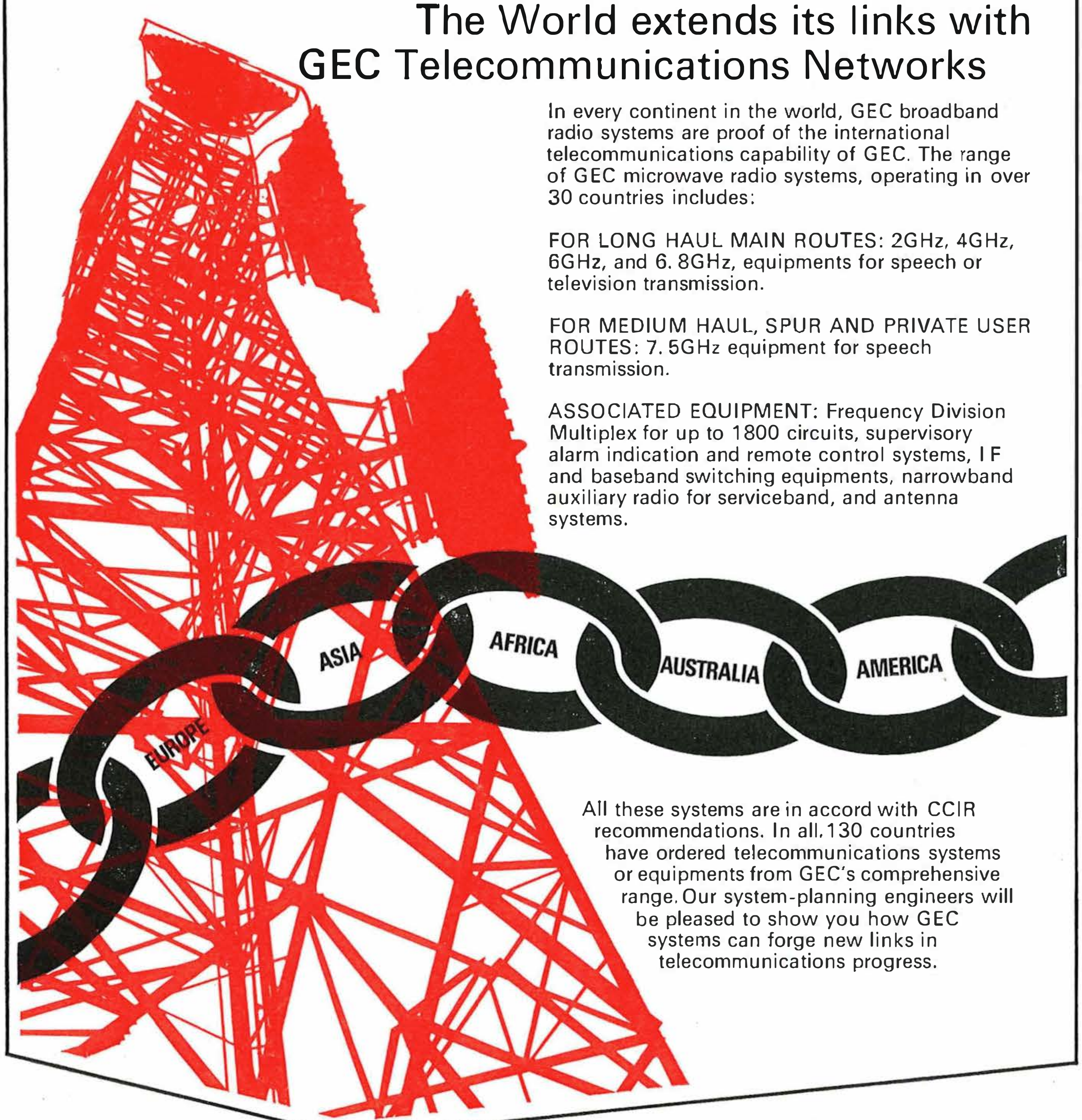
HEWLETT hp PACKARD

Sales, service and support in 172 centres in 65 countries.
224 Bath Road, Slough. Bucks SL1 4DS. Tel: Slough 33341.


This is the new
STC QUICKSTEP DELTAPHONE–
it replaces the rotary dial with
push buttons and a memory.
And it needs no battery.
1 2 3
4 5 6
7 8 9
0
01-368 1234

comprehensive telecommunications

The World extends its links with GEC Telecommunications Networks



In every continent in the world, GEC broadband radio systems are proof of the international telecommunications capability of GEC. The range of GEC microwave radio systems, operating in over 30 countries includes:

FOR LONG HAUL MAIN ROUTES: 2GHz, 4GHz, 6GHz, and 6.8GHz, equipments for speech or television transmission.

FOR MEDIUM HAUL, SPUR AND PRIVATE USER ROUTES: 7.5GHz equipment for speech transmission.

ASSOCIATED EQUIPMENT: Frequency Division Multiplex for up to 1800 circuits, supervisory alarm indication and remote control systems, IF and baseband switching equipments, narrowband auxiliary radio for serviceband, and antenna systems.

All these systems are in accord with CCIR recommendations. In all, 130 countries have ordered telecommunications systems or equipments from GEC's comprehensive range. Our system-planning engineers will be pleased to show you how GEC systems can forge new links in telecommunications progress.

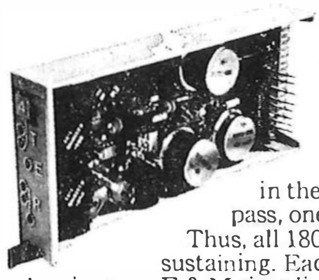
G.E.C.

MICROWAVE AND LINE TRANSMISSION · MULTIPLEX · V.F. TELEGRAPHY DATA MODEMS · TELEPHONE SWITCHING SYSTEMS · PRIVATE TELEPHONE SYSTEMS · TELEPHONES · TOTAL SYSTEMS CAPABILITY

GEC TELECOMMUNICATIONS LIMITED of Coventry, England.
A Management Company of The General Electric Co. Ltd. of England. IBB60

The Simplified

Now 600 voices can go directly to supergroup.



Not since satellites started floating above the equator has there been such an important development in large-scale telecommunications. We can now offer you a greatly simplified 1800-channel multiplex system (3 x 600 channels).

The system, which meets or exceeds CCITT and North American standards, incorporates three major breakthroughs.

The first is our development of a miniaturized bandpass filter made of thin layers of quartz. It takes just one cubic inch of space instead of the 20 to 30 cubic inches needed for conventional inductance-capacitance filters.

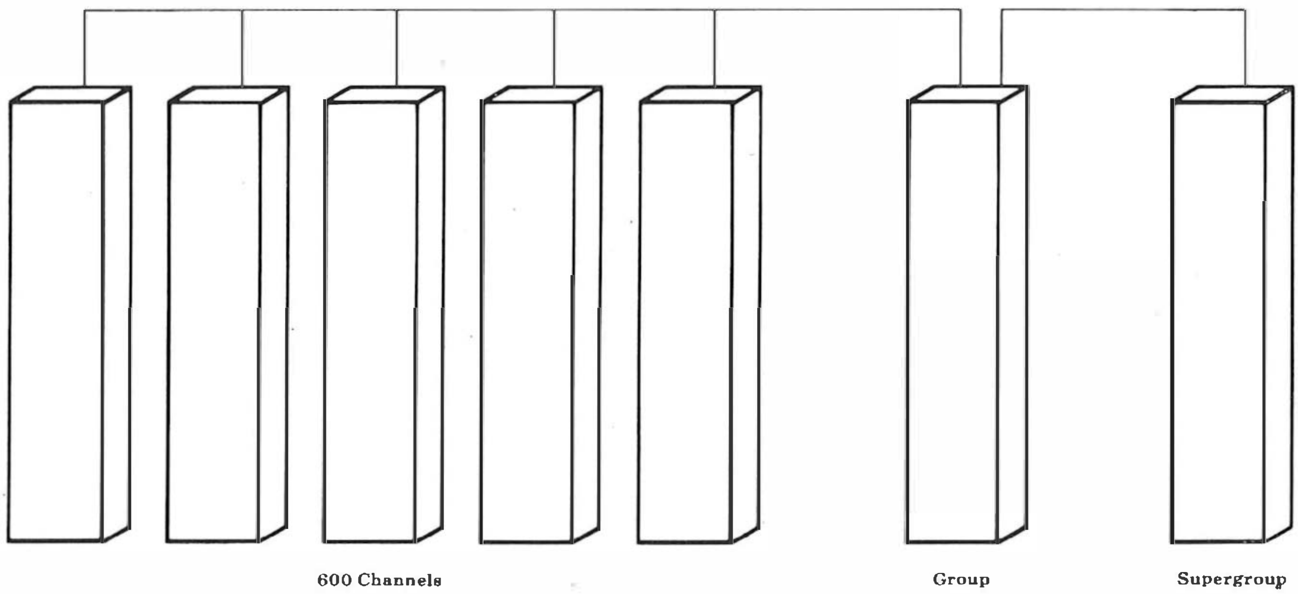
This polylithic quartz filter makes possible the second breakthrough: a modular, plug-in channel unit of completely new design. We were able to miniaturize the channel unit, by using the filter with integrated circuits and thick-film technology.

Each channel unit contains three of the new quartz filters (the little round capsules in the photo). There's one for transmitter bandpass, one for receiver bandpass and one for signaling.

Thus, all 1800 channel units are identical and self-sustaining. Each has complete transmitting, receiving, E & M signaling and power functions. The first modulation stage boosts the channel into an 8140 kHz slot, while one of the filters selects the sideband. A second modulation stage puts the channel into its line-frequency slot.

So the work of the group frequency modulator is done

Conventional system.



Multiplexer.

right inside the channel unit.

Which makes possible the third breakthrough: we got rid of group modulation altogether!

Now signals in a high-capacity multiplexer can go directly from voice to supergroup frequencies.

By doing away with the whole middle modulation process (by the way, we're the only ones who've done so) we've achieved a number of things.

Simplicity. (Look at the diagrams.)

The system needs much less space.

It's more reliable.

You don't need as many channel spares (3 to 5% instead of 10 to 15%).

Installation costs are reduced. (Because we've cut out group and group carrier supply cabling.)

There's less distortion. (Because there's one less stage of modulation.)

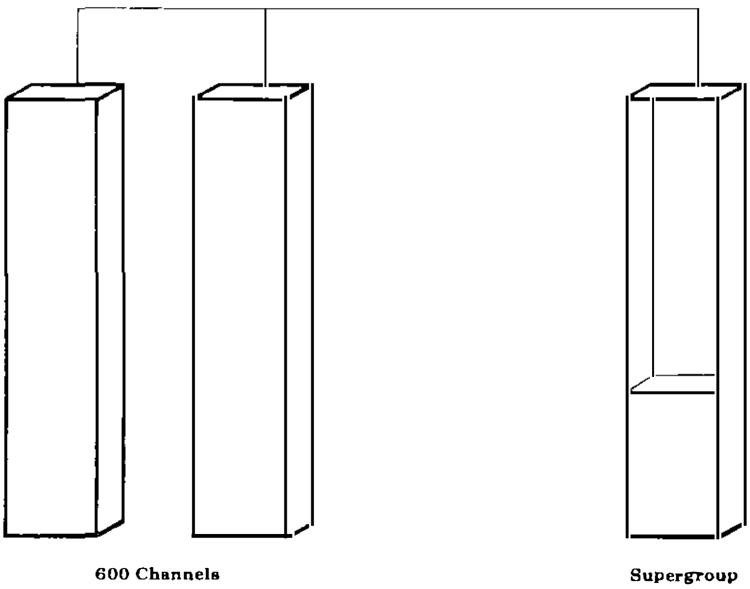
The new system will not only handle voice, it will also take data, telemetry and facsimile signals. It's compatible with existing systems. And we can still perform the group insert and extraction functions.

We'll be glad to send you a brochure on the Simplified Multiplexer, Model 46A3-C. If you have any questions, we'll try to give you a simple answer.

Write to: GTE International Inc. at 909 Third Avenue, New York, N.Y. 10022 or GTE Telecomunicazioni S.p.A., Via Turati 27, 20121 Milan, Italy.

GTE INTERNATIONAL

Our new system.



The Post Office Electrical Engineers' Journal

The first four years of the Post Office have seen dramatic growth and change in telecommunications. The part played by Engineers in meeting that growth and in stimulating change has been recorded by this *Journal* mostly as events happened. However, during that time, and in accordance with Business Plans and Corporate Plans, the form of a possible long-term modernization strategy for Britain's telecommunications system has emerged. The dominant engineering characteristics are already evident—digital, microelectronic, and with electrically alterable control—and are apparent in many recent articles in the *Journal*. But, other aspects of modernization must be dealt with—factors affecting its rate—engineering realities of modernizing without interfering with operations—new equipment—new service aims and possibilities—and how to plan, procure, and run systems quite different from today's. An important future role of the *Journal* is to declare to colleagues in the Post Office, in Industry, and in other telecommunication Authorities the engineering fundamentals of this twin task of system growth and renewal in the service of our customers.

For 65 years, the *Journal* has recorded change, through the persistent, persuasive and progressive work of Honorary Editors and Assistants in their "free" time. Volumes of past issues reflect their efforts, and pay tribute to their high editorial standards. Their success and the resultant growing circulation means that "part-time volunteers" cannot reasonably be faced with the severe problems of management of printers, editorial content, and new publishing techniques. I am, therefore, very pleased to welcome Mr. D. Millington and Mr. B. Stagg as Managing Editor and Assistant Editor respectively, who will continue to work under a Board of Editors chaired by Mr. J. F. P. Thomas, as they too seek to maintain and enrich the traditions of this *Journal*.

President of the Institution of
Post Office Electrical Engineers
Board Member for Technology and
Senior Director: Development

A Long-Term Study of the United Kingdom Trunk Network

Part 1—General Methodology: Forecasts: Plant Study

D. BREARY, C.ENG., M.I.E.E.†

U.D.C. 621.395.374.001.1: 621.395.31

Recognizing the rapid advances in technology in recent years and the continuing high growth of trunk telephone traffic, the British Post Office set up a team to undertake a long-term study of the United Kingdom trunk network. Part 1 of the article outlines the overall study methods adopted by this team, details their work on forecasting connexions, traffic and costs and describes the cost studies undertaken relating to transmission and exchange plant.

INTRODUCTION

In the last two decades, there has been rapid growth in telephone traffic accompanied by a significant change in the relative importance of long-distance telecommunication. This is illustrated in Fig. 1 which shows the general trend, over the last decade, of how the relative proportion of trunk calls to total originated calls has been growing. Currently (1972) some 14 per cent of all originated telephone calls are trunk calls, accounting for 30 per cent of the total British Post Office (B.P.O.) telecommunications revenue, and peak-rate trunk traffic is growing at a rate of about 13 per cent per annum.

The technologies available to handle long-distance traffic have, until recently, been changing relatively slowly. They have been based on analogue transmission and electro-mechanical space-division switching systems, and the rate of changes on the latter have been even slower than on the former. The planning rules and strategy appropriate to them are now highly developed, being built on principles established over many years. More recently, the rate of change of technology has accelerated and many new technological advances relevant to long-distance telecommunications are either available or are in prospect. For example, rapid advances in micro-electronics, and in the techniques for handling digital information, are leading to revolutionary changes in the design of telephone exchanges and transmission systems, and new technologies using waveguides, or perhaps glass fibres, are leading to the development of very-high-capacity transmission systems. Some of the implications of such developments on network plant are illustrated in Figs. 2 and 3. Fig. 2 shows how continuing developments in transmission systems provide increasing capacity and Fig. 3 is a smoothed curve showing how costs per speech circuit are forecast to decrease as newer systems and media are introduced with increasing circuit capacities.

Rapidly-changing technology, coupled with high growth, prompted the B.P.O. to initiate a study in depth of the United Kingdom (U.K.) trunk network to obtain information on the types of plant and planning strategy which would most likely meet the best interests of the service for the next 30 years. In particular it was necessary to study

(*a*) the extent to which the strategy of the future would differ from that of the past or present,

(*b*) the extent to which new technologies offered economic advantages, and the penalties of their co-existence with earlier technologies, and

(*c*) whether the economics of the available technologies suggested that the long-distance network should become a progressively more diffuse mesh structure or a more concentrated backbone structure, and whether there should be the same number, more or fewer switching points.

Recognizing that it was necessary to cater for a telecommunications network rather than simply a telephone network, and that the long-term forecasts of the requirements for our society 20 or 30 years ahead can, at the best, be regarded as unreliable, it was necessary to carry out sensitivity studies to find out whether the results of the investigations were critically dependent on the forecasts about future costs, future volumes of traffic and about the nature of the services themselves.

To carry out the studies, the B.P.O. set up a small specialized team, the U.K. Trunk Task Force (U.K.T.T.F.), and this article is largely based on its work, and on the methodology that was used.

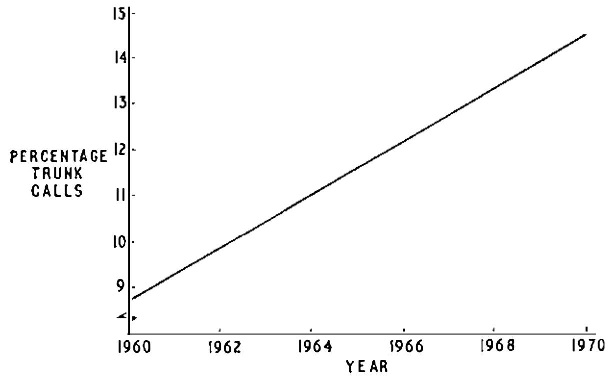


FIG. 1—Growth of relative proportion of trunk calls to total originated calls

† Formerly with the United Kingdom Trunk Task Force.

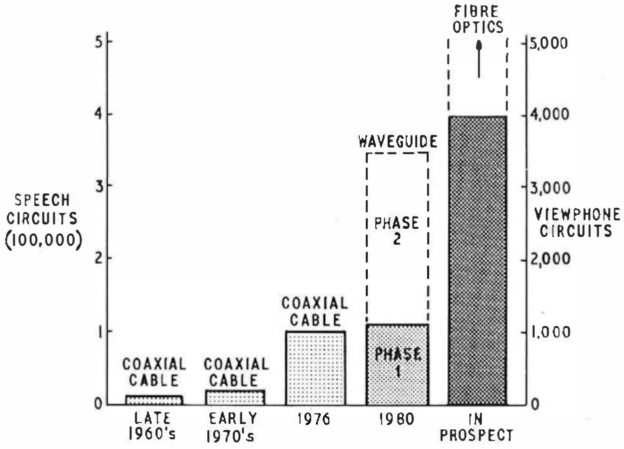


FIG. 2—Transmission system capacity

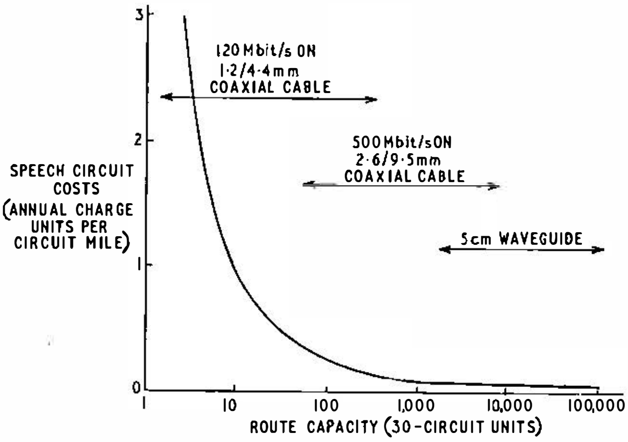


FIG. 3—Speech circuit costs as a function of system capacity

OVERALL STUDY METHODOLOGY

The progressive steps in the underlying strategy of the long-term study of the switched network were as follows:

(*a*) determination of the requirements of the society of the future,
(*b*) determination of the technologies likely to be available in the future,
(*c*) using the expected technologies and taking note of the current plant provision situation, to draw up the alternative means of meeting society's future needs,
(*d*) study of the alternatives, and
(*e*) testing the sensitivity of the conclusions to variation of the original data and assumptions.

A basic work pattern for such a study as used by the U.K.T.T.F. is illustrated in Fig. 4. The nature of society up to the end of the century was studied and sociological futures prepared. These enabled the various telecommunications services to be forecast, thus enabling a comprehensive picture to be drawn up: several such futures were needed to represent a range of possible future evolutions. In parallel with this work, the types and quantities of plant currently in use were studied, together with plans for its extension, and any studies or ideas for the future, available in the B.P.O. or elsewhere, were examined. The work of research establishments, inside and outside the B.P.O., was examined and forecasts made of the nature and timing of the availability of future technology. When this preliminary work was completed, a range of network scenarios was drawn up, each representing a step in a possible way that the network could develop from the present day into the long-term future. To enable costing to proceed, the essential features of each scenario were extracted and formally stated and the basic costs of the various plant items forecast. Costing then proceeded, usually using a combination of manual cost calculations and computerized costing techniques based on a computerized network model specially produced for the purpose. As each result emerged, sensitivity tests were made.

The study of the whole trunk network was a very large problem, and to be manageable, had to be broken down into smaller, though inter-related, parts. Customer services and their associated forecasts were divided into four; switched telephone, switched wideband (e.g. Viewphone), separately-switched data and miscellaneous. Each of the switched services was deemed to include certain miscellaneous services mixed in with them (e.g. the data services carried on the switched telephone network were included in the forecasts for that network, not with those for the separately-switched data network). The first three services were considered to be major plant-using services, though it was recognized that some of the miscellaneous requirements such as Confravision,

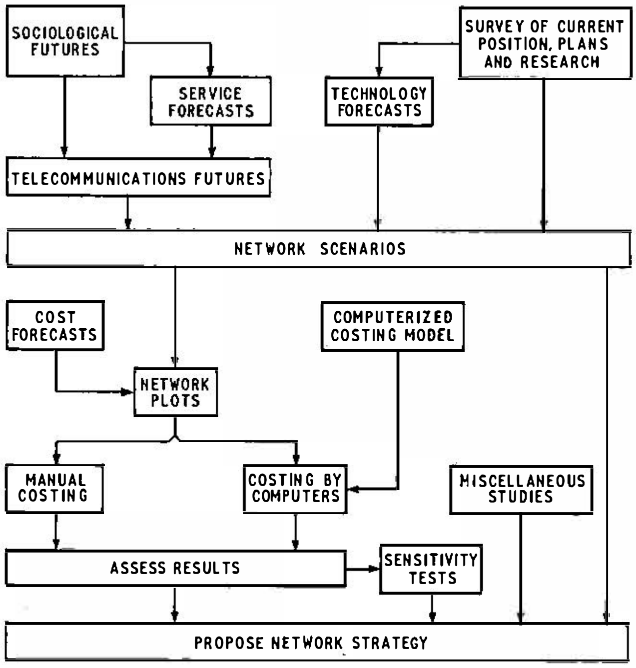


FIG. 4—Network study strategy

closed-circuit television and British Broadcasting Corporation and Independent Broadcasting Authority television circuits could sometimes have a significant effect on network planning, and these were given special attention within the miscellaneous group. Telecommunications plant was divided into transmission, switching, signalling and control plant, and it was considered that each customer service would have transmission and switching plant dedicated to its exclusive use although signalling and control plant might be shared. The dedicated transmission plant was assumed to come from a common pool of such plant, though it was recognized that this common pool might be in two parts, one employing analogue transmission techniques and the other, digital techniques. Network planning was divided into two parts, one concerning itself with the long-term consequences on the network of using new plant types, and the other concerning itself with the shorter-term economic and planning consequences of introducing the new types of plant into the existing network, that is, with the problems of interworking and phased changeover from old to new. Finally, certain problems were separated for individual study. These were:

(*a*) network protection and management,
(*b*) traffic routing philosophies,
(*c*) site and accommodation problems and features,

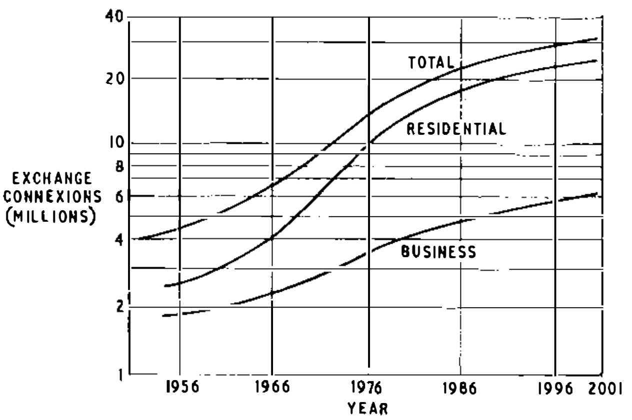


Fig. 5—Telephone service forecast

(*d*) decentralization of plant in large towns,

(*e*) a range of subsidiary matters concerned with numbering scheme capacity,

(*f*) the probable nature of a Viewphone service,

(*g*) cost trends,

(*h*) network performance, and

(*i*) tariff considerations and similar matters.

All studies were to some degree interactive and the results of earlier studies often had to be reviewed in the light of later ones.

All the costs collected were corrected to the value of the pound sterling at a selected base year, and all cost forecasts were expressed in terms of the value of the pound at that base date. A discount rate of 10 per cent was used.

FORECASTS

Connexion and Traffic Forecasts

For each foreseeable telecommunications service, forecasts were produced of connexions or customer terminals and the volume and distribution of traffic for a series of dates between 1975 and 2001. With the exception of the starting date (1975), dates were chosen which aligned with the established pattern of national population censuses: the starting date was the earliest date at which studies could have a practical effect on the network.

Telephone exchange connexion forecasts were, in the case of residential customers, based upon forecasts of population growth produced by the Registrar General, broken down into numbers of household units, and, in the case of business customers, upon the numbers and sizes of businesses. The trends of incomes and costs were also taken into account. These factors led to the telephone service forecast illustrated in Fig. 5 in which 100 per cent penetration of households is reached at the year 2001, leading to a total number of connexions, including the business element, of some 32 million. A more recent population forecast would have led to a slightly lower connexion forecast. The forecasts of traffic quantities are illustrated in Fig. 6 and suggest that the trunk component of busy-hour traffic will amount to about 0·5 million erlangs by the end of the century, nearly 12 times that which was handled in 1967 (the base date for the studies).

For studies of network layout, the source and distribution of this traffic is of great importance. In order to define geographical locations, use was made of the existing 640 or so charging groups which are of a convenient size for this purpose: it was considered to be extremely unlikely that the studies would eventually suggest that the number of future switching centres would be greater than this. Traffic distribution surveys, using sampling techniques, had been made in 1957 and 1967, and the results of these were available. From these, the traffic from each charging group to each other

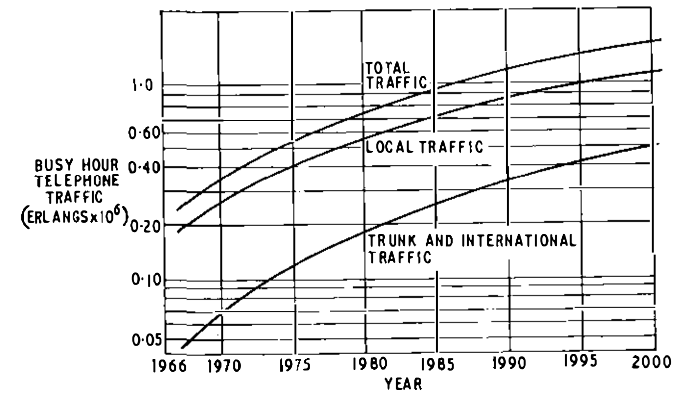


Fig. 6—Telephone traffic forecast

charging group was deduced and assembled in the form of a matrix, the 1967 traffic matrix. Treating each matrix entry separately, the 1967 traffic was split into business and residential components, and these were expanded separately. In doing this, different growth factors were applied to the numbers of connexions, and different growth rates to the traffic that these connexions generated. Finally, the figures were aggregated to get a new traffic quantity for that traffic matrix entry. By these means, a series of new traffic matrices was derived for later years up to 2001. During this process, some allowance was made for the geographical redistribution of telephony traffic, but the scope for this is not particularly great: even over a period of 25 years net migration of population within the U.K. is unlikely to exceed 2-million people. New towns take 25 years or so to grow from choice of site to occupation by some 200,000 people, and the large cities of London, Birmingham, Manchester, Cardiff, Glasgow, etc., will still be in their same locations at the end of the century. Most of the traffic is between the larger towns, and 80 per cent of the 400,000 or so matrix entries were less than 0·01 erlangs.

In addition to this detailed development of telephony forecasts, studies were made of other telecommunications services including data, telex, Confravision, facsimile and Viewphone. For these services, a certain amount of forecasting of a sociological nature was necessary to establish a likely pattern of demand in the latter decades of this century, during which public attitudes towards the telecommunications service are likely to be increasingly different from those experienced in the past. There was some interaction between the level of demand and prices, and also between prices and net disposable income. Consequently, some iteration was necessary. The switched wideband service estimates were based on a Viewphone concept that included facsimile, visual access to data banks and other services that could profitably make use of a bandwidth of 1 MHz or 6 Mbit/s, but alternative concepts of future broadband services could be expected to have an approximately similar effect on overall network dimensions. A broad assessment of likely system costs was made to enable possible prices for the service at various future dates to be assessed. Comparing these with forecasts of net disposable income enabled estimates of probable penetration to be prepared for residential customers. Estimates of growth and penetration of the service into businesses was forecast, being related to the size and types of business. The forecasts of such a novel service must inevitably be extremely speculative and, therefore, more than one forecast was made using varying assumptions. In one alternative, it was postulated that the service started in 1976 (such an early start would not now be possible) and would grow rapidly to about 5-million customers by the end of the century. In the light of more recent knowledge, both the upper and lower limits would probably be set rather lower, and the cost studies did, in fact, take zero Viewphone penetration throughout the study period as the lowest limit.

It is not possible to forecast with certainty the inventions that will become available in the next three decades. However, inventions or discoveries of such a fundamental nature as to dramatically alter technical operations are extremely rare. Furthermore, the lead time between invention and application in the field is rarely less than a decade (it is often more) and large-scale production of any new system takes some time to build up, so that it follows that systems which will form the backbone of our supply during the 1980's and early 1990's are likely to be based upon ideas which are already in being in the research laboratories or development organizations. Thus, in the transmission field, one can envisage a repertoire of techniques ranging from the present day use of coaxial cables and digital transmission on junction cables through a series of developments leading eventually to circular wave-guides and perhaps transmission via optical fibres. In the switching field, development from mechanical crosspoints through reed relays to electronic crosspoints and increased use of digital techniques and large-scale integration can be foreseen, with alternative systems based on analogue and digital transmissions being available. Similarly, a range of possibilities in the control and signalling fields can be fore-seen leading to computer-like stored-program-control devices interconnected by digital signalling systems using addressed packets of data.

Cost Forecasts

The forecasting of future systems costs is daunting, but, nevertheless, analytical techniques permit rational forecasts to be developed. To study the likely cost of a major item of plant such as a switching system, the plant can first he broken down into the items of cost such as raw materials, bought-in components, labour for assembly and factory overheads. This is illustrated in Fig. 7. For each of these items, an appropriate trend rate can be assessed which may well be quite different from item to item. For example, labour costs are likely to become relatively higher in real terms and regression analysis exercises based on data from past years suggests that labour costs will double by the end of the century in real terms, but off-setting this is an expectation of a smaller labour content in manufacturing. By contrast, the average cost of components is falling and these trends may be expected to continue under the influence of new techniques such as integrated circuits and large-scale integration. Each item of the cost is treated in turn, in this way, and the results combined to give a new plant cost for each of the forecast dates. It should be remembered that these estimates are all in terms of real value in which the effects of inflation are eliminated.

It is easier to produce a forecast of cost trends for items having a history than for items yet to be developed. There are, however, circumstances that mitigate the difficulties of such forecasts. Consider the case of a new digital transmission system. Fig. 8 shows how the major items of plant can be divided into different categories. Thus, in 1970, 16 per cent is represented by cable, 5 per cent by duct, 4 per cent by accommodation for terminal equipment, 45 per cent for first-order multiplexing, 19 per cent for second and higher-order multiplexing and 11 per cent for the line system itself. Of these items, cable, duct, accommodation and first-order multiplexing are all items with a past history and represent 70 per cent of the total cost of this particular system. The novel items represent only about 30 per cent of the total cost, so that errors in the overall estimate are proportionally diluted, e.g. an error of 25 per cent in an estimate of the cost of such items would produce a $7\frac{1}{2}$ per cent error in the overall forecast. In later years, such errors would be even smaller.

PLANT COST STUDIES

Transmission Plant

The U.K. trunk network is growing fast, so that transmission plant and its associated line or radio bearers are installed to meet a rapidly-growing demand. Hence, these systems meet rapidly-increasing circuit requirements throughout their life and this has important consequences on cost comparisons of these types of plant. Both the optimum capacity of systems and the economic advantages of alternative system types and sizes are critically dependent on the growth rates they have to serve. It would be exceptional for a new system to be installed and immediately loaded to its full circuit capacity and to base cost studies on this assumption would obviously give incorrect results. Equally, it would be unsatisfactory to assume some average circuit loading constant throughout the system's life, because this would fail to take account of the timing of plant provision and, hence, the timing of costs for discounting calculations. A realistic study must, therefore, start by assuming an initial traffic requirement in the first year to determine the plant costs which are incurred immediately: it must then assume the system to be augmented

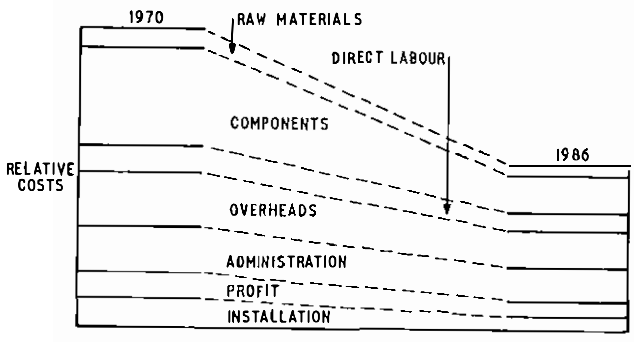


FIG. 7—Switching plant costs—breakdown and forecast

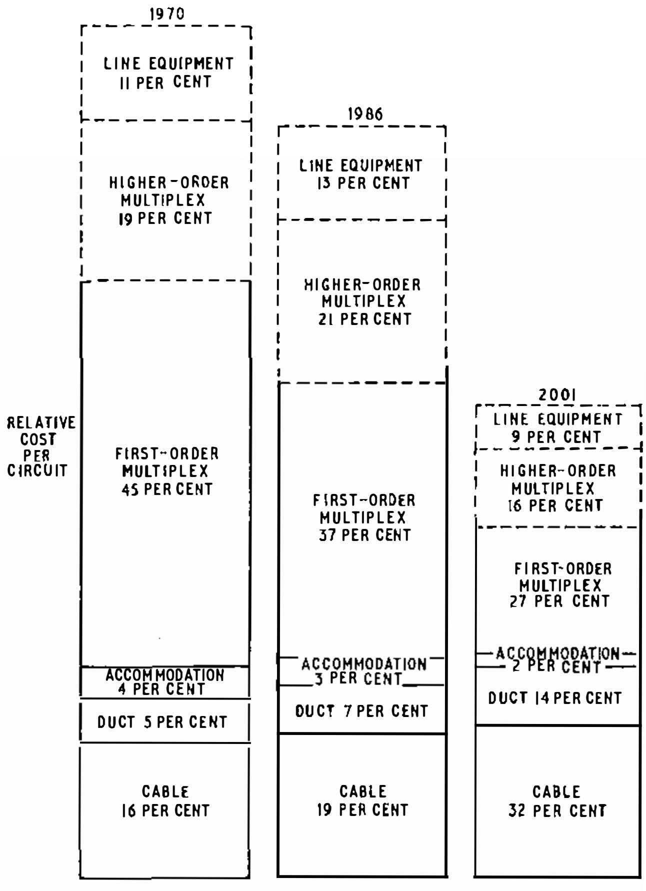


FIG. 8—Digital transmission system costs—breakdown and forecast

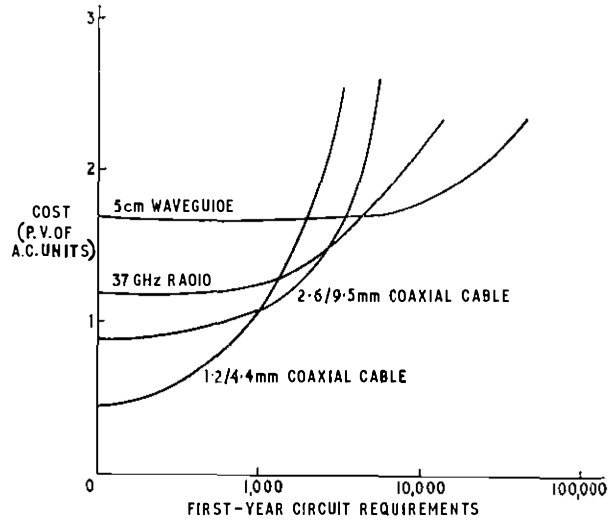


FIG. 9—Comparison of costs for new-route provision

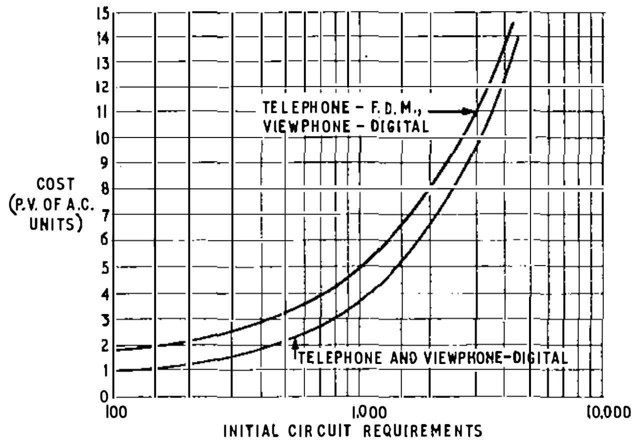


FIG. 10—Comparison of costs for digital and mixed systems

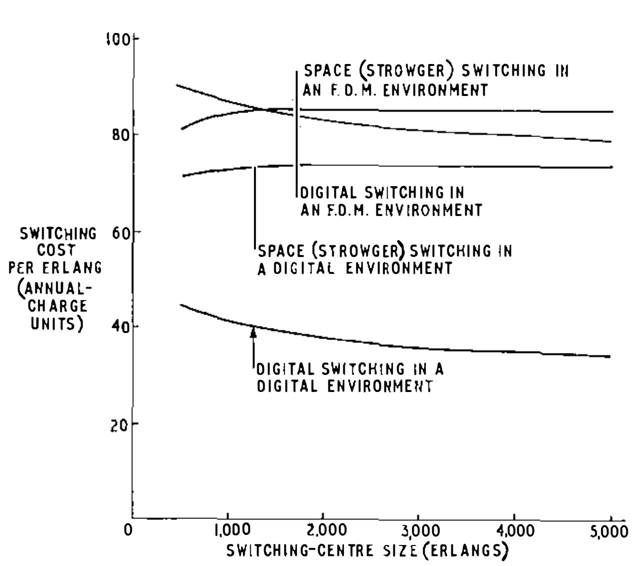


FIG. 11—Comparison of switching costs for various equipment arrangements

at appropriate intervals to meet the requirements for circuit growth, to determine what this means in terms of the costs of plant added at these intervals. For the U.K.T.T.F. studies, the traffic growth rates were, for the most part, derived from the traffic matrices described earlier. The systems were then costed over an appropriate period, usually 20 years, and, by discounting, an overall present value found. The calculations were repeated for a range of growth rates, system sizes and route lengths, so that a very large number of studies were necessary to obtain a complete and a realistic picture. These studies were repeated for different plant technologies, for different assumptions about the unused capacity of existing plant and for different assumptions about the extent to which different types of plant had to interwork, one with the other. These different studies are described briefly in the next few paragraphs.

A series of studies was carried out to establish the types and sizes of digital line plant most suited to the various growth rates found in the network. These studies assumed that the surrounding line plant was also digital, and hence, in these particular studies, inter-working costs did not arise. Signalling and first-order multiplexing costs were common to all alternatives, and did not, therefore, enter into the calculations. Numerous curves were prepared for different growth rates and plant types, each curve showing the present value of annual charges (p.v. of a.c.) for routes of 0–320 km in length. The studies showed that, in a digital network, there is an appropriate field of application for systems of the order of 120 Mbit/s and 500 Mbit/s for use on coaxial cable, microwave radio links and waveguides, the choice of system depending mainly on the transmission circuit capacity required in the first year and the rate at which growth was occurring. A curve summarizing the results from a route 320 km long is shown in Fig. 9. This particular summary represents the situation facing an officer planning to install the 1986 requirements in a digital network.

A series of studies was carried out to identify the most economic way of interworking digital and frequency division multiplex (f.d.m.) line plant covering a wide range of situations. Fifty or so alternatives were identified and costed. The study first examined interworking between digital and f.d.m. line plant in a network containing only space switching, and, having established interworking principles, went on to study the inter-working problems that would arise as space switching systems were progressively replaced by digital systems. In this case, signalling and first-order multiplex costs were included as they vary depending on the different alternative schemes envisaged. These studies were carried out on an annual charge basis and tentatively indicated that, depending on the number of circuits involved, interworking should be at audio level or at supergroup level via appropriate equipment. It also seemed likely that it would, in most cases, be preferable to replace f.d.m. systems by digital systems rather than to transmit digital signals over them (because of the loss of circuit capacity this would entail).

Making use of the previous two series of studies, a further series of studies was carried out to examine the economics of introducing digital transmission into the existing coaxial-cable network. This entailed over 100 curves being drawn, each showing the p.v. of a.c. over a range of route lengths for various situations. The situations covered included the following alternatives:

(*a*) that there were alternatively 6, 2 or no spare coaxial tubes available in existing cables (in the last case, new cables etc. were provided),

(*b*) that the percentage of digital speech circuits that had to interwork with f.d.m. circuits took alternative values from 0–70 per cent, and

(*c*) that the circuit growth rate took alternative values from 64–8,192 circuits per annum.

These studies showed that, when suitable sizes of digital transmission systems become available, digital working would be economic under a very wide range of growth rates and interworking situations.

Another series of studies was carried out to compare the economics of digital and f.d.m. line plant under long-term conditions assuming that interworking between f.d.m. and digital line plant was no longer necessary, and that some form of separate-channel signalling had been introduced (so that digital systems could no longer take advantage of reduced line-signalling equipment costs).

The results of numerous such studies for a 160 km route are summarized in Fig. 10. This shows that it is cheaper to handle both telephony and Viewphone traffic digitally than to use f.d.m. transmission for telephony and digital transmission for Viewphone. Other studies had already shown that it is expensive and technically difficult to handle Viewphone in a switched trunk network using f.d.m. techniques.

The sensitivity of the results of all the above studies to the various assumptions made is important. One of the more speculative elements in the forecasts is the extent to which a Viewphone service is likely to reach significant dimensions in the study period and many of the studies were repeated making alternative assumptions about the penetration of this service. It was concluded that the relative economic merits of f.d.m. and digital working are not critically dependent upon the provision of a Viewphone service or upon forecast of the digital transmission costs.

Exchange Plant

Exchange plant normally consists of switching, signalling and control plant, but in studies comparing digital with analogue switching plant, it was found convenient to include the first-order multiplexes of any digital transmission plant. In a line-plant environment, containing given amounts of f.d.m. and digital transmission plant, the need for first-order digital multiplexes is dependent upon the type of switching plant, and hence, properly costed with it. Studies were made on a discounted-cost basis, thus making allowance for the initial and subsequent instalments of plant at the appropriate times. It was recognized that the cost per line or cost per erlang of the initial instalment of a new exchange type would often be significantly higher than that of subsequent instalments, especially in the case of stored-program-control and digital exchanges. Hence, costs were based realistically on the plant to be provided, and not on averaged costs per line, erlang, etc. When introducing new exchange plant types into the existing network, allowance was made for inter-working the new with the old. This normally involved additional switching capacity (for switching traffic between the two parts of the exchange) and special interfacing plant. The costing method recognized that this interfacing plant might have a limited life and limited re-use value.

However, before embarking on these discounted-cost studies or network-layout investigations, a range of network-switching situations was investigated, involving individual space and digital switching units in f.d.m. and digital transmission environments and using annual charge costing. Fig. 11 shows four cases compared: space switching in an analogue environment, digital switching in an analogue environment, space switching in a digital environment and digital switching in a digital environment. The switching costs per erlang are shown as a function of switching centre size, based on 1986 upper confidence limit forecasts for digital plant and median cost forecasts for the remaining plant (though studies based on other forecasts were prepared). The economic advantage of using digital switching in a digital transmission environment is very marked. This figure relates, however, to a network in which there is 100 per cent digital or 100 per cent f.d.m. transmission on the trunk routes connected to the particular switching centre. In practice, while digital transmission plant is being introduced into the network, many switching centres will exist in a non-homogeneous environment in which both analogue and digital transmission systems will co-exist for many years. The consequences of such a mixed environment are illustrated in Fig. 12 which shows a comparison between a space-division switching system (crossbar) and a digital time-division switching system expressed as a function of the percentage of digital transmission penetration at the switching point concerned (which will normally be different from the average penetration for the network as a whole). Upper confidence limit costs have been used for the digital switching equipment. For penetrations above 30 per cent for large exchanges, and above 70 per cent for small exchanges, costs are significantly lower with digital switching. This figure also illustrates the economic advantages which can be derived from large switching centres compared with small switching centres. For a given percentage penetration of digital transmission, the costs per erlang switched are progressively lower for the larger switching centres.

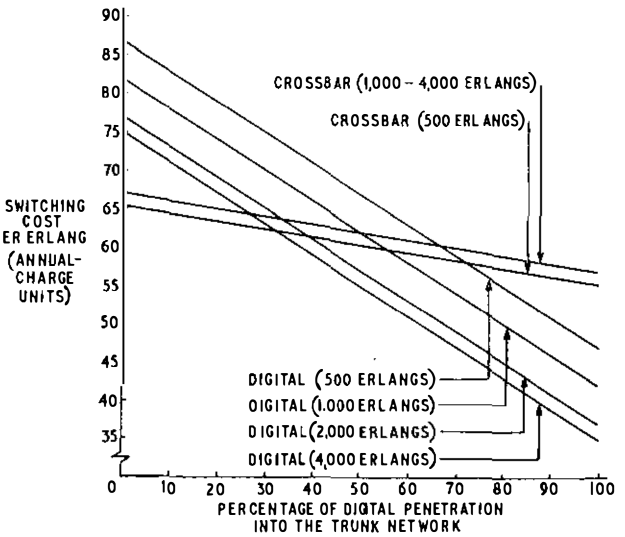


FIG. 12—Comparison of costs for space switching and digital switching

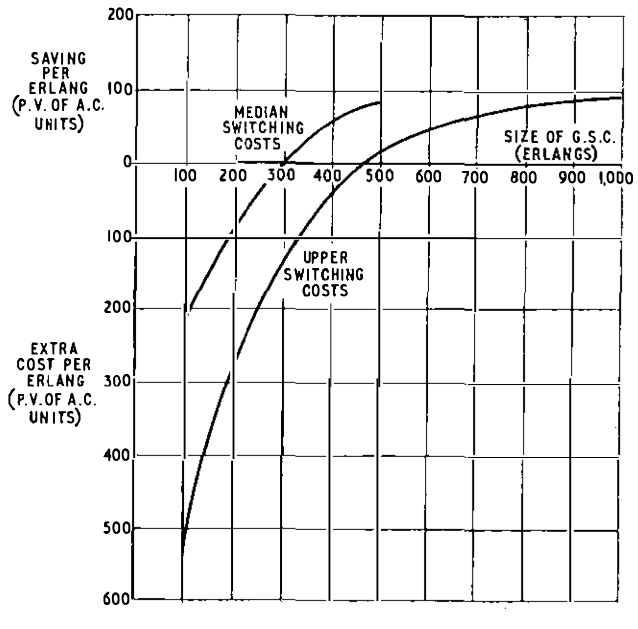


FIG. 13—Possible cost saving by extending a strowger exchange by digital switching plant

In practice, if digital switching were to be introduced, it would almost certainly have to be installed in a network where the transmission plant was initially largely f.d.m., but was progressively being augmented with more digital transmission systems. Also, the new digital switching equipment would have to inter-work with existing space-switching trunk units. This environment, containing a mixture of analogue and digital plant, would raise a whole range of interworking problems, progressively changing as time went on, and the amount of digital switching and transmission plant in the environment of each new digital exchange increased. The range of such changing, mixed, situations that will occur in practice is very great. Investigations of typical situations have shown that the larger space-division trunk switching units, typically those switching 300–500 erlangs or more at 1980, could be extended economically with digital switching equipment. This is illustrated in Fig. 13. The results are sensitive to the arrangements adopted for the change-over from space to digital switching, which, in turn, depend on the exchange equipment situation, the line plant layout and network environment that exist at each individual switching centre.

INTERIM CONCLUSIONS

The studies described in Part 1 of this article have shown that there are many line plant routes in the present space-switched network where digital transmission plant would be cheaper than f.d.m. plant even when they are considered in isolation, and many more if they are considered as part of a transmission plant network that is in process of being converted to digital working. The studies have also shown that switching centres, particularly large ones, can be economically converted to digital working, leading ultimately to a much cheaper network with greater potential for carrying new services, greater potential for long-term cost reduction and a greatly improved transmission performance. The implication on network layout, both during the change-over phase and in the ultimate network, will be dealt with in Part 2.

Introduction to the British Post Office Experimental Packet-Switching Service (E.P.S.S.)

R. C. BELTON, M.I.E.E., C.ENG., M.B.C.S., and M. A. SMITH, B.SC.(ENG.), M.SC.†

U.D.C. 621.394.4: 681.32: 681.3.08

Many computer systems now include a considerable communications content. A form of switched communication facility that can provide computer-to-computer and computer-to-terminal communications is known as packet switching. This article introduces the basic features of the technique and outlines the system defined for the British Post Office experimental packet-switching service (E.P.S.S.).

INTRODUCTION

For some years, the British Post Office (B.P.O.) have been conducting studies into the design of future data networks to meet new customers' requirements and interwork with similar networks established by other Administrations.

Up to the present, circuit-switched data networks operating in a synchronous digital system have received most attention and, at the 1972 C.C.I.T.T.‡ Plenary sessions, agreements were reached on a basic framework for internationally interconnected networks of this type.

In parallel with this work, but undertaken largely by the academic users of computers, has been the development of an alternative to the circuit-switched network known as packet switching. There is some prospect that such a system could be required on a national and international basis, and, to explore the various facets arising from the provision of such a service both from the customers' and the B.P.O. point of view, an experimental packet-switching service will operate in the United Kingdom from mid 1975.

This article introduces the concept and gives, in very simple and broad outline, the techniques adopted in the B.P.O. realization of a packet-switching system. Further articles will be produced later dealing with the system in more detail.

BASIC CONCEPTS

The original concept is based on work carried out by a research organization in the U.S.A.[1] and on communications methods used in computer systems. It also resembles telegraph message store and forward systems.

Basically, the technique consists of carrying packets, i.e. groups of binary digits, through the communications network

† Telecommunications Development Department, Telecommunications Headquarters.

‡ C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

as an entity, with the address, routing and error-control data included. The format of the packet is rigidly defined and the customer is expected to transmit and receive packets adhering to this format.

Customers will communicate with the packet-switching exchanges at a fixed data rate. However, as the formats of the customer's data are all known, the exchange can take in data at one rate from one customer and transmit it to another customer at a different rate, provided that the exchange can control the mean packet rate at which data is received from the customer. The customer equipped with a high-rate data channel may be able to receive packets from a number of different low-data-rate terminals. As each packet is clearly identifiable, the customer's computer can arrange packets received from different terminals to form coherent messages. Similarly, the customer with the high-rate line may transmit a sequence of packets which may be sent to different distant terminals.

The packet-switching exchange (p.s.e.) and customer's computer multiplex packets onto whatever rate data circuit is provided. This is particularly useful in the case of an expensive high-rate circuit between the customer's computer and his p.s.e. and on long trunk links between p.s.e.s. Packets arising from a number of terminals will be transmitted sequentially over the circuits with a resultant data density, that is, the number of useful data bits as a proportion of the total bits, much higher than can be achieved by other methods of multiplexing.

If a customer is not able to generate and receive packets in his terminal device, facilities can then be provided in his p.s.e. to receive data from him character-by-character and, from these, generate correctly assembled and formated packets. It would also be possible for packets to be disassembled and the information contained to be transmitted to the customer in character-by-character form.

The B.P.O. have devised a system with which to determine

(*a*) the way in which customers can use such a communication system,
(*b*) the optimum design parameters within the switching network, and
(*c*) how such a system will function in daily service.

The customers' equipment must be able to work with the very carefully defined system. This has been designed to meet, as far as possible, the requirements of a wide range of customers' computer systems and terminals, but it is a compromise which meets all of the requirements of only very few of the customers. Thus, it is necessary for customers to undertake a quite considerable amount of work on their system hardware and software to interface correctly with the E.P.S.S. Customers are, therefore, being given the opportunity to discuss and influence some aspects of the E.P.S.S. design.

The basic details of the system design are set out below.

PACKET FORMATS

The packet consists of three main sections or fields, these being the header field, the customer's data field and the error-check field.

Packet-Control Information (Header Field)

The packet-control information usually precedes the data field in the sense that it is the first part of the packet to be transmitted. It contains information relating to

(*a*) the packet address (for example, customer's number),
(*b*) the process or the part of the computer to receive the data in the particular packet,
(*c*) the number of bits or bytes, where one byte equals eight bits, in the data field,
(*d*) information relating to the individual packet-switching system, such as packet type, when there are more than one type, and
(*e*) packet sequence number, where packets are delivered in the same order as they are received.

The control information is one of the inescapable overheads with a packet-switching system and every effort is made to keep the number of bits required to a minimum. The most efficient method of inserting information is by the use of binary coding. However, other factors may have to be considered, for example, the need to use a standard coding system such as the C.C.I.T.T. International Telegraph Alphabet Number 5 (I.A. 5) which is based on a 7-bit character code, often with an extra bit for parity. The control information might be easier to handle in the byte form but usually contains some redundancy. This reduces the efficiency of the packet to carry data, but allows some coding flexibility. For example, an address of 8 digits (decimal) would require 8 bytes (64 bits) if I.A. 5 were used, 4 bytes (32 bits) if 4 bits are used per digit or, in the limit, only 27 bits need be used with binary coding. Because of the requirement for flexibility in coding, semi-bytes (4 bits per decimal digit) are used in the E.P.S.S., and these are not much more difficult to handle than bytes.

Customer's Data Field

This should be ideally of a form where the customer can transmit any number of bits, with the bits following any sequence the customer may desire. Usually, there are certain constraints to be observed, one of which relates to the maximum number of bits to be transmitted in a packet. To reduce to a minimum the effect on efficiency of overheads, such as the contents of the header field, and to reduce the number of packets to be switched in a given time, the data field should contain as many bits as possible. However, to limit the size of packet storage (buffers) and to speed up data-transfer, the data area should contain the minimum number of bits. It is also important to consider customers' requirements, for example, it may be desirable to relate the data-field size to a particular use such as the data to fill the screen of a visual-display terminal. The number of bits in the data area is also affected by the particular application, such as, whether the packet-switching service undertakes packet assembly and disassembly for character terminals. A data field that appears to be a good compromise is one with a maximum of 2,040 bits (0–255, 8-bit bytes) and has been chosen for the E.P.S.S.

Another factor in the design of the data field is whether to make it of fixed or variable length. A fixed length packet is easier to handle in that, after the start of the packet is detected, a simple count of bits can determine the end of the packet as it is received in a continuous bit stream. However, the customer may often only use a small part of the data area and would have to fill the rest with padding bits. This padding is an undesirable overhead which is avoided in the E.P.S.S. by using a packet based on a variable length data field.

The length of the data field can be determined by

(*a*) indicating, in the control area, the number of bits in the data field and setting a counter to that number after the start of packet indication is received, and
(*b*) providing a start and finish-of-packet signal.

The start of the data field is fairly simple to determine as it terminates the control area information, whose length may be deduced from the packet-type indicator. Certain precautions have to be taken with an end-of-packet indicator terminating a group of data bits with uncontrolled bit sequences in which the end-of-packet signal may be imitated. To avoid this, the customers' data is monitored and any bit sequence imitating the end-of-data signal is recoded before transmission to line. This new code has to be clearly recognizable so that it can be decoded at the receiver and the correct bit sequence sent to the customer.

Taking a simple example of this method, where a code 01111110 is used to indicate end of packet, every time the sequence 011111 appears in the customer's data field, the coding device would have to insert a zero before transmission to prevent imitation of the terminating code. The probability of such a sequence occurring in customer's data is quite high, being about once every 64 bits after 6 bits have been transmitted. Hence, in a 2,040-bit data field followed by an error check field of 16 bits, the overhead is 2,055/69 or about 30 bits.

Because the overhead to indicate data field length (in bytes) in the header field need only be one byte, this method is preferred, and is used in the E.P.S.S.

Error-Check Field

An essential facet of a packet-switching service is to deliver packets in a form which enables the recipient to detect any errors occurring in transmission. The normal method of achieving this is to add a short sequence of bits to each packet before transmission, either by the p.s.e. or customers' equipment, the added bits being derived from the preceding bits by a mathematical division process.

The error-check mechanism used is based on that recommended by C.C.I.T.T.[2] and requires that 16 bits are allocated at the end of the packet for this purpose in a form known as a cyclic redundancy check.

ERROR-CONTROL PROCEDURES

There are several systems which can be used to control the occurrence of errors in packets. In systems with high error rates and where low efficiency can be tolerated, forward error correction may be used. This technique works by coding data in a highly redundant manner and it may almost double the number of bits immediately before sending so that the recipient can deduce the original data even when several errors occur in transmission. Because of the overheads of such systems and because B.P.O. data communication services do not have high error rates, an efficient method based on the receipt of an acknowledgment from the recipient to confirm that the packet has been transferred without detected error has been specified for the E.P.S.S. In the event of an incorrect acknowledgement being received, the packet would be retransmitted. There are variations in the technique that can be used, such as to acknowledge only when defective packets are received, or to acknowledge only those packets which are received error-free. It is preferable that the system adopted should guard against loss of packets in the event of corruption or imitation of the acknowledgement signal. This signal may consist of 3 bytes or a complete packet depending upon the part of the E.P.S.S. involved and, in each case, a degree of acknowledgement-signal error protection exists.

(a) Customer-to-P.S.E. Error-Control Procedures

The distance between customers and their serving p.s.e. is generally less than that between p.s.e.s and will probably not include transmission media with "difficult" parameters, such as, varying propagation times, discontinuities and digital errors normally hardly noticed by telephony users. Consequently, advantage has been taken of a loop-synchronized transmission method for the E.P.S.S which gives a significant increase in throughput compared with non-loop-synchronized systems. In this technique, both the p.s.e. and the customer's terminal transmit contiguous bytes during and between packets, and the customer returns his stream of bytes with a fixed relationship to the stream received from the p.s.e. Acknowledgment signals consist of 3 bytes inserted into the stream, which the recipient can remove without spoiling a packet that may have been interrupted by the signals. This technique should be compatible with the future digital transmission data service which will operate synchronously. The receipt of an incorrect acknowledgement signal will cause the packet to which it refers to be retransmitted. In the customer-to-p.s.e. error control procedure, an acknowledgement should be received before another packet is sent.

(b) P.S.E.-to-P.S.E. Error-Control Procedures

The transmission medium between p.s.e.s may be less than ideal and, even if it is not so initially, experiments may be conducted over various transmission media to investigate their suitability for high-validity (low-redundancy) data-packet transmission. Also, the loop transmission delay may be significant, for example for London to Glasgow it will be about 7 ms when the modems and filters are taken into account. As the transmission rate of these circuits will be 48 kbit/s, this means at least 40-bytes delay between sending a packet and receiving an acknowledgement. Clearly, this would be an unacceptable overhead if no other packet could be sent whilst waiting for an acknowledgement. Hence, for the E.P.S.S. a system has been defined where several packets may be sent before an acknowledgement is received. A packet will be retransmitted when

(*a*) no acknowledgement has been received within a specified time, or
(*b*) following the receipt of an acknowledgement relating to a later packet.

Acknowledgements are transmitted in the form of short packets and these packets may contain more than one acknowledgement signal.

NETWORK CONFIGURATION

A number of approaches have been considered including one used in the U.S.A. where packet-switching equipment is installed in customers' premises. However, it was decided to use a conventional centralized switching system with the switching equipment on B.P.O. premises

(*a*) to permit access for maintenance purposes at all times, and
(*b*) to avoid data security problems due to the possibility of customers' traffic being routed through equipment in other customer's premises not taking part in the call.

The E.P.S.S. initial configuration consists of three exchanges, in London, Manchester and Glasgow.

ACCESS ARRANGEMENTS

In order to evaluate a wide range of data communication facilities as methods of access to the E.P.S.S. p.s.e.s, the services detailed in Table 1 may be utilized.

TABLE 1

Service	Rate (bit/s)	Character		Packet	
		Dial-up	Direct	Dial-up	Direct
Telex	50	*			
Datel 200	110 300	* *	* *		
Datel 2400	2·4 k			*	*
Datel 48 k	48 k				*

References

1 Baran, P., *et al.* On Distributed Communications. Rand Memorandum Series, Aug. 1964 (RM-3420).

2 C.C.I.T.T. White Book, 1968, Vol. VIII, Recommendation V41.

Stored Program Control for Telephone Exchanges: The World Scene

K. W. STOATE, B.SC., C.ENG., M.I.E.E. and D. W. BARFOOT, C.ENG., M.I.E.E., M.I.E.R.E., M.B.C.S.†

U.D.C. 621.395.345: 681.326.3.065

Stored-program-control systems have been introduced into the telephone networks of several countries. Some systems are fully-operational and others are still in the experimental stage. This article presents a brief summary of the mode of operation of these systems with emphasis on the control by computer.

INTRODUCTION

The central control of a switching system is not a new concept. Numerous systems have been in service, the latest example in the British Post Office (B.P.O.) being the proposed TXE 4 exchange.[1] In all these systems, any changes in functions, facilities, etc. have to be made by wiring modifications.

The advent of process-controlled computers and their introduction to the control of switching networks has introduced the idea of being able to modify the facilities provided in an exchange by altering the programming of the computer. The term stored program control (s.p.c.) has, therefore, been introduced to describe a system which is controlled by a computer, and the computer, in turn, is controlled by a stored program. This method of control is now recognized as an effective way of meeting the increasing demands of a telecommunications system.

GENERAL WORLD SCENE

At present, there are approximately twelve different types of s.p.c. system, either in service or at the point of commissioning, throughout the world .These are listed in Table 1 and a brief description of each follows with emphasis on the control (i.e. the computer) section.

TABLE 1

S.P.C. Systems in Service throughout the World

Country	Contractor	System	Approximate Number in Service
U.S.A.	Bell	ESS 1 and 2	300-400
Sweden	L.M. Ericsson	AKE 120	12
Canada	Bell (Northern Electric)	SP 1	10
Japan	Fujitsu Ltd. and Nippon Telephone Administration	DEX 2 and 10	8
Holland	L.M. Ericsson	AKE 13	1
Denmark	L.M. Ericsson	AKE 13	1
Belgium	I.T.T.	Metaconta 10C	1
West Germany	Siemens Ltd.	EWS 1	1
Morocco	I.T.T.	Metaconta L	1
Australia	I.T.T.	Metaconta 10C	1

UNITED STATES OF AMERICA

ESS 1

The stored-program-control concept has been considerably developed by the Bell Telephone Company with the introduction of the Electronic Switching System No. 1 (ESS 1). This has a capacity of 15,000–65,000 lines, and was the earliest s.p.c. system to go into public service, in May 1965, at Morristown. There are more ESS 1 installations than all the remaining s.p.c. installations in the world put together.

The system consists of two central processor units (c.p.u.), one running in an on-line mode and the other off-line, normally running in synchronism with the on-line processor; both processors receive and work on call information but only the on-line processor sends instructions to the switching equipment. The following methods are used to maintain service.

(*a*) All common equipment is duplicated.
(*b*) Internal hardware check circuits are liberally used.
(*c*) There are continuously-running fault-detection programs.
(*d*) A mismatch unit and emergency-action sequencer is provided to cater for system failures.

When the on-line processor fails, central control attempts to re-organize the system and establish a working configuration. In the last resort, the emergency-action sequencer takes control and exercises different combinations of duplicated units and highways until it finds a working system.

Each c.p.u. has two stores, the program store and the call store, the former containing read-only elements and the latter using the normal ferrite-core matrix. Line scanning can take place at various intervals from 10–120 ms; any changes are placed in store "hoppers" for the stored program to act upon. In the first models, this scanning was effected by the central processor but, in later models, a pre-processor is used.

The stored program is sub-divided into five functional groups, each controlling a stage in the call processing. These consist of input programs, operational programs, subroutines, output programs and executive-control programs, the last of which control the other functional programs on a scheduling basis.

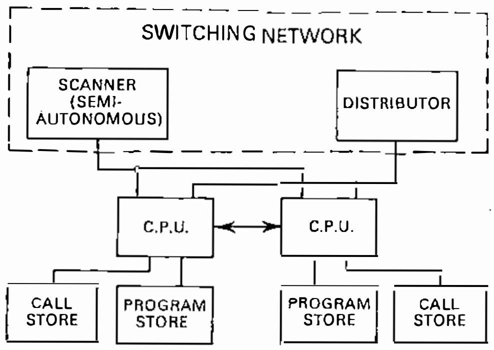


FIG. 1.—Block diagram of the Bell ESS 1 and ESS 2 systems

† Telecommunications Development Department, Telecommunications Headquarters.

The initial objective of down-time for the system was not more than two hours in 40 years. This objective has not been achieved but figures quoted in 1969 gave 60 hours down-time in 50 years experience over all offices then installed.

ESS 2

The Electronic Switching System No. 2 (ESS 2) is a simplified version of the ESS 1, and caters for local exchanges in the range 2,000–10,000 lines. The system is very similar to the ESS 1 except that the instruction word length is 22 bits instead of 44 bits. Some refinements have been made to the fault monitoring and to the re-configuration after faults.

The ESS 2 has only been in service for a short time and no meaningful figures on its performance have yet been published. The block diagram is similar to that for the ESS 1 system and is shown in Fig. 1. The mode of operation of both systems is space division using Ferreed switches.

SWEDEN

There are three types of s.p.c. exchange in service in Sweden, viz, the AKE 120, the AKE 12, and the AKE 13.

AKE 120

The AKE 120 was the first s.p.c. exchange to be brought into service in Sweden, in April 1968, at Tumba, near Stockholm. It was also the first s.p.c. exchange in the world to use 4-wire switching. There are approximately 11 AKE 120 exchanges now in service in Europe. The original capacity at Tumba was 4,800 subscribers and 700 trunks; this has now been extended to 9,600 subscribers and 1,400 trunks. The mode of operation is space division and uses the Ericsson code switch. A block diagram is given in Fig. 2.

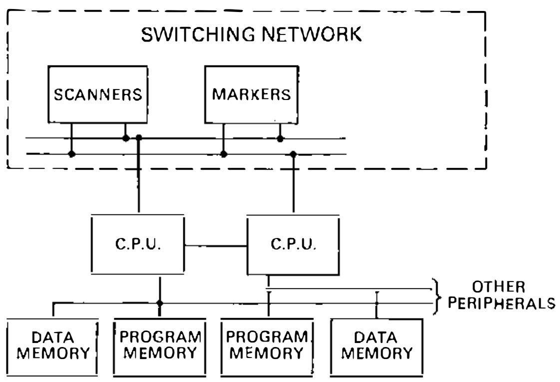


FIG. 2—Block diagram of the L.M. Ericsson AKE 120 system

Two computers—each consisting of a processor, a program store and a data store—operate synchronously, the output of one being inhibited. The output of the two processors are compared and, if a disparity occurs, suitable fault routines are instigated by a supervisory unit. The faulty unit, when found, is isolated and the system reconfigured to maintain service.

The stored program is divided into a number of functions, the main groups being:

(*a*) monitor, which controls scheduling of all the programs,
(*b*) traffic handling, which handles all signalling tasks and route selection and switching,
(*c*) exchange administration, which covers utilities and input/output messages, maintenance and testing facilities, subscriber facilities and traffic measurements, and
(*d*) supervision, which covers fault detection, alarm and fault localization.

Experience with Tumba showed that less than 0·1 per cent of rejected calls were due to technical faults in the system. Between 1968 and November 1970 there were 33 processor hardware faults giving mean time between failures of 600 hours and a mean time to repair of 126 minutes. In 1971, six hardware faults were recorded for the processors.

AKE 12 and 13

The AKE 12 is the production-type model of the AKE 120, and is primarily designed for trunk 4-wire switching. The AKE 13 is also a development of the AKE 120 but designed for local 2-wire systems as well as 4-wire switched trunk systems. The mode of operation is space division and uses the Ericsson code switch. The first AKE 13 in service was at Rotterdam in Holland in October 1971; since then, systems have been installed in Sweden and Denmark. The maximum design capacity is 60,000 lines. A block diagram of the exchange is given in Fig. 3.

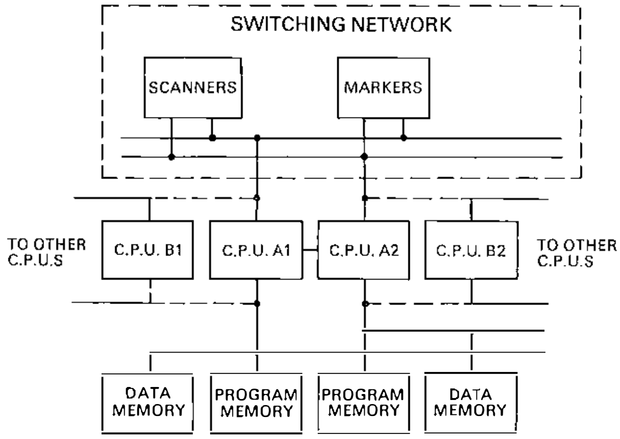


FIG. 3—Block diagram of the L.M. Ericsson AKE 13 system

The same processor configuration is used for both types of exchanges. Processors are connected in pairs, in proportion to the load, with a maximum of eight pairs. During normal running, the output of one of the pairs is inhibited. The working processors share the exchange load. Each processor consists of a control section, program store and supervisory unit. When a fault occurs, the supervisory unit initiates action to isolate the fault and re-configure the system.

The data store, into which all data (both temporary and permanent) on the exchange parameters is stored, can have up to 16 independent access channels. Information from the switching network passes over up to eight independent transfer channels which are allocated to the certain parts of the network with no overlays. Processors, data store and transfer channels are connected via a multiplexer and are duplicated for increased reliability.

Each combination of data-stored channel and transfer channel imposes a certain amount of processing which is performed by one processing unit according to the parameters in the particular data store. Programs within each area are allocated into a number of priority levels depending on the functional task being performed. The supervisory program (job monitor) in each processor unit is activated once every time interval and then allocates the work according to the priority of the task.

The performance to date is believed to be similar to the AKE 120 system.

CANADA

SP 1

The system in use in Canada is the Northern Electric (Canada) SP 1, Northern Electric being a subsidiary of the Bell Telephone Company Ltd. The SP 1 is similar in design and construction to the ESS 1 and has a maximum capacity

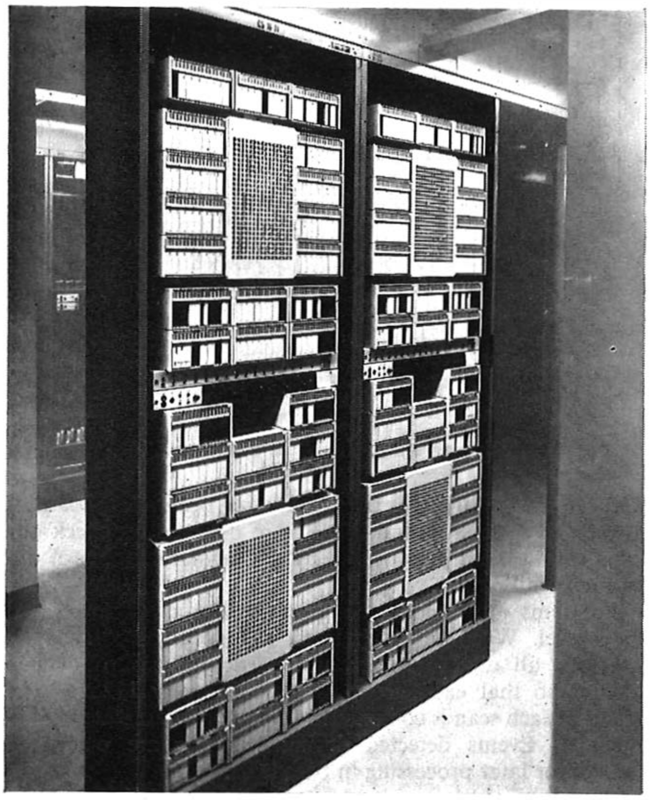


FIG. 4—Typical racks of the Canadian SP1 system

of 20,000 lines. Typical racks are shown in Fig. 4. The mode of operation is space division using a miniature crossbar switch (mini-bar) controlled by markers which, in turn, are controlled by the processor.

The stored program is split into two levels:

(*a*) a clock level* at which high-priority input/output jobs are executed, and

(*b*) a base level at which most of the programs are run.

Two classes of jobs are run at base level:

(*a*) synchronous, e.g. the scanning of incoming lines every 200 ms, and

(*b*) asynchronous, which are those processes run when necessary.

There is no available information giving the service experience of the systems installed to date.

JAPAN

The first s.p.c. exchange in public service in Japan was the DEX 2 at Ushigone, Tokio, in December 1969. A further development, the DEX 21, was placed in service at Kasumigaseki, Tokio, in December 1971.

These systems were the forerunners of the present standard system, the DEX 10. It is not known how many of these are now in service although there appears to be about six systems at the point of installation. The DEX 10 system was designed for local and toll switching centres, and for local exchanges catering for about 40,000 subscribers. The mode of operation is a space-division system employing small crossbar switches. A block diagram of the system is given in Fig. 5.

The central-processor system consists of fully-duplicated central-processor units, channel multiplexor and multiplex sub-channel. The main memory, which is common to both central processor units, is divided into

(*a*) a temporary memory, which is magnetic core and stores temporary data and program over-lays, and

(*b*) a semi-permanent memory, which is plated-wire and holds program and data that is not changed frequently. A core memory is provided as a stand-by reservoir.

The main memory is backed up by fully-duplicated magnetic drums. Other optional peripherals are magnetic tape and slow input/output devices.

The software is divided into two sections:

(*a*) basic, which is common to all exchanges, and

(*b*) additional, which has to be generated for a particular exchange requirement.

The basic section consists of the fault-processing programs for maintenance, a diagnostic program and execution-control program. The additional section consists of the call-processing program, which processes calls and switches connexions, and the administration program. The general philosophy is towards a function-oriented system.

The recovery system is structured into three levels of increasing severity with the first phase only affecting the call in progress and taking about 20 s to recover. In the second phase, all calls in speech are disconnected and the hardware has to be initiated, taking about 160 s. The final recovery phase includes phase 2 plus the re-loading of all semi-permanent memories, taking in all about 8 min. Information given at a recent conference is that phase 3 has not yet been used on a working system.

The initial objective for system reliability was set at system down-time not exceeding 30 min once in 10 years during a life span of 22 years. Information on the operation of the DEX 2 system from December 1969 to January 1972 gives 24 re-starts due to program in error, six re-starts due to hardware troubles and six from undiscovered causes. Of the re-starts, one system down and two phase 2 re-starts were recorded shortly after opening; since then only phase 1 re-starts have occurred.

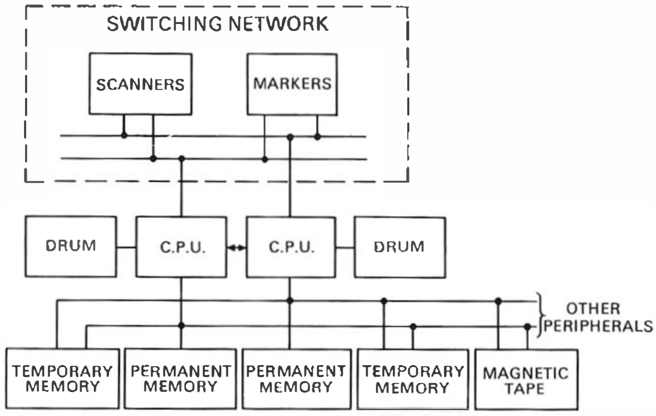


FIG. 5—Block diagram of the DEX 10 system

HOLLAND

PRX 205

In addition to the AKE 13 installed at Rotterdam, the first public s.p.c. exchange produced by Philips Ltd., the PRX 205, was installed at Utrecht in 1971. The system is intended for local exchanges of up to 10,000 lines. The mode of operation is through 2-wire reed relay matrices and a block diagram is given in Fig. 6.

The system employs dual synchronized processors which operate simultaneously on all information, the output of one being inhibited. Each processor has a store which contains

* Clock—An electronic device which provides pulses at fixed time intervals.
Clock level—Generally refers to programs which are activated by clock pulses.

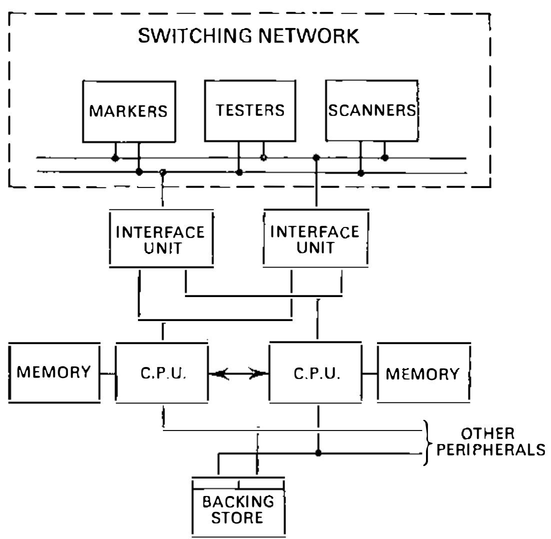


FIG. 6—Block diagram of the Philips PRX 205 system

both program and data. Fault diagnosis of a c.p.u. can be achieved by running test programs in the faulty machine under the control of the good c.p.u. over a test facility.

The stored program is composed of independent functional modules controlled by an operating system. The program modules perform the following tasks:

(*a*) control of switching network,
(*b*) control of configuration of duplex processors, input/output channels, network interfaces and simplex network components,
(*c*) control of access for maintenance purposes, and
(*d*) modification of exchange description via a man/machine interface.

Calls in the system are handled separately, one section dealing with the calling party and the other with the called, communication between the two sections being via the operating system. Line scanning is performed every 125 ms by an autonomous hardware unit which stores changes, and interrupts the processor at the end of the scan period.

No reliable information is available concerning the performance of this exchange.

BELGIUM

METACONTA 10C

The I.T.T. Metaconta (10C) system was developed by the Bell Telephone Company at Antwerp (a subsidiary of I.T.T., Europe). The first exchange was put into service at Wilrik, Belgium, in March 1968 and was a local exchange of 1,000 lines. The minimum size system has a capacity for switching 500 erlangs of trunk traffic, and the maximum size 25,000 erlangs. The range of sizes for local exchanges is not known although the maximum is planned to exceed 10,000 lines. The mode of operation is space division using a cross-point matrix of miniature reed relays; 2- or 4-wire versions are available for either local or trunk equipment. A block diagram of the equipment is given in Fig. 7.

The basic configuration is a load-sharing dual-processor system, which can be expanded up to a maximum of six processors. The first processors designed for the system used a 16-bit word but later systems used a 32-bit word. The latter processor is known as the I.T.T. 3200.

The processors operate out of phase with each other and each is arranged to accept only half the offered work. The control philosophy requires all exchange functions, including line scanning and signalling, to be directly controlled by the processor. Status units monitor the state of each processor

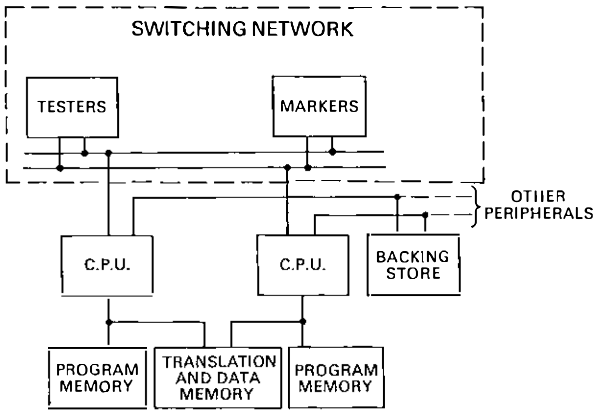


FIG. 7—Block diagram of the I.T.T. Metaconta 10C system

and can initiate suitable action, including program re-loads, if any or all processors fail. Faults are detected by check circuits within the processor and by the regular running of on-line test routines.

Programs are divided into two classes: clock level, and base level. When in clock level, each processor scans all junctors, all digit receivers and particular groups of line circuits so that each group is scanned every 112 ms. The result of each scan is compared with the previous state held in memory. Events detected during scanning are placed in queues for later processing in base level.

Programs which arrange later for the processing of these queues are called base-level programs. These programs are functionally organized and perform such tasks as translation, path selection, set-up and clear-down. All changes to the state of the network must be communicated to the other processors via the inter-processor link, or common memory in later systems.

The design lifetime of the equipment is 30 years. There is a claimed mean time between total system failures of 95 years for the hardware. During the first 18 months of public operation at Wilrik there were 29 single processor failures and four total system failures. All the total failures were due to software as were 90 per cent of the single processor failures.

THE I.T.T. METACONTA L (10R, 11A, 11C) SYSTEM

The Metaconta L system is a development of the 10C system and the first was put into service at Rabat, Morocco, in February 1972. The capacity of the system is for a maximum of 30,000 lines. The mode of operation is space-division switching using a cross-point matrix of latching reed relays (for the 10R) and miniature cross-point switches "mini-switch" (for the 11A and 11C). The system is capable of controlling satellite exchanges remote from the main exchange. A block diagram of the system is given in Fig. 8.

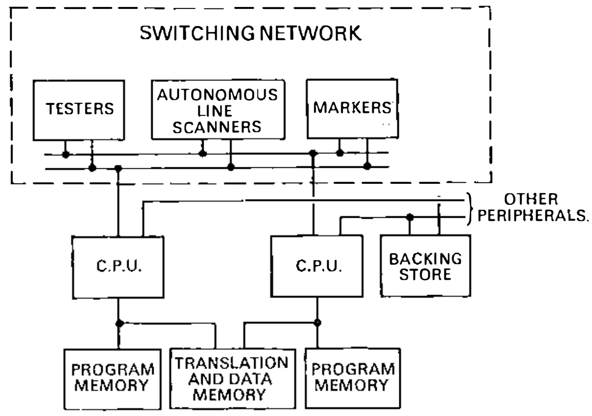


FIG. 8—Block diagram of the I.T.T. Metaconta L system

The control system of Metaconta L exchanges is very similar to that used in the Metaconta 10C system. Initial systems used the 16-bit word-length processor in a load-sharing dual configuration but later systems used the 32-bit processor. The control philosophy differs from the Metaconta 10C in that the processors are not required to scan line-circuits for calling conditions. This task is performed by autonomous line scanner units, thus reducing the load on the processors considerably.

The structure of the software appears to be very similar to that used in Metaconta 10C with the obvious exception of the line-scanning routines. Clock- and base-level programs are used to perform much the same functions as in the 10C; new calls can only be accepted during clock level.

The design life time of the system is 30 years. During the first three months of public operation at Rabat there were 30 single processor failures and five total system failures, all due to software. No figures for hardware failures are available.

WEST GERMANY

The first s.p.c. exchange in West Germany was brought into service in Frankfurt early in 1973. This system, the System 4 EWS 1, was designed and developed by Siemens Ltd. Little information is available at present, but the brief facts are as follows:

(*a*) The system is based on a pair of synchronized processors which control the switch-block through peripheral controllers.

(*b*) The controllers have a large degree of autonomy and perform many of the simpler repetitive tasks such as calling-line identification. One of the major functions of these peripheral controllers is to facilitate remote control of the exchanges by reducing the amount of data that must be interchanged with the central processor.

(*c*) The processor works on an interrupt* basis, there being eight interrupt levels of different priorities, the highest priority being reserved for processor errors.

UNITED KINGDOM

The only working system in service at the moment is the I.B.M. 2750 p.a.b.x., which has been working since 1970 at I.B.M. (U.K.) headquarters at Wigmore Street, London. No further systems of this type are being manufactured, the superseding system being the I.B.M. 3750 p.a.b.x. This system is, at present, being appraised by the B.P.O. at the I.B.M. Research Centre, Hursley. The minimum size system has a capacity of 248 extensions and 32 exchange lines. Maximum-size systems will accommodate 2,264 extensions and 192 exchange lines. In addition, a number of optional data-collection and switching facilities are available. The size of control system is fixed for all installations and consists of two computers. The mode of operation is space-division using a thyristor cross-point matrix. A block diagram of the exchange is given in Fig. 9.

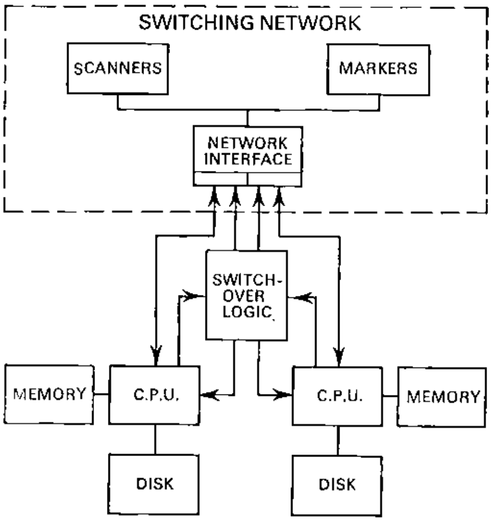


FIG. 9—Block diagram of the I.B.M. 3750 system

Two independent computer systems are used on an active and "cold" stand-by basis (the stand-by computer has no knowledge of the current state of the switching network). Special-purpose computers are used each having its own private program and data store. Volatile semiconductor stores are used and each computer is provided with an independent disk-backing store. There is no provision for inter-computer communication. The control philosophy requires that all p.a.b.x. functions are directly controlled by the on-line computer, including such tasks as line scanning and transmission of Strowger dial pulses. This enables the system to meet the requirements of different administrations by software modifications only. A highly-redundant hardware module is used to monitor the sanity of both active and stand-by control systems. It can initiate control-system switch-overs and program re-loads under fault conditions. A routine switch-over is performed every 24 hours during fault-free working.

As in other systems, the programs are divided into two phases viz. a clock level and a base level, each clock phase being initiated by a 6 ms clock interruption. At the clock-level scanning, impulse counting is effected. The results of each scan are compared with the previous state held in memory and events thus detected are queued for later processing at base level. The base-level programs are functionally organized.

No field experience on performance is yet available.

Experimental Systems

There are two experimental s.p.c. systems at present in service in the United Kingdom. The G.E.C. Mark II processor is in use at the new international switching centre at Wood Street in London, as one terminal of a trial network involving nine foreign administrations testing the proposed C.C.I.T.T.* No. 6 signalling system. Forty circuits and six data links are involved and the network is designed to obtain operational experience of the signalling system carrying customer traffic and with full interconnexion with the existing national and international networks.

Controlling the switching of this new system are two G.E.C. Mark IIB processors, the equipment comprising two central processors, two drum stores, and two store blocks. The processor uses an 18-bit word. The store block is in modules of 16,000 words with an access time of 5 μs.

The second trial system[2] is at Moorgate telephone exchange in London where the I.T.T. 1600 processor is used in conjunction with a pulse-code modulation (p.c.m.) tandem exchange switching a total of 50 erlangs of traffic originating at Bishopsgate, Mile End and Shoreditch. Twin processors are used, identical with those first used in the Metaconta 10C system. They are 16-bit machines with a store capacity of 64,000 words and an access time of 10 μs.

Both the above systems are still under trial and performance details are not yet available.

CONCLUSIONS

Many countries have introduced the s.p.c. concept into their telephone systems and it may seem that, by doing so, they have introduced a continuity-of-service problem which did

* Interrupt—A forced break in a program which causes control to pass temporarily to another program.

* C.C.I.T.T.—International Telegraph and Telephone Consultative Committee

not exist in the old distributive control, step-by-step systems. But as telephone networks grow in magnitude and complexity, accurate surveillance of all kinds is necessary to provide the best service. This can be provided by computer control operating under a stored program which can be amended easily to meet changing requirements.

Customers are becoming more facility-conscious and, to make such facilities available at economic cost, the service must be able to provide and re-arrange them quickly and easily e.g., by modification of a software program instead of by making wiring modifications. The plans for the network must be made to cater for the needs and environment of 1980 and beyond. Ease of production, standardization of equipment, and case of maintenance are of prime importance. These requisites can best be met by divorcing switching from control and today's method of control is by computer.

References

[1] MAY, C. A. Electronics Exchanges: The Steps Leading to TXE 4. *P.O.E.E.J.*, Vol. 65, p. 134, Oct. 1972.

[2] HARRIS, A. S. Digital Switching Systems. *P.O.E.E.J.*, Vol. 65, p. 154, Oct. 1972.

The Seventh International Teletraffic Congress, Stockholm, 1973

U.D.C. 621.395.31: 061.3

The range and scope of subjects discussed at the Seventh International Teletraffic Congress, held in Stockholm in 1973, are described briefly in this article.

The Seventh International Teletraffic Congress (7th I.T.C.) was held in Stockholm from 13 to 20 June 1973, under the joint sponsorship of the Swedish Telecommunications Administration and the Swedish Telephone Industries. The Congress working sessions took place in the main Assembly Hall of the Riksdagshuset (Parliament Building), which was inaugurated in 1971 when the Swedish two-House Parliament was constitutionally changed to a one-House Parliament.

At the opening ceremony, chaired by Dr. Ch. Jacobaeus, Chairman of the 7th I.T.C. Organizing Committee, welcoming addresses were given for the Minister of Communications by Dr. B. Furubäck (Assistant Undersecretary, Ministry of Communications) and for the Sponsors by Mr. B. Bjurel (Director General, Swedish Telecommunications Administration) and Dr. G. Borg (Dean of the Royal Technical Institute, Stockholm, and representing the Swedish Telephone Industries).

The First Congress, held in Copenhagen in 1955 at the initiative of Dr. Arne Jensen and other internationally-known persons concerned with the application of the theory of probability to telephone traffic engineering, was attended by 69 delegates and 26 papers were presented. Since 1955, the Congresses have been held every 3 years, and interest has increased with the wider appreciation of the opportunity provided by these occasions for critical and constructive discussion of a topic essential to economic communications to such an extent that the Seventh Congress was attended by 332 delegates from 30 countries and 129 papers were presented.

The 7th I.T.C. papers were arranged for presentation during 21 quarter-day sessions covering such wide-ranging fields of activity as: traffic theory, simulations, statistical problems, switching networks, queueing systems, common-control, computer-control and stored-program control systems, t.d.m. switching systems, gradings, overflow and smooth traffic, subscribers' behaviour, data traffic, traffic measurement, forecasting and economic considerations, network planning, engineering and management, and C.C.I.T.T.†

The large number of papers necessitated their division into read and non-read categories, as at the 6th I.T.C., Munich, 1970. Authors were allocated about 15 minutes for presentation of each read paper, a speaker being chosen for each session to give a critical synopsis of the non-read papers of his session and to lead the discussion on all that session's papers.

It would be invidious, and very much a matter of personal choice, to select any particular papers for comment. In general, the impression gained was one of great interest in many areas of activity, with the progress of modern technologies and techniques used in system and equipment design and engineering continually stretching the teletraffic theorists' and engineers' ingenuity to keep up, while, at the same time, improving their knowledge of earlier, but thinly-studied areas within their fields of activity.

Theoretical, analytical and simulation studies were the subject of a number of papers and they were also the underlying techniques used in studies reported in many of the other papers. The study of switching and control systems was well represented, but, on this occasion, network considerations had much more emphasis than at the 6th I.T.C. with three sessions devoted to their planning, engineering and management. For the first time, a session was given over to data-traffic studies: it is clear that this will be an important area during the next few years and, where data is switched over a public-switched telephone network, could influence future sessions on subscribers' behaviour and traffic measurement. The influence of subscribers' repeated call-attempts is still receiving considerable attention, and, in conjunction with the current related question in the present C.C.I.T.T. study period, its study will undoubtedly receive further impetus.

Although this Journal is normally concerned with technical matters, it would be inappropriate not to mention the excellent planning and management of the Congress itself, the impressive Assembly Hall facilities made available to the Congress members, and the highly successful social events arranged for delegates and their wives, culminating in the farewell banquet at the Golden Hall in the Stockholm City Hall.

At the invitation of the Australian Post Office and the Australian manufacturers of telecommunications equipment, the Eighth International Teletraffic Congress will be held in Australia in 1976.

A. G. L.

† C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

Queueing Problems in the Cordless Switchboard System No. 1

C. HARVEY, B.SC., and D. J. SONGHURST, M.SC.†

U.D.C. 621.395.65: 621.395.722: 519.21: 681.3

Following the first large installation of the Cordless Switchboard System No. 1 at Croydon in 1969, problems were encountered that were thought to be attributable to the call-queueing process. This article describes the application of queueing theory and computer simulation to this problem.

INTRODUCTION

Approximately 96 per cent of the telephone subscribers in the United Kingdom now have subscriber-trunk-dialling (s.t.d.) facilities and can dial most of their own calls, yet, the demand for operator assistance is still growing. The British Post Office (B.P.O.) needs to use its operating staff as efficiently as possible, and any suggestion that might reduce the fairly high staff costs of operator services must be investigated.

Operators are grouped together in auto-manual centres (a.m.c.s), each of which serves the subscribers in several telephone exchange areas, and usually houses 20–100 operators. After dialling the operator assistance code, the subscriber's call enters a queue at the a.m.c. and waits for a free operator to answer it. While the call is queueing, the subscriber hears ringing tone. The B.P.O. regards the mean delay-time (or time-to-answer) of calls in this queue as the main indication of the efficiency of the a.m.c.

The Cordless Switchboard System No. 1 (C.S.S. No. 1), designed to provide increased operator efficiency, was introduced in 1955. All the early installations were small and operated at the expected levels of efficiency, but, much later, the system was expanded to take account of larger centres controlling up to 96 operators. This was intended as a short-term measure until a new design of cordless switchboard became available. Studies indicated that the new operating procedures should result in staff savings of 7·4 per cent over the old cord-type switchboard. However, the expanded cordless system uses different call-queueing disciplines and this factor was not seriously examined at the time of designing and commissioning the larger exchanges. As a result, severe problems were encountered following the introduction of the first large system.

The first four-queue system was installed at Croydon in 1969. Shortly after its opening, the operating staff complained of queues associated with positions adjacent to free-operator positions containing waiting calls while the free operators had no means of serving them. The staffing had to be increased to 15 per cent above that required for a cord-type switchboard in order to maintain the same mean delay-time of five seconds. Staff morale began to suffer, and it was possible for general staff inefficiencies to be blamed on the system. Since many more of this type of a.m.c. are to be installed, the problem, thought to be totally attributable to the queueing discipline and call-allocation process, was examined with considerable urgency.

† Telecommunications Development Department, Telecommunications Headquarters.

FIG. 1—Cord-type switchboard

FIG. 2—Operator's position of cordless switchboard

QUEUEING DISCIPLINES

Standard Cord-Type Switchboard

The standard cord-type switchboard (Fig. 1) is called a sleeve-control switchboard. The operators obtain access to the incoming or outgoing circuits by plugging a cord into the relevant jack. These jacks are mounted in long banks of vertical panels in front of the operators with $2\frac{1}{3}$ panels per operator position and, with every incoming circuit normally, repeated on every sixth panel. Each operator can just reach over six panels, and, thus, has full access to all the incoming circuits. Associated with each incoming circuit is a lamp which lights when a call is waiting to be answered. When an operator becomes free she answers any waiting call chosen at random, since no indication is given of how long the call has been waiting. This can result in some unfortunate calls having to wait a long time before being answered, while calls which arrive later are answered sooner.

Considered solely as a queueing discipline, the cord-type switchboard can be regarded as a full-access system with a single queue and random order of service.

Cordless Switchboard

The cordless switchboard (Fig. 2) is much neater and quieter in its operation than the cord type. Operators gain access to calls by pressing an ACCEPT key. Each operator position has access to two queues of waiting calls, each queue operating on a first-come-first-served (f.c.f.s.) basis. The lengths of the two queues are shown by a waiting-call indicator displayed in front of the operator and the operators always answer calls from the longer queue.

The original two-queue C.S.S. No. 1 was designed using readily available electro-mechanical equipment,[1] but the physical limitations of the equipment used resulted in the extended version having up to four separate queues into which the incoming traffic is evenly divided. Fig. 3 is a block diagram showing the call-queueing arrangements. However, as each operator only has access to two of the four queues, she only has access to 50 per cent of the total call arrivals. Each operator controls seven connecting circuits which are rigidly divided with four serving one queue and three serving another. Each queue has approximately the same number of operators able to access it.

Thus, the C.S.S. No. 1 queueing system can be considered as approximately a f.c.f.s. system, with any operator associated with the four-queue type having access to only 50 per cent of the incoming traffic.

PROPOSED QUEUEING REARRANGEMENTS

After preliminary studies of the existing four-queue arrangements five solutions to the problem were suggested, but it was soon clear that only the following three suggestions needed to be examined in detail.

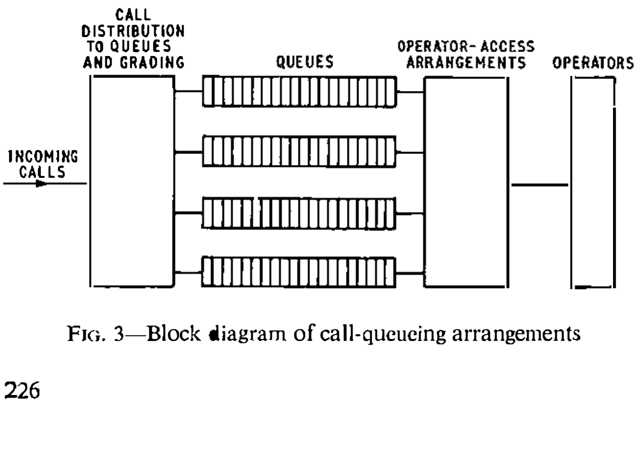


FIG. 3—Block diagram of call-queueing arrangements

Two-Queue Full-Access

The conversion of the system to only two queues would give the operators full access to all calls, the only remaining limitation being the number of circuits with which each operator could connect calls. To perform such a conversion would not only involve considerable cost, development effort and extra space for the additional equipment, but it could not be completed for some time ahead and would cause considerable disruption to service during conversion.

Four-Queue Full-Access

The conversion of the system to give each operator full access to all four queues but with the operator still having seven connecting circuits would give her only one or two circuits for serving each queue. This conversion could be carried out with much less cost, delay, and disruption than conversion to a two-queue full-access system, but it would place more responsibility on the operator to select the call from the longest queue.

Queue Balancing

This solution requires the addition to the present four-queue limited-access system of a queue balancing device which could monitor the length of each queue and direct new calls into the shortest queue. It would not monitor the queueing time, but merely bar access to the longer queues. The advantage of this proposal was that the additional equipment was readily available, and could be installed at a very small cost and with negligible disruption to service.

In addition to the above three solutions, it was considered that further improvement might be obtained by informing the operator of any call which has waited more than a specified time. For example, this could be achieved by fitting a flashing lamp at the head of the waiting-call indicator strip-lamp and instructing the operator to select a call from the queue with the flashing lamp rather than from the longest queue.

COMPARISON OF PROPOSALS

In order to decide which one of the above three proposals should be adopted for the existing and future large C.S.S. No. 1 installations, it was necessary to have a method for comparing the levels of improvement which could be obtained from them.

The comparison had to have a basis which specified the relevant parameters and provided a solution depending on the values of these parameters. The most important parameters are the relative costs, mean delay-time, distribution of delay-time, probability of loss, and probability of delay. The delay-time distribution is important mainly in that the variance should be as small as possible. The probability of loss is virtually negligible except when the system is heavily overloaded and calls are lost owing to congestion in the grading, which is an arrangement of switches necessary to connect incoming calls with empty queue places (see Fig. 3).

Even if all the relevant parameters were known exactly for each of the proposed systems, it would still not be easy to compare them. Ideally, each call should be assigned a cost this being a function of the delay which the call encounters, and then the proposals could be compared strictly on a cost basis. This would be difficult, however, as not much is known about the effect of delays on subscriber behaviour.

ESTIMATION OF PARAMETERS

To estimate the relevant parameters, it was first necessary to specify the traffic distributions: these were assumed throughout the study to be that call arrivals formed a Poisson process, and that service times had a negative exponential distribution.

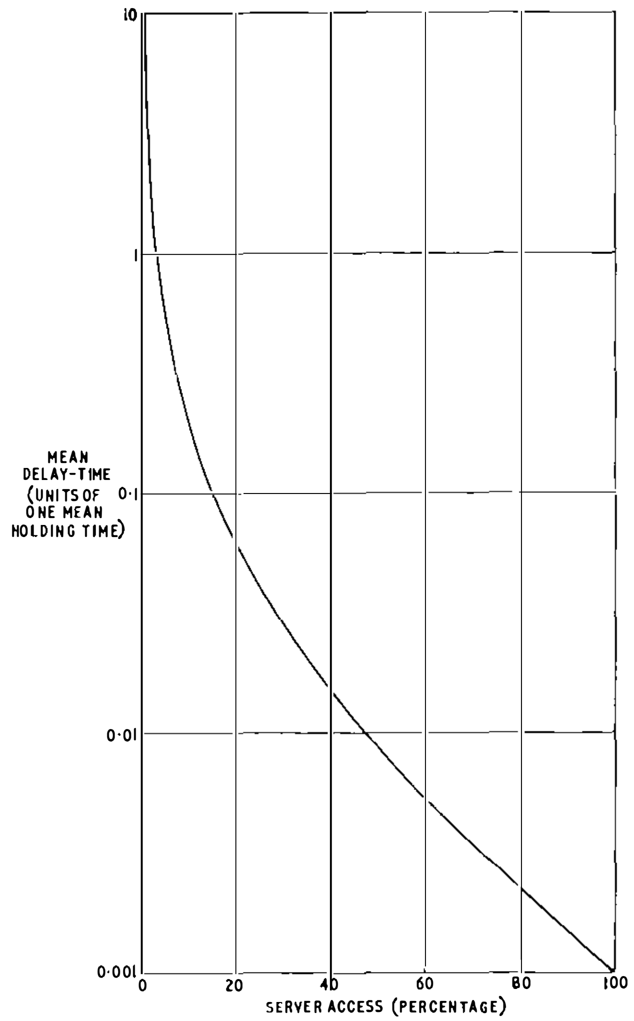


FIG. 4—Mean-delay-time/server-access characteristic

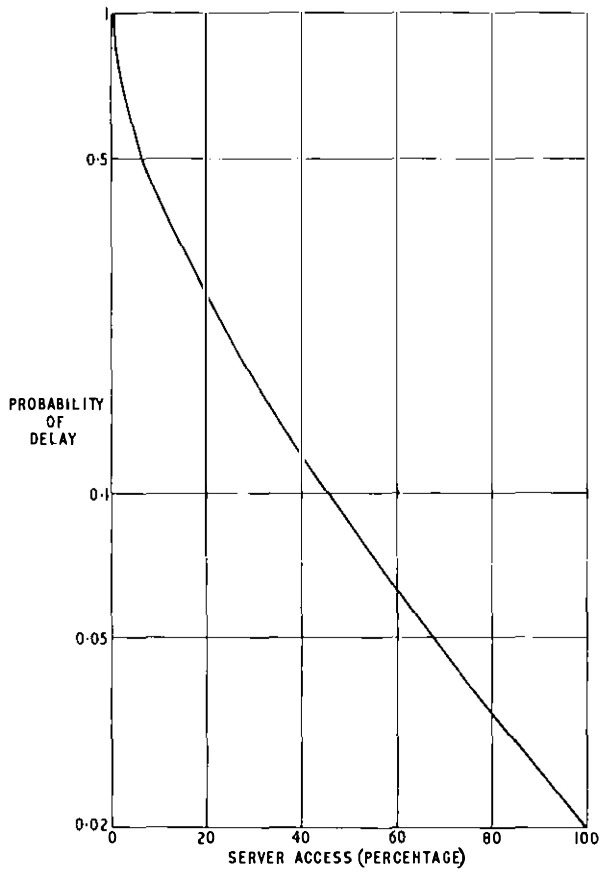


FIG. 5—Probability-of-delay/server-access characteristic

Application of Standard Results from Queueing Theory

With the traffic distributions specified, it was possible to investigate, to some extent, the main differences between the proposed systems by using standard results from queueing theory and considering the effect of varying the operator-access arrangements and the number of queues, and of providing a queue balancer.

Operator Access. When the system allows full access, that is, when any operator can always answer any incoming call, the mean delay before answer and the probability of delay are independent of the number of queues and are the same as in the single queue case. Thus, these two parameters are known from the standard theory for the M/M/N queue,* where N is the number of operators.

For limited operator access, these parameters are not known, but are certainly greater than in the full-access case. Figs. 4 and 5 give an indication of the adverse effect on the mean delay-time and probability of delay of limiting operator access. These results correspond to a very simple queueing situation, and cannot be directly applied to the system under consideration.

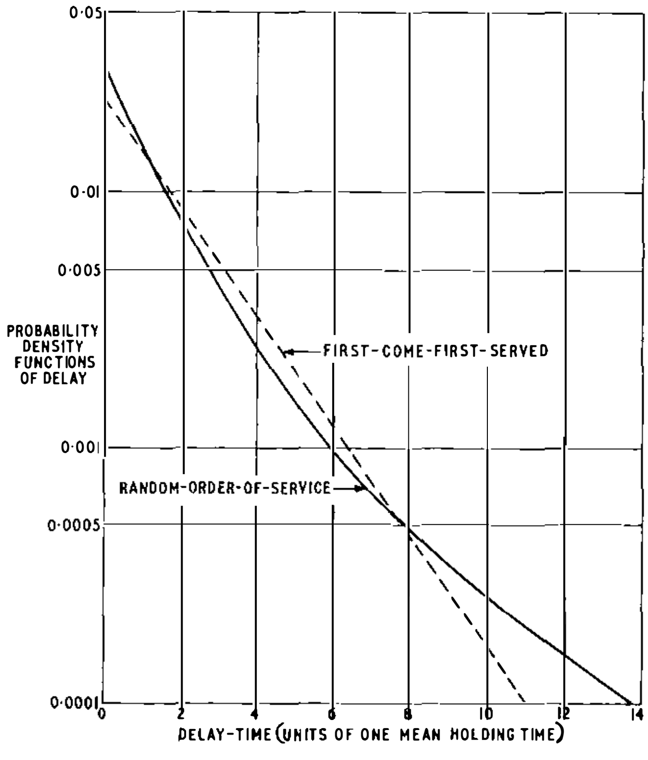


FIG. 6—Probability density functions of delay.

* This is the Kendall notation for queueing systems in which the first letter signifies the form of the demand or call interarrival-time distribution, the second the service or holding-time distribution, and the third the number of servers or trunks.

Number of Queues. For all proposed improvements, the order of service in each queue is f.c.f.s. With just one queue, all incoming calls would be served in order of arrival, but with a very large number of queues, and incoming calls distributed to them at random, the order of service would be approximately random. Changing the order of service has the effect of changing the shape of the delay distribution without affecting the mean delay. Fig. 6 shows the density functions of the delay time for an M/M/N queue with the service either in order of arrival or in random order. It is evident that, for random-order-of-service, relatively more calls have either a very short delay or a very long delay, and so the delay time has a greater variance than when service is in order of arrival.

In the proposed systems with two to four queues, the delay distributions lie between these two limiting cases, and the greater the number of queues, the greater the variance of the delay.

Queue Balancing. With limited access, where each operator has access only to two of the four queues, it is possible for the situation to arise where a free operator finds both of her queues empty and yet she cannot answer any of the calls waiting in the other two queues. It is for this reason that the mean delay-time and probability of delay are greater than in the full-access case. By reducing the frequency of these situations, the queue balancer increases the effective operator access and, therefore, reduces the mean delay-time and probability of delay.

Exact Theoretical Approach

In order to obtain any exact results for the limited-access systems, it was necessary to set up and solve the relevant systems of birth and death equations. Unfortunately, the systems of equations obtained were so large that they could only be solved by assuming a small number of servers and a very small number of queue places in each queue. The results obtained confirmed the general results already described, but still gave no numerical information about the full-size systems.

By ignoring the costs of the proposed systems, and simply considering their performance from the point of view of queueing theory, they can be rated in order of merit (see Results). However, the better the system, the more expensive it would be. It was, therefore, necessary to make a cost comparison. To do this, it was essential to have reasonably accurate numerical estimates of all the relevant parameters and computer simulation had to be used.

DETERMINATION OF PARAMETERS BY SIMULATION

Simulation Model

Simulation programs were written to represent models of the system as installed at Croydon and of the three proposed solutions. By using simulation techniques, it was possible to study the effect of a head-of-queue alarm applied after any specified time, and also to determine any complications which could arise, in practice, with any of the proposals. The system could be studied under traffic conditions which were actually observed at Croydon, and also under any conditions likely to occur in any other installation in the country. Variable parameters included operator service time and mean call-holding time.

The model was built to represent the queue-allocation process and the operators' access to the calls exactly as in the existing design. Negative exponentially-distributed call inter-arrival-times and conversation times were assumed. This left two major assumptions in the model, which were

(*a*) the representation of the behaviour and performance of the operator, and
(*b*) the behaviour of calling subscribers encountering long delays.

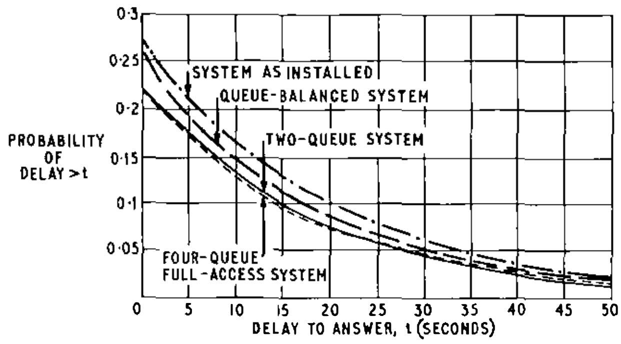


FIG. 7—Typical delay distributions

For assumption (*b*), reneging (i.e. delayed subscriber's clearing down) was assumed not to occur, and a fixed delay was inserted in the program to represent assumption (*a*).

Simulation Programs

The programs were written in the Elliott Algol language and used a simulation package derived from the Elliott Simulator Package (E.S.P.).[2] They were run on an Elliott 503 machine which has an average instruction time of $3 \cdot 6\ \mu s$. Each program occupied about 10k words of store and took from 4–8 hours to simulate 100,000 calls. The running time of the program was between 5 and 25 times faster than the simulated time, depending on the size of the installation and the traffic level under examination, but, in general, the computer had to deal with about 50,000 machine instructions per call.

It was found necessary to simulate 100,000 calls in each run to ensure sufficiently accurate results. This was about 125 simulated hours at low traffic, and 42 simulated hours at high traffic.

RESULTS

Theoretical Study

The non-numerical estimations of the relevant parameters, obtained by applying the standard results of queueing theory, are summarized in the table, which also indicates the order of merit of the arrangements studied.

System	Comments	Order of Merit
Two-queue full-access	(*i*) Good delay distribution (*ii*) Low mean delay	1
Four-queue full-access	Low mean delay	2
Four-queue limited-access with queue balancer	Reasonable mean delay	3
Four-queue limited-access	Original system	4

Simulation Study

With low traffic, the simulation results indicated that, compared with the four-queue limited-access system, reductions in the mean delay of 28 per cent for the two-queue system, 27 per cent for the four-queue full-access system, and

19 per cent for the four-queue, limited-access, queue-balanced system could be expected. Greater improvements were found when the system was studied at high traffic-levels. Fig. 7 shows the delay distributions recorded in a typical simulation run.

The head-of-queue alarm was shown to have a fairly small effect in that it assisted in reducing abnormally long waiting times if applied after an appreciable delay but had negligible effect if operated too soon.

Since preliminary results suggested that the queue-balanced system was reasonably favourable in comparison with the other proposals, and considerably more favourable on cost grounds, this system was studied further, in detail, for any practical complications. The only complication found was that the queue-allocation equipment had a slightly reduced capacity. This occurred because the equipment used for queueing is also used to connect the circuits. The availability of queue places, therefore, does not depend exclusively on the number of calls queueing, but, rather, on the total number of calls in the system at the time of the arrival. Thus, the probability of loss is not a direct function of the queue length. In the simulation model, the maximum permitted queue length was made quite large, and the system was offered traffic at its maximum design value.

Fig. 8 shows the relationships found between the loss probability and mean delay-time for the existing system and that system provided with a queue balancer, both operating at the maximum design traffic. In each case, no calls are lost owing to insufficient queue places. The grading of the queue-balanced system causes greater loss because circuits are artificially busied in order to direct new calls into the shorter queues. Alternative gradings were studied to see if the capacity could be improved, but the results showed that little improvement could be made.

Another measure of efficiency, in practice, is the proportion of calls delayed longer than a specified time, typically 15 s. From the delay distributions obtained by simulation, it was possible to compare these figures for the four systems over a range of input conditions. The four-queue full-access system was found to be marginally favourable (see Fig. 9).

Fig. 9, drawn on a logarithmic scale, shows typical distributions more clearly, and they are seen to be approximately negative exponential up to about 50 s delay. This indicated that the mean time to answer was a fair measure of the level of improvement obtained.

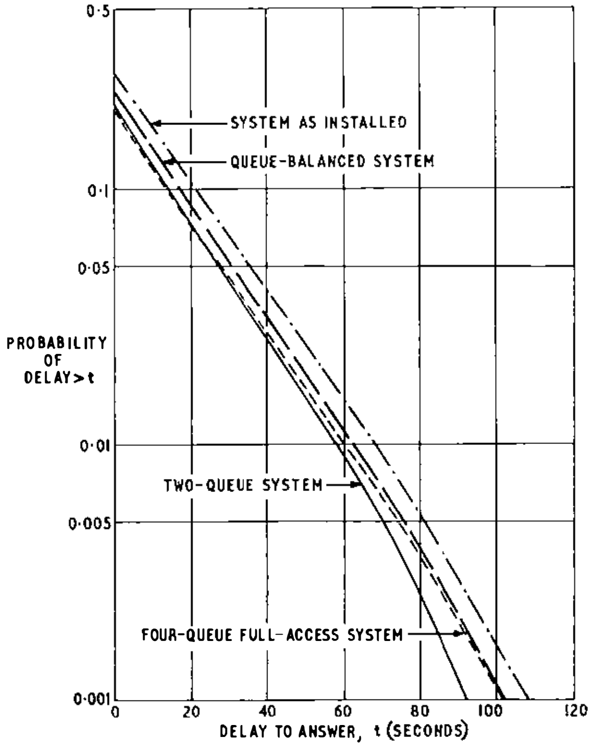


FIG. 9—Typical delay distributions

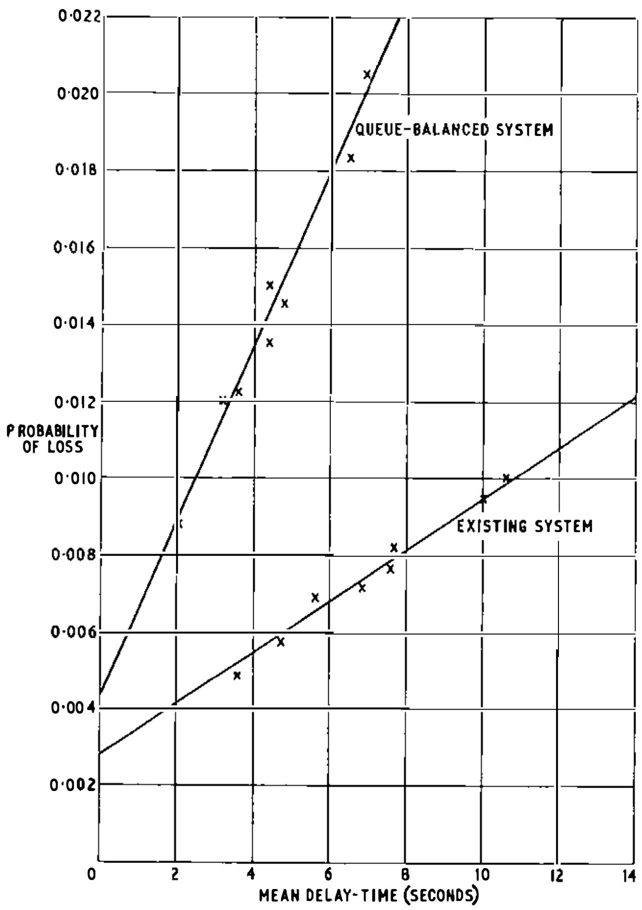


FIG. 8—Probability-of-loss/mean-delay characteristics

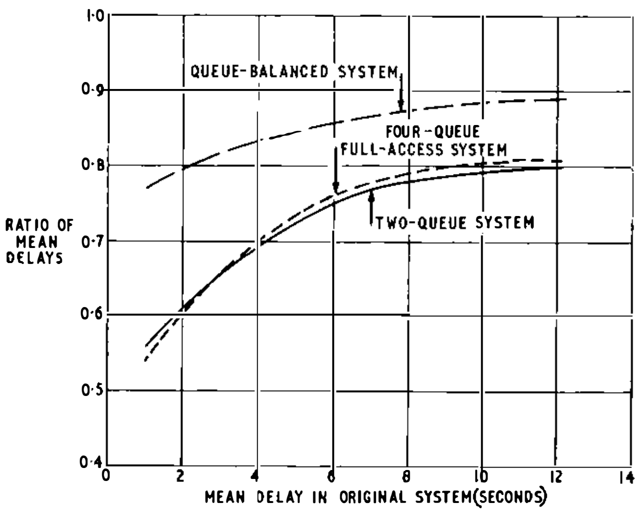


FIG. 10—Improvement ratios in mean delay

Fig. 10 gives typical results as to the improvement in mean delay-time obtained, but there was great difficulty in defining this relationship as there was an obvious association with many of the other parameters, such as operator handling time. Most other relationships were impossible to establish owing to the interdependence of the parameters or the inability to accurately estimate some parameters within a reasonable run time.

CONCLUSIONS

This article has outlined a practical problem and the use of simple queueing theory and simulation techniques in providing a solution. It shows that standard queueing theory could provide generally applicable, albeit approximate, results quickly and cheaply, but that simulation techniques were necessary to give more accurate results which took account of the detailed working of the systems studied.

References

[1] Missen, L. A., Snook, R. A., and Hitchen, E. J. T. Thanet Cordless Switchboard. *P.O.E.E.J.*, Vol. 48, p. 102, July 1955.

[2] Povey, J. A., and Cole, A. C. The Use of Electronic Digital Computers for Telephone Traffic Engineering. *P.O.E.E.J.*, Vol. 58, p. 203, Oct. 1965.

Book Reviews

"Telecommunication by Speech: The Transmission Performance of Telephone Networks." D. L. Richards, B.Sc.(Eng.), C.Eng., F.I.E.E. The Butterworth Group. xix + 589 pp. 143 ill. £12.

The professed aim of the author, to provide a *vade mecum* for engineers concerned with the task of planning networks or of refining and extending the basic concepts and data upon which such planning is founded, has been very substantially achieved.

It will be interesting to the casual reader to learn of the continuous evolution of transmission planning from the inception of the early telephone network until the present day and to note the gradual improvement in standards and also to mark the consequence of overlooking significant facts or ignoring fundamental principles when setting performance targets.

The major part of the work is appropriate to the serious student of telephony and the practising engineer engaged in network planning studies or in research of this area of combined science and art (the latter being gradually eroded by the former). For such people, it should form a valuable standard for instruction and reference.

Considerable space is devoted to the human factors aspect of telephonic communication. The mechanisms of speech and hearing and conversational behaviour are very satisfactorily described, particularly as they interact with telephone circuit transmission characteristics in the assessment of the degree of satisfaction of a communication. A wealth of data concerning characteristics of B.P.O. telephone sets and the measurement of performance of the subscriber's circuit is collected together, the importance of accurate and appropriate measurement being properly stressed. Hitherto, much has depended on subjective assessments to ascertain the impairments due to transmission characteristics, noise, sidetone, echo, various types of distortion, etc., and the design of experiments to isolate these and determine their interactions has been an onerous task to provide a satisfactory foundation for the progress now being made in the application of computational assessment methods.

Attention is drawn to the shift of emphasis on various types of impairment due to the introduction of newer transmission methods and media, such as pulse-code modulation and earth satellites, and also the use of loudspeaking telephones.

Throughout the work, appropriate reference is made to the role of international organizations in standardization of telephony transmission performance. The reader is acquainted with the meaning of SFERT, SRAEN, NOSFER, SETED and other transmission reference systems and guided to important Recommendations of the C.C.I.T.T., in the formulation of which the author has played no mean role. From this aspect alone, many will appreciate the book as a ready source of information.

Finally, the application of data produced by assessment of the transmission performance of component parts of a telephone network to the formulation of plans for a whole network to provide a given standard of satisfaction to the population of customers is illustrated.

The whole work is supported by an extensive bibliography conveniently arranged and co-ordinated with the sections of the text.

L. K. W.

"Data Telecommunication." R. N. Renton, C.G.I.A., C.Eng., F.I.E.E. Pitman Publishing. viii + 227 pp. 145 ill. £2·75.

The title of this book is all embracing, but the fact that 80–90 per cent of all data transmission in the world takes place in North America has been ignored and the reader may be misled unless he reads the preface carefully. Nevertheless, accuracy is the hall-mark of this book and it is well recommended provided the words "Now read on" are marked in large letters on the last page.

The book has only a minor theoretical content and consists mainly of descriptions of equipment. The art of data telecommunication is advancing at a tremendous pace and, inevitably, some of the equipments described in excessive detail are now obsolete whilst others of current interest are only sketchily described, or not mentioned at all. The author was a well known Post Office engineer, yet some of the equipments described represent B.P.O. "first efforts" and have been superseded since 1967, or earlier.

The subjects covered are data codes and alphabets, line characteristics, some terminals (mostly mechanical), B.P.O. Datel modems, testers and automatic calling and answering equipments, some aspects of error control, basic user systems, switched networks, and future developments. Probably the best chapter is the one describing line circuits. The descriptions in this are very clear and mostly of about the right length and detail for the student of data transmission. If this standard had been maintained throughout, and a much broader and more modern field covered, then the book would have been essential to the library of all concerned with this subject.

R. H. T.

Steel Masts and Towers in the British Post Office

Part 1—Principles

D. G. CLOW, C.ENG., M.I.MECH.E.†

U.D.C. 624.97.014.2: 621.396.7: 624.04

Most of the tall structures used at British Post Office (B.P.O.) radio stations are fabricated from structural steel. Their design and construction represents a specialized aspect of B.P.O. engineering activity and this part of the article outlines some of the principles involved. Part 2 will describe some of the physical aspects of modern masts and towers, and their foundations. The final part will report on some of the experimental work which has been carried out on model and full-scale structures with the intention of correlating theoretically-predicted behaviour with results obtained in practice.

INTRODUCTION

The British Post Office (B.P.O.) has considerable capital invested in tall structures for use on radio systems and it has been associated with many noteworthy developments in this field. To take two well-documented examples, for about 40 years the twelve 820 ft high masts for the GBR aerial system at Rugby[1] were the tallest structures in the United Kingdom (U.K.). When they were built in 1923, they were probably the largest single project undertaken to date by the B.P.O. Another unique operation was the encasing in reinforced concrete of ten 305 ft-high tubular-steel masts at Leafield Radio Station[2] during the second world war with only 28 minutes interruption to the low-frequency (l.f.) transmission. Such structures are no longer novel; the Rugby masts, although still the highest in B.P.O. use, are now dwarfed by the structures of the broadcasting authorities in the U.K. and tall reinforced-concrete towers are now commonplace. In recent years, the rapid expansion of radio for many purposes has led to a great increase in the numbers of masts and towers; the B.P.O. alone has in service a total approaching 1,000.

The design of very tall structures throughout the world has given considerable impetus to the advancement of design procedures. This has been helped by the similarity of mast and tower problems to others in the structural-engineering field, especially large suspension bridges and offshore drilling rigs. The common factors are that such structures are relatively flexible and that they are subjected, predominantly, to the natural hazards of wind, ice or sea. Developments now taking place affecting mast and tower design may be grouped under the headings of:

(*a*) overall philosophy of design with particular reference to structural safety,

(*b*) changes in the law relating to provision of means of safe access for staff,

(*c*) greater understanding of the nature of the wind, the predominant load on the majority of tall structures (This is manifested in increased design wind speeds and in the recognition that the wind gusts constitute a dynamic load.),

(*d*) use of computers permitting much more thorough methods of stress analysis,

(*e*) new materials and fabrication methods available to the designer,

(*f*) much more frequent revision of British Standards and the introduction of metrication causing considerable problems for the design office, and

(*g*) refined analytical methods and progressive increases in allowable loads in structural members reducing the hidden factors of safety which were present in many older structures.

This article deals with the design and testing of steel masts and towers although many of the matters discussed apply equally to reinforced-concrete structures[3, 4, 5]. The B.P.O. follows the convention of referring to structures maintained in the vertical position by guy ropes as *masts* and those supported solely on the footings for the main post members as *towers.*

THE B.P.O. PARTICIPATION IN DESIGN

Most of the guyed masts and a significant number of the steel towers in B.P.O. service have been designed entirely by the B.P.O.; most of the remaining structures have been designed in detail by contractors to B.P.O. specifications. A group exists in the Operational Programming Department of Telecommunications Headquarters to provide a structural engineering advisory and design service to users, primarily the Network Planning Department for the microwave network and the International and Maritime Telecommunications Region for overseas and ships' communications. The structural design of reinforced-concrete towers is carried out by the Department of the Environment. The B.P.O. is taking an active part in new developments in design: it is one of the sponsors for programs of research into wind structure being carried out by the Electrical Research Association (E.R.A.) and the Construction Industry Research and Information Association (C.I.R.I.A.); it is represented on the code-drafting committee which is producing a British Standard Code of Practice for the design of masts and towers. Hitherto, design has usually followed B.S.449[6] although variations have

† Operational Programming Department, Telecommunications Headquarters.

been accepted to account for the peculiar problems of tall structures.

Many of the new developments in design need to be verified by observation of the behaviour of practical structures and the B.P.O., as a major user, has the opportunity for carrying out such work. This experimental work is especially important as many of the structures cannot be fitted simply into the categories in which theoretical work has been carried out. To take two examples, all B.P.O. masts over 600 ft high carry heavy head loads, and microwave towers include a substantial amount of ancillary steelwork for supporting aerials, waveguides, ladders and platforms. In neither case does the structure approximate to the simple mast or tower skeleton considered in research studies. Some tests, which have been carried out on full-scale structures, are described later.

FUNCTIONAL REQUIREMENTS

The basic structural size and shape is dictated by the requirements of the radio aerials supported by the mast or tower, and these vary widely with very-low frequency (v.l.f.) and super-high frequency (s.h.f.) aerials posing the greatest problems. Most aerials for the band from v.l.f. to high frequency (h.f.), that is, the 3 kHz to 30 MHz band, consist of wire arrays supported between two or more masts. The systems for v.l.f. transmission require very high structures capable of sustaining heavy head loads. Three such systems exist in the B.P.O., these being

(*a*) at Rugby, where the 12 masts are 820 ft high and are designed to withstand a head pull on each of nearly 18 tonf[1],

(*b*) at Anthorn,[7] where 13 masts are used, of heights ranging from 617–748 ft, and

(*c*) at Criggion,[8,9] where three towers 600 ft high, three masts 700 ft high and a 1,000 ft high hilltop anchorage are used, the masts being designed for a 40 tonf maximum head load.

Most of the smaller guyed masts are used for supporting h.f. (3–30 MHz) aerials of which the rhombic[10] is the most extensively used. The rhombic aerial typically requires four masts up to 187 ft 6 in high, capable of withstanding one or two point loads of up to 1 tonf in addition to the wind. The B.P.O. Mast No. 1[11] was designed specifically for this purpose. A few of these masts are used at coast radio stations where the mast itself acts as the radiating element. The mast has then to be insulated from ground by incorporating insulators in the guys and at the mast base.

For very-high frequency (v.h.f.) and ultra-high frequency (u.h.f.) services, the aerials are usually light in weight and impose low wind loads (up to 100 lbf at 100 miles/h); often they share structures with other services.

The requirements of microwave aerials impose severe restrictions on the structure in several respects. The area presented to the wind by a microwave dish or horn aerial is such that the wind loads imposed are very high; examples are given in Table 1.

TABLE 1

Typical Wind Loads on Microwave Aerials

Aerial Type	Wind Load with Face-on Wind (tonf)	
	At 100 miles/h	At 150 miles/h
12 ft-diameter dish	2·5	5·6
Large Horn	3·2	7·1
Small Horn	1·4	3·2

The directionality requirement is stringent; it is usually required to maintain the aerial alignment in the direction of propagation to within ± 45 minutes of arc in the worst weather conditions. High bending and torsional stiffnesses are, thus, required from the structure and this is best achieved by using towers. Masts are used, occasionally, where the numbers of aerials are small and where heights in excess of 350 ft are necessary. At busy microwave stations, considerable numbers of aerials are likely to be required, sometimes exceeding twenty 12 ft-diameter dishes on one tower. In such circumstances, a large face area on the structure is necessary for mounting the aerials. A tower can be designed with face widths sufficient to permit mounting of aerials side-by-side at the minimum heights required for propagation requirements. In contrast, on a mast, aerials have to be stacked vertically with a consequent increase in attenuation in radio-signal level from long lengths of waveguide.

The horn aerial poses a particularly difficult structural problem. It is very desirable to continue the circular waveguide feed straight down from the base of the aerial to a point as near as possible to the microwave equipment. The effects of this requirement will be apparent in some of the examples to be given. The supersession of the horn aerial by the paraboloidal dish was a welcome relief to the designer of aerial-supporting structures.

It is desirable to use standard structures as far as possible, since considerable economies in design and fabrication are then possible. This standardization has been very successfully applied to lightweight guyed masts. Of the B.P.O. Mast No. 1 design, approximately 10,000 mast sections 12 ft 6 in long have been purchased since is was first designed. The heavier B.P.O. Mast No. 2A was fabricated in a batch sufficient for over 40 masts, each 300 ft high. It is difficult to apply such a high degree of standardization to microwave radio towers because of the many different heights, numbers of aerials and environmental-planning requirements. A useful degree of standardization has been established, notably with the use of a modular type of construction, as described later.

An integral and significant part of the design process is to ensure safe means of access to the structure. A warning in this respect was the case of an older tower which had to be scrapped because it could not support a climbing ladder conforming to the current requirements of the law.

A structure which is likely to be in use for many years needs to be designed for economic maintenance. Hot-dipped galvanizing is usually employed as the basic protection. For light masts, the policy is often to dismantle the mast for re-galvanizing and re-use, or else to scrap it, when the zinc coating has reached the end of its useful life. On more elaborate structures, such a policy is out of the question and regular repainting is adopted in addition to the original galvanizing.

Appearance is playing an increasingly important part in the design of tall structures and the final decision on the type of structure employed can well depend on environmental impact rather than on purely technical considerations. There is little scope for varying the appearance of a guyed mast which is not very intrusive visually but a number of options are open for sites where a massive self-supporting tower is needed. The outline of any proposed structure has to be negotiated with planning authorities and, sometimes with the Royal Fine Arts Commission, at an early stage in the design procedure.

THE EFFECT OF THE WIND

The underestimation of the effects of the wind is a major source of damage to buildings and other structures, as indicated by such events as the Sheffield gale of 1962 which damaged over 220,000 buildings, and the 1968 Glasgow gale which damaged more than 340,000 buildings. Some major structures, such as cooling towers and high masts, have collapsed and there have been many instances of pylons and floodlighting towers failing. In some cases, bad workmanship and maintenance can be blamed but, frequently, the cause has been under-estimation of likely wind speeds and wind pressures, and this in spite of the Tay Bridge disaster in 1879.

The latter failure stimulated the first serious attempt to measure wind pressures in the course of preparing the design for the Forth railway bridge. A large windgauge on the island of Inchgarvie in the Firth of Forth registered a maximum pressure of 35¼ lbf/ft^2 over a period of five years. The bridge itself was designed for a wind load of 56 lbf/ft^2 giving a total force of over 8,000 tonf spread over 7½ acres of steelwork. It is interesting to note a comment made at the time of the measurements, that smaller gauges in the same locality had indicated a higher pressure at the same time "probably due to the wind acting in small whirls of higher intensity than the average over large surfaces."[12] In the light of present knowledge, the pressure assumed for design purposes was certainly adequate and only in recent years has the effect of the relationship between gust size and velocity been taken into account.

It is convenient, in visualizing the effect of the wind, to consider it as a steady mean flow of air with a fluctuating component superimposed upon it, in much the same way as sea motion can be considered as a relatively slow variation due to the tide with the waves supcrimposed on this. The significance of wind-load in relationship to B.P.O. structures will be evident from some recent analyses summarized in Table 2. It can be seen that the wind load on the microwave aerials is of the same order as that on the supporting structure.

There are two distinct methods of calculating the effect of the wind on "wind-sensitive" structures, into which category masts and towers fall. The most widely-used assumes that the wind exerts a quasi-static load while the other approach attempts to take full account of the dynamic nature of the wind load. The latter method is still being developed and it may be some years before it is in a generally-accepted form suitable for design-office use.

CALCULATION OF WIND FORCES BY QUASI-STATIC METHOD

One method of computing the aerodynamic drag on a structure is to assume that a gust of a particular duration acts for sufficient length of time for the structure to react fully to it. The Meterological Office can provide forecasts in the form of basic wind speeds appropriate to a gust of 3 s duration for locations in the U.K.; these values can then be adjusted according to the size of the structural component. The 3 s gust is assumed to act fully on structural components such as cladding; structures whose maximum dimensions do not exceed 50 m are designed on the basis of a 5 s gust; for larger sizes, a 15 s gust is used.

It is possible to analyze wind records using extreme-value statistics. The practical implication is that the longer a structure is exposed to the wind, the higher will be the likely maximum wind speed encountered. For most engineering structures and buildings, 50 years is the period used for design purposes; other periods are used for temporary structures or for structures where exceptional security or longevity is required. Fig. 1 shows the variation of probable wind speed with structural life. It may be noted that if this wind is exceeded—if, say, the once-in-200-year wind occurs on a structure designed for a 50-year wind—the mast or tower may not necessarily be destroyed as they are designed so that, at the maximum design wind speed, the stresses are still well within the elastic range.

Fig. 2 is a flowchart summarizing the method of computing the wind load on a simple tower. The practical calculation for a microwave tower is a tedious operation because of the presence of aerials, ladders, platforms, waveguides, cables, supports and other ancillary steelwork. The effect of wind from several directions has to be considered if it is not immediately evident which will give rise to the worst loads on the tower. In general, the "wind-on-face" case gives rise to the maximum bracing loads and the "wind-on-corner" case gives the worst leg loads; these two constitute the minimum number of wind directions considered.

TABLE 2
Wind Loads on Typical Structures

Structure	Location	Number and Type of Aerials	Design Wind Speed (miles/h)	Wind Load in Worst Direction (tonf)			Deadweight (tonf)		
				On Aerials	On Structure	Total	Aerials	Structure	Total
Tower No. 5A 120 ft high	S.W. Scotland	Twenty 12 ft diameter dishes	155	89	79	168	13	95	108
Pylon-type tower with aerial galleries 222 ft high	Midlands	Twenty-two 12 ft diameter dishes	100	50	64	114	15	95	110
Pylon-type tower 127 ft 6 in high	Central Scotland	Fifteen 12 ft diameter dishes + two large horns	143	46	60	106	11	31	42
Mast 206 ft high	South Coast	Two 12 ft diameter dishes + four 10 ft diameter dishes + one helical aerial	112	21	16*	37	5	9·2*	14·2

*Excludes guys

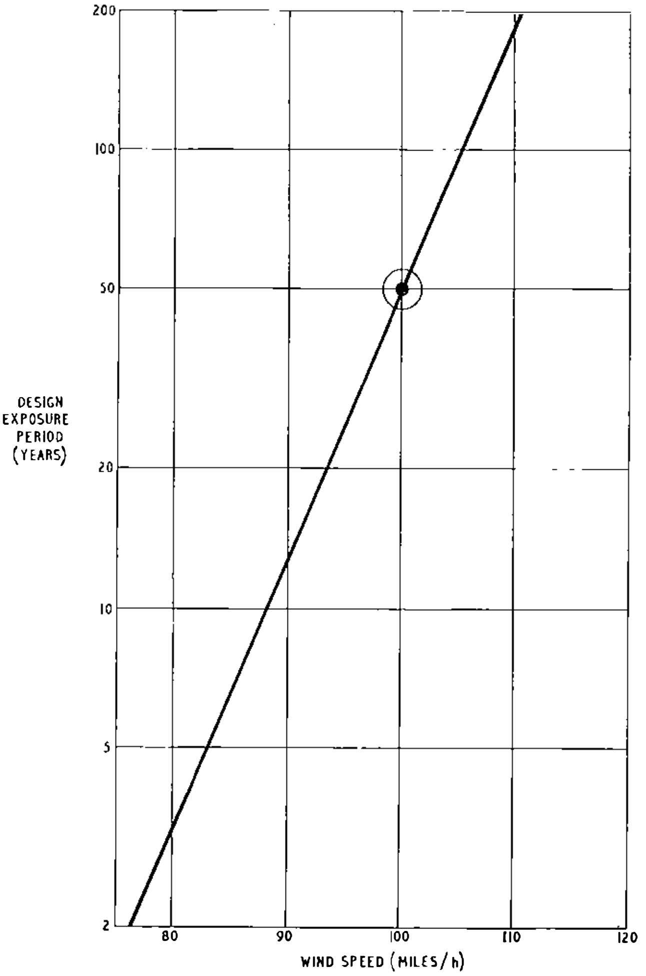


FIG 1—Effect of varying exposure period at a site where the forecast once-in-50-year wind is 100 miles/h

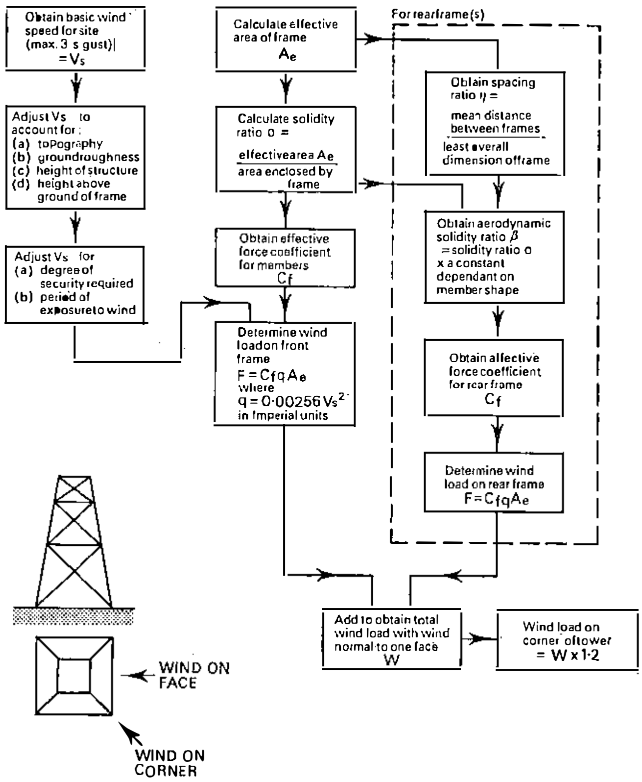


FIG. 2—Calculation of wind loads on lattice masts and towers by the quasi-static method

The calculation of wind loads is, without doubt, the time-consuming part of an analysis and one that needs the exercise of judgement, for different answers can be obtained by different methods. There is a great need to verify such theoretical calculations by measurement on actual structures. For very large and costly structures, or for standard structures to be used in quantity, a program of wind-tunnel investigations is essential for safety and economy.

There has been a considerable increase in design wind-speed for many sites in the U.K. in the past few years, as methods of analyzing wind data have been improved and as more data has become available. Aerodynamic drag varies as the square of the wind-speed, and the raising of the design wind-speed from, say, 100 miles/h to 140 miles/h has serious structural implications. Many older microwave towers have had to be strengthened, sometimes substantially, at a cost exceeding the first cost of the tower. Such extensive work may be preferable to replacement with an entirely new structure, as radio services do not have to be transferred and the planning-permission process necessary for a new tower is obviated.

There is ample evidence that the very high wind speeds now being designed for are not unrealistic as there have been a number of instances in the U.K. of speeds in excess of 130 miles/h having been measured.

DYNAMIC RESPONSE TO WIND

The method described earlier assumed an equivalent steady force applied to the structure by the wind. However, the wind imposes an oscillatory force on structures and, if there is sufficient energy input in the wind at a frequency near to one of the natural frequencies of oscillation of the structure, then dynamic magnification of response could result which might give rise to stresses and deflexions greatly in excess of those predicted by a quasi-static assumption of loading.[13] The best-known example of destruction by dynamic action was the torsional vibration set up in the Tacoma Narrows suspension bridge in 1940. The wind speed then was only 42 miles/h, well below that for which the bridge was designed.

Structural oscillations as a result of wind action can result from a number of causes of which two are of importance to the present discussion—vortex shedding and response to atmospheric turbulence. So far as lattice masts and towers are concerned, the first is likely to be significant if circular sections are used as structural components, with vibration leading to possible fatigue problems at connexions or undesirable localized deflexions. The response to atmospheric turbulence or gusting is potentially more dangerous as this could set an entire structure into oscillation.

Vortex Shedding

This effect is usually associated with structures of circular cross-section although other shapes suffer to some extent. When the air flows past an obstacle such as a cylinder, the flow separates to either side and complementary pairs of vortices are shed (Fig. 3). The frequency of shedding is dependent on the wind velocity and the diameter of the cylinder. These vortices give rise to alternating increases and

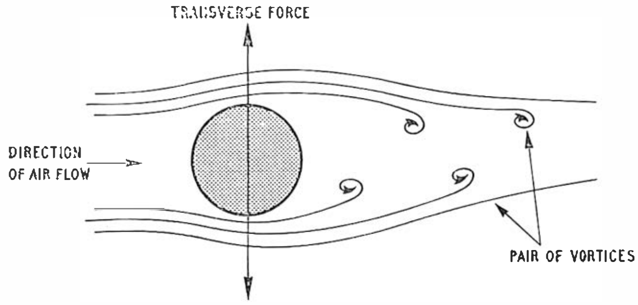


FIG. 3—Vortex shedding around a cylinder

decreases of pressure at the sides of the cylinder which generate a force transverse to the direction of air flow. If the frequency of this force corresponds to a structural resonance, then undesirable oscillations may result. Such oscillations may be prevented by either inhibiting vortex formation, or reduced by providing additional damping. Fig. 4 shows a Stockbridge type of damper fitted to a member of a microwave tower which had been subject to severe localized vibration.

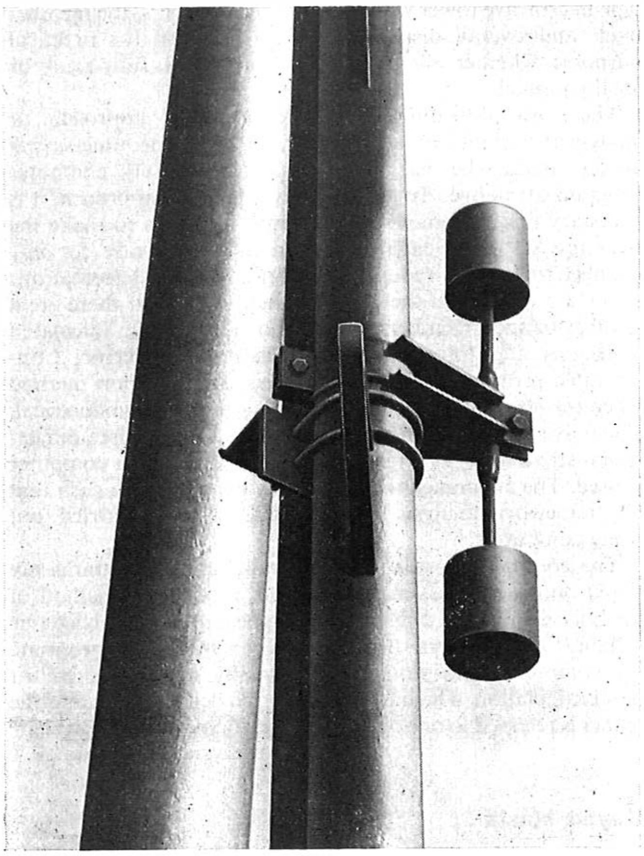


FIG. 4—Damper fitted to a tubular member of a tower

Turbulent Wind Effects

As mentioned earlier, it is convenient to consider the wind as a steady mean air flow with a superimposed fluctuating gust component. The mean wind results from atmospheric changes as illustrated by isobars on the weather map. The fluctuations are random in nature and are caused by the stirring of the mean wind by ground roughness. City-centre conditions give a rough surface which causes greater turbulence although the mean wind speed is reduced by the increased surface friction. Open country has a higher wind speed, but a proportionately lower level of turbulence.

Fig. 5 shows the Van der Hoven spectrum of the wind which illustrates the typical distribution of energy over the frequency range corresponding to a period of one year down to one second. Two peaks of energy are apparent, one centred about a "weather-map" peak of about four days and the other a gust peak of one minute. There is appreciable energy at periods down to one second and below. It is this latter gust energy which is of interest to mast and tower designers as the structural natural frequencies likely to be encountered are in the range 0·5–10 Hz and the low end of this frequency band defines those structures where turbulent flow excitation is of greater significance. Whether or not the structure is adversely affected depends on how this energy input is dissipated.

Damping

Damping is the means by which the oscillatory energy imparted to the structure by the wind can be dissipated. This energy absorption takes place on masts and towers in the form of structural and aerodynamic damping. In a typical steel tower with bolted gussetted joints, a considerable amount of energy is dissipated in slip between surfaces at the joints. Structural damping is considerably reduced if there is extensive use of welded connexions in which slip cannot occur, or of friction-grip bolted joints where slip only occurs when the joint is subjected to very high shear forces. Other contributions to structural damping arise from movement of the foundations in the ground and the hysteresis loss during strain cycles within the steel itself. Hysteresis damping is small for structural steels at normal stress levels but, should plastic deformation take place, it then increases rapidly. The other important mechanism is aerodynamic damping resulting from the drag of the air on the vibrating structure. The relative velocity between air and structure is usually too low to give much increase in this damping.

Knowledge of damping is a vital parameter in any attempt at predicting the dynamic responses of structures to wind action. Unfortunately, relatively little information is available on damping of typical structures to guide the designer but some measurements of damping are currently being made on B.P.O. microwave towers. For an unconventional structure, structural engineers accept that it may be necessary to provide additional damping after the structure has been completed.

Calculation of Wind Forces by the Dynamic Method

The dynamic approach to wind loading of structures was first propounded by Davenport[14] and developed by others; Fig. 6 summarizes Davenport's approach in general terms. The analytical aspect of such methods is complicated by the fact that the wind can only be described by statistical techniques which take account of the randomness of wind turbulence. It is necessary to be able to describe the spatial dimensions and energy/frequency content of gusts in a meaningful manner.

Various simplications for practical design have been suggested.[13,15,16] The applicability of any of these theoretical approaches has yet to be adequately demonstrated by results from a sufficient number of field measurements. When proven, the dynamic method should enable a design to be better matched to acceptable risks of safety and serviceability.

ICE

A substantial corpus of information on the wind has been built up over the years which can be used for design. For icing, the data is much less adequate, for various reasons. Unlike wind, which can be recorded simply and remotely by anemometers and direction-vanes, icing conditions cannot readily be recorded as the deposition of ice depends on the shape of the surface and is not likely to be of regular cross-section. At present, the only practical means of determining the size of deposit and density of ice is by visual observation. On high remote sites, it is unlikely that such human observations would be possible in extreme conditions for reasons of accessibility and visibility. Such observations as have been made so far are insufficient to permit a statistically-reliable basis for design.

The latest edition of the British Standard on loading[17] does, however, give tentative guidelines for the designer. Three types of ice deposit are considered:

(*a*) glazed frost, otherwise known as freezing rain or drizzle, which is the most dense,

(*b*) rime ice, which is the least dense, and is formed when fog or cloud is blown on to a cold surface, as forming an ice deposit with entrapped air, and

(*c*) ice, midway in density, which is deposited as melting snow and freezes on contact with cold surfaces.

It is not considered likely that extreme winds will occur with extreme ice and, for design purposes, a reduced wind velocity is usually applied to the iced-up structure.

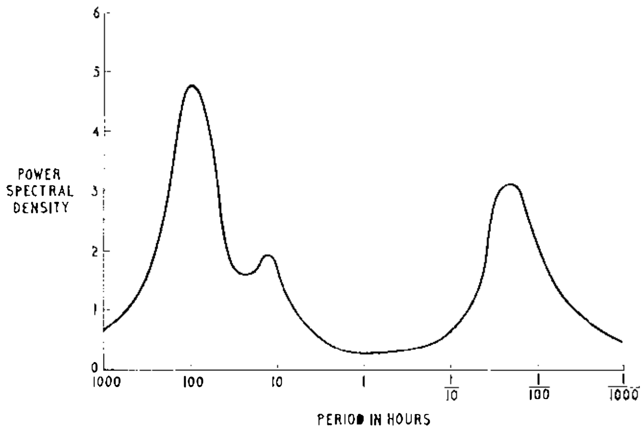


FIG. 5—Spectrum of wind speed (after Van der Hoven)

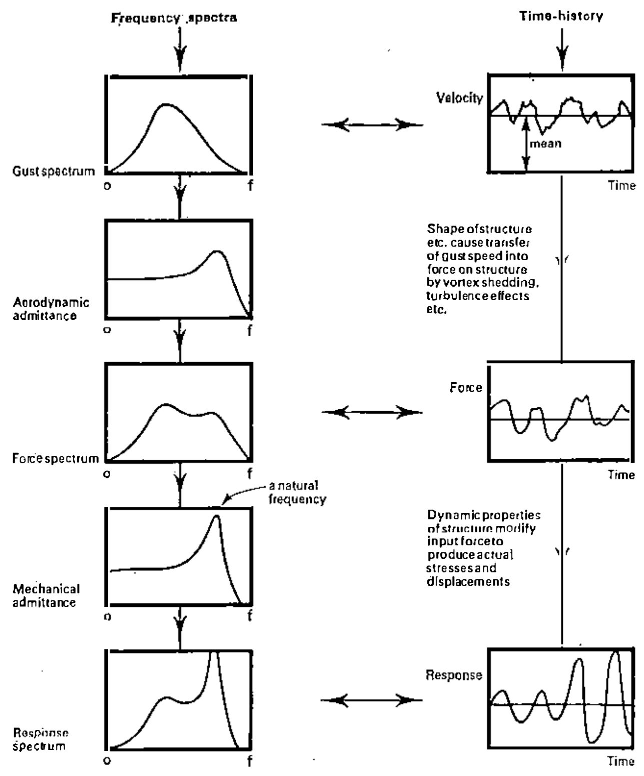


FIG. 6—Representation of statistical design approach of Davenport

STRESS ANALYSIS

Towers

Until recent years, most stress-analysis work for towers was carried out using a graphical method based on the Maxwell force diagram in which the tower is considered as a plane truss, that is, with all members lying in one plane and each member connected to its neighbours by frictionless pin-joints. Obviously, the average structural joint is not a pin-joint but it has been shown that, on a conventional pylon-type microwave tower with long slender members, the member loads and overall displacements are identical for practical purposes whether the joints are considered fully-rigid or ideally-pinned.

There are difficulties with the graphical approach or analytical variants of it which, apart from the time-saving aspect, make the use of a structural-analysis computer program attractive. To use the force-diagram approach, it is necessary first to remove "redundant" members to make the structure statically determinate. In fact, it is rare for any member to be truly redundant because of axial deformations which are ignored in the graphical method and, if there are a number of such members to be removed, then the calculated deflexions and forces can be substantially in error. Considerable problems can arise with the force-diagram method when the structure itself or the loading on it is asymmetrical. The only satisfactory method, then, is to adopt a three-dimensional stress analysis which is feasible only when a computer is used. The advantages of analysis by computer are such that all framework analysis in the B.P.O. is now carried out using computers.

The commonly-available structural-analysis programs are based on the stiffness-matrix method, a powerful method of analysis which has only recently appeared in the academic syllabus for engineers. It is essentially a method appropriate for computers and would not normally be considered for hand calculation. The method cannot be detailed here and the reader is referred to one of the many textbooks now available.[18]

Guyed Masts

The structural analysis of guyed masts poses a completely different class of problem to that of self-supporting towers. The latter are analyzed as linear structures in that, provided the elastic limit of the material is not exceeded, the displacement at any point is directly proportional to the applied load. This does not apply to guyed masts which are non-linear structures and, in common with other non-linear problems, manual solution is generally complex, lengthy and tedious as iterative techniques have to be employed. In the past, the complexity of mast analysis was such that only a few configurations were adequately analyzed. This limited the use of standard designs of mast to situations obviously within the original design parameters. The much higher predicted wind speeds at many sites and the need to investigate the use of new types of guy made the development of a computer-based method of analysis very desirable.

The principal difficulty in mast analysis arises from the nature of the support provided by the guys which is non-linear in that there is no simple relationship between the deflexion at the guy attachment point on the mast and the restoring force generated by the guys at that level. A typical load/deflexion characteristic is shown in Fig. 7 where it can be seen that, for small movements of the guy attachment, relatively small increases in the restraining force are generated. This results from the fact that the ropes are of finite weight and so hang in the form of a catenary; small movements of the mast tend to remove the initial sag without appreciably increasing the restraint exerted on the mast. As more and more of the sag is removed so the magnitude of the restraining force tends to increase rapidly until, at larger deflexions, the load/deflexion curve becomes linear. The actual shape of the characteristic curve varies considerably with the guy properties: for example, short highly-tensioned guys are likely to be linear over virtually the whole range; long heavy guys may never work within the linear portion.

The fact that the mast is supported on non-linear yielding supports means that a conventional continuous-beam analysis does not give an accurate representation of the distribution of bending moment, shear force or deflexion of the structure. The situation is further complicated in that, when the mast heels over under load, the guys on one side tighten and those on the other slacken. As these guys do not terminate on the centre-line of the mast, the vertical components of guy tensions provide an unbalanced couple acting at each guy-attachment point which the mast has to resist.

It is unlikely that the mast will remain straight as it heels over and further moments and forces are generated as a result. Fig. 8 shows the contributions to the total bending moment of the principal mechanisms acting on a 125 ft-high B.P.O. Mast No. 1 for which the design wind speed was 168 miles/h at the top of the mast. If this mast had been treated as a simple continuous beam on rigid supports then the moments would be equal to the algebraic sum of the simply-supported moments plus the fixing moments. The more realistic analysis gives a substantial redistribution of the moments with considerably higher maxima. For this particular mast, many trial runs had to be made before a satisfactory solution was achieved which gave safe stress levels in both the mast column and the guys. Such a difficult case would have been virtually insoluble without the use of computers.

Fig. 9 gives a basic flowchart of a program which can perform a mast analysis in less than 40 s of computer time.

FINITE ELEMENT

The type of stiffness-matrix method already mentioned is restricted to handling skeletal framework problems in which the structural members are long and slender. When structural elements do not conform to the criterion, as in the simple example of a plate in Fig. 10, then other methods of analysis must be used. One approach which is eminently suited for computer solution is the finite-element method. Instead of idealizing the structure as a system of line-like components of the stiffness-matrix method, the finite-element analysis permits the structure to be divided up into a system of continuous elements. The plate problem shown is divided into a number of triangular plate elements connected at their nodes. One is not restricted to 2-dimensional triangular

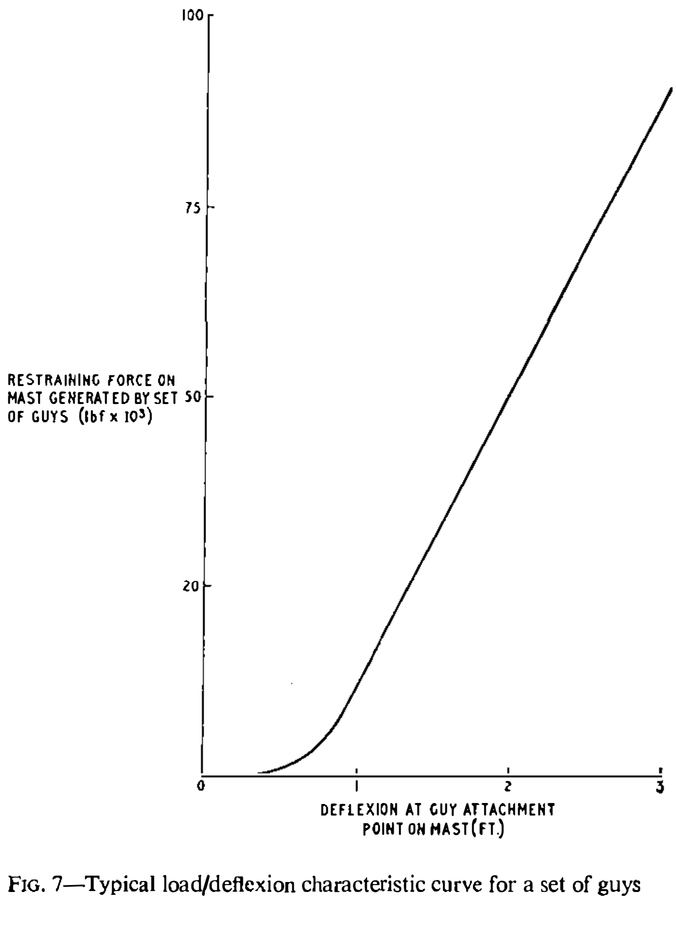


FIG. 7—Typical load/deflexion characteristic curve for a set of guys

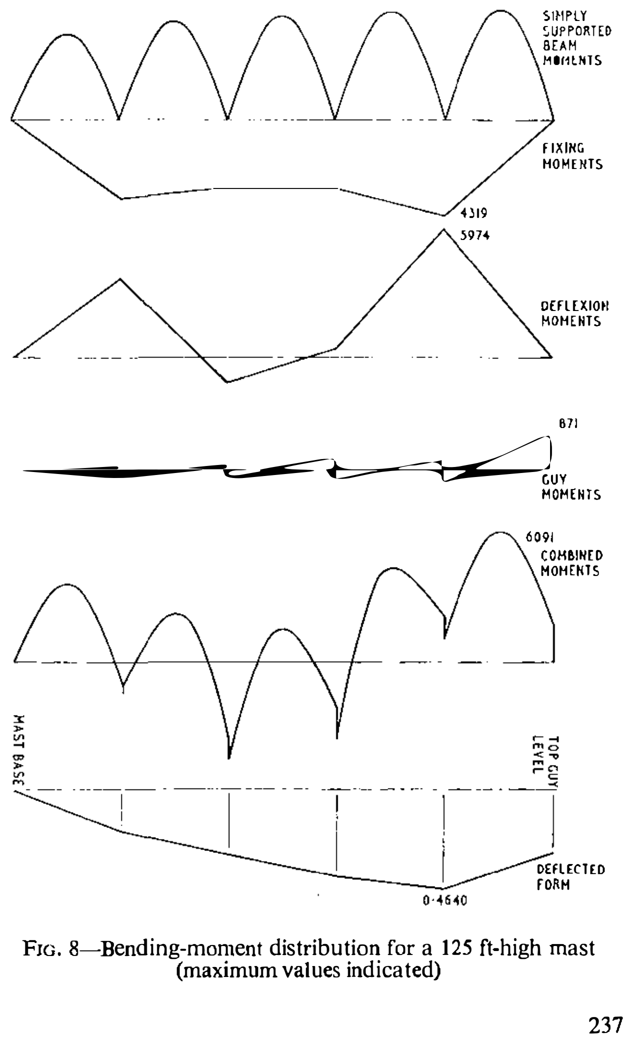


FIG. 8—Bending-moment distribution for a 125 ft-high mast (maximum values indicated)

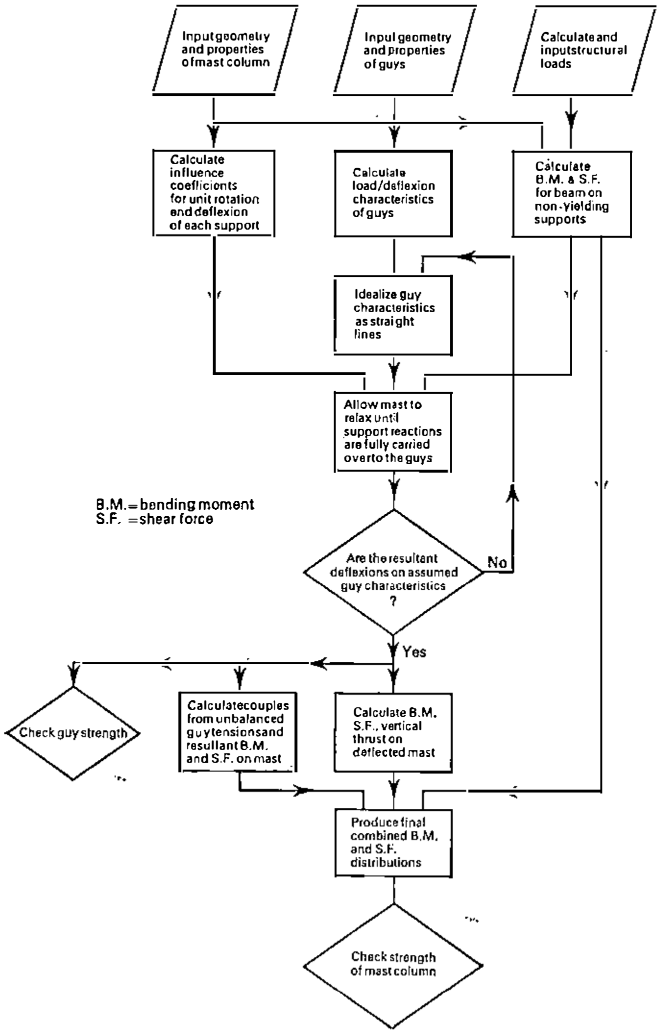


FIG. 9—Flowchart of mast-analysis computer program

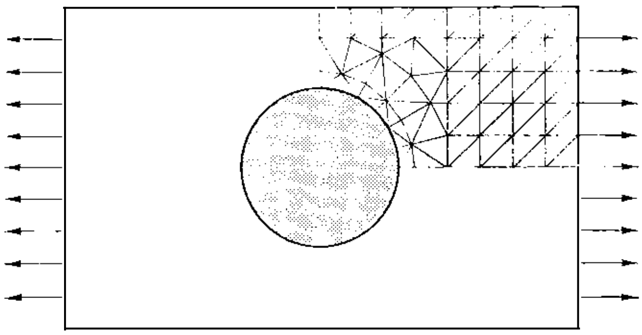


FIG. 10—An axially-loaded plate with a central hole, a typical problem suitable for stress analysis by the finite-element method

elements, and computer programs often have facilities for utilizing a wide range of 2- and 3-dimensional elements which allow complex shapes to be analyzed. The size of elements can be varied so that areas of stress concentration on the component can be investigated in detail by using small elements; a coarser pattern can be used for areas with lower stress gradients. The finite-element method, at present, tends to be expensive in computer time and needs to be used with discretion to achieve valid results. Its principal potential for the mast and tower designer is for analyzing complex critical components in which structural integrity is vital.

CONCLUSION

It is probably true to say that, a few years ago, tall masts and towers were designed with confidence using wind forecasts, British Standards and elegant methods of stress analysis. Recent work on the study of the nature of structural loading has demonstrated that there are, potentially, sources of considerable error in the process. Error bounds in design, which have been suggested,[19] are shown in Table 3. Even if these tolerances are unduly pessimistic for B.P.O. masts and towers, there is still considerable scope for improving the design process to produce economic and safe structures.

Subsequent parts of this article will describe the materials and methods of construction of modern structures and the experimental work which is being carried out to correlate theoretically-predicted behavior with actual performance.

REFERENCES

[1] WALMSLEY, T. Rugby Radio Station. *P.O.E.E.J.*, Vol. 18, p. 59, Apr. 1925.

[2] HARDING, J. P. and HARMON, J. F. The Reconstruction of Leafield Long Wave Radio Masts. *P.O.E.E.J.*, Vol. 40, pp. 1 and 63, Apr. and July 1947.

[3] MILLAR, J. B. Reinforced-concrete Radio Towers. *P.O.E.E.J.*, Vol. 58, p. 178, Oct. 1965.

[4] BIRCHBY, G., and MOXON, R. L. A New Concrete Tower for Purdown Radio Station. *P.O.E.E.J.*, Vol. 63, p. 138, Oct. 1970.

[5] CREASY, L. R., ADAMS, H. C., and SILHAN, S. G. Radio Towers. *The Structural Engineer*, Vol. 43, p. 323, Oct. 1965.

[6] British Standard 449:1970. Specification for the use of structural steel in building.

[7] HALL, L. L. Anthorn Very-low-frequency Radio Station. *P.O.E.E.J.*, Vol. 58, p. 114, July, 1965.

[8] COOK, A., and HALL, L. L. Criggion Radio Station. *P.O.E.E.J.*, Vol. 41, p. 123, Oct. 1948.

TABLE 3

Percentage Error in Stress Estimation

	Source of Error				
	Wind Speed	Pressure Coefficients	Structural Model	Computational Method	Total Error ±
Static Effects	50	20	Concrete 20 Steel 10	1–10	60
Gusting	50 and 100	100	25	25	150
Vortex Excitation	50	200	25	1–10	200

[9] HALL, L. L. The New Criggion. *P.O.T.J.*, Vol. 21, No. 2, p. 20, Summer, 1969.
[10] MORRIS, D. W., SHADDICK, W. G., and THURLOW, E. W. Shortwave Directional Aerial-systems. *P.O.E.E.J.*, Vol. 47, p. 212, Jan. 1955 and Vol. 48, p. 29, Apr. 1955.
[11] YOUNG, S. G. A 150-foot Mast for Radio Stations. *P.O.E.E.J.*, Vol. 53, p. 271, Jan. 1961.
[12] WOOD, E. M. On the Structure and Progress of the Forth Bridge. *Proceedings I.Mech.E.*, p. 310, Aug. 1887.
[13] C.I.R.I.A. Symposium. The Modern Design of Wind-Sensitive Structures. (C.I.R.I.A. 1971).
[14] DAVENPORT, A. G. Application of Statistical Concepts to the Wind-Loading of Structures. *Proceedings I.C.E.*, Vol. 19, p. 449, Aug. 1961.
[15] DAVENPORT, A. G. Gust-loading Factors. *Proceedings American Society of Civil Engineers—Journal of the Structural Division*, Vol. 93, No. ST3, June, 1967.
[16] MACDONALD, A. J., and MORGAN, J. A Method for Calculating the Vibration Amplitudes of Slender Structures in Turbulent Winds. *Proceedings International Symposium on Wind Effects in Buildings*, Tokyo, Sep. 1971.
[17] British Standard Code of Practice CP3: Ch. V: Pt. 2: 1972. Code of basic data for the design of buildings.
[18] COATES, R. C., COUTIE, M., and KONG, F. K. Structural Analysis. (Nelson, 1972).
[19] WALLER, R. A., DUKES, T. P., and DALLEY, E. J. A comparison between the quality of the techniques and the data available to the environmental engineer with regard to wind loading. *Proceedings Symposium on Wind Effects on Buildings and Structures.* Loughborough, Apr. 1968.

Book Reviews

"Telecommunication Principles for Final Certificate. Vol. I. Principles B." S. A. Knight. Butterworth. 273 pp. 182 ill. £2·50 and "Vol. II. Principles C." 266 pp. 205 ill. £3·00.

So many books have been written covering the syllabus of the City and Guilds of London Institute in Telecommunication Principles that one wonders whether there can be any market for a new one. The Principles syllabus is fundamental in that it covers basic matters on which Telecommunications Engineering and, in fact, Electrical Engineering in general, is built up. There is little need for variation of presentation on engineering fundamentals and, fortunately, changes in fashion in teaching make less disarray amongst engineering curricula than in, say, the Arts or Mathematics.

However, after this has been said, it must be acknowledged that good and bad presentations have been published even on the traditional engineering syllabuses. These two books by S. A. Knight come into the former category. The author had a wide experience of teaching Telecommunications, both in the U.K. and in Nigeria. The West African students need a different presentation for effective teaching from that normal in the U.K. They have less practical background and need to be led by example and practical demonstration. This has been reflected in Mr. Knight's books, especially the first volume. He has not dodged some of the classical difficulties by omitting them or glossing over them with inadequate explanations; for example a description of electric flux is given and it is related to electric force, with units, and the relevance of absolute permittivity emerges clearly.

Another similarly satisfactory account, at this syllabus level, is given over to transistors and the various parameters relating to them that are useful in Telecommunications.

The chapters in the books are arranged roughly in accordance with the individual syllabus sections in 271–3–12 and 271–4–19 of the current City and Guilds Telecommunications Principles, grades B and C. The text is presented in traditional form with lists of examples at the end of each chapter, mostly drawn from past City and Guilds examination papers and to which many of the model answers have been published by the *P.O.E.E.J.*

The presentation is good, with well-drawn diagrams and few misprints.

C. F. F.

"Modern Data Communication." William P. Davenport. Pitman Publishing. 200 pp. 114 ill. £2·75.

The subtitle of this book is "Concepts, Language and Media" and the preface states that it is written "to explain the theories and concepts of data transmission to the operators and managers of information systems and students of information handling. An attempt has been made to reduce intricate theories to clear and understandable terms without losing the essence of their meanings." The attempt has failed and, frankly, the reviewer is unable to recommend this book as a reliable source of information.

The first three chapters define data source, data sink and transmission medium, and briefly explain binary notation and bits and bauds. Storage codes for paper tape, punched cards and magnetic tape are given fairly detailed treatment and start/stop transmission is briefly mentioned (7.42 elements per character). There is little scope for going wrong in such material but, nevertheless, there are some errors.

The next three chapters concern transmission and abound in disputable statements. For instance, on the first page alternating currents are explained and "either half of the cycle is called a baud". Three pages later "There are three types of distortion that a channel may impart to a signal: delay distortion, attenuation distortion and jitter". Jitter is revealed to be telegraph distortion measured as a percentage of two signal elements duration instead of the normal one. Later on, in the modulation chapter, concerning frequency-modulated (f.m.) modems we find that "an f.m. signal is said to be fully modulated when it has reached $\pm$ 75 kHz from the carrier frequency". Phase-modulated modems are described in terms of absolute rather than differential phase and the diagrams are not consistent with one another. The above examples are only a small selection of the peculiar snippets of information which can be found in these chapters.

The final chapters mention the transmission channels and services offered by the U.S. common carriers, give a muddling description of switching systems and methods, and an extraordinarily terse mention of data sets (modems).

The author concentrates almost entirely on American data transmission and American terms are used throughout. The language is authoritative and plausible and between the errors some clear and simple descriptions occur. Therein lies the danger for the non-expert. The treatment is far too shallow to contribute anything of significance to the knowledge of the expert.

R. H. T.

A New Power-Feeding Equipment for Coaxial Line Systems

B. HALL and J. A. JACKSON, B.SC.†

U.D.C. 621.315.212: 621.395.64.031

This article describes a new power-feeding equipment for energizing the underground repeaters of 60 MHz coaxial line systems. The equipment provides a d.c. series power-feeding current of 110 mA whilst still maintaining the high level of safety for the protection of the staff that was inherent in earlier 50 mA power-feeding systems.

INTRODUCTION

On coaxial line systems, power to energize the dependent repeaters is fed over the inner conductors of the coaxial pairs. In the British Post Office (B.P.O.), one of the dominant design requirements of a power-feeding equipment is that it should ensure maximum safety to personnel working on the associated line system. In modern line systems,[1] this has been achieved by using direct-current series power feeding and restricting the current flowing in the coaxial pair to 50 mA with a voltage limitation of 250 volts to earth.[2]

To provide adequate power to energize the dependent repeaters on the 60 MHz coaxial line system,[3] it has been necessary to use a power-feeding current in excess of 50 mA. To meet this increased power requirement, a new power-feeding equipment has been developed (see Fig. 1) which provides a line current of 110 mA with a voltage limitation of 1,000 volts to earth. To ensure the safety of personnel with this higher voltage and current, the following safety precautions have been taken.

(*a*) A code of practice has been established which should be observed by all personnel working on cables equipped with the new power-feeding system. This code ensures that contact will not be made with any live conductor.

(*b*) The power-feeding equipment has been designed to ensure that the current passing through a person who accidentally touches a live conductor shall be reduced to less than 50 mA within 250 ms.

† Telecommunications Development Department, Telecommunications Headquarters.

THE POWER-FEEDING SYSTEM

A block diagram of the power-feeding arrangement is shown in Fig. 2. Current from two line power generators is fed to the inner conductor of each coaxial pair via control units and the low-pass section of power-separation filter units. Under normal conditions, the inner conductors of two coaxial pairs complete the power-feeding loop and four line power generators are connected in series aiding. The outer conductors of the coaxial pairs are connected to the common point between the two generators and earthed. Each pair of generators delivers an output current of 110 mA. The voltage drop along the line is proportional to its length, with a maximum of 1,000 volts for a power-feed section of 66 km. Normally, this voltage is shared between the two generators, although each generator is capable of delivering the full voltage. The normal voltage distribution along one of the

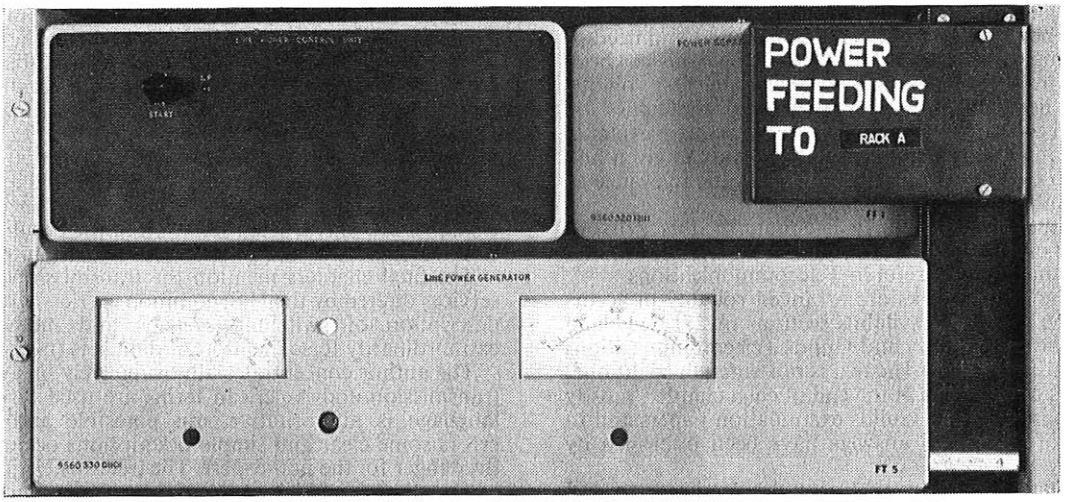


Fig. 1—Power-feeding equipment

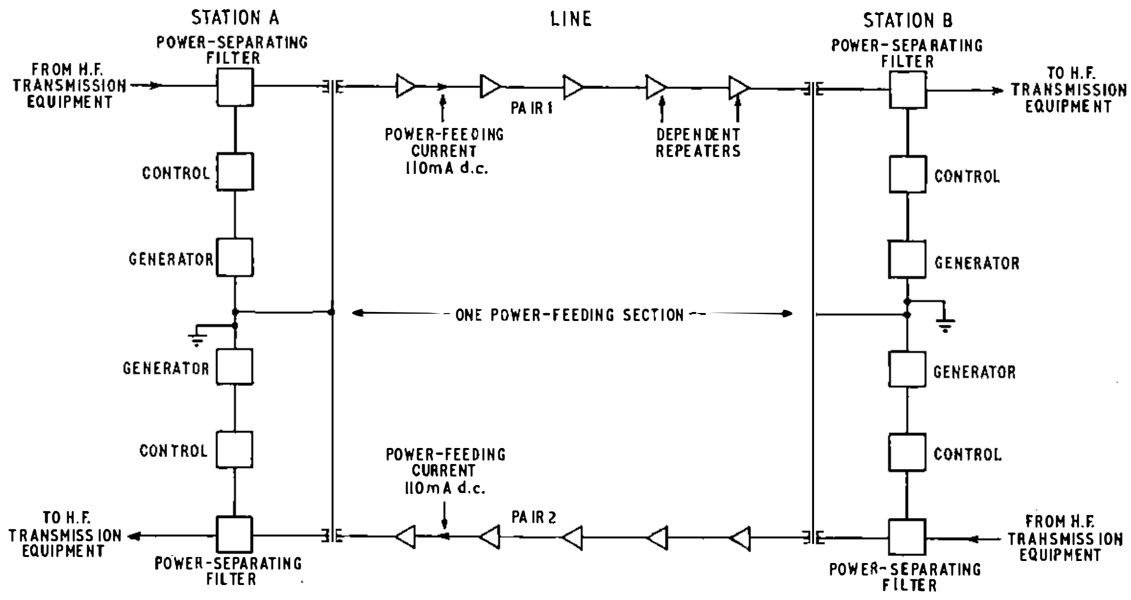


FIG. 2—Block diagram of the power-feeding system

coaxial pairs is shown in Fig. 3. This shows that, at one point between the two stations, the voltage between the inner conductor and outer conductor (earth) is zero.

Although two coaxial pairs usually complete the power-feeding loop, power to each pair is controlled independently. The occurrence of a fault on one coaxial pair does not affect power being fed to the other coaxial pair, the power-feeding loop being maintained via the inner and outer conductors of the other pair. This is of particular importance if the associated transmission is unidirectional, such as for television.

The current through a person, who accidentally touches a current-carrying conductor, must be reduced to less than 50 mA within 250 ms. A person touching the inner conductor and outer conductor, or earth, may be represented by the resistor R as shown in Fig. 4. Because the line power generators have a high output resistance, the output voltages of both generators automatically readjust so that the voltage distribution along the coaxial pair becomes as shown in Fig. 5. One generator is then working at a reduced output voltage whilst the other is working at an increased output voltage. Thus, the current through the resistor R and the voltage across it should be zero. However, because the output resistance of the generators is not infinite, a small current flows through the resistor R representing the person, but this current will not exceed 50 mA for longer than 250 ms. In practice, this current does not exceed 15 mA. Under these conditions, the power-feeding system can continue to feed power to line and when the contact is removed, the voltage distribution reverts to normal. If contact is made between the inner conductors of two coaxial pairs, the output voltages of all four generators readjust and a similar balancing action occurs. The initial current through a person who makes contact in series with the inner conductor is 110 mA, but the power-feeding current is switched off within 250 ms by a process described later.

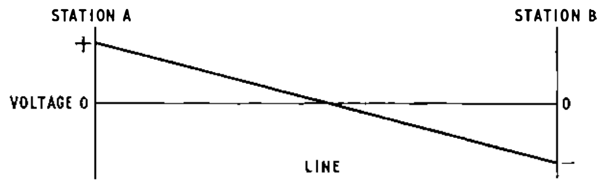


FIG. 3—Normal voltage distribution along a coaxial pair

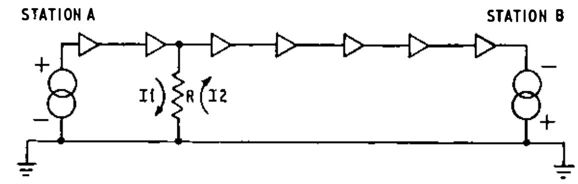


FIG. 4—Balancing of power-feed circuit during a fault

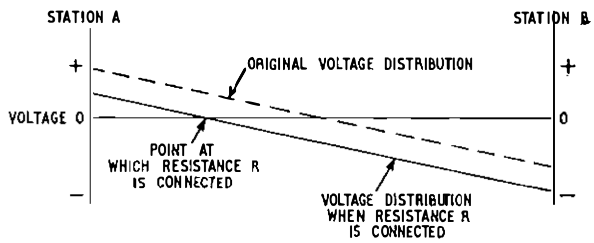


FIG. 5—Redistribution of voltage during a fault

THE LINE POWER GENERATOR

The line power generator, shown in Fig. 6, operates from the 50-volt station battery. The incoming supply is fed through a low-pass filter to prevent noise from the generator feeding back into the station supply. The supply is then fed to the inverter which produces a square-wave output under the control of the P relay at a frequency of about 25 kHz. To drive the inverter, the P relay removes two short circuits and makes two connexions as shown in Fig. 7, this arrangement being used to improve reliability. As this is a low-current switching

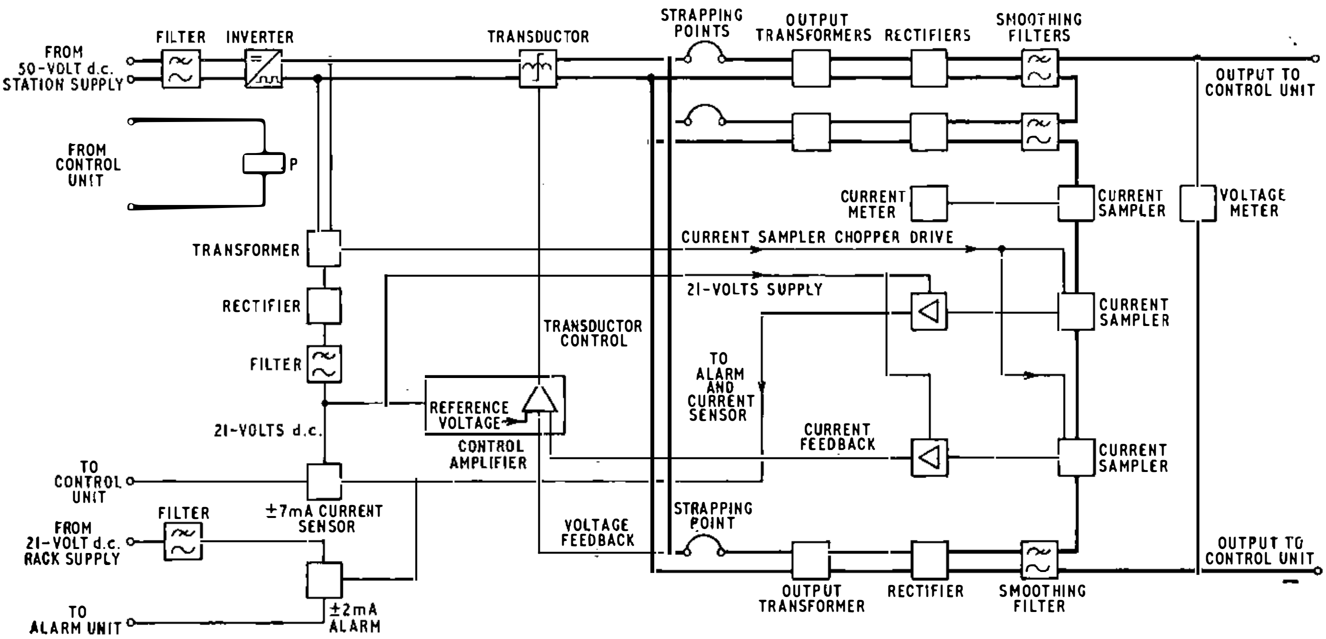
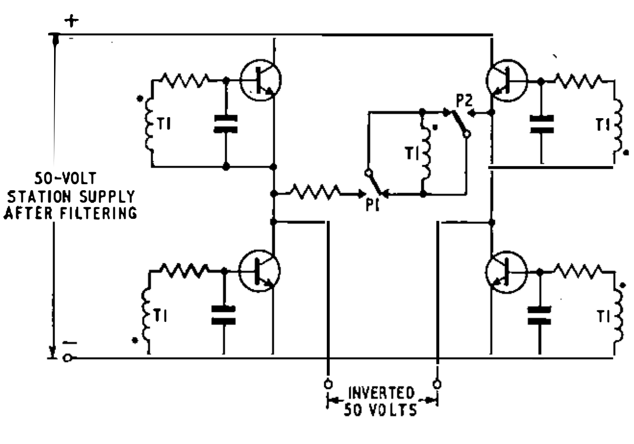


FIG. 6—Block[diagram of the line power generator

circuit, arcing across the contacts is reduced to a minimum. On operation of the P relay, the generator produces full power within 120 ms in the following manner.

The square-wave output from the inverter is fed via a transductor to the primary windings of the three output transformers. The transductor consists of two ferrite cores each carrying a winding through which the load current passes. A third winding links both cores and a d.c. control current from a low-impedance source is passed through this winding. The sense of the windings is such that, in any half cycle of the inverter output, the load and control currents oppose in one pair of windings and aid in the other.

For zero control current, the cores act as inductors, allowing only a leakage current to flow through the load. When a d.c. control current flows, then in each half cycle of the inverter output, one of the cores is magnetized by a leakage load current and control current which aid each other. Thus, that core becomes saturated during part of the half cycle and the impedance of the load winding on that core falls. This low



Note: Transformer T1 has five windings whose sense is indicated by the dots

FIG. 7—Action of P-relay contacts in inverter

impedance is reflected by the control winding into the non-saturated core, so that the impedance of the load winding on that core also falls. This allows the full load current to flow, but only during part of each half cycle. As the control current increases, saturation occurs for a greater portion of each half cycle, and, therefore, the net load current also increases.

The primary windings of the output transformers are connected to the transductor via straps, to allow one, two or three outputs to be energized. This enables the generator output resistance to be matched to the length of the line. The transformer outputs are bridge rectified, smoothed and the d.c. outputs are permanently connected together in series.

The voltmeter is connected directly across the generator output. Three current sampling points are provided in series with the d.c. output. One sampling point is a single resistor across which the current meter is connected. The current sampling circuits for the alarm and current monitor and for the control amplifier feedback are both of the chopper type, the current being passed alternately through each half of a centre-tapped primary winding of a transformer, using transistor switching. The chopper drive is taken from a low-voltage winding on the 21-volt transformer. The chopper transformers provide the d.c. isolation between the generator output and the lower-voltage control circuitry. The outputs of the chopper transformers are rectified, smoothed and fed to their respective circuits via operational amplifiers.

Voltage feedback is taken from the primary side of the output transformers and, together with the current feedback, is passed to the control amplifier. This is an integrated circuit with self-contained zero-temperature-coefficient zener-diode reference voltage. The amplifier produces the d.c. control current for the transductor, thus completing the feedback loops. The combined effect of the voltage and current feedback is to produce the required source resistance at the output.

The voltage feedback also controls the open-circuit voltage of the generator and as it is taken from the primary side of the output transformers, the d.c. output resistance and open-circuit voltage are proportional to the effective turns ratio of the output transformers. When all three transformer primary

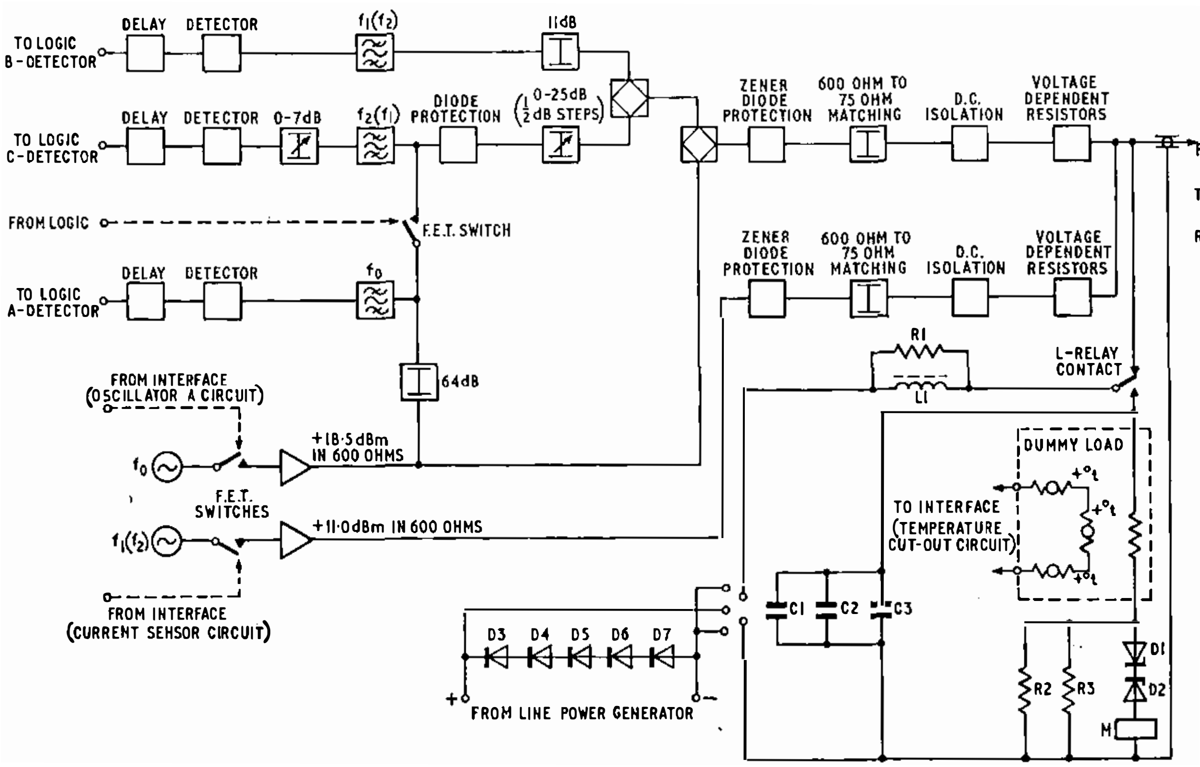


FIG. 8—Tone and power section of the control unit

straps are connected, the output resistance is 50 kilohms and the open-circuit voltage is 1,200 volts.

The current sensor gives a *correct* condition to the control unit when, and only when, the output current is within the range 110 ± 7 mA. The alarm circuit gives a *Line-Current* alarm, which is displayed elsewhere, whenever the generator current is outside the limit of 110 ± 2 mA. This is provided only as a warning of current drift, and does not form a link in the safety system.

The power for all internal circuitry, with the exception of the alarm, is derived from the inverter output, using a 50-volt-to-21-volt transformer with rectification and smoothing. Thus, when the generator is switched off, all the control circuits are also switched off. The ± 2 mA alarm circuit requires a separate supply so that it will still give the alarm when the generator is switched off. This supply is taken from the normal rack 21-volt d.c. supply via the fuse which feeds the control unit.

THE CONTROL UNIT

Two control units, one at each end of the power-feeding section, automatically supervise the switching on of line power, continuously monitor the current from the line power generators and automatically switch both generators off if the current is out of limits. Communication between the two control units is by means of three audio tones transmitted over the associated coaxial pair. Communication must be possible even when line power is switched off, so audio frequencies are used because they can traverse the system unamplified and bypass the line repeaters via the power-feed path. A block diagram of the tone and power sections of the control unit is given in Fig. 8 and the interface section, between the logic and the rest of the control unit, is shown in Fig. 9.

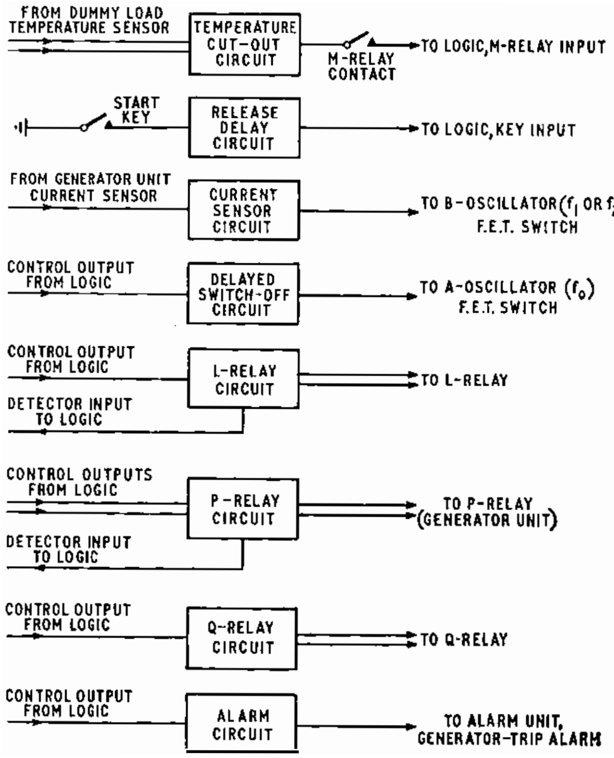


FIG. 9—Interface section of the the control unit

The design functions of the control unit are as follows:

(*a*) Before feeding power to line, both generators are tested by connecting them to dummy loads which simulate the line. The generators are switched on and checked to ensure that they produce the correct current, that is, 110 $\pm$ 7 mA.

(*b*) When both generators are proved correct they are connected to the line within a few milliseconds of each other, whilst still switched on.

(*c*) Once power is being fed to line, both generators are monitored continuously and, if the current becomes out of limits, both generators are switched off within 250 ms.

(*d*) If the generators are switched off, for whatever reason, there is no automatic restart attempt and no change-over to a standby generator.

(*e*) If there is a short circuit between the inner and outer conductors of the coaxial pair, a disconnexion of the inner conductor, or a man in series with the inner conductor, it is not possible to start feeding power to line. If power is already being fed to line when any of these conditions arises, both generators are switched off within 250 ms.

(*f*) The control system fails safe so that any single functional failure does not render the line dangerous.

(*g*) It is possible to start the power-feeding system from either station without attendance being required at the other station.

(*h*) In addition to the *Line-Current* alarm given by the generator, the control unit gives a *Generator-Trip* alarm if the generator is switched off in response to a fault external to the generator and control unit.

(*i*) A relay switches off the 21-volt d.c. supply to the line system receive amplifier when line power is switched off, and switches the supply back on 1 s after line power is restored. The 1 s delay prevents the line power switching surges from passing into the subsequent transmission equipment.

CIRCUIT OPERATION

Both stations have a start key and an oscillator and detector working at a frequency f_0 (6·3 kHz). The power-feeding system can be started from either station by operation of the start key. This causes tone f_0 to be connected to the local f_0 detector and to the inner conductor of the coaxial pair over which power will be fed. The f_0 detectors operate at both stations, causing the L relays to connect the generators to their dummy loads. The P relays then operate, switching on the generators, which feed their currents into the dummy loads. The monitoring M relays then operate, proving that the L relay contacts have correctly switched to dummy load.

When the generator in each station produces the correct current, its associated current sensor connects a control tone to the line, tone f_1 (5 kHz) being connected at one station and tone f_2 (8 kHz) being connected at the other. These tones traverse the line so that, at each station, both f_1 and f_2 detectors are operated. This causes tone f_0 to be removed from the line, and the f_0 detectors at both stations release, causing the L relays to release. Thus, power is connected to line at both stations simultaneously. As power is no longer flowing into the dummy loads, the monitoring M relays release, indicating that the L relay contacts have correctly switched back to line. The control unit allows the generators to feed power to line indefinitely, as long as no fault develops and no disturbance occurs on the line.

If either generator fails to produce the correct current, its current sensor removes the associated control tone from line. Thus, the detectors of that tone release at both stations, causing the generators to be switched off. When a failure occurs, both control tones disappear within 250 ms, but, if the distant control tone disappears first, this indicates that either a fault in the local power-separating filter, a cable fault or a fault at the distant station has occurred and the *Generator-Trip* alarm is given. If the local control tone disappears first, this indicates that the local generator or control unit is failing, so the *Generator-Trip* alarm is not given at this station, but it will be given at the distant station.

FEATURES OF THE TONE SECTION OF THE CONTROL UNIT

In this and following sections, frequency *A* means frequency f_0, frequency *B* means the frequency of the local control oscillator f_1 or f_2, and frequency *C* means the corresponding frequency of the distant control oscillator f_2 or f_1.

The tones pass to, and from, the line via the power-separation filter unit.

A separate path to the output of the control unit is provided for outgoing tone *B*, so that it checks the continuity of the path for incoming tones before operating the local *B* detector. At the input, voltage-dependent resistors are used to reduce ringing and impulse magnification in the inductors and capacitors in this part of the circuit. Isolation against the power-feeding voltage is provided by four capacitors, each tuned with an inductor to pass one of the tones *A*, *B* or *C*. Tuned circuits are used because a single capacitor having an impedance much less than 75 ohms at 5 kHz and of 6-kilovolts rating would be impractically large. Simple resistive pads match the 75-ohm line to the internal 600-ohm circuitry. Zener diodes provide protection against high voltages between inner and outer conductors, the zener voltage in each case being a little above the peak amplitude of the outgoing tone *A* or *B*.

The control unit has been designed to withstand impulses of up to 5 kilovolts d.c. as caused by lightning or up to 1·3 kilovolts r.m.s. a.c. as induced by power lines in addition to the 1 kilovolt d.c. maximum power-feeding voltage.

The oscillators, which are of the Colpitts type and run permanently, are connected to output amplifiers by field-effect transistor (f.e.t.) switches when it is desired to transmit the tone. The f.e.t. switches are controlled by circuits in the interface section.

The detectors are all designed to operate at the same signal level. The level of transmitted tone *A* is reduced to nominal at the *A*-detector input by a 64 dB pad and the level of transmitted tone *B* is reduced to nominal at the *B*-detector input by an 11 dB pad. An adjustable 0–25 dB pad equalizes for any length of the power-feeding section up to 66 km to give nominal level to incoming tones *A* and *C* at the inputs of the *A* and *C* detectors. An additional 0–7 dB pad equalizes any difference in level between incoming tones *A* and *C* due to unequal cable attenuation at these two frequencies.

Final protection to the *A* and *C* detectors is given by silicon diodes which limit the peak signal amplitude to 0·7 volt. The *B* detector is adequately protected by the 11 dB pad and the zener diodes. An f.e.t. switch disconnects the *A* detector from the line when the local start key is pressed. This avoids spurious effects should tone *A* be sent from the distant station at the same time.

Each detector is preceded by an inductor-capacitor-type filter to provide discrimination between the tones and to provide isolation against spurious signals which may be present on the line. Each detector has a threshold not more than 6 dB below the nominal operate level so that, if the tones are attenuated more than 6 dB, the respective detectors do not operate. This ensures that the line is continuous and has the expected attenuation, for example, it ensures that there is no person in series with the inner conductor. This threshold also guards against spurious lower-level tones which happen to have the correct frequency, for example, due to crosstalk from power-feeding systems on other coaxial pairs in the same cable. In addition, the threshold helps guard against any level of tone at incorrect frequency since only a maximum level of signal can pass the protection circuits and the filter stop-band attenuation is quite sufficient to reduce the signal level to below the operate threshold of the detectors.

The detectors also incorporate on- and off-delays. The on-delay ensures that tones are being transmitted properly, not just momentarily, and guards against short-duration spurious tones. The off-delay guards against the detectors releasing unnecessarily if short interruptions occur due, for example, to a spike on the station battery supply or a high-voltage impulse on the line. The off-delay of the *B* and *C* detectors is a compromise between spurious switching off and the system taking too long to switch off the generators in the event of a fault. The *A*-detector release time is short and when it releases, causes the working generator to be switched from the dummy load to the line. This short delay ensures that this switching occurs at both ends of the line almost simultaneously.

FEATURES OF THE POWER SECTION OF THE CONTROL UNIT

The L relay is the only line-power-switching relay in the whole of the power-feeding equipment. It is a vacuum-type relay and its single-pole change-over contacts are rated to handle the normal power-feeding voltages and currents, the power surges occurring during switching and the high-voltage surges coming from line. In the unenergized state, it connects the generator to the line and, in the energized state, it connects the generator to the dummy load.

In the unlikely event of all the L-relay contacts become welded together, the capacitors C1, C2 and C3 provide protection by short circuiting the control tones and causing both generators to be switched off. Correct operation of the contacts of the L relay is otherwise checked by the monitor relay M as described earlier. The inductor L1 provides a high impedance at the control tone frequencies to prevent them from being short circuited by the generator whose output impedance at these frequencies is lower than at d.c. Resistor R1, which actually consists of six resistors in series, absorbes energy which is stored in the inductor if a high voltage impulse occurs on the line.

The dummy load consists of eight high-wattage resistors which can be strapped to simulate any length of line up to half of the maximum power-feeding distance of 66 km. These resistors are mounted on a metal plate in the rack framework and, as they are normally only used for less than one second at a time, they have not been rated to dissipate full generator power continuously. However, if a fault should cause power to be fed continuously into the dummy load, three positive-temperature-coefficient resistors sense when the mounting-plate temperature reaches 130°C and cause the generator to be switched off. Full generator power can be dissipated for about five minutes before this occurs.

The M relay is used as a monitor to check whether or not current is flowing in the dummy load. Zener diodes D1 and D2 and resistors R2 and R3 arrange that the M relay only operates for dummy load currents of about 80 mA or more.

As all generator-unit outputs are of the same polarity, a strapping field is provided in the control unit for adjustment of polarity. The generator and protection diode network D3–D7 are both capable of withstanding 6-kilovolt impulses of reverse-biassing polarity. For forward-biassing polarity the diodes can pass a current of up to 10 amps.

INTERFACE SECTION OF THE CONTROL UNIT

The interface section, shown in Fig. 9, forms the interface between the logic circuit and the rest of the control unit. There are eight distinct circuits in this section and these are described below.

Temperature cut-out circuit

The resistance of the three positive-temperature-coefficient resistors, which sense the temperature of the dummy-load mounting plate, increases greatly when the mounting-plate temperature rises above 130°C. The temperature cut-out circuit detects this increased resistance and removes the supply of −5 volts to the M relay contact. This causes the logic to switch off the generator.

Start key release delay circuit

When the start key is operated, a signal is sent to the logic. When the key is released, there is a 2 s delay before the signal ceases. Thus, even the shortest start-key pulse lasts 2 s, giving the control system time to carry out the starting-up sequence.

Current sensor circuit

This circuit converts the current-sensor signal from the generator unit into a form suitable to operate the *B*-frequency oscillator f.e.t. switch. There are no connexions between this circuit and the logic.

A-frequency oscillator off-delay circuit

The control signal from the logic switches on the *A*-frequency oscillator immediately, but when the control signal releases, there is a delay before the oscillator is switched off. As the normal triggering event for switch off is the operation of both the *B*- and *C*-frequency detectors, the delay ensures that the detectors have not operated momentarily but are remaining on, before proceeding with the switch-on sequence.

L-relay circuit

This circuit converts the L-relay control signal from the logic into a form suitable to operate the L relay. It also includes a detector circuit which feeds back an output to the logic to indicate when the L-relay coil is energized.

P-relay circuit

This circuit converts the two P-relay control signals from the logic into a form suitable for operating the P relay. One control signal causes one end of the relay coil to be connected to earth and the second causes the other end of the coil to be connected to the 21-volt d.c. supply. Thus, if either control signal is absent, the P relay does not operate. This guards against all single failures in the P-relay operating logic, because one control path can still switch off power even though the other control path has failed. The logic circuit contains a further guard circuit should both of these control paths fail. A detector circuit is also included to feed back an output to the logic to indicate when the P-relay coil is energized.

Q-relay circuit

The Q relay connects the 21-volt d.c. supply to the line system receive amplifier. This circuit converts the Q-relay-control signal from the logic into a form suitable for operating the Q relay.

Alarm circuit

This circuit converts the alarm output from the logic into a form suitable to operate the *Generator-Trip* alarm.

LOGIC CIRCUIT

The logic circuit is a central feature of the control system and controls the L, P and Q relays, the f_0 oscillator and the *Generator-Trip* alarm. It takes its inputs from the *A*-, *B*- and *C*-frequency detectors, the L- and P-relay detector circuits, the M relay and the start key. These inputs are converted into the complex interlocking arrangements needed to satisfy the safety requirements and produce the correct sequences of operation of the whole system.

These logic elements are of the transistor-transistor logic integrated-circuit type. The power for the logic circuit is derived from a 21-volt-to-5-volt converter contained in the control unit. The logic circuit has been exhaustively investigated to prove that element failures do not create unsafe conditions in the power-feeding system.

CONCLUSION

The safety requirements of previous systems have been fully respected in the new power-feeding equipment. Although designed for the 60 MHz f.d.m. transmission system, the equipment could be used to supply power to other types of coaxial cable systems. Each element of the power-feeding system has been investigated to ensure that its failure would not create unsafe working conditions.

ACKNOWLEDGEMENTS

The authors wish to thank their colleagues within both the British Post Office and Pye TMC Ltd., whose joint efforts have made the development of the system possible.

References

1 Miller, J. R., and Gipp, J. A. Recent Developments in F.D.M. Transistor Line Systems. *P.O.E.E.J.*, Vol. 63, p. 234, Jan. 1971.
2 Endersby, J. C., and Sixsmith, J. Coaxial Line Equipment for Small Diameter Cables. *P.O.E.E.J.*, Vol. 55, p. 44, Apr. 1962.
3 Hall, B., and Buffin, J. D. The 60 MHz F.D.M. Transmission System: The Line System. *P.O.E.E.J.*, Vol. 66, p. 135, Oct. 1973.

High-Frequency Studies on Coaxial Cables

G. J. CRANK, B.SC.(ENG.), C.ENG., M.I.E.E., and H. A. HATHAWAY†

U.D.C. 621.317.361: 621.315.212: 621.394.44.029.62

The decision to use coaxial cable for 60 MHz frequency-division-multiplex systems and for high-speed digital systems made it necessary to undertake appropriate high-frequency studies on coaxial cables of current design. The results of the investigations have indicated the considerable potential of these cables for use in the high-capacity analogue and digital systems of the future.

INTRODUCTION

For many years, two basic types of coaxial cable have been used in the trunk network, namely the 1·2/4·4 mm and 2·6/9·5 mm cables, better known before metrication as types 174[1] and 375[2], respectively. In recent years, it has been the policy to use 1·2/4·4 mm coaxial cable for the provision of new systems, but, when 60 MHz frequency-division-multiplex (f.d.m.) systems were proposed, the lower attenuation of the 2·6/9·5 mm cable led to its return to favour for this application. It was planned to use 18-pair, 2·6/9·5 mm coaxial cable for the first systems and, to assess the feasibility, the appropriate mechanical and electrical studies were put in hand. The British Post Office (B.P.O.) Research Department was given the job of measuring the electrical characteristics of the cable and Telecommunications Development Department undertook the mechanical evaluation and, later, the field testing.[3]

In order to bring the cable makers into the picture, at an early stage, a study contract was also placed with industry to measure the electrical parameters of the cable and recommend suitable test equipment for field and factory use.

CABLE STUDY REQUIREMENTS

The cable study programs undertaken by Research Department had a short-term objective to assess the suitability of 2·6/9·5 mm cable for 60 MHz f.d.m. systems and a longer-term objective to determine the potential of both 1·2/4·4 mm and 2·6/9·5 mm cables for the very-high-speed digital systems of the future. For the latter purpose, a frequency range of 0–500 MHz was considered appropriate for the 1·2/4·4 mm cable and at least 0–1 GHz, and preferably up to 2 GHz, for the 2·6/9·5 mm cable.

The first necessity was to determine the behaviour of the important electrical characteristics over the frequency range and to find out whether or not there was any significant departure from the theoretical performance as predicted by normal transmission theory. Early warning was required of any factors that might limit the use of these cables at high frequencies, particularly within the frequency range of the 60 MHz systems.

For the purpose of the initial feasibility studies, it was sufficient to make the measurements on drummed cables at ambient temperatures, and this work was undertaken at Dollis Hill. At a later stage, more comprehensive measurements were required to provide the detailed information necessary for system design. These additional requirements included

(*a*) temperature coefficients of all relevant electrical parameters over the frequency range,

(*b*) the effect on the electrical characteristics when the cables were pulled into ducts, or possibly mole-ploughed into the ground,

(*c*) the effect of gas pressurization on the electrical parameters, and

(*d*) measurement on a wide cross-section of production cable to provide information on the likely spread of characteristics, in practice.

For the more detailed studies, the facilities at Dollis Hill

† Research Department, Telecommunications Headquarters.

were inadequate and arrangements were made to provide a cable test installation at Martlesham. This was to contain the necessary precision test equipment, temperature-controlled cable-chamber, duct route, and cable-handling facilities to enable this and other allied cable studies to be undertaken. For both the initial feasibility studies and the later more detailed investigation, tests were made on representative cable samples from each of the four British manufacturers.

TEST EQUIPMENT AND TEST FACILITIES

After consultation with the system design groups, it was decided that the main parameters to be evaluated were attenuation, impedance, crosstalk, phase-delay and group-delay.

A factor of major significance was that suitable test methods and equipments were not available, either within the B.P.O. or commercially. It was necessary, therefore, to develop appropriate test equipment and test facilities before the cable investigations could be commenced. In the event, this proved to be the most difficult and time-consuming part of the program.

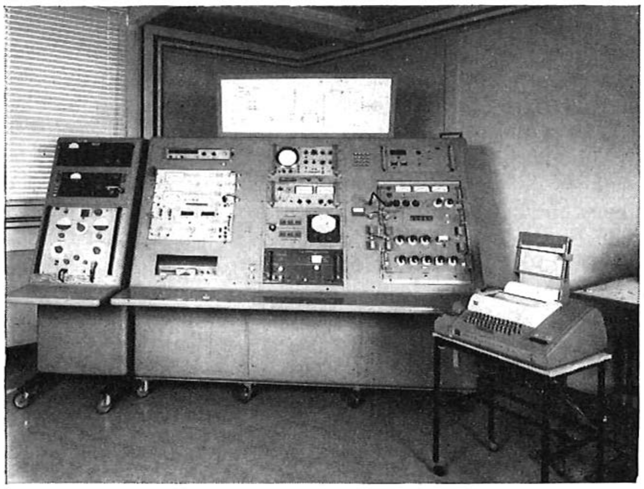


FIG. 1—Semi-automatic test equipment

TESTS AT DOLLIS HILL

For the initial feasibility study, tests were made on one drum of 2·6/9·5 mm cable from each of the four manufacturers. At that time, only one manufacturer produced an 18-pair cable so the initial test samples comprised one 18-pair and three 8-pair cables, each of about 400 m in length.

As this was the first time that measurements over such a wide frequency range had been made on this type of cable, the cable makers were invited to participate in the test program. In this way, information on test methods and high-frequency cable parameters was passed over in the most efficient manner. Accordingly, each cable manufacturer contributed one member to the test team for the tests on their particular cable.

The broad findings of these initial tests showed that the cables were suitable for 60 MHz f.d.m. systems and had considerable potential application for high-speed digital transmission although, for the latter purpose, some improvement in performance was desirable.

TESTS AT MARTLESHAM

Subsequent to the initial B.P.O. feasibility studies, and to parallel investigations in industry, detailed attention was given by the cable makers to modifications in manufacturing processes in an effort to improve the high-frequency performance of the cable.

Tests have been made at Martlesham on a further five drums of 2·6/9·5 mm coaxial cable comprising one 4-pair, two 8-pair and two 18-pair cables. The four latter cables all contained design modifications.

Due to a change in priorities, many of the detailed investigations on 2·6/9·5 mm cables have been deferred due to a more urgent requirement for studies on 1·2/4·4 mm coaxial cables for 120 Mbit/s and higher-speed digital systems.

For the measurements, a number of test consoles were developed. The main console used for loss and delay measurement is illustrated in Fig. 1. This uses semi-automatic measuring techniques with automatic data-logging facilities.

In the following sections, the relevance of the various tests together with a number of the associated problems are discussed separately for each parameter. Brief summaries are also given of the results of each of the tests in relation to the suitability of the cable for 60 MHz f.d.m. and high-speed digital applications. Although tests have been made on other types of cable, the findings in this article relate only to 1·2/4·4 mm and 2·6/9·5 mm air-spaced main-line cables.

ATTENUATION

Attenuation is the most fundamental of the electrical characteristics and is the prime factor in determining the repeater-section spacing. For system design purposes, it is necessary to know the magnitude and shape of the basic attenuation/frequency characteristic at various temperatures and the likely spread of attenuation due to manufacturing tolerances. For these investigations, a B.P.O loss-and-gain measuring equipment[4] was used.

Attenuation/Frequency Law

Above about 1 MHz, the attenuation/frequency characteristic of a coaxial cable follows a trinominal law to a close degree of approximation

$$\alpha = A + B\sqrt{(f)} + Cf \qquad \ldots\ldots (1)$$

where A is a constant $\approx$ 0·013 for 2·6/9·5 mm, cable,
B is the copper-loss coefficient $\approx$ 2·3 for 2·6/9·5 mm cable,
C is the dielectric loss coefficient $\approx$ 0·003 for 2·6/9·5 mm cable,
f is frequency in MHz,
α is the attenuation in dB/km at 10°C.

Re-arranging equation (1) and dividing by $\sqrt{(f)}$ gives

$$\frac{\alpha - A}{\sqrt{(f)}} = C\sqrt{(f)} + B$$

which may be expressed as the familiar straight-line law:

$$y = mx + c.$$

Thus, if $(\alpha - A)/\sqrt{(f)}$ is plotted against $\sqrt{(f)}$ this should yield a straight-line law where the slope of the line C gives the dielectric loss and the extrapolated straight line intercept on the y-axis gives the copper loss coefficient B. As the dielectric loss of a nominal air-spaced cable is extremely small, the dynamic range of the $(\alpha - A)/\sqrt{(f)}$ characteristic is also small. This method of plotting the results provides a very sensitive check on the measurements, and any aberrations from the expected law are clearly displayed.

Spread of Attenuation Characteristic

Due to normal manufacturing tolerances, variations occur in the copper and dielectric coefficients and, as apparent from equation (1), these give rise to a spread in the attenuation characteristics which increases with frequency. This is illustrated in Fig. 2 which shows the measured maximum and minimum deviations from the nominal specification value of attenuation obtained on eight drums of cable supplied to

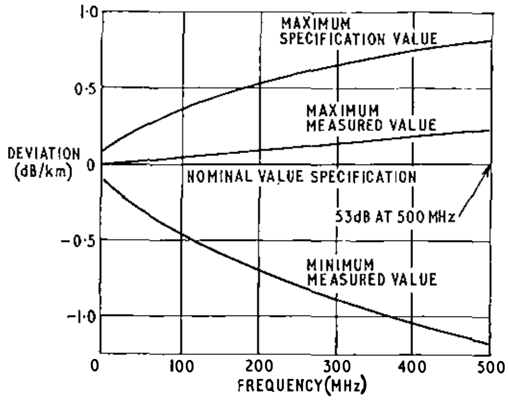


FIG. 2—Deviation of attenuation from nominal specification value

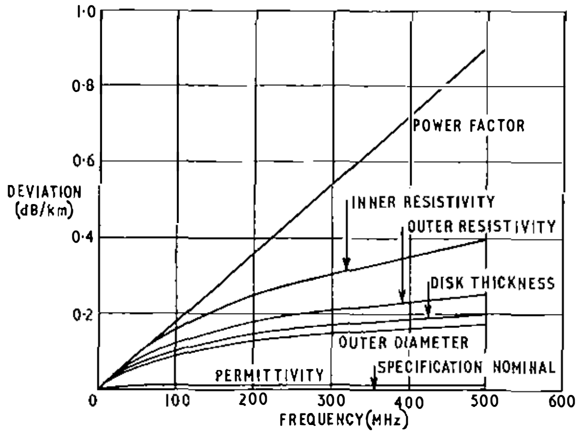


FIG. 3—Maximum deviation from nominal attenuation due to tolerances on cable parameters

the 2·6/9·5 mm cable specification. The maximum permissible specification value is also shown.

From Fig. 2, it is apparent that, apart from the increase in attenuation spread with frequency, the specification values are high in relation to the measured results. From the system-design point of view, it is desirable to reduce both the mean attenuation and the spread. This is particularly true for the digital systems which must be based on worst-case attenuation values where the upper specification limit would probably be the basis for system design.

Before an attempt can be made to improve the situation, it is necessary to identify the material tolerances which contribute to the spread of attenuation. Fig. 3 shows the maximum extent to which typical tolerances can influence the attenuation characteristic and, in order of priority, these are

(*a*) power factor of the polyethylene spacer disks between inner and outer conductors,
(*b*) resistivity of the inner conductor,
(*c*) resistivity of the outer conductor,
(*d*) thickness of the polyethylene disks,
(*e*) diameter of the outer conductor,
(*f*) permittivity of the polyethylene disks, and
(*g*) diameter of the inner conductor.

At the frequencies under discussion, the skin depth is extremely small (approximately 6μm at 100 MHz) and it is the surface resistivity of the conductor, rather than the bulk resistivity, that is important. Due to local work-hardening that takes place during the drawing-down process, the resistivity of the surface is adversely affected.

With the co-operation of one of the cable manufacturers, an attempt was made to reduce the power-factor and inner-

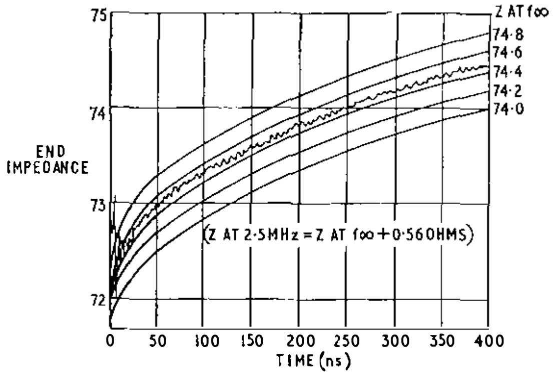


FIG. 4—Typical 2·6/9·5 mm end-impedance characteristic

conductor-resistivity contributions and two drums of cable were produced in which a lower-loss polyethylene dielectric was used. In addition, modifications were made to the final drawing-down process of the inner conductor.

Subsequent evaluation of this cable at Martlesham showed that a useful reduction in attenuation had been achieved, as shown by the lowest characteristic of Fig. 2, which was measured on the modified cable. It is understood that the manufacturer has since introduced these modifications into normal production.

Although a reduction in attenuation was achieved by the methods described, detailed measurements on the processed inner conductor and polyethylene disks suggested that further reduction should be possible and it is hoped to make further investigations in due course.

Results of Attenuation Tests

The main findings of the attenuation measurements at Dollis Hill and Martlesham are summarized below.

(*a*) For 60 MHz f.d.m. transmission,

- (*i*) the attenuation of the 2·6/9·5 mm cables is compatible with the nominal repeater-spacing requirement of 1·5 km, and
- (*ii*) the spread of the measured characteristics should not introduce any significant problems in system equalization.

(*b*) For high-speed digital transmission,

- (*i*) the attenuation characteristics of the 1·2/4·4 mm coaxial cables were satisfactory for 120 Mbit/s digital transmission having a nominal regenerator spacing of 2 km, and
- (*ii*) for higher-speed systems, some reduction in the spread of the attenuation characteristics would be desirable for both 1·2/4·4 mm and 2·6/9·5 mm coaxial cables.

(*c*) A large number of attenuation temperature-coefficient measurements have been made and these have revealed no unusual phenomena at high frequencies.

(*d*) So far, only a limited amount of investigation has been possible on cables after they have been pulled into ducts. The results to date show that there is no significant change in attenuation as a result of installation.

IMPEDANCE AND IMPEDANCE IRREGULARITIES

The impedance of the cable is an important parameter for the system designer, but it is the uniformity of this characteristic, throughout the length, that plays a large part in determining the ultimate transmission capacity of a cable.

Unfortunately, it is not possible to manufacture a cable having a perfect, uniform, coaxial structure and all cables contain numerous small imperfections causing impedance irregularities. These have a wide variety of distribution throughout the length of the cable ranging from random to periodic.

Because of the extreme complexity of the impedance characteristic of a coaxial cable, it has been necessary to use three separate test methods to provide the information required on

(*a*) the input impedance, commonly referred to as end impedance,
(*b*) the magnitude of the random impedance irregularities, and
(*c*) the magnitude of the periodic and near-periodic irregularities.

In high-frequency cable applications, it is not practical to measure impedance directly and most measurements are made on a return-loss basis, where the cable is referred to a standard impedance. The resultant return-loss characteristic indicates the impedance irregularities due to imperfections in the cable structure and, for this reason is often termed structural return-loss (s.r.l).

End Impedance

Stringent specification requirements are placed on cable end-impedance to ensure that successive cable sections are closely matched when jointed into the system. The parameter is also important in the design of repeater/regenerator input and output circuitry, and tail cables.

For the purpose of the cable studies, it was considered that available test methods gave somewhat limited and arbitrary results and, for this reason, a new test method using a raised-step technique was developed. In this method, the distributed impedance of the cable can be displayed over lengths typically up to 100 m, and the absolute impedance value can be accurately referred to d.c. standards. Fig. 4 shows a typical impedance test on a 2·6/9·5 mm coaxial pair using this method. The calibration lines represent the specified C.C.I.T.T.† impedance/frequency law for a 2·6/9·5 mm cable transposed into the time domain.

So far, all 2·6/9·5 mm cables tested by the B.P.O. Research Department have met the 60 MHz cable specification requirements for end impedance and no additional problems have been encountered at much higher frequencies.

Random Impedance Irregularities

The occurrence of irregularities in a transmission line gives rise to partial reflexion of the incident signal at each point of irregularity. Single, i.e. first-order, reflexions are returned to the sending end while double, (or second-order) reflexions arrive at the receiving end as delayed echoes of the transmitted signal. For all practical purposes, the effects of higher-order reflexions can be neglected.

Where the impedance irregularities are randomly distributed, the resultant echoes arrive at the sending and receiving ends in a random manner and are manifest as noise. Unlike thermal noise, however, the ratio of wanted to spurious (reflected) signal is independent of signal level. Existing specification requirements ensure that this type of noise signal is contained within acceptable limits.

Random impedance irregularities are most readily resolved by time-domain methods and, for this purpose, the pulse-echo test method,[5,6] is specified. Fig. 5 shows a typical pulse-

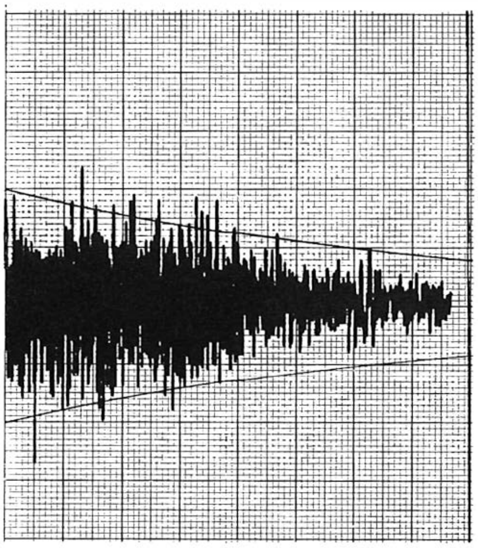


FIG. 5—Pulse-echo response

echo response on a 2·6/9·5 mm cable which effectively indicates the distribution of irregularities along the cable.

Pulse tests made at Dollis Hill and at Martlesham show that,

(*a*) for 60 MHz systems, the magnitude of the random impedance irregularities is well within acceptable limits, and
(*b*) no significant problems are likely to occur due to random irregularities in the design of high-speed digital systems.

Periodic Impedance Irregularities

Due to the repetitive nature of manufacturing processes, periodic and near-periodic irregularities are inevitably introduced into the cable. At frequencies where the spacing of the periodic irregularities corresponds to a half wavelength, or an integral number of half wavelengths, the individual echo signals are in phase and are, therefore, additive. This gives rise to magnified return and forward echo signals at discrete resonant frequencies, commonly referred to as spikes.

As the individual periodic irregularities are of the same order of magnitude or smaller than the random irregularities, they cannot readily be identified on a time-domain display of the type shown in Fig. 5. Sweep-frequency techniques are used, therefore, to resolve periodic irregularities; typical return loss and forward echo/frequency characteristics are shown in Figs 6 and 7.

Referring to the return-loss characteristic (Fig. 6) the s.r.l. spike at about 200 MHz can readily be seen. This particular irregularity results from the laying-up operation where the separate coaxial pairs are twisted together to form a multi-pair cable. The frequency of 200 MHz corresponds to a periodicity of the irregularities of about 0·75 m, which in turn corresponds to the lay length of the cable.

Referring to the forward-echo characteristic of Fig. 7, it can be seen that the general echo level is much smaller than the major discontinuity at 200 MHz. This is because the forward echoes are the result of double reflexions and their magnitudes are a function of the square of the reflexion coefficient. Only the more significant periodic irregularities, therefore, provide an effective contribution to the forward echo content.

At each discrete irregularity, the reflected signal is in phase quadrature with the incident signal and, as forward echoes are a result of double reflexion, they are in anti-phase with the incident signal. This gives rise to a sharp increase in

† C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

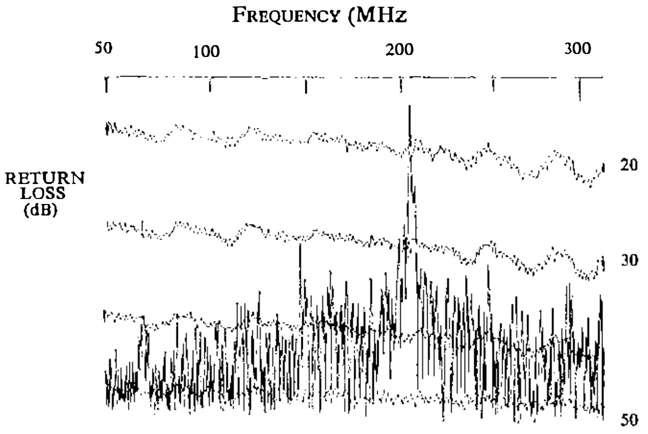


FIG. 6—Return-loss characteristic

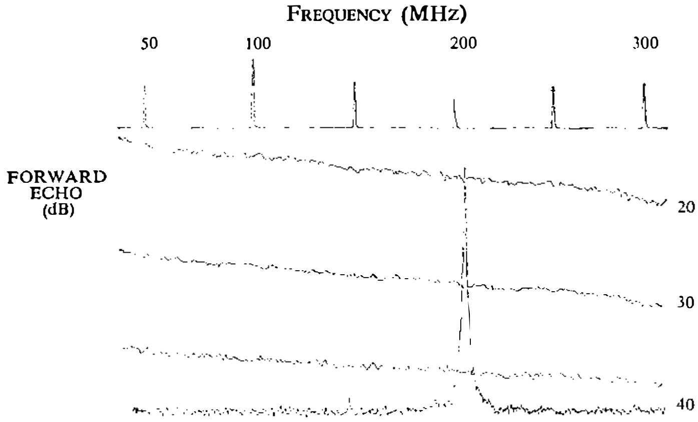


FIG. 7—Forward echo characteristic

attenuation at each resonant frequency of the periodic irregularities. The resulting attenuation spikes, often termed suck-out, are virtually impossible to equalize and must, therefore, be contained within acceptable limits.

Due to the equal spacing of successive periodic irregularities, families of discrete forward echoes are formed as indicated in Fig. 8. These arrive at the receiving end as successively-delayed echoes of the incident signal and form a possible source of inter-symbol interference on digital systems. To ensure that the magnitude of the periodic irregularities is contained within acceptable limits, stringent specification requirements are imposed on peak return-loss values. Two factors must be considered in this context. These are

(*a*) the maximum value of the return-loss spikes, and

(*b*) the reflected mean power in successive bands over the frequency range. (10 MHz bands have been chosen in the 2·6/9·5 mm cable specification).

The latter requirement arises because s.r.l. spikes are not always as sharply defined as indicated in Fig. 6 but may, for example, constitute a number of lower peaks distributed over a wider bandwidth. This occurs because the periodic irregularities are not always of a precisely-spaced, discrete, form and both periodic-distributed irregularities and near-periodic irregularities may occur in practice.

For analogue transmission, the magnitude of the return-loss spikes tends to be the more important parameter as this determines the extent to which a group of channels will be adversely affected. For digital transmission, however, it is the ratio of the wanted signal power to spurious reflected power that is important and, thus, the reflected power-in-band is likely to be the more significant parameter.

While it is possible to predict the effect that periodic irregularities will have on the performance of an f.d.m. system, the effect on digital systems is less straightforward. Much depends upon the frequencies at which the spikes occur in relation to the spectrum of the particular digital system concerned; clearly, they are more serious where they coincide with areas of high spectral-density.

Although some improvement has been achieved in the s.r.l. performance of 2·6/9·5 mm cables[7] it is clear that, for both 1·2/4·4 mm and 2·6/9·5 mm cables, this is likely to remain a problem area for the very-high-speed digital systems of the future. While it may be difficult to achieve further significant improvement in the s.r.l. performance of coaxial cables, considerable control can be exercised in the positioning of the major s.r.l. spikes in the frequency spectrum. This may well prove to be an area for future investigation.

The findings from the B.P.O. Research Department return-loss tests on a limited number of cables may be summarised as follows:

(*a*) For 60 MHz f.d.m. systems, most, but not all, of the cable tested met the specification requirements.

(*b*) For high-speed digital transmission the specified test frequency range for 2·6/9·5 mm cables is extended up to 500 MHz, and no cables tested so far have met the stringent specification requirements for return power-in-band and not all have met the peak return-loss specification. However, it is understood that more recently produced cables have improved performance in this respect, but samples of these have not yet been received at Martlesham.

(*c*) No significant change in s.r.l. has so far been discovered due to temperature change over the range −10 to +50°C, or to pulling the cables into duct. However, cable installation to date in the duct route at Martlesham has been under favourable conditions and further tests are proposed where more arduous conditions will be simulated.

Distribution of Periodic Irregularites

At present, the specification is based on return loss and return power when, in reality, it is the forward-echo and the forward-power requirements that are the more important from the system point of view. The main reason for this policy is the lack of suitable test methods and equipment. Although forward-echo test methods have been developed in the B.P.O. Research Department,[8] further development work remains to be done to improve the sensitivity.

It is possible to calculate forward echo from return loss if the distribution of the periodic irregularities is uniform throughout the length of the cable. The specification values for return loss are based on this assumption. However, the results of return-loss measurements are heavily biased to the end of the cable tested, and the ends are not always typical of the rest of the cable. The danger arises that areas of severe periodic impedance irregularity may exist in the middle of the cable. These will not be revealed by return-loss testing but will contribute to the forward-echo content. For this reason, a test program is being arranged to evaluate the distribution of periodic impedance-irregularities along cables of different manufacture. Test equipment for this purpose, using carrier-wave burst techniques,[9,10] is in the final stages of development.

CROSSTALK

Although coaxial cables have to meet extremely stringent crosstalk specification requirements, typically better than 160 dB, this has not proved to be a problem on any of the previous lower-frequency systems. Little was known, however, of the performance at very-high frequencies and concern was expressed that the butt seam in the outer conductor might represent a possible source of r.f. leakage. From the B.P.O. Research Department tests on both 1·2/4·4 mm and 2·6/9·5 mm cables, no measurable crosstalk has been

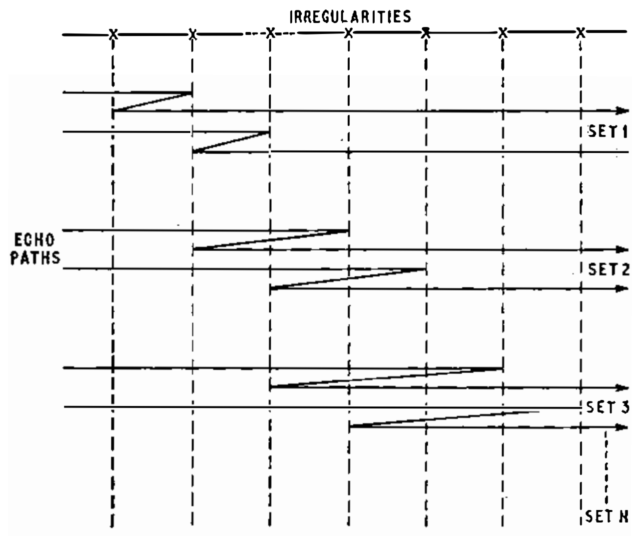


FIG. 8—Forward echo paths

detected within the frequency range of the 60 MHz f.d.m. system and the ranges likely for future high-speed digital systems.

PHASE AND GROUP-DELAY

The main requirement for this part of the program was to ascertain whether there were any significant aberrations in the phase and group-delay characteristics. The tests showed that the cables should not introduce significant phase or group-delay distortion.

LENGTH

Although relatively high precision had been achieved in the test equipment assembled for the cable study program, there remained the problem that the manufacturers were not able to quote the lengths of cables supplied for test to better than 1 per cent uncertainty. Thus, regardless of the accuracy with which measurements were made, errors of up to 2 per cent could arise due to length uncertainty when comparing the attenuation of cables (in dB/km) from different manufacturers.

Therefore, the length of the cable was determined by electrical methods. A number of parameters may be used for this purpose, in particular, resistance, capacitance and delay (or its reciprocal, velocity). The first two parameters are very dependent upon cable dimensions. Additionally, the resistivity of the copper is not known to a high degree of accuracy and it has a relatively high temperature coefficient.

In the case of delay, however, the situation is more favourable as the total delay of a cable is proportional to the product of the length and the square root of the effective permittivity. In the case of an air-spaced coaxial cable, the effective permittivity varies very little for cables of the same type. Provided the delay per unit length for a particular cable type is known, the length of any other similar cable can be determined accurately by means of delay measurement. This technique has the further advantage that the delay is almost independent of temperature.

For the initial investigations, delay per unit length was determined either from the best information available or by theoretical methods. Since that time, accurate measurements have been made on the length of the cable ducts at Martlesham. After each type of cable has been pulled into duct, it is possible to replace the theoretical delay figures by accurately measured values and, in due course, it is hoped to be able to provide precise delay information on a variety of cables.

In the case of multi-pair coaxial cables, the lengths of the individual coaxial pairs are greater than the sheath length of the cable. The ratio of coaxial pair length to sheath length is known as the take-up factor. As any electrical test effectively measures the coaxial pair length due allowance must be made for the take-up factor quoted by the manufacturer when converting to sheath length.

Use of delay techniques has considerably reduced errors due to length uncertainty with consequent improvement in consistency of overall results, and this procedure has now been adopted in the 2·6/9·5 mm cable specifications.

CONCLUSION

The program of measurements and studies carried out by the B.P.O. has shown that 2·6/9·5 mm cable from each of the four British manufacturers is suitable for use in 60 MHz f.d.m. systems. Although the cables just failed to meet the specification requirements for high-speed digital transmission, this does not imply that they are unsuitable for this purpose. Indeed the results show the considerable potential of both 1·2/4·4 mm and 2·6/9·5 mm cables for high-speed digital applications. There is also the strong possibility that some improvement of the high-frequency characteristics of these cables may be a practical proposition. Many and the investigations have been made in close collaboration with other B.P.O. Departments and industry on behalf of the Joint Technical Committee for Trunk, Junction and Local Telecommunications Cables (J.T.C.C.). A large part of the program has involved the development of test methods and equipment and comprehensive cable test facilities have now been provided at Martlesham. The results of this development have also found wider application; much detailed information on test methods and equipments has been supplied to members of the J.T.C.C. and some items have been produced commercially for coaxial system applications.

When it is realized that the present 2·6/9·5 mm coaxial pair design dates back some 25 years and that the potential of even this design is far in excess of its proposed use for 60 MHz f.d.m. systems, the possibilities of new or improved cables are, at once, obvious. As a medium of transmission for wide-band systems of the future, coaxial cable is likely to remain a serious competitor to other forms of transmission media for many years to come.

ACKNOWLEDGEMENT

The authors wish to acknowledge the excellent work of their colleagues in Research Department on the development and construction of test equipment and the execution and analysis of the large number of measurements associated with the cable study programs.

References

1 ALLEN, A. F. G. Small-Diameter Coaxial-Cable Developments. *P.O.E.E.J.*, Vol. 57, p. 1, Apr. 1964.

2 BAGULEY, E. Modern Coaxial-Cable Technique in Great Britain. *Electrical Communication*, Sept. 1963.

3 STILL, L. H., STEPHENS, W. J. B., and BUNDY, R. C. H. The 60 MHz F.D.M. Transmission System: Cable Testing. *P.O.E.E.J.*, Vol. 66, p. 174, Oct. 1973.

4 CRANK, G. J., and SMITH, H. O. J. The 60 MHz F.D.M. Transmission System: Loss-and-Gain Measuring Set. *P.O.E.E.J.*, Vol. 66, p. 182, Oct. 1973.

5 ROBERTS, F. F. Pulse Techniques in Coaxial Cable Testing. *P.O.E.E.J.*, Vol. 41, p. 13, Apr. 1948.

6 BAGULEY, E., and COPE, F. B. A Pulse Echo Test Set for the Quality Control of Impedance Uniformity of Coaxial Cables. *P.O.E.E.J.*, Vol. 44, p. 164, Jan. 1952.

7 PRITCHETT, J., and BARTLETT, G. A., The 60 MHz F.D.M. Transmission System: Cable Design and Manufacture. *P.O.E.E.J.*, Vol. 66, p. 158, Oct. 1973.

8 ROSMAN, G. Provisional Patent Specification No. 15176. Method and Apparatus for Testing Transmission Lines and Channels.

9 ROSMAN, G. Assessment of Coaxial Cable for Frequency Division Multiplex Transmission by means of C. W. Burst Test Signal. *Proceedings I.E.E.* 1970, Vol. 117, p. 45.

10 ROSMAN, G. Swept-Frequency Measurement of Structural Return Loss by a Carrier Burst Method. *Electronic Letters*, Vol. 7, No. 9.

The Estimation of Pulling Tension for Cables in Ducts—A Guide for Planners

J. O. KNIGHT, ASSOCIATE MEMBER I.E.E.†

U.D.C. 621.315.232: 621.395.741

The requirement to pull in long lengths of heavy coaxial cable means that careful planning of the duct route is necessary if excessive cabling tensions are to be avoided. The theoretical relationship between pulling tension and duct alignment is examined, and a method of estimating the tension, and so facilitating the work of the planner, is proposed.

INTRODUCTION

For a new cable route, the nominal spacing between amplifier points is determined by the needs of the transmission system. A certain latitude does, however, exist and the exact location of amplifier points, and of the intermediate joints, depends upon local site conditions.

For the new 60 MHz f.d.m. transmission system, using the 18-pair 2·6/9·5 mm coaxial cable, a spacing of 1,500 m between amplifier points is specified and, where possible, 500 m cable lengths will be installed, giving two intermediate joints in each repeater section. The decision to plan for the installation of 500 m lengths was based on friction tests in the laboratory and practical trials in the field; these assumed the use of a straight and level duct. It was appreciated that the presence of bends or inclines in the duct line would increase the pulling tension and that this increase might be sufficient to impose a restriction on the length of cable that could safely be pulled in. Since this, in turn, could affect the location of jointing points, it was necessary to determine, with reasonable accuracy, the tensions likely to be encountered.

This article reviews the problems associated with estimating the pulling tension of cable in ducts and presents rules for estimating these tensions in such a way as to reduce the calculation required and enable the location of intermediate joints to be determined to suit local conditions.

THEORY

When a cable is pulled into a duct, friction between the inner wall of the duct and the cable sheath offers some resistance to the passage of the cable. The magnitude of the resistance can be related to the coefficient of friction μ which is given by

$$\mu = \frac{P}{W}, \qquad \ldots\ldots(1)$$

where P is the force required to pull the cable (kN), and W is the weight of the cable (kg). The conditions are as shown in Fig. 1.

The tension T required to pull a cable into a straight duct is given by

$$T = 9{\cdot}81\ \mu l w \times 10^{-3}\ \text{kN}, \qquad \ldots\ldots(2)$$

where l is the length of the cable (m), and w is the weight of the cable per unit length (kg/m).

When the duct follows a bend, the tension in the cable approximates to that experienced by a rope traversing a pulley-wheel, as shown in Fig. 2. The ratio of the tensions is given by

$$\frac{T_1}{T_2} = e^{\mu\theta},$$

where θ is the angle turned through, in radians.

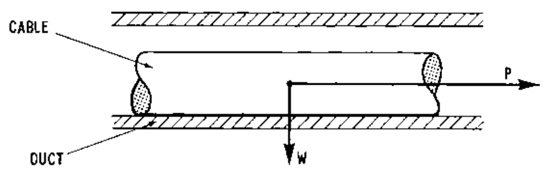


FIG. 1—Relationship between coefficient of friction, tractive force and weight of cable

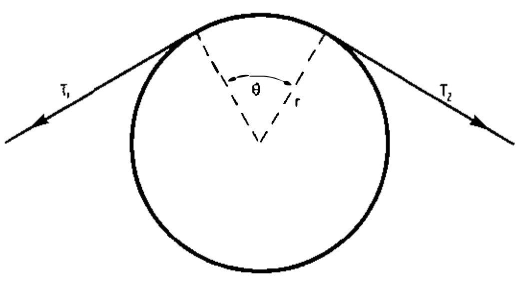


FIG. 2—Tension in a rope traversing a pulley

† Operational Programming Department, Telecommunications Headquarters.

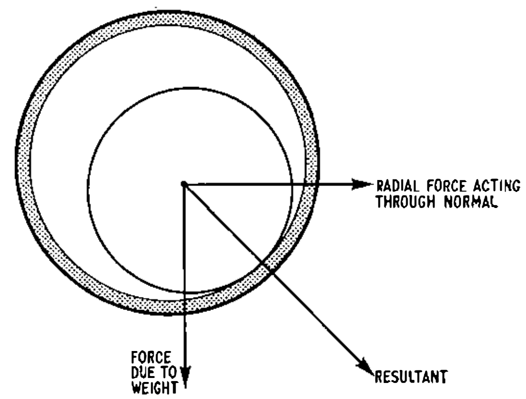


FIG. 3—Forces encountered when cabling round a bend

In practice, the cable tends to ride up the duct wall on the inside curve of the bend, giving the conditions shown in Fig. 3.

The resultant frictional force is given by

$$dT = \mu\sqrt{\{T^2 + (wr)^2 d\theta\}},$$

where dT is the increase in tension due to angle of bend $d\theta$,

T is the tension in the cable before the bend,

r is the radius of the bend, and

w is the weight of the cable per unit length.

The following equation has been derived[1] for the ratio between the tensions in a cable before and after a bend:

$$\frac{T_1}{T_2} = \frac{wr}{T_2}\left[\sinh\left(\mu\theta + \sinh^{-1}\frac{T_2}{wr}\right)\right]. \qquad \ldots\ldots(3)$$

This forms the basis of the calculation for tensions round bends in the planning rules. In these rules, equation (3) is applied to bends in both the horizontal and the vertical planes, the latter being figuratively turned through 90° and taken consecutively with those in the horizontal plane.

For a stiff cable, an additional amount of energy has to be exerted in the actual bending and straightening of the cable as it traverses a bend, but it is considered that its effect on the cabling tension is negligible, and is ignored in the rules.

When the duct to be cabled is inclined, the conditions are as shown in Fig. 4. The equation relating force, weight and resistance then becomes

$$\frac{P}{W} = \mu \cos\alpha + \sin\alpha, \qquad \ldots\ldots(4)$$

where α is the angle of inclination.

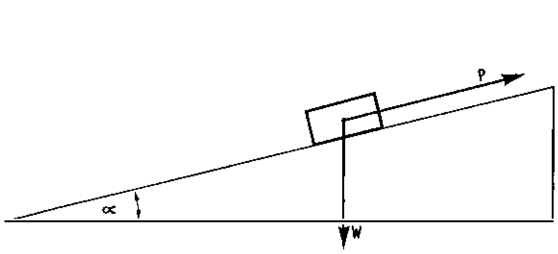


FIG. 4—Conditions governing tensions encountered when cabling an inclined duct

This means that the work done in drawing a body up an inclined plane is equal to the work done in lifting it against gravity through a height equal to the height of the plane, plus the work done in drawing it along the base of the plane against friction.

For cabling downhill, the relationship becomes

$$\frac{P}{W} = \mu \cos\alpha - \sin\alpha. \qquad \ldots\ldots(5)$$

Using these equations, it is possible to estimate the likely pulling tensions for any particular cable and configuration of duct. Such calculations can, however, be tedious and, for this reason, a set of rules has been prepared to simplify the procedure.

BASIS OF THE RULES

The planning rules are based on the foregoing theoretical considerations but the figures for coefficient of friction in Table 1 have been enhanced to allow for minor, but inevitable, deviations in duct alignment. The values quoted also take into account the difference between static and dynamic friction. The figures for static friction have been used and, since these are usually the greater of the two, this provides an additional margin of safety.

TABLE 1

Duct Material	Coefficient of Friction
Earthenware	0·22
P.V.C.	0·32
Steel	0·64

The radius of curvature of a bend has been assumed to be 20 m and this value has been assumed for r in equation (3). Pulling tests on the 18-pair 2·6/9·5 mm coaxial cable have shown that a suitable limit for safe pulling tension is 25 kN and this value has been adopted in the rules.

Inclines need only be taken into account if they exceed 30 per cent of the length of a cabling section: single-curve

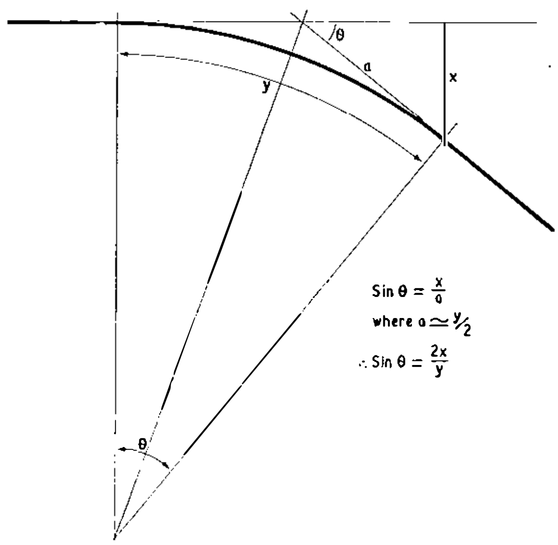


FIG. 5—Method of estimating the value of a small angle from linear measurements

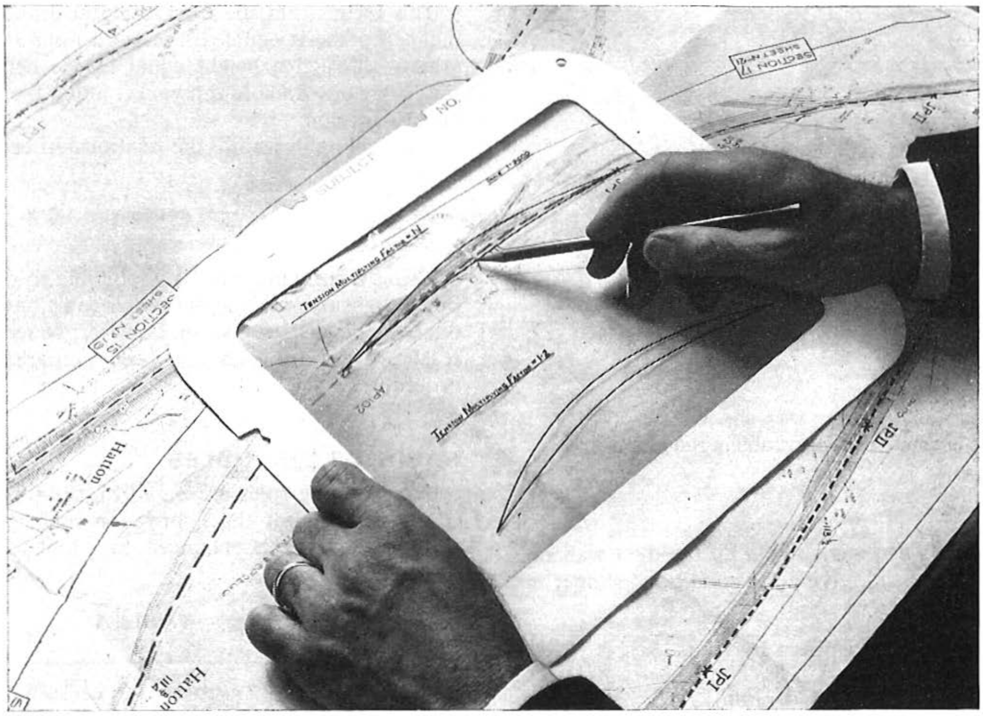


FIG. 6—Curves used to estimate tension-multiplying factor directly from a scale map

bends can be disregarded if the angle of deviation is less than 7°; double-curve bends (S-bends) can be ignored if the two bends are equal and each is less than 4°.

PRESENTATION OF THE PLANNING INFORMATION

For convenience and ease of use, the rules have been presented as a series of tables which are reproduced here, in part, as Tables 2–6. It is intended that the planner should select those that are appropriate to the calculation in hand and apply them as shown in the example.

Table 7 enables linear measurements to be converted into approximate angular measurements, as shown in Fig. 5. It is used when it is not possible to measure the angle but possible to measure the length of arc (y) and the separation between the start and finish of a bend (x).

A series of transparencies has been prepared for use with

TABLE 2

Tension (kN) to which a Straight Length of Cable is Subjected when Pulled into a Duct of the Stated Type

(a)

18-pair 2·6/9·5 mm coaxial cable (Weight 10·3 kg/m)

Length l (m)	Tension (kN) for Stated Type of Duct		
	P.V.C. ($\mu = 0{\cdot}32$)	Steel ($\mu = 0{\cdot}64$)	Earthenware ($\mu = 0{\cdot}22$)
1	0·03	0·06	0·02
2	0·06	0·13	0·04
3	0·09	0·19	0·07
.	.	.	.
.	.	.	.
.	.	.	.
700	22·63	—	15·56
800	25·87	—	17·78
900	—	—	20·01

(b)

8-pair 2·6/9·5 mm coaxial cable (Weight 5·9 kg/m)

Length l (m)	Tension (kN) for Stated Type of Duct		
	P.V.C. ($\mu = 0{\cdot}32$)	Steel ($\mu = 0{\cdot}64$)	Earthenware ($\mu = 0{\cdot}22$)
1	0·02	0·04	0·01
2	0·04	0·07	0·03
3	0·06	0·11	0·04
.	.	.	.
.	.	.	.
.	.	.	.
700	12·97	25·92	8·91
800	14·81	—	10·18
900	16·67	—	11·46

scale maps. When matched to the curve of the duct route on the map, these give a direct reading of the tension-multiplying factor, without recourse to tables. Fig. 6 shows such a transparency being used.

USE OF THE RULES

The use of the rules can best be explained by an example; the one chosen depicts a cabling section which has rising and falling inclines, and bends in both the horizontal and vertical

TABLE 3

Tension-Multiplying Factors for Cabling on an Incline in Duct of the Stated Type

(*a*) Uphill

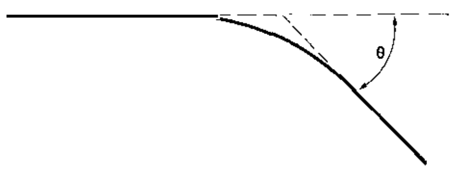
Gradient	Angle	Tension-multiplying Factor: P.V.C. ($\mu=0\cdot32$)	Steel ($\mu=0\cdot64$)	Earthenware ($\mu=0\cdot22$)
1 in 50	1°9′	1·06	1·03	1·09
1 in 30	1°54′	1·10	1·05	1·15
1 in 20	2°52′	1·16	1·08	1·23
.	.	.	.	.
1 in 4	14°29′	1·75	1·36	2·10
1 in 3	19°28′	1·98	1·46	2·46
1 in 2	30°0′	2·43	1·65	3·14

(*b*) Downhill

Gradient	Angle	Tension-multiplying Factor: P.V.C. ($\mu=0\cdot32$)	Steel ($\mu=0\cdot64$)	Earthenware ($\mu=0\cdot22$)
1 in 50	1°9′	0·94	0·97	0·91
1 in 30	1°54′	0·90	0·95	0·85
1 in 20	2°52′	0·84	0·92	0·77
.	.	.	.	.
1 in 4	14°29′	0·19	0·58	0·17
1 in 3	19°28′	0·10	0·42	−0·57
1 in 2	30°0′	−0·70	0·08	−1·41

TABLE 4

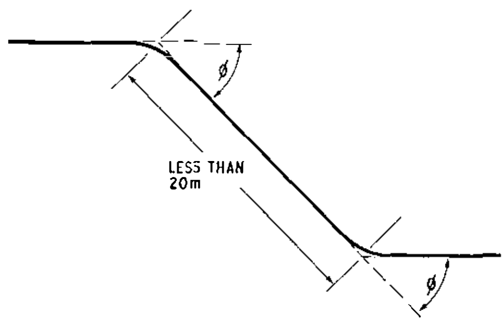
Tension-Multiplying Factors for a Single-Curve Deviation



Angle of Deviation θ (degrees)	Tension-Multiplying Factor $\frac{T_1}{T_2}$
0–7	1·0
8–23	1·1
24–38	1·2
.	.
66–77	1·5
78–89	1·6
90	1·65

TABLE 5

Tension-Multiplying Factors for a Double-Curve Deviation



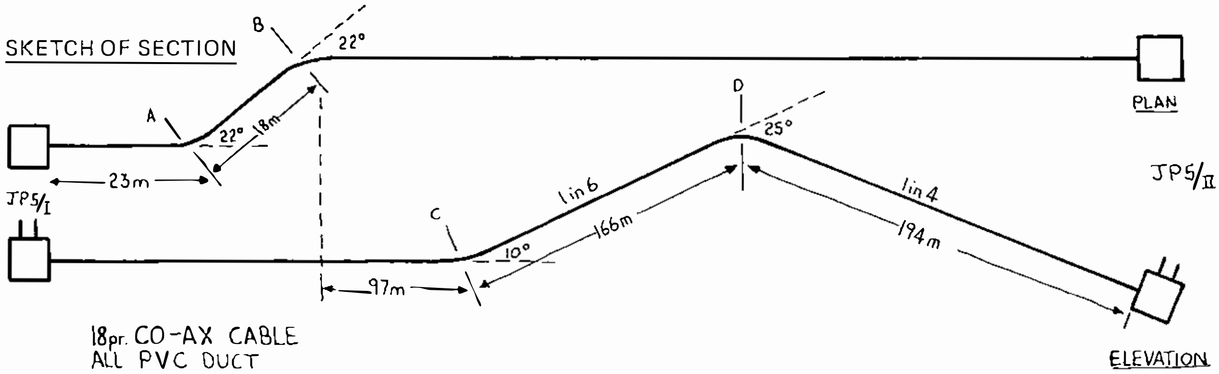
Angle of Deviation ϕ (degrees)	Tension-Multiplying Factor $\frac{T_1}{T_2}$
0–4	1·0
5–11	1·1
12–18	1·2
.	.
39–43	1·6
44–48	1·7
49–54	1·8

60MHz f.d.m. TRANSMISSION SYSTEM

ROUTE: GRID REFERENCE: 012345

CABLING SECTION: ~~AP~~/JP 5/I to ~~AP~~/JP 5/II

SKETCH OF SECTION

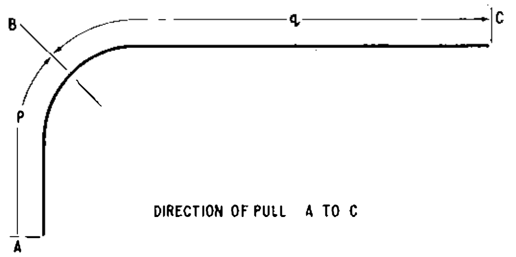


TENSION SECTION OR POINT OF BEND	LENGTH OF TENSION SECTION l (m)	TENSION TO PULL IN l (kN)	Y (m)	X (m)	$2x/y$	ANGLE OF DEVIATION	$\frac{T_1}{T_2}$	CUMULATIVE TENSION (kN)	REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Back Tension								1·25	
JP5/I – A	23	0·74 [Table 2(a)]						1·99	
A – B	18	0·58 [Table 2(a)]						2·57	
At A & B						22°	1·3 (Table 5)	3·34	
B – C	97	3·14 [Table 2(a)]						6·48	
At C						10°	1·1 (Table 4)	7·13	
C – D	166 at 1 in 6 up	5·36 x 1·51 = 8·09 [Tables 2(a) and 3(a)]						15·22	
At D						25°	1·2 (Table 4)	18·26	
D – JP5/II	194 at 1 in 4 down	6·27 x 0·19 = 1·19 [Tables 2(a) and 3(b)]						19·45	

FIG. 7—Outline of a printed form used for estimating cabling tension

TABLE 6

Tension-Multiplying Factors for a Right-Angled Deviation



Distance p (m)	Distance q (m)	Tension-multiplying Factor $\frac{T_1}{T_2}$
32–89	411–468	1·1
90–160	336–410	1·2
.	.	.
.	.	.
421–468	32–79	1·6

TABLE 7

For Finding the Angle of a Bend from Linear Measurements

$\frac{2x}{y}$	Bend Angle (degrees)	$\frac{2x}{y}$	Bend Angle (degrees)
0·01	0·5	0·26	15·0
0·02	1·0	0·27	16·0
0·03	2·0	0·28	16·5
.	.	.	.
.	.	.	.
0·22	13·0	0·47	28·0
0·23	13·5	0·48	29·0
0·24	14·0	0·49	29·5
0·25	14·5	0·50	30·0

planes. Starting at one end of the cabling section, data concerning the length, deviation and inclination of portions of the route is entered on a printed form (Fig. 7). The tension for each portion is derived from the appropriate table and also entered.

For a straight portion, the cumulative tension is obtained by adding the last figure in column (9) to that in column (3). When a bend is present, the last figure in column (9) is multiplied by the factor $\frac{T_1}{T_2}$ from column (8). When the cumulative total has been obtained, the calculation is repeated starting from the opposite end of the section. Unless the section is completely straight and flat, a different result is usually obtained. In the example shown, the total cumulative tension is 19·45 kN. If the opposite direction were calculated, the total would be found to be 21·32 kN. Both are below the safe pulling tension limit of 25 kN but this is not always so and the direction of pull must be selected to give the best result.

The figure of 1·25 kN shown in Fig. 7 for "back tension" represents the tension needed to pull the cable off the drum and down the flexible guide into the duct mouth.

As an alternative to the tables and transparencies already described, a computer program has been written which calculates and lists the cumulative value of cable tension, the length of cable it is possible to pull in without exceeding the safe pulling tension and the total tension for any given cabling section. This program will, generally, be used for more exact calculations than are possible with the manual method and will be used to check on doubtful sections. Using the program, it will be possible to substitute exact calculations for some of the approximations used in the tables and the results will be, correspondingly, more accurate.

CONCLUSIONS

The rules described were used to estimate pulling tensions for the Marlborough field trial[2] and the Marlow pilot installation.[3] The values obtained were compared with the tensions measured in practice and good agreement was observed.

The rules have been edited into a general planning guide and this is being used at present for planning the 60 MHz system route. The guide will be under constant review during use and modifications to improve its accuracy will be made as required.

For the future, it should be possible to produce a similar guide for general planning to cover all sizes and types of cable in various ducts. The use of computer techniques should reduce the work content of the operation considerably. The allocation of equipment to match the expected cabling requirements is possible. More efficient utilization of plant and labour can be achieved and longer cabling lengths, with their consequent savings, may eventually be more commonly employed.

References

1 BULLER, F. H. Pulling Tension during Cable Installation in Ducts or Pipes. *General Electric Review*, p. 21, Aug. 1949.

2 BOLTON, L. J., WELLER, J. M., and BAKKER, H. L. The 60 MHz F.D.M. Transmission System: Test Results of a Field Trial. *P.O.E.E.J.*, Vol. 66, p. 202, Oct. 1973.

3 BISSELL, D. R., KING, W. T., and GIBBONS, R. B. The 60 MHz F.D.M. Transmission System: Cable Installation. *P.O.E.E.J.*, Vol. 66, p. 192, Oct. 1973.

Special-Purpose Maintenance Vehicles

R. W. MARTIN†

U.D.C. 65.011.54: 621.394.44.029.62: 621.315.212

This article describes briefly three special-purpose mechanical aids which have been developed for cable maintenance on the 60MHz route.

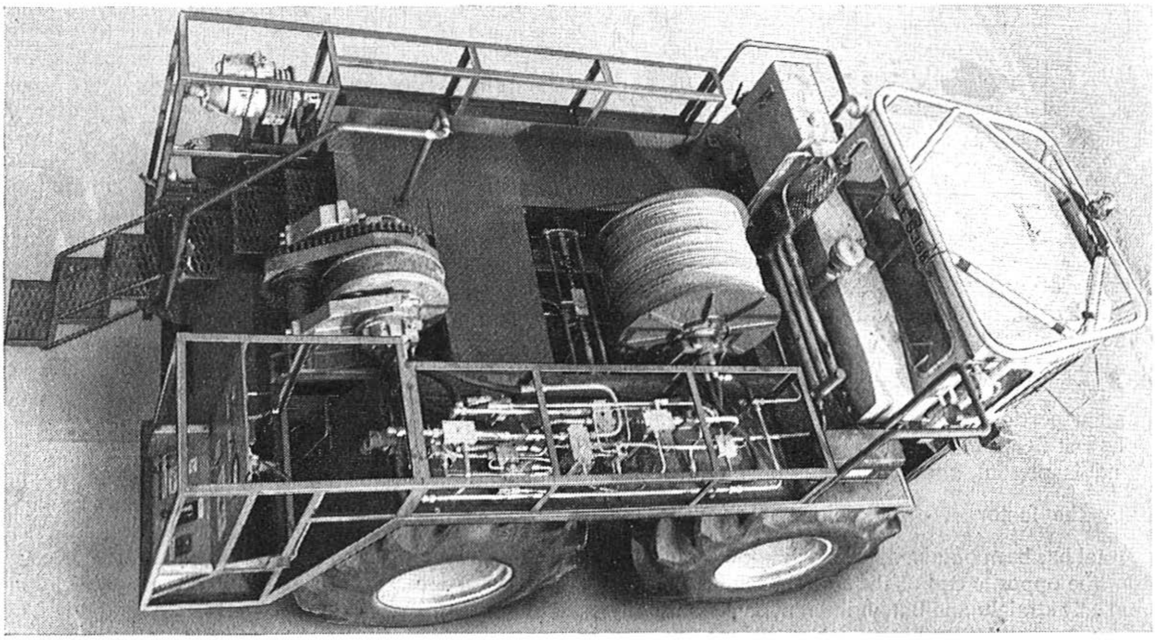


FIG. 1—Self-Mobile Winch

INTRODUCTION

Much of the 60 MHz cable system will be laid across country or in situations where normal road access cannot be relied upon. The cable will be laid in nominal 500 m lengths supplied on large drums which are beyond the capacity of existing British Post Office (B.P.O.) drum trailers and the special techniques developed for jointing require electrical power greater than that available from the portable generators in general issue.

These requirements have led to the development of three special-purpose vehicles capable of travelling across country and negotiating soft and uneven ground.

† Operational Programming Department, Telecommunications Headquarters.

SELF-MOBILE WINCH

The Self-Mobile Winch, shown in Fig. 1, is based on a 4-wheel drive, forward-control Model FC 1004 County Tractor chassis and is equipped with an hydraulically-driven bull-wheel type winch similar to that fitted to Heavy Cabling Equipment.[1] The winch can exert a maximum line pull of 35·58 kN (8,000 lbf) at a maximum rope speed of 45·72 m/min. A 1,200 m length of steel wire rope, 11 mm in diameter, is fitted and is automatically wound, in controlled layers, on to a storage reel after passing around the winch capstans. To resist the pull of the winch, an earth-anchor system is fitted at the rear of the vehicle.

The unit carries ductmotor rodding equipment to provide rodding capability over 500 m lengths for use in the event of a drawline or rope failure. This equipment is powered by an hydraulically-driven air compressor of the same type as those fitted for similar purposes to B.P.O. Rodding and Light-Cabling Vehicles.[2] Tools, rope-guiding and guarding equipment and other small ancillary items are carried in lockers ranged along the sides of the vehicle. The tractor is fitted with a British Standard Safety Cab and no bodywork extends above cab height.

Power for the winch hydraulic system is taken from the vehicle engine through a specially designed power take-off to which is fitted a reversible-flow, variable-delivery axial piston pump which is driven at constant speed. The winch hydraulic circuit is a closed-loop system and winch speed and direction are controlled by a manually-operated servo system which regulates pump output. Maximum flow is 159 litres/min (35 gal/min) and maximum system pressure is 151·75 bar (2,200 lbf/in^2). Temperature control is effected by bleeding off oil from the low-pressure side of each motor and returning it to a reservoir via an oil cooler. A maximum of 18 litres/min is taken from the system in this manner and is replaced with filtered oil from the reservoir by a boost pump which is in unit with the main pump.

Hydraulic power for the air compressor is provided by a separate fixed-displacement pump driven from the standard agricultural power take-off at the rear of the tractor. This pump also supplies power for raising the earth anchor. All special controls and instruments are on the right-hand side of the vehicle at the rear. There are three instruments showing line pull, length of rope out from the winch and tractor engine speed and four controls, one each for winch, air compressor, earth anchor and manual engine-speed control. An automatic interlock ensures that the tractor cannot be driven until the manual engine-speed control is restored to idling-speed position.

The unit is designed to travel over soft and uneven ground and to traverse steep slopes. The minimum turning circle is under 6 m and ground loading for a total weight of 10·16 tonnes (10 tons) will be about 103 kN/m^2 (15 lb/in^2) at 25 mm sinkage. The machine is statically stable at angles in excess of 30° when tilted sideways, and, greater than 50°, when tilted to to the front or rear. The vehicle can also be used on the public highway, but, in this case, its speed is restricted by legislation to 12 miles/h.

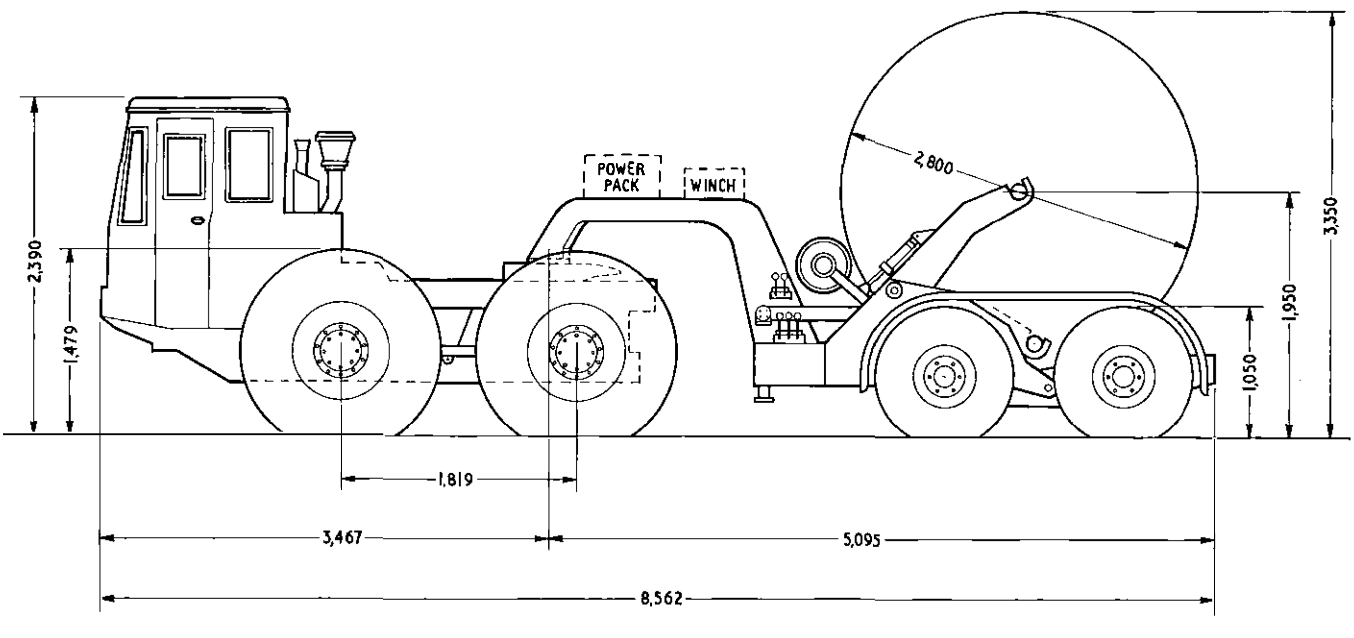
CABLE CARRIER

The Cable Carrier, shown in Fig. 2, is an articulated-type vehicle consisting of a motive unit and semi-trailer connected by a standard fifth-wheel coupling. A 3-line, air-pressure braking system is fitted.

For cross-country operation, the motive unit is a specially adapted 4-wheel drive, forward-control, Model FC 1004 County Tractor and provision is made for driving the front pair of wheels on the semi-trailer hydraulically in order to improve traction under difficult conditions. Power for the trailer wheel drive is supplied by the motive unit and the trailer wheel speed is synchronized with the tractor ground speed. The loaded weight of the complete unit will be approximately 15 tonnes and the ground loading, at 25 mm sinkage, will be about 138 kN/m^2. The minimum turning circle will be under 9·1 m. For normal road operation, the semi-trailer can be connected to a standard road-going motive unit and, in this case, the trailer wheel drive is inoperative. The carrier is designed to carry a single drum of cable having maximum dimensions of 2,800 mm diameter by 1,360 mm wide and a maximum weight of 8 tonnes. The unit is self-loading and provision is made for driving the drum at a maximum speed of 2 rev/min so that cable can be taken off for feeding through a guide system, or short lengths of cable remaining can be wound back on to the drum. Drum-braking facilities are also provided to stop the drum rotating during transit and to give control during cabling to ensure that the drum does not over-run and throw loose turns of cable.

A drawrope winch, capable of exerting a line pull of 4·45 kN, at rope speeds up to 55 m/min, is fitted and is used to pull the cabling winch rope through the duct from the Self-Mobile Winch Unit.

Drum-loading and driving mechanisms, drawrope winch and stabilizing jacks are all hydraulically operated by means of a power pack on the semi-trailer. The engine on the power pack is an air-cooled diesel engine and it provides power for all the functions needed during a cabling operation so that the motive unit may be disconnected. The drum-braking facility is manually operated and the drum-loading arms can be moved independantly to allow levelling of the drum if the trailer is set up on sloping ground.



Note: All dimensions in millimetres.

Fig. 2—Cable Carrier

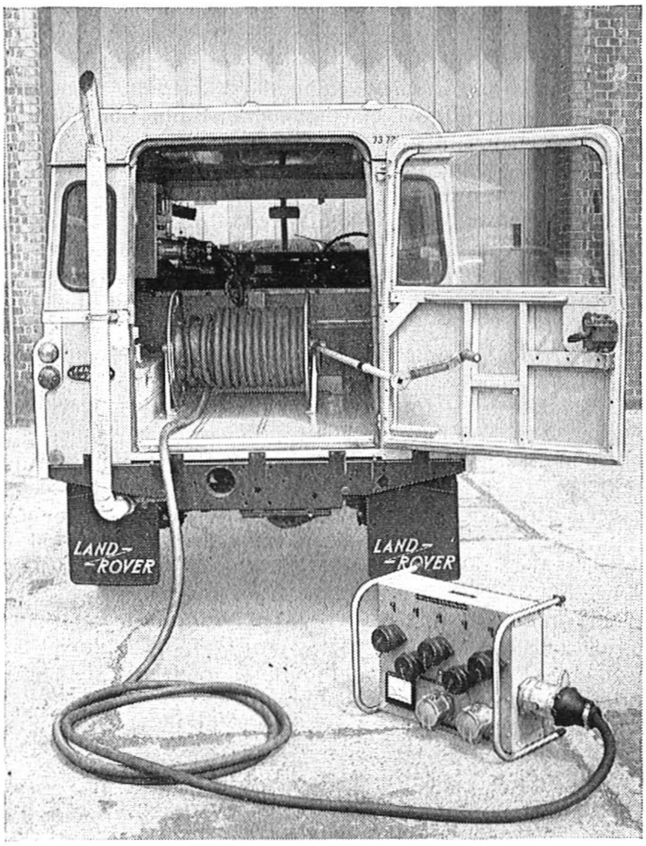


Fig. 3—Mobile Generator

MOBILE GENERATOR

Power demand for specially developed jointing techniques and ancillary services is met by a 10 kVA, 110-volt, 50 Hz, single-phase generator, mounted on a long-wheel-base Land Rover and driven by the vehicle engine through a standard gear box power take-off (see Fig. 3). The generator is a drip-proof, screen-protected, self-excited and self-regulating type meeting the requirements of BS 2613.

A 30·5 m extension lead is accommodated on a live centre reel and feeds a remote switching panel which is lowered into the manhole or jointing pit. The switching panel incorporates an ammeter, five 15-amp socket outlets and two 40-amp socket outlets. The 15-amp outlets are individually switched and the 40-amp outlets are of a load-breaking, butt-contact type.

Guarding against overload is provided by a double-pole circuit breaker fitted on a control box which also houses an ammeter and a voltmeter. The control box is fitted in the Land Rover adjacent to the generator.

Regulation of generator voltage is such that the voltage does not fall below 110 volts nor rise above 120 volts at any condition of load for power factors within the range unity to 0·8 lag. The generator is centre-tapped at 55 volts and the centre-point connexion is through a third slip ring which is fully insulated from the generator frame. The third (earth) pin on all outlets is connected to the 55-volt slip ring. All generator connexions are isolated from the vehicle.

The vehicle has a 2·6-litre, 6-cylinder petrol engine and a special engine-speed governor is fitted to provide rapid response to changing generator load conditions. An engine oil cooler is fitted to allow running for long periods with the vehicle stationary and the engine exhaust is mounted vertically to carry exhaust gasses clear of the jointing area. A hard-top body with side-hinged rear door is fitted and the door is mounted on lift-off hinges so that it can be removed easily if required to erect a tent close to the rear of the vehicle.

References

[1] Lund, A. E. A Progress Report on Heavy Cabling Equipment. *P.O.E.E.J.*, Vol. 66, p. 53, Apr. 1973.

[2] Martin, R. W. Rodding and Light Cabling Vehicle. *P.O.E.E.J.*, Vol. 64, p. 22, Apr. 1971.

Notes and Comments

Post-graduate Scholarships for Courses in Engineering and Science 1973

Each year, the British Post Office makes a number of awards to selected staff to pursue post-graduate courses in engineering and science. The following candidates have been awarded scholarships for post-graduate courses in engineering/science.

One-year M.Sc. course in Telecommunications Systems at the University of Essex:

Mr. J. W. Atkins, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. C. G. Golder, Executive Engineer, London Telecommunications Region.

Mr. J. H. M. Hardy, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. C. R. Harris, Executive Engineer, Operational Programming Department, Telecommunications Headquarters.

Mr. B. R. Kerswell, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. R. I. Kimpton, Assistant Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. J. A. O'Regan, Assistant Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. I. Sloboda, Assistant Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. J. Tuppen, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. R. A. Clark, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters has been awarded a one-year Diploma in Communications course at Imperial College, London.

Mr. R. G. Courtney, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

Mr. J. W. Graves, Executive Engineer, Service Department, Telecommunications Headquarters, has been awarded a one-year Diploma in Communications course at Imperial College, London.

Mr. K. J. Maynard, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Computer Studies at the University of Essex.

Mr. D. Pollard, Assistant Executive Engineer, Service Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Telecommunications Technology at the University of Aston in Birmingham.

Mr. D. W. Poole, Assistant Executive Engineer, Midlands Telecommunications Region, has been awarded a one-year M.Sc. course in Telecommunications Technology at the University of Aston in Birmingham.

Mr. A. Lindsay-Scott, Programmer, Data Programming Services, has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

Mr. A. J. Stubbs, Higher Executive Officer, Data Programming Services, has been awarded a one-year M.Sc. course in Computing Science at London Institute of Computer Science.

Mr. P. C. R. Squires, Higher Executive Officer, Data Programming Services, has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering, technical or other aspects of articles published in the *Journal*.

Letters of sufficient interest will be published under "Notes and Comments". Correspondents should note that, as it is necessary to send copy to the printer well before publication date, it will only be possible to consider letters for publication in the April issue if they are received before 25 February 1974.

Letters intended for publication should be sent to the Managing Editor, *P.O.E.E. Journal*, NPD/NP 9.3.4, Room S08A, River Plate House, Finsbury Circus, London, EC2M 7LY.

Articles on Current Topics

The Board of Editors would like to published more short articles dealing with topical subjects. Authors who have contributions of this nature are invited to contact the Managing Editor.

Notes for Authors

Authors are reminded that some notes are available to help them prepare the manuscripts of the *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal's* printer and draughtsmen, and help ensure that authors' wishes are easily interpreted. Any author preparing an article for the *Journal* who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

It is emphasized that all contributions to the *Journal*, including those for Regional Notes and Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that are required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Negatives or plates are not needed and should not be supplied.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are always given at the end of the Supplement to the *Journal*. The Board of Editors has reduced the price of Line Plant Practice A to 37½p (42½p post paid).

Regional Notes

London Telecommunications Region

Information on Communications Equipment installed in the new Stock Exchange Permanent Market

The new Market was one of the largest communications changeovers ever to take place, and was completed over the weekend 9–10 June, 1973.

The British Post Office (B.P.O.) had been working on the new installation since February, 1970, and had a full-time staff of between 40 and 110 engineers employed during this period.

The B.P.O. installation is the largest to be centred in any one building. Some 150 miles of multi-circuit cable is used and the installation comprises over 2,800 key-and-lamp units having 28,000 separate circuit appearances, 550 lamp signalling telephones, 3,000 ordinary telephones, 260 special switching circuits, over 1,850 direct private circuits and in excess of 750 stock-exchange lines, 1,000 member firm's own office extensions, 170 internal private circuits, 25 B.P.O. teleprinters and over 500 individual exchange lines.

Other contractors installed some 120 paging system call-pads, four member firm's own closed-circuit television systems, 130 stock-exchange television monitors, 30 Reuter video master or video scan units and approximately six extel machines. Also, the largest radiating cable ultra-high-frequency two-way speech mobile radio system in the world was installed; this comprises in excess of 80 separate channels controlling over 300 pocket sets. Four and a half miles of cable has been installed for this system alone.

The contractors had a total of approximatly 250 men on site on the changeover weekend.

J. M. Gillespie

Cables damaged by fire in an excavation at St. John's Wood.

In the late afternoon of Tuesday 14 August 1973, the London Fire Brigade attended a fire in an excavation, the site of a demolished manhole, in St. John's Wood Terraces. The excavation had been timbered in readiness for the construction of a larger manhole and nine local cable and four junction cables were exposed at this position. The cause of the fire, which was particularly intense, has not been clearly established but the fire brigade suggested that it might have been caused by a cigarette or match casually thrown by a passer-by igniting debris and subsequently timbering and those cables having plastic sheaths. As a result of the fire, no sheath remained on any of the cables and, in each cable, the conductors had fused into a solid mass.

Restoration work was started immediately and as many staff as possible called out on the emergency. General clearing of water and mud, together with the erection of temporary shuttering, was carried out with the conductors still glowing red.

Restoration neccessitated enlarging the excavation to get at unaffected cable, and borrowing cable from the area cable store.

During the early part of the restoration, the only means of communication was by radio to the Regional Precision Test Centre at Faraday, who relayed instructions from the site calling staff from home and dealing with the multiplicity of problems which arose.

All the cables had been jointed at this point and this meant that the four junction cables had to be "tapped back" from the terminals each side of this position. These, together with the subscribers' cables affected, represented 11,274 pairs to be changed over.

On Wednesday morning, the contractors retimbered the hole and, to obviate noise nuisance from portable lighting sets the London Electricity Board provided temporary lighting.

Two subscriber cables were of the multiple-twin type, and, because there were no conductor markings on this type of cable, it was decided to "straight change" these cables and clear whatever faults that resulted on terminal ends.

At 06.30 hours on Sunday 19 August 1973, all the damaged cables had been changed over to temporary interruption cables, the air pressure re-applied and service restored.

R. M. Harris
W. A. Waller
J. S. Blackburn

Midland Region

Ford Motor Company Exhibition at Bramcote

Ford Motor Company held an exhibition at the Gamecock barracks (formerly a Services airfield) Bramcote, near Nuneaton, between 2 and 14 July. It took the form of a Trade Fair with approximately 100 exhibitors from the motor trade. Although the main attendance was from the motor trade, there were two open days for the general public. Expected total attendance was 90,000. Only six-weeks notice of the required facilities was given, and intensive effort was needed by the staffs of the Midland Telecommunications Region and Leicester and Coventry Telephone Areas to provide temporary communication facilities, which included out-of-area exchange lines over a radio link.

Tentative enquiries about communication facilities for the event were received in April, when it was realized that the serving exchange, a U.A.X. 13 at Wolvey, had neither the line plant nor the equipment capacity necessary to carry the high levels of trunk traffic anticipated. Eventual requirements included 55 exchange lines, six coin boxes, two telex circuits and one datel circuit.

A radio link was used between the site and Bedworth Exchange (three miles away) to carry the exchange lines, and to provide the other services, with the exception of the datel circuit, on Wolvey Exchange. The datel circuit was routed on one of three spare pairs on an old cable between the barracks and Nuneaton.

At Wolvey, it was necessary to install three additional units, which were required, not only to provide calling equipment, but also coin and fee checking and outgoing junction relay-sets to cope with the expected increase in traffic. The level 1, 9 and 0 junction route to Leicester was also increased by eight circuits.

Transmission equipment comprised four racks of translating equipment and four racks of signalling equipment for each end of the radio link. One set was installed in Bedworth Exchange and the second in the old flying-control building on the exhibition site. The 51-type emergency transportable equipment provided one supergroup to feed the exchange lines to the radio equipment which was provided in an outside-broadcast van and relayed over an 11 GHz radio link via a dish aerial on top of the water tower.

The area external staff provided coaxial links from the flying-control tower to the water tower (about 0·5 mile) in existing ducting, aerial cable back to Wolvey Exchange (3 miles), and a considerable amount of site wiring to the various exhibitors' marquees. Customer Services Group co-ordinated the very large installation. All this was achieved with a minimum disturbance to the site.

From the initial regional meeting on 18 May, the whole installation was completed and working in six weeks. The project was co-ordinated by a Leicester Area Committee, and the co-operation and assistance given by Midland Telecommunications Region and Coventry Telephone Area staff is gratefully acknowledged.

D. J. Wortley

Confravision

Midlands Postal Region have been using the Confravision link to cut out repeated journeys to London in connexion with building projects. The Coventry main loading office scheme in particular has been most successful; it has been possible to resolve technical queries on drawings at very short notice without time wasted due to travelling or exchanging plans by post.

A full building project team meeting has been held with 12 participants in Birmingham and six in London. All concerned appreciated the time saving and the non British Post Office members were particularly impressed.

D. C. Turner

Cable Damage at St. Neots

The country town of St. Neots, situated in the Peterborough Telephone Area some 57 miles north of London, was recently the scene of an unusual and serious case of damage to British Post Office ducts and cables. Motorists leaving or entering the northern end of this fast-expanding London overspill town may make use of a secondary access road passing through a large expanse of common grazing land which embraces the outskirts of the town. In an attempt to rid this land of a persistent influx of uninvited gipsy caravan dwellers, the St. Neots Common Rights Proprietors decided to erect a fence along the roadside as a deterrent to their unwelcome guests and to restore peace and tidyness to the neighbourhood.

The fence was duly erected during the weekend 2 and 3 June 1973 by means of a pneumatic fencing attachment fitted to a tractor. A total of about 400 8 ft × 2 in "T" iron section fence posts spaced at regular 8 ft intervals over a distance of 0·6 miles were driven into the ground to a depth of 3 ft. Unfortunately, the chosen fence-line coincided almost exactly with a 4-way SAD route containing three underground cables. The External Plant Maintenance Control was not advised of the proposed work and, as a result, a new 1,000-pair local cable was damaged in 33 places and beyond repair. Twelve sheath fractures were also found on a 294-pair Huntingdon–St. Neots cable in addition to six other cases of damage to a 100-pair local cable. The 4-way track was pierced and damaged extensively throughout.

In view of the serious physical damage to the cables and ducts, the 100 faulty subscribers' lines together with approximately 50 faulty circuits in the Huntingdon–St. Neots cable seemed surprisingly few under the circumstances. Fortunately, only 28 local subscribers' circuits were routed via the new 1,000-pair cable and arrangements were made to transfer these to another cable as a first priority together with the early clearance of the 100-pair cable. The majority of local faults were cleared by 1800 hours on 5 June 1973 and all faults affected by the damage were restored by 1200 hours on 8 June 1973.

The problems in effecting temporary clearances and in localizing the large number of faults were considerable. The first fault located by a Precision Testing Officer on 3 June 1973 using normal d.c. methods was cleared *in situ* by piecing out 70 pairs of wires in the 294-pair Huntingdon–St. Neots cable. It was soon realized, however, that further faults existed and that the situation was more serious than was at first thought, although, at this stage, only 14 circuits had been reported faulty. A large number of faults were subsequently found by means of track-locating equipment, with a jointer systematically testing for a tone connexion at each fence post. The remainder of faults were located by means of an Echometer TO 3/3 and considerable use was made of a mechanical digger which was hired from the local council for carrying out the extensive amount of excavation work involved.

Normally, interruption cable would be used for repair of faults of this kind and arrangements were, in fact, made during the early stages of fault for cable to be made available if required. It was fortunate, however, that *in situ* repairs were possible because interruption over a length of 0·6 miles would have presented many problems, particularly in the case of the balanced Huntingdon–St. Neots cable. Due to duct damage, the cable would have had to be laid overground and liable to further damage or theft. A new duct track is at present being provided to accommodate the replacement cables.

T. A. Measures

North Western Region

The first Mobile Electronic Telephone Exchange

The first Mobile Electronic Telephone Exchange (m.e.x) to be used in the country was delivered to site at Padgate near Warrington at the beginning of June 1973.

The m.e.x. will be used to provide service to meet the rapid growth of the Warrington New Town area prior to the opening of Padgate Exchange in July 1975.

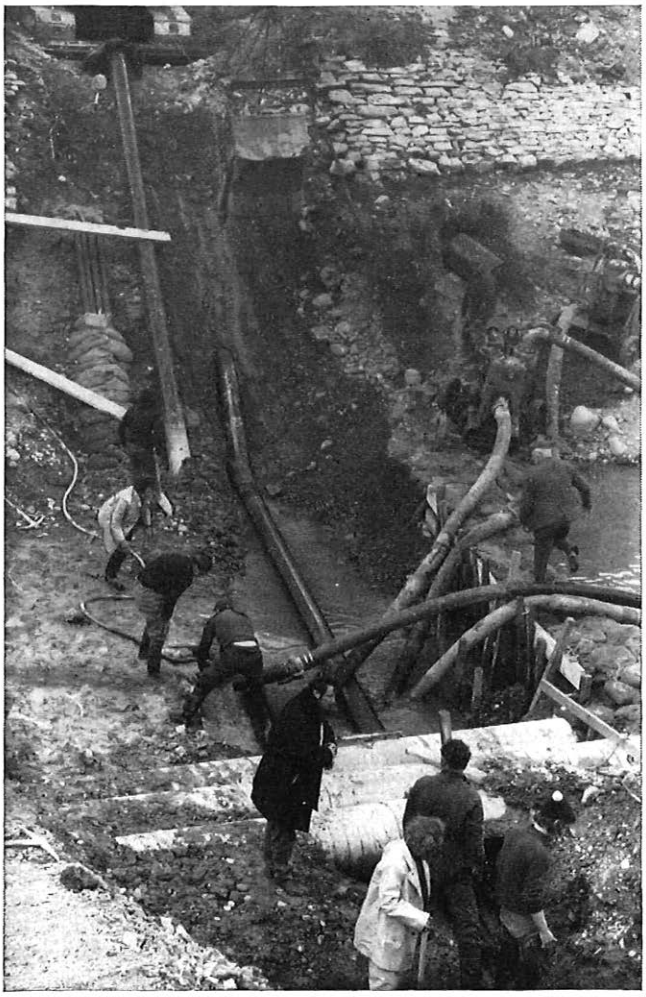
A 1,000-line unit has been provided initially and provision has been made to increase this to 2,000 lines, should the New Town grow faster than expected. Tests carried out on the exchange proved the ability of the TXE2 equipment to travel as a complete unit. The m.e.x. was in service by the end of August 1973 after being re-strapped for on-site requirements.

D. G. B. Scott

Scotland

New Ductways across the Caledonian Canal

The need to establish a suitable duct across the Caledonian Canal arose when some 400 acres of agricultural land was zoned for housing in the amended Inverness Town Development Plan of 1972.



British Post Office duct with sand bag protection on the left and the other two services in position before reinstatment of canal bed and embankments.

Negotiations were started in October 1972, when it was learned that the canal would be closed to navigation during the period 3 March to 16 April 1973 and certain sections drained. These negotiations revealed that the other utilities, water, gas, sewer and electricity, were also proposing making new crossings to serve the proposed development of approximately 2,400 houses, equally split between private and local authority.

Joint meetings were held, and by 15 December 1972 the British Post Office (B.P.O.), Water and Gas Boards had reached an agreement to go jointly into this venture.

The Water Board had recently made a similar crossing of the river Ness and still had the necessary material available to establish coffer dams with by-pass pipes for the residual water in the drained sections of the canal.

The trenching work was to be undertaken by the Water Board using hired plant and direct labour, the actual cost of this work to be divided equally between the three parties and each party responsible for its own pipe laying in the open trench. The Water and Gas Boards were to lay 250 mm steel pipes and the B.P.O. eight 89 mm polyvinylchloride (p.v.c.) pipes laid in formation four wide and two high. The Water Board pipe was ultimately to be connected into the high-pressure main, and because of this, it was necessary for them to build swabbing and discharge chambers in the east bank. The B.P.O. required a turning chamber on the same bank so, in order to avoid congestion, it was decided that the B.P.O. duct would take the upstream position in the trench, the Gas Board the middle position, and the Water Board the downstream position, with approximately 0·6 m spacing between the services.

Negotiations with contractors to lay B.P.O. pipes in the open trench were unfruitful. Some were not interested and others were too highly priced, the average negotiated price being around £40 per metre. This problem was put to the Water Board who volunteered to lay our pipe by direct labour on a time used basis.

A survey by the Water Board revealed that 22·5° bends would be required at four points in the total crossing length of 46 m. The Water Board engineer did not approve of B.P.O. proposal to set our p.v.c. pipes to the required radius *in situ* and, to save further problems, bends were ordered from Capperneil Plastics, Edinburgh.

Work was eventually started on Monday, 5 March 1973 and good progress was made in establishing coffer dams of sand bags. Three 450 mm pipes were necessary to allow the by-pass of the residual water flow, estimated at 500–600 gallons per minute. Trenching work was started on the Wednesday but, because of further civil engineering works taking place further downstream, the work had to be abandoned when the downstream coffer dam collapsed because of back pressure from the temporary reservoir formed between the two works. This problem was overcome when the lower works increased their by-pass of residual water flow.

By the Wednesday of the following week, the water main had been laid in position across the bed of the canal and work had started on B.P.O. duct. The Water Board pipe layers found no difficulty in laying B.P.O. pipe and by the week-end it was laid across the bed and up the embankment on either side. At this stage it was decided to protect the B.P.O. duct by building around the duct sand bags filled with dry concrete mix. This also served to keep B.P.O. ducts in position when the trench filled at night after the pumps were shut down.

During this time, the gas pipe was being prefabricated on the west bank of the canal and was ready to be dropped in position as soon as the Water Board pipe and B.P.O. duct was laid above the normal water level of the canal. This was completed by the end of the third week and everything was ready for restoration of the canal bed and embankments.

The restoration work was completed by the end of the fifth week, one week ahead of the time laid down by the Waterways Board. The canal was opened to navigation on schedule and the fishing fleet sailed through on Monday, 16 April 1973.

Our thanks must go to the Inverness Water Board for their co-operation before the event and their excellent administration of the whole operation.

The cost to the B.P.O. for this work was finalized at £1,640.

J. Y. Lilley

South Western Region

Gas Main Explosion

A major gas explosion occurred at 1630 hours on Wednesday 23 May 1973. Gas Board contractors were cutting off a 24 in gas main to attach a spur at the Charles Church end of Ebrington Street, in Plymouth city centre, when the explosion happened. Exchange maintenance staff noticed an increase in *permanent glow* (p.g.) conditions at about 1635 hours. It was quickly established that air alarms were operating on certain local distribution cables. Cable plans were checked and it was confirmed that all the affected cables were routed via Ebrington Street.

In the exchange, all first group selectors not engaged on calls were in the p.g. condition. Preference service was introduced at 1645 hours and the battery cut off. A number of faulty conditions were quickly checked to confirm the record of faulty cables. Subsequently, urgent action was necessary to clear the exchange congestion which was aggravated by a local radio and television newsflash of the explosion, the immediate effect of which being to make nearly every subscriber try their telephone. In the meantime, main distribution frame (m.d.f.) verticals of the affected cables were checked for line fault conditions.

Initially, it was found that all the cables appeared to have faults i.e. earth, short circuits, and battery contacts, and all fuses on these cables were quickly removed. This local disconnexion action within the exchange considerably eased the congestion and, at about 1748 hours, the battery cut-off keys were restored. Exchange traffic was still high and effort was concentrated on keeping the p.g. conditions down. Checks of the line side of the m.d.f. proved frustratingly slow and confusing although it was apparent that, whilst the pairs of one cable were all faulty to line, other cables were not consistently so. It was also necessary for faultsmen to take emergency action and to give service by expedients where possible on those police, fire and hospital lines affected.

Gas Board officials stated that the Post Office would not be permitted in the damage area at the earliest until 0600 hours on the following day and this was later altered to 0800 hours.

Plans were prepared for cable lengths and staff to be available as soon as the Post Office could move into the affected area.

Provisional plans assumed all cables would require renewal, and, in view of the likely unacceptable jointing time which single changeovers would take, *leap-frog* length renewals were planned to permit extra jointers to operate and speed-up restoration of service.

Fortunately, inspection of the damage site early on Thursday 24 May revealed damage to be less serious than anticipated. Some ducts were broken, others only cracked. One cable was badly affected but another cable only affected by expansion and bubbling in the sheath causing an air leak. Immediately the situation was confirmed, testing of the m.d.f. pairs was speeded up and all but two cables were fused up and service restored to these lines. A special sheath repair was made on the cable affected by expansion using Thermofit, a method of sheath sealing using a shrink seal. Repair group activities were directed to major repair of the two cables still affected. It was subsequently proved that a cable fault already existed in one cable in the Mount Gould area, remote from the damage point and this accounted for the faults noticed in this cable.

After new cables were laid (fortunately new ducts were part of the overall contract scheme at the damage site), jointers were asked to pay particular attention to unit-to-unit jointing on the distribution joint side of the damaged 1,200, pair cable and note unit number, making changeover less likely to give further faults.

The restoration proceeded along normal lines and final service was restored to all outstanding circuits on Wednesday 30 May. This major civil emergency alerted the local Corporation officers to the inadequacies of their present communications system for dealing with events of this nature. The whole street had to be evacuated and 24 elderly people accommodated overnight in old peoples' homes. In addition because the fierce and spectacular blaze put 1,500 telephone lines out of order, Corporation relief workers found that their efforts were seriously handicapped.

J. J. Malone

Associate Section Notes

Aberdeen Centre

The 1972–73 Session for the Aberdeen Centre culminated as usual in the annual general meeting. Unfortunately, the meeting, held in a local hotel on the evening of Friday 11 May, was not very well attended, but in his remarks, the Chairman hoped that, with increased publicity and effort from the Committee, this trend could be halted. During the meeting, a large agenda was dealt with quickly and effectively, the election of office bearers being one item. The final list is as follows:

President: Mr. J. Sharp; *Area Lines Officer:* Mr. J. Lawrence; *Chairman:* Mr. J. Davidson; *Secretary:* Mr. J. H. McDonald; *Treasurer:* Mr. R. Mathewson; *Vice-President:* Mr. D. S. C. Buchan; *Vice-Chairman:* Mr. J. Stephen; *Assistant Secretary:* Mr. I. Booth; *Librarian:* Mr. B. G. Rae.

When the evening's business was completed, those attending enjoyed a dinner which was followed by entertainment in the form of music and song.

J. H. McDonald

Ballymena and Coleraine Centres

In November 1972, it was decided to form a new section of the I.P.O.E.E. jointly between Ballymena and Coleraine.

Inspired by the drive of George McConnell, a series of quizzes were held between the two headquarters. People discovered the faces behind the names at the other end of a telephone and new friendships were formed.

Such was the enthusiasm that, even before the joint centre was formed, it was decided to form two separate centres in Ballymena and Coleraine. Using Dr. P. R. Bray's notes for guidance in setting up a new centre, both centres formed their respective bye-laws and progressed to set out a very interesting syllabus for their members.

To enable the centres to get off the ground, the program tends to be social rather than technical with lectures ranging from fire prevention to drug taking, local history, wine making and including rally film shows.

Both new centres were fortunate in having early representation to the National Committee and, through friendships forged, were largely responsible for an I.P.O.E.E. first. On the 5th September, a public lecture was held in Ballymena, the subject being unidentified flying objects.

With a few successful months behind them, both centres are looking forward to greater things in the future.

J. P. McDonald
J. Cameron

Bletchley Centre

On Wednesday 5 September, an autumn conference and presentation dinner was held at the Post Office Training Centre, Bletchley.

This event was organized to present a farewell gift to Mr. Bill Allen, secretary, founder member of this centre 11 years ago, who retired from the Post Office on 3 October 1973.

Speeches were given by Mr. H. Baker, Mr. Joe Missen, Mr. F. Philcox and Mr. R. H. Stanesby. Mr. S. H. Sheppard regional Liaison Officer was chairman. All centres of the Eastern region contributed towards the gift, which was a Galleon tray suitably inscribed. This was presented to Mr. Allen by the retiring national President Dr. Bray.

The Bletchley Centre has lost an excellent secretary and secretaries of Mr. Allen's calibre are hard to replace.

R. H. Stanesby

Bournemouth Centre

In March, a visit was made to Southampton Sorting Office, where we saw the highly mechanized parcel-sorting equipment in operation.

Our annual general meeting was held on the 24 April, and officers elected were: *Chairman:* R. H. Ough; *Vice-Chairman:* D. M. Woodley; *Secretary:* G. H. Seagroatt; *Assistant Secretary:* R. Hillditch; *Treasurer:* L. F. A. G. Limburne; *Committee:* Messrs. M. B. Smithers, D. Fox, T. Pardy, P. Dorey, F. G. Kendrick, G. R. White, K. Neilson, P. Dykes, M. Wigmore.

It was agreed, at the meeting, that a large committee gave a greater coverage of information to members.

The question of electing a Centre Quiz Organizer was discussed, and the post was later filled by Mr. B. Fielder.

On the 6 June, a film show was arranged, the main feature being the N.A.S.A. film on Apollo 16, entitled, "Promise of the Moon". This was a well-attended and successful evening.

G. H. Seagroatt

Dundee Centre

The annual general meeting held on 1 May 1973 was well attended and resulted in the following office bearers and committee being elected:

Chairman: Mr. R. L. Topping; *Vice-Chairman:* Mr. D. Moore; *Secretary:* Mr. R. T. Lumsden; *Treasurer:* Mr. A. Vaughan; *Assistant-Secretary:* Mr. J. M. Low; *Committee:* Messrs. J. Chisholm, A. Dowie, J. Duncan, J. C. Howe, A. W. Smart, G. Stephen, M. Williamson.

Several interesting subjects were suggested for next season's activities and it is hoped to create a Trainee Technician (Apprentice) award for first-, second- and third-year students.

The committee make an earnest appeal to all who read these notes to take an active interest in the Centre's activities.

R. T. Lumsden

Edinburgh Centre

On Thursday 18 January 1973, 21 of our members enjoyed an afternoon visit to Ben Sayers, makers of golf clubs, at North Berwick. Everyone appreciated the amount of work involved in the making of one club, but were surprised that much of it is still done by hand. Unfortunately, no free samples were given.

During February, a talk entitled "Exchange Equipment and Allied Problems," was given by Mr. H. J. Revell, Chairman of the Scottish Telecommunications Board. Mr. Revell explained the technical and economic problems of running a business such as the British Post Office (B.P.O.). He outlined the plan to phase out the Strowger system, the interim use of crossbar equipment and the ultimate change to an all electronic system. A lively discussion followed when Mr. Revell invited members to ask questions on any aspect of the B.P.O.

In March, 15 members enjoyed a visit to Scottish and Newcastle Breweries at Holyrood, Edinburgh. The complete process, which nowadays is completely automated, was shown, starting with the barley and finishing with keg beer.

The final event of the 1972–73 session was the annual general meeting and dinner in April. The following Office-bearers and Committee were elected:

Chairman: Mr. M. K. Finland; *Secretary:* Mr. M. I. Collins; *Treasurer:* Mr. R. R. Thomson; *Assistant Secretary:* Mr. J. L. M. Alexander; *Librarian:* Mr. J. H. King; *Committee:* Messrs. R. Bailey, J. Samson, I. D. Hoseason, S. Barr, R. S. Elder, J. Edwardson, G. Scott, A. Johnstone, C. Little.

M. I. Collins

Exeter Centre

At the annual general meeting on 18 April, the following members were elected as officers and committee for the 1973–74 session, the ***President*** Mr. B. L. E. Yeates kindly accepting office for the second year:

Chairman: Mr. T. F. Kinnaird; *Vice Chairman:* Mr. C. K. Sanders; *Secretary:* Mr. E. Soper; *Assistant Secretary:* Mr. J. J. F. Anning; *Treasurer:* Mr. W. F. Lambert; *Librarian:*

Mr. G. W. W. Abbott; *Committee:* Messrs N. H. B. West, J. L. Petherick, J. Brown, S. G. Page, D. N. Miller, C. W. Paterson, D. R. W. C. Oddy and A. C. Bayley.

This meeting completes a season of well-attended meetings averaging 96, which was rewarding to the committee in choosing a well-balanced program as set out below:

17 October	"The Post Office and Its Technology" by Professor J. H. H. Merriman, C.B., O.B.E.; Board Member for Technology, who gave us a realistic look into the future of telecommunications.
29 November	"The Mountains of Glass" by John Earle, British Broadcasting Corporation television describing the climbing of two unclimbed mountains in the Darwin Range.
18 January	"Isambard Kingdom Brunel" by K. Hickman (Brunel Society, Bristol) describing some of the work of this famous engineer.
20 February	"Communication—Satellite Earth Stations" by V. C. Neller who gave us an appreciation and understanding of the development in this field over the past 10 years.
21 March	"Crossbar" by I. P. Lightfoot described the outline of the Crossbar (TXK) Exchange, installation and aspects of maintenance. This was a Centre member's paper, which gave credit to Ian and the Centre in its search for talent within the membership.
18 April	Annual general meeting followed by another enjoyable film quiz by Clem Millman.

It is indeed gratifying to see the continuing trend of papers presented by members, and, in this vein, we anticipate a further paper next season. Our appreciation and thanks are extended to those concerned.

The Rougemont project is now under way—this will show a comprehensive photographic report of the development of the new Exchange, until it is commissioned in 1977.

With a view to stimulating further interest in telecommunications, Trainee Technician (Apprentices) in their second and third years and Improvers during their first two years are invited to enter an essay competition given by the centre. Each eligible officer will be informed personally.

The response and enthusiasm by the participating teams and the audience in the second leg of the National Technical Quiz against Bath at Taunton on the 7 September was very encouraging. Our congratulations to Bath on a closely fought contest—with equal points at question 20 our opponents gained a victory with the final score at 37–34 points. Teams: Exeter—J. J. F. Anning (Captain), R. E. Allen, M. T. Rowe, I. Lightfoot, J. Blamey, A. Smith. Bath—P. G. Martin (Captain), R. Sleman, C. R. Jenkins, A. Proctor, E. G. Banks, W. J. Rossiter.

Our sincere thanks to the Host and questionmaster, Mr. T. D. Keat (Head of Planning and Works, Taunton), assisted by Mr. Long, Executive Engineer, and Mr. Nelson, Area Training Officer, adjudicator and timekeeper respectively.

During August, a tour of the Rank Bush Murphy Assembly Plant and the Browne and Sharp Precision Engineering Works at Plymouth was followed by a visit to the Devonport Dockyard. Support for summer visits are requested, together with suggestions for future outings. Please contact the Assistant Secretary, Mr. J. J. F. Anning.

The following talks took place in October and November respectively:

Some Aspects of the Pre-Historic Remains on Dartmoor by G. F. Cload.

Cable Pressurization by C. J. Bond.

The program for the rest of the session is as follows:

24 January	The Planning and Operation of the Grid System by J. I. Bird (System Operation Engineer, Central Electricity Generating Board).
19 March	Above Us the Waves by D. Craig.
25 April	Annual general meeting.

The talk in November was presented by a Centre member as will be the March talk. We extend our grateful thanks and appreciation to these members.

E. Soper

Glasgow Centre

The 1972–73 session is now well behind us, the syllabus concluding with our annual general meeting on Friday 18 May 1973, held in Sloans Victorian Dining Rooms, Argyle Street, Glasgow.

The past session was interesting, informative and varied, attendance at meetings, however, remaining much the same as recent years.

At the annual general meeting, the following were elected as office bearers and committee:

President: Mr. J. L. Sommerville; *Chairman:* Mr. R. Johnston; *Vice Chairman:* Mr. Witheringham; *Secretary:* Mr. R. W. Stevenson; *Assistant Secretary:* Mr. R. I. Tomlinson; *Treasurer:* Mr. K. Gordon; *Librarian:* Mr. A. Cochrane; *Committee:* Messrs J. Bannerman, S. Anderson, J. Blane, M. Kane, P. McBride, J. Roney, J. McCallum, H. McCraig, H. McNamarra.

Preparations are now under way for the 1973–74 session, arrangements having already been made for: a visit to "The Central Scotland Water Development Board" at Balmore, Torrance, near Glasgow, a lecture by Mr. R. S. McDougal, Executive Engineer, Glasgow Telephone Area, entitled "The Effect on Maintenance of the latest Maintenance Aids", and a probable visit to the "Standard Telephones & Cables Co Ltd" East Kilbride. We look forward, therefore, with enthusiasm to the forthcoming session.

R. I. Tomlinson

London Centre

The tenth annual conference was held in the Council Chamber, Institution of Electrical Engineers, Savoy Place, on Friday 11 May.

There were one or two changes to the London Centre Committee this forthcoming year, the committee is:

Chairman: P. D. Southgate; *Vice-Chairman:* J. Carver; *Treasurer:* R. A. Gray; *General Secretary:* P. Harding; *Assistant Secretary:* N. V. Clark; *Editor:* C. Fry; *Visit Secretary:* D. Denchfield; *Librarian:* D. Randall: *Technical Quiz Organizer:* D. Thomas; *Registrar:* D. Randall.

It is with pleasure we can announce that Mr. John Dow received the C. W. Brown award at the annual conference. This highly coveted award was well deserved as the amount of time and attention John has given to the London Centre over a period of years as a committee member shows his zeal and enthusiasm for the I.P.O.E.E. As Chairman of the National Committee his experience will prove invaluable.

Dr. P. R. Bray has retired recently. The London Centre Committees past and present must accept with a great deal of regret, that he is no longer our President. His arduous and exacting duties in the British Post Office must have left him little spare time, yet, he managed to be so active, as spokesman and adviser for so long. We all wish him well, hoping that he has a long and happy retirement, health and opportunity to continue his leisurely activities, which his working life must have curtailed. Also we thank Dr. Bray for all he has done for the London Centre through the past years.

The City Area has opened a workshop; it has good accommodation and lighting and several projects have already been started.

The lectures at Fleet Building for the forthcoming year are arranged and there is a variety of subjects. Please see notice boards for the posters. There are subjects such as unidentified flying objects, human-factor research, communications in the Netherlands, an informal talk from the police, canal recreation, satellite communication and the last one from the B.P.O. cableships. We welcome all who would like to hear, and see, what makes the world tick; please come along.

I hope everyone has had a happy leave, and has returned fit and well for the forthcoming season.

P. Harding

Oxford

After a summer program of visits to Thor Cryogenics, Reading Signal Box, and the Hydraulics Research Station, the winter program included the following:

A talk entitled Police and the drug problem and the Land Line Quiz.

The meetings for the rest of the winter session are as follows:

Talks entitled The Future of Local Line Systems by Mr. H. J. C. Spencer, on 24 January, and Sailing by Mr. D. M. Betts on 20 February.

The annual general meeting will be in March. For further details, contact me on Oxford 41317.

D. R. WARD

Salisbury Centre

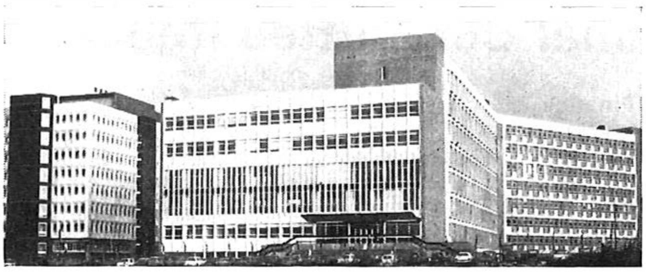
After repeated attempts, the Committee was finally successful in arranging a visit to B.A.C., Filton, in September, to see something of the Concord project. After a number of interesting films, a tour was made of the works to see the current aircraft production assembly and a full-scale mock-up.

Other visits made were to Pirelli General Telecommunications Division, Bishopstoke, and to the Hambledon Vineyard in Hampshire.

A. PATTERSON

Scotland West Centre

A new venue has been obtained by Scotland West Centre of I.P.O.E.E. for their meetings. The Glasgow College of Technology has kindly allowed the Centre the use of its premises and facilities. The College itself, located centrally in Glasgow, is a Polytechnic of higher education concerned exclusively with advanced work, including its own degree courses.



Glasgow College of Technology

The Scotland West committee have agreed to donate an annual prize of £5 to the best student in Microwave Engineering as a token for the offer of free accommodation by the College Director R. J. Beale, B.Sc.(Eng.), Ph.D., C.Eng., F.I.Mech.E.

D. M. DICKSON

Southampton Centre

The 1972–73 session ended with a well-attended annual general meeting. The positions of Chairman, Secretary and Treasurer were vacated this year and new Committee members joined as follows:

President: Mr. J. E. Collins; *Vice-Presidents:* Messrs. S. Luther, P. Wiltshire, W. Luff and K. Hampson; *Chairman:* Mr. K. J. Mann; *Vice-Chairman:* Mr. R. G. Genge; *Secretary:* Mr. T. F. Axton; *Treasurer:* Mr. R. P. Kindred; *Librarian:* Mr. M. C. Short; *Committee:* Messrs. R. Wilkins, D. Rolfe, E. W. Green, P. Bates, G. Meering, and I. Rowsell.

Our year's activities opened with a new venture, which involved our Vice-Presidents in a Question Forum. Mr. P. Wiltshire and Mr. W. Luff kindly consented to sit on the panel to answer informal questions put from the members. It was explained that so long as personal matters and items of negotiation were excluded, all questions were welcome. An enthusiastic number of members and friends were enlightened on diverse subjects which included area statistics, planning techniques, promotion procedures, provision of crossbar and electronic exchanges in the Southampton area and telecommunications requirements in the future. These, and many other questions, provoked informal discussions during a very enjoyable evening.

The following day, a visit was made to the Astron Byrd premises at Poole. Astron Byrd combine the manufacture of electronic organs, ship's radar and other marine aids at this site. We all enjoyed this worthwhile visit but regretted that the organ demonstrator was engaged elsewhere.

To provide light entertainment and a get-together with our wives and friends, Mr. Tom Axton, of our committee, arranged a Disco Dance. Its success can be judged by the request for a repeat next year.

When Mr. J. E. Howarth gave his lecture on "Computer Applications to British Post Office (B.P.O.) Engineering", we found ourselves involved in the historical abacus as well as the modern techniques. At this lecture, Mr. K. F. Jallard of the South Western Telecommunication Region presented certificates for lectures given to G. Gay and R. Genge. The lectures, "Transit working" and "Introducing subscriber trunk dialling" were given in the Salisbury and Southampton Centres. Mr. J. E. Collins had previously entertained the recipients and centre representatives to tea.

It was a pity that more people were unable to hear Mr. R. T. Mayne on "International Telephony". He outlined future plans and was very frank when answering our questions.

Mr. D. C. Jones, talking from behind a row of specimen switches and other equipment, gave us much information on private automatic branch exchanges (p.a.b.x.s) as well as "New p.a.b.x.s for the B.P.O."

Later in the year, Mr. B. Copping gave illustrations of how our actions can be equated and used to benefit all. His lecture "Some aspects of B.P.O. Human Factor Research" opened our eyes to this valuable advisory service.

R. G. GENGE

Stirling Centre

The 1972–73 session ended with our annual general meeting on 16 May 1973. Members participating in visits and talks seem to have enjoyed the program of events arranged for them. Visits were made to Glasgow Airport, and local printing works of the Falkirk Herald, and the S.S.E.B. Grid Control Centre at Kirkintilloch. The General Manager, Scotland West Area, Mr. Warnock, gave a talk on "Scotland West: Past, Present and Future."

One notable outcome of our annual general meeting was the filling of the Chairman and Vice-Chairman offices by associate members, which in the past had been filled by senior members. The office bearers for the 1973/74 Session were nominated as follows:

President: Mr. E. Taunton; *Chairman:* Mr. W. Burns; *Vice-Chairman:* Mr. A. Moffat; *Secretary:* Mr. J. Hannah; *Treasurer:* Mr. R. Henderson; *Committee:* Messrs W. McGregor, G. Nicol, R. Turner.

Many suggestions for visits and talks were put forward at the annual general meeting and it is hoped to have a program made up within the next month.

Once again, we had average attendance over the session of 18 and hope this will continue, if not improve, over 1973–74.

The 1973–74 session started in October with a visit to Longannet Power Station. Other visits were to Falkirk Lapidary Club in November and the Observatory and Planetarium in the University of Glasgow in January 1974.

General subscribers' apparatus maintenance will be the topic of a talk by Mr Low from Scotland Telecommunications Board Headquarters. Two further items have still to be arranged and we hope the program, as a whole, will interest our members and encourage their participation.

Our working committee is now fully covered by Associate Section members. Mr W. Burns, Technical Officer, Falkirk, and Mr. A. Moffat, Technical Officer Falkirk, have accepted the offices of Chairman and Vice-Chairman.

J. HANNAH

Swansea Centre

The centre continues to grow.

During a recent visit to A.T.V. studios, Birmingham to see "The Golden Shot", Mr. G. E. Jones, our Assistant Secretary, appeared on the program and won a colour television receiver.

In October we visited the "Evening Post" Offices, Swansea, and in November the B.B.C. Radio Studios, Cardiff.

The remainder of the winter program is as follows—

January: Visit to Gowerton sewage works; February: A talk and film show on The Development of Swansea During the Past 60 years; March: Visit to the Guinness Brewery, London.

Our membership has increased to 175 and we hope to reach 200 soon.

Most important of all, we have great hopes that a Centre at Carmarthen will be constituted soon. This would replace the Centre at Haverfordwest which has unfortunately not been able to survive.

We shall do all we can to help the new centre.

P. EVANS

Swindon Centre

Other centres may be interested to hear of the recent activities we have enjoyed at Swindon. Although the centre was inactive for a period it is now quite alive.

We commenced our rebirth "Under New Management," with a visit to a new local electronic exchange at Shrivenham in May 1972. This was followed in September with a lecture by a local J.P. (who is a member of the Senior Section and our Liaison Officer) on his work for the Community, and a visit to Royal Air Force Brize Norton in October. In November, we visited the British Leyland pressed steel works in Swindon which was most impressive.

In January and February 1973, we were given a further two lectures, one by our President, Mr. P. Evans, and the other by member P. E. King on "subscriber trunk dialling and transit working". In March, we visited the works of Pye-TMC at Malmesbury, Wilts., and the Royal Air Force Museum, Collerne.

May brought a change of activity with a very enjoyable inter-departmental skittles match at Lea, Malmesbury. In September 1973, we visited the Avon tyre factory at Melsham, Wilts.

We are now up to date with just having completed a visit to Whitbreads Brewery at Luton, which proved to be a most enjoyable excursion. The Company provided us with the most excellent hospitality and made us feel very welcome. For Centres interested in a similar visit, there is, unfortunately, a two-year waiting list!

Our future plans include a visit to Times Newspapers, London, in December 1973 and the Houses of Parliament in Spring 1974.

T. J. MARTIN

The Associate Section National Committee Report

The last meeting of the Associate Section National Committee and delegates was held at the Technical Training College (T.T.C.) Stone, on Saturday, 8 September.

This meeting proved to be of great use and much work was completed by those delegates that attended. Many new ideas were put forward for activities and some were accepted.

Visits and Lectures

Brian Hickie (Wales and the Marches), has been trying to collect information about talks and visits. He has been sent some literature, but requires a lot more. Would all centres please help by sending him this information. Also, would any centres stuck for ideas try his list and see if he can help you.

Projects

A new projects competition is to start, and Eric Philcox will be contacting all centres asking for ideas. Please assist him with this preliminary search, the results of which will be of interest to us all.

An Associate Section National Telephone Archive is to be set up, with the object of forming a National Telephone Museum at a later date. If you would like to submit any old papers, documents, or other historical items (including equipment), please contact Eric Philcox, National Committee Projects Officer. Please do not remove any equipment or send any without first contacting Eric to find out the correct procedures.

Finance

Some good news for centres having difficulties with their figures of membership is that the National Committee Treasurer is to negotiate the possibility of getting a computer payout sheet of all national figures. On receipt of this information he will supply all centres free of charge with all details currently issued.

Technical Quiz Competition

The National Quiz will take place this year, and the Bray Trophy will be awarded to the winning team after the final match in February 1974. Watch for publication of your Region's matches and give your team support. The competitions should be of high quality and great interest.

National News

The National News is now running very smoothly and appears to be bridging the gap between a high technical content and the 'social-chat' type journals available elsewhere. The Editor, Colin Newton, is doing a fine job and is constantly on the lookout for new stories. Members who would like to contribute material for this journal should contact him for further advice.

P. L. HEWLETT

Book Review

"Introduction to Telegraph Engineering." Josef Lehnert. Pitman Publishing/Siemens. 155 pp. 89 ill. £3·10.

This is a direct translation from German of a small volume published by Siemens in 1969 and written by the Head of the Telegraph Training Department of Siemens AG. The book aims to describe the fundamentals of telegraphy and the implementation of telegraph systems in terms which are within the grasp of the "uninitiated reader." The extent to which it achieves this objective is doubtful but it does give a fairly concise introduction to telegraph machines (with the emphasis on teleprinters), telegraph switching, signalling and transmission systems.

The section dealing with telegraph machines is very clear, well illustrated and includes a useful discussion of start/stop distortion and receive margin. The other sections after briefly describing basic principles quickly become involved in detailed system description.

In general, the text has suffered very little in this translation from German, but it does not always use U.K. terminology. This does not cause any real difficulty but makes some 'passages less easy to read than they might otherwise be. The most serious criticism of the book is that circuit diagrams and block diagrams of systems appear to be reproduced directly from the German edition. For example, a single-to-double current converter appears in block diagrams as [Ft An (St.)]

For the U.K. reader these diagrams would be much clearer if they had been redrawn to conform to U.K. practice and U.K. symbols and abbreviations used.

M. S.

Institution of Post Office Electrical Engineers

Election of Members of Council 1973–74

The results of the recent elections of members of Council are as shown below, the names being shown in order of votes counted.

Grade Representation

Members in Provincial Regions holding posts in Bands 5 to 8 of the Senior Salary Structure.

Mr. A. NESS, Scotland Telecommunication Board, returned unopposed.

Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants, Assistant Experimental Officers, Third Officers, Fourth Officers, Third Engineers, Fourth Engineers, Electrical Engineers, and Assistant Technical Costs Officers of the Post Office Headquarters Departments and Assistant Factory Foremen of the Factories Division (London).

Mr. M. G. GRACE, Service Department, Telecommunications Headquarters, returned unopposed.

Assistant Executive Engineers and Technical Assistants of the London Regions.

Mr. T. AUSTIN, London Telecommunications Region, returned unopposed.

Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants and Assistant Experimental Officers of the Provincial Regions. Assistant Factory Foremen of the Factories Division (Provinces).

Mr. D. W. SHARMAN, Leicester.
Mr. J. F. AMEY, Cambridge.
Mr. J. HEGGIE, Edinburgh.
Mr. R. E. CHAPMAN, Cardiff.
Mr. E. A. W. PAGE, Dundee.

Inspectors of the Provincial Regions.

Mr. B. A. B. WOOD, Basildon.
Mr. G. A. GALLAGHER, Birkenhead.
Mr. R. WILSON, Edinburgh.

Corporate Members holding non-engineering posts in the Post Office (Rule 11 A).

Mr. A. J. BARKER, Telecommunications Pay and Grading Department, Telecommunications Headquarters, returned unopposed.

Honorary Treasurer.

Mr. R. T. MAYNE, International Maritime Telecommunications Region, returned unopposed.

The constitution of the Council for the year 1973–74 will, therefore, be as follows:

Mr. J. F. P. THOMAS—Chairman.

Mr. D. WRAY—Vice-Chairman.

Mr. J. PIGGOTT—Vice-Chairman.

Mr. R. T. MAYNE—Honorary Treasurer.

Mr. H. BANHAM—Representing the Members holding posts in Bands 5 to 8 of the Senior Salary Structure of the British Post Office Headquarters Departments and of the London Regions.

Mr. A. NESS—Members in the Provincial Regions holding posts in Bands 5 to 8 of the Senior Salary Structure.

Mr. A. H. ELKINS—Members in the British Post Office Headquarters Departments holding posts in Bands 9 and 10 of the Senior Salary Structure.

Mr. K. F. MARSHALL—Members in London Regions holding posts in Bands 9 and 10 of the Senior Salary Structure.

Mr. M. W. BAYLEY—Members in Provincial Regions and of the Factories Division (Provinces) holding posts in Bands 9 and 10 of the Senior Salary Structure.

Mr. J. C. FLETCHER—Members of the British Post Office Headquarters Departments and of the Factories Division (London) listed in Rule 4 (a) with the exception of those in Groups 14 and 15.

Mr. M. S. ARMITAGE—Executive Engineers, and Assistant Regional Motor Transport Officers of the London Regions.

Mr. D. L. STEVENSON—Executive Engineers, Assistant Regional Motor Transport Officers Experimental Officers and Scientific Officers of the Provincial Regions. Factory Executive Engineers and Factory Overseers of the Factories Division (Provinces).

Mr. M. G. GRACE—Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants, Assistant Experimental Officers, Third Officers, Fourth Officers, Third Engineers, Fourth Engineers, Electrical Engineers and Assistant Technical Costs Officers of the British Post Office Headquarters Departments, and Assistant Factory Foremen of the Factories Division (London).

Mr. T. AUSTIN—Assistant Executive Engineers and Technical Assistants of the London Regions.

Mr. D. W. SHARMAN—Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants and Assistant Experimental Officers of the Provincial Regions. Assistant Factory Foremen of the Factories Division (Provinces).

Mr. M. COCKERELL—Inspectors of the British Post Office Headquarters Departments and of the London Regions.

Mr. B. A. B. WOOD—Inspectors of the Provincial Regions.

Mr. C. F. GOLDSMITH—Draughtsmen and above and Illustrators and above but below Senior Salary Structure, of the British Post Office Headquarters Departments and of the London Regions.

Mr. K. CHINNER—Draughtsmen and above, but below Senior Salary Structure, of the Provincial Regions and of the Factories Division (Provinces).

Mr. A. J. BARKER—Corporate Members holding non-Engineering posts in the British Post Office (Rule 11(A)).

Mr. E. C. OFFORD—Affiliated Members of the British Post Office Headquarters Departments and of the London Regions.

Mr. R. B. LLOYD—Affiliated Members of the Provincial Regions.

A. B. WHERRY
General Secretary

London Centre

Meetings will be held at Fleet Building, Shoe Lane, London, E.C.4., commencing at 1700 hours:

Tuesday 22 January

Introduction to stored program control for telecommunication switching networks by K. W. Stoate.

Wednesday 20 February

Development of cable repair ships, by D. N. Dick and Southampton central marine depot:—a new concept in cable handling by D. F. Malcolm.

Tuesday 2 April

Software standards for stored program control, by D. J. Roche

The annual general meeting of the Institution will precede the last meeting of the 1973–4 session to be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, commencing at 1700 hours:

Monday 13 May

The role of the Purchasing and Supply Department in telecommunications by J. M. Harper. Director. Purchasing and Supply Department.

Institution of Post Office Electrical Engineers

Local Centre Secretaries

The following is a list of Local Centre Secretaries to whom inquiries about the Institution may be addressed. It would be particularly useful if members would notify any change in their own address to the appropriate Secretary.

Centre	*Local Secretary*	*Address*
London	Mr. J. S. Gilroy	Telecommunications Headquarters, TD1, Procter House, 100–110 High Holborn, London WC1V 6UD.
Stone-Stoke	Mr. G. P. Austin	Technical Training College, Stone, Staffs ST15 0NQ.
Eastern (Colchester)	Mr. B. J. Miller	Eastern Telecommunications Region, Planning Division, St. Peter's House, St. Peter's Street, Colchester, Essex.
Eastern (Bletchley)	Mr. R. A. Hughes	General Manager's Office, 16 Paradise Street, Oxford OX1 1BA.
South Eastern	Mr. J. M. Smith	South Eastern Telecommunications Region, Planning Division, Grenville House, 52 Churchill Square, Brighton BN1 2ER.
North Eastern	Mr. H. Teale	North Eastern Telecommunications Region, Planning Division, 36–37 Park Row, Leeds LS1 1EA.
Northern	Mr. L. G. Farmer	General Manager's Office, Newcastle Telephone Area, Hadrian Telecommunications Centre, Melbourne Street, Newcastle-upon-Tyne NE1 2JQ.
Birmingham	Mr. D. F. Ashmore	General Manager's Office ED3/7 84 Newhall Street, Birmingham B3 1EA
East Midland	Mr. D. W. Sharman	General Manager's Office, 200 Charles Street, Leicester
North Western (Manchester and Liverpool)	Mr. S. Hart	North Western Telecommunication Board, Planning Division, Bridgewater House, 60 Whitworth Street, Manchester M60 1DP.
North Western (Preston)	Mr. J. W. Allison	Post Office Telephones, Clifton Road Depot, Marton, Blackpool FX4 4QD.
Wales and the Marches	Mr. R. J. Jones	Wales and the Marches Telecommunications Board, Planning and Works Division, 2 Plymouth Street, Cardiff CF1 4XZ
Scotland East	Mr. T. C. Watters	Scotland Telecommunications Board, Service Division, Canning House, 19 Canning Street, Edinburgh EH3 8TH.
Scotland West	Mr. D. M. Dickson	Telephone House, Pitt Street, Glasgow, C2.
South Western	Mr. R. G. Willis	South Western Telecommunications Region, Planning Division, Mercury House, Bond Street, Bristol BS1 3TD.
Northern Ireland	Mr. W. J. Gawley	General Manager's Office, Churchill House, Victoria Square, Belfast BT1 4BA.

A. B. Wherry
General Secretary

Post Office Press Notices

D.Sc. for Post Office Research Man

One of the world's leading authorities on speech transmission, Mr. Dennis Richards (58), head of the telephony transmission performance section of the Post Office Research Department, has been awarded the degree of Doctor of Science by the University of London.

The doctorate recognizes Mr. Richards's substantial research contribution over the past 25 years into speech transmission.

The award follows publication of his most recent work, *Telecommunication By Speech* (Butterworth, £12), already gaining recognition as a definitive work on the foundations of telephone performance, assessment, objectives and planning, and looked upon as required reading for the design and planning of telephone systems.

The book, which took all his spare time for 3½ years is based on Mr. Richards's research work into telephony and speech. Its basic objective is to provide a comprehensive guide for those who design telephone equipment and plan telephone networks. It was conceived as Mr. Richards was reviewing his research indexing system with Mr. John Bray, the Post Office's Director of Research: "It looked so much like the contents list of a book that John Bray suggested I give the idea a try."

Mr. Richards has spent his working life in the Post Office Research Department. He quickly became interested in the problems associated with speech transmission and telephony—a subject which has continued to absorb and fascinate him.

He is now regarded as a leading world figure in his sphere, and his work has contributed internationally to telecommunications. He is vice-chairman of the telephone transmission performance study group of the C.C.I.T.T. (the international body of telecommunication organizations) and is chairman of the study group's laboratory working party, concerned with the establishment and maintenance of an international reference of telecommunication standards.

Mr. Richards has played a leading part in the preparation and establishment of internationally-agreed standards for using pulse-code modulation (p.c.m.) for international communication—in particular, the setting-out of basic technical specifications and characteristics for the encoding and decoding process (p.c.m. enables many more telephone conversations to be carried on existing cables).

More recently, he has been concerned with the establishment of a revised method of quantifying "loudness ratings", the measurement of signal loss between different links in the transmission of a telephone conversation, for the British Post Office. His method is now being considered by the C.C.I.T.T. and could lead to international standardization For papers on this subject, Mr. Richards has been awarded the I.E.E. Electronics Division Premium and the Marconi Premium.

These papers, together with his new book, formed the basis of the portfolio of published work which he submitted to the University of London for his doctorate.

Mr. Richards was born in Chiswick and educated at Gunnersbury preparatory school and St. Paul's School, London, where he studied Classics. "I don't know why," he says, "I was never very good at languages."

He registered at Battersea Polytechnic (now part of the University of Surrey) as an internal student of the University of London where he gained a first-class honours B.Sc.(Eng.).

He now lives at Watford.

Monitor on Target with R.A.F.

Computer programs which will control the operation of the Royal Air Force's automatic data processing (ADP) Supply System was today accepted by the Central Computer Agency from the Post Office's National Data Processing Service. They are based on the MONITOR operating system that controls LACES (London Airport Cargo EDP Scheme). The complete package for the R.A.F.—which took 10 man-years to produce—was delivered on August 20, ten days ahead of time. N.D.P.S. will provide software support staff for at least two years after the R.A.F. scheme goes live, and maintain software and provide associated services until 1981.

The R.A.F.'s system is an on-line scheme for world-wide stock control using two ICL System 4/72 central processors and more than 550 Cossor visual display units at R.A.F. units and depots throughout the U.K. and Germany. The system handles requisitions, documents issues, and automatically produces orders to suppliers to replenish stock.

Under the contract signed this June, N.D.P.S. has modified the MONITOR operating system to take account of the R.A.F.'s hardware configuration and needs. The main differences between the new software and MONITOR are that the communication system has been completely revised, there is new database management and two new methods of file access.

Subscriptions and Back Numbers

The *Journal* is published quarterly, in April, July, October and January, at 21p per copy: 31p per copy including post and packing (£1·24 per year) (3 dollars Canada and U.S.A., per year). Back numbers will be supplied if available, price 24p (34p post paid). At present copies are available of all issues from October 1969 to date, with the exception of April 1971 which is now sold out. Copies of the October 1966, July 1967 and January 1968 issues are also still available at present. Orders, by post only, to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £2·25p including return postage, by sending the complete set of parts, with a remittance to Press Binders Ltd., 4 Iliffe Yard, London, S.E.17.

Remittances

Remittances for all items (except binding) should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Advertisements

All correspondence relating to advertisement space reservations, copy, proofs, etc., should be addressed to the Advertisement Manager, *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, EC2V 7AG.

Distribution and Sales

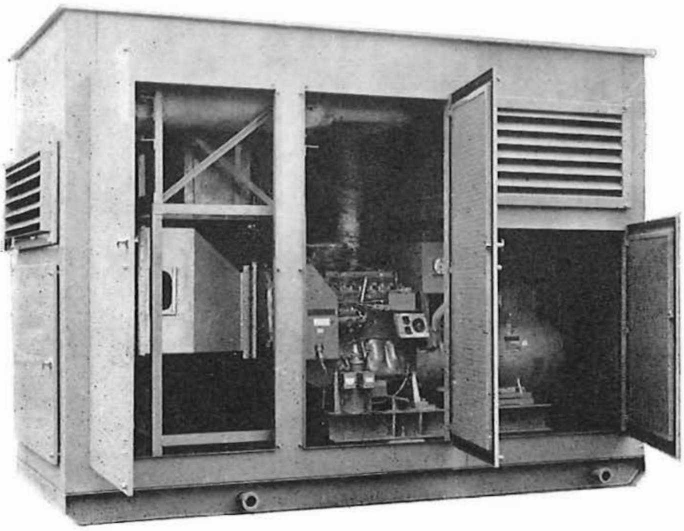
Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London, EC2V 7AG.

Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NPD/NP 9.3.4, Room S 08A, River Plate House, Finsbury Circus, London, EC2M 7LY.

Model Answers Books

Books of models answers to certain to the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.



package generating set 1/31 Mk3 ....

Post Office Type Approval Serial No. OP8 .1. 2/9

The Dupar Pelapone package generating set, approved by the Post Office for batch production for Power Plant No. 426, is now available enclosed as shown, in an all-weather steel canopy treated to reduce acoustic noise to a level of not more than 68 db A overall (noise rating curve NR70 at 2 metres distance).

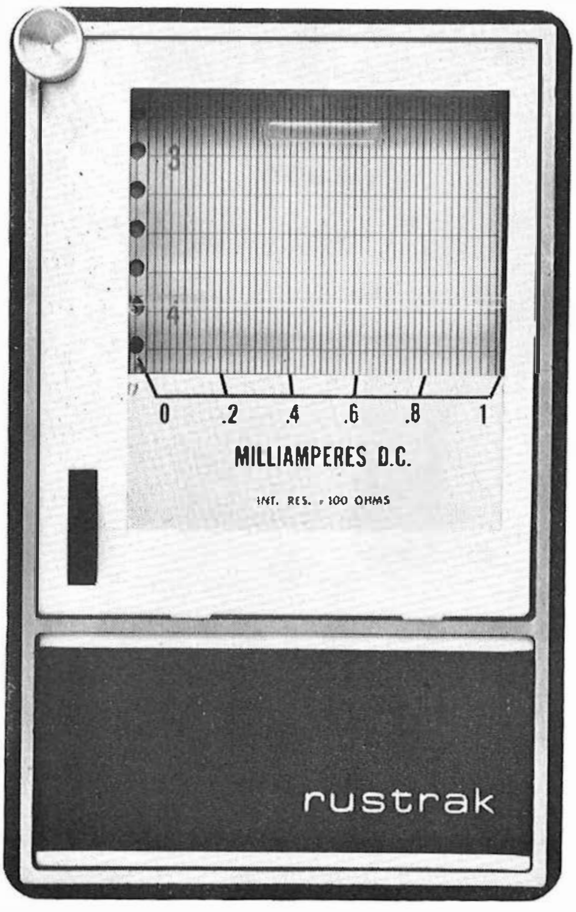
In addition to the 1/31 type set, Dupar Pelapone are able to supply canopied sets rated at 22 KW to 100 KW with noise ratings down to NR65 at two metres distance. Noise reductions better than NR65 can be achieved but costs rise steeply beyond this point. Planning is proceeding for a 340 KW canopied generating set based on the Specification for Power Plant No. 432 with dual frequency output. Our control cubicle for Power Plant 432 has been given Post Office type approval.

Available from

dupar pelapone ltd

PO Box 4 Slack Lane Derby

Tel: 0332 45436 Telex: 37 - 570



Rustrak Miniature Strip Chart Recorder

Rustrak miniature strip chart recorders are available as potentiometric or galvanometer type instruments which produce a permanent record of virtually any parameter that can be converted into an electrical signal; temperature, pressure, flow, level, watts, frequency, humidity, events and many more.

Data is recorded on pressure sensitive paper, obviating the many problems that can result from the use of ink. A wide range of motor speeds and interchangeable gearboxes is available to give over 50 chart speeds.

Of attractive design, the low-cost Rustrak recorder measures only $5\frac{5}{8}''$ high by $3\frac{5}{8}''$ wide.

Considerable savings in time and cost are made by hand from indicator readings.

Delivery of the standard instrument is 2–3 weeks and a complete advisory service on your particular recorder problems is available from our experts.

Gulton

EUROPE

Rustrak Instrument Division

BRIGHTON BN2 4JU

EHPL-

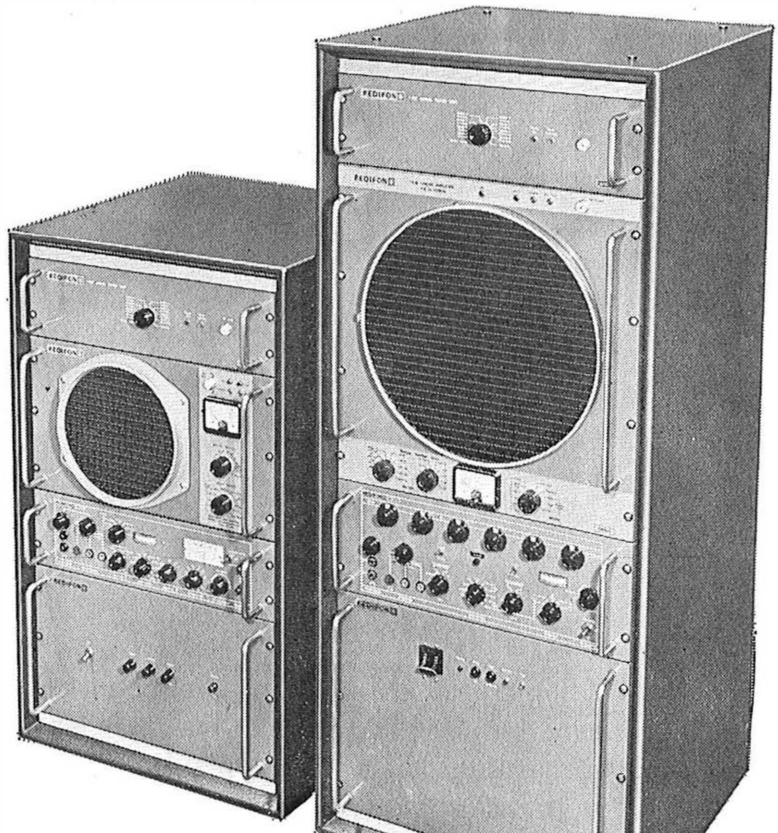
it takes over where MTBF leaves off

While others talk of MTBF, we introduce a new concept—EHPL, Estimated Half-Power Life. Our 400W and 1kW all-solid-state broadband HF linear amplifiers have over five years of it, counted in operational hours. Which, with a remarkably low Mean Time To Repair, means 99.9% up-time.

The multiple p.a. modules of these compact units, arranged in parallel for maximum reliability, ensure that even in the unlikely event of several component failures occurring together, the amplifiers go on working—long after others have stopped.

Moreover, thanks to Redifon's unique Transmit Level Control, they always deliver to any antenna—even to a badly damaged one—the maximum power that is safe, whatever the mismatch.

All of which means that the pair of transmitters in the picture represent the finest and most reliable in the world, whether in fixed, mobile or containerised stations. And they are in production and service, right now.



400W

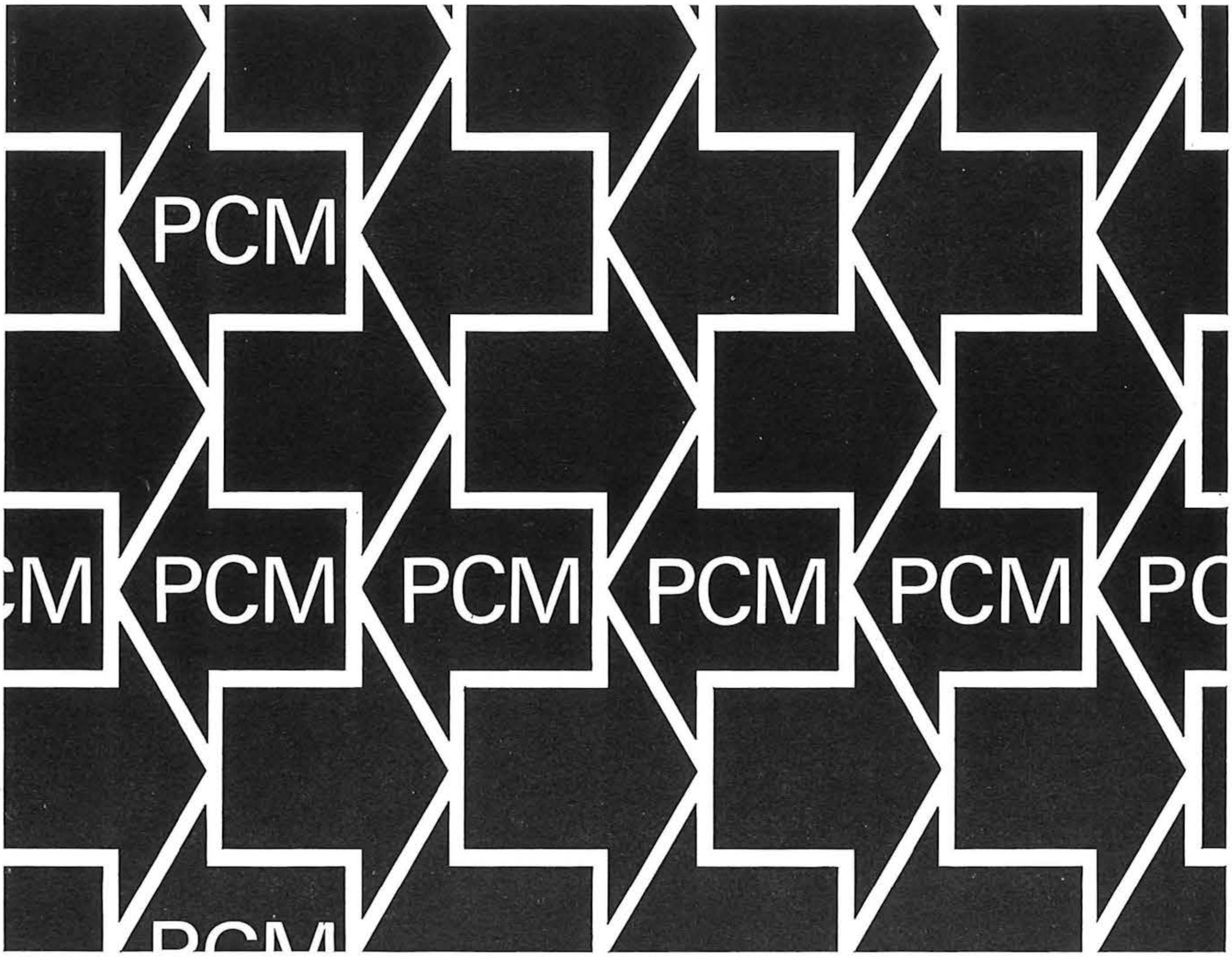
1kW

Redifon Telecommunications Ltd,
Radio Communications Division,
Broomhill Road, London, SW18 4JQ
Telephone: 01-874 7281 Telex: 264029

A member of the Rediffusion organisation

Redifon Telecommunications Limited

1973 THE QUEEN'S AWARD TO INDUSTRY



TELETTRA DIGITAL EQUIPMENTS

10 YEARS OF EXPERIENCE IN PCM PLANTS IN ITALY AND ABROAD

2 Mbit/s SYSTEMS

PCM Multiplex Terminals for 30 + 2 telephone channels (CEPT standards)
Cable Line Terminals and remote power -fed, remote-supervised Regenerative Repeaters
Line Terminals for Radio Relay Links
13 GHz Transceivers for 20 km typical hops

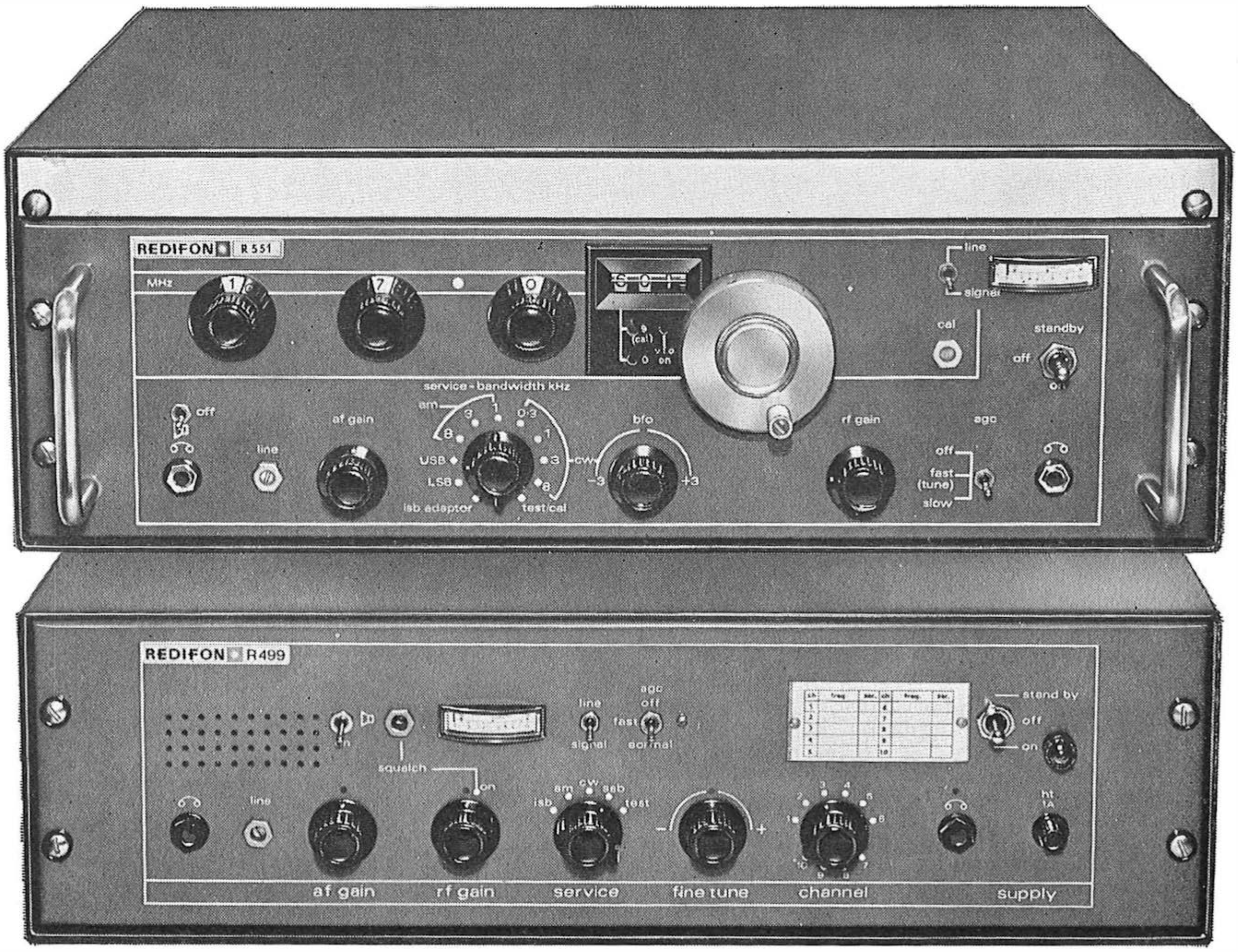
8 Mbit/s SYSTEMS

PCM Multiplex Terminals for 120 telephone channels
Cable Line Terminals and Regenerative Repeaters
13 GHz Microwave RF system with Modem, for PCM transmission up to 35 Mbit/s
Asynchronous Multiplexer for two 8 Mbit/s digital streams

Telettra S.p.A. TELEFONIA ELETTRONICA E RADIO - VIMERCATE MILAN ITALY

Superstars

HIGH-PERFORMANCE MF-HF RECEIVERS for
* P & T Stations * Civil Aviation Networks * Naval & Military Forces * Maritime Mobile Service



High-grade receiver designs with a choice of tuning wide enough to span the whole world of MF-HF communications.

Here is simply unbeatable performance. Outstanding frequency stability. Unyielding front-end protection. Unrivalled AGC. Plus exceptional dynamic range and blocking characteristics. From this great twosome:

R551 Selection of continuously variable or full frequency synthesis tuning 15kHz – 30MHz. Supplied to leading P & T authorities and adopted by the Royal Navy. Type approved by British Ministry of P & T and overseas administrations as a ship's main receiver and in use by major shipping companies.

R499 10 switched channels, 255–525kHz, 1.5–30MHz. Optional filters, BFO and carrier reinsertion to provide any or all of CW, MCW, USB, LSB, ISB and DSB modes with choice of bandwidths and remote control over more than 25km. In service with P & T organisations, in civil aviation networks and in coast stations throughout the world.

Redifon Telecommunications Limited
Radio Communications Division
Broomhill Road London SW18 4JQ
Tel: 01-874 7281 Telex: 264029

* A member of the Rediffusion organisation

Redifon Telecommunications Limited

1973 THE QUEEN'S AWARD TO INDUSTRY

INDEX TO ADVERTISERS

Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, E.C.2,
and printed in Great Britain by Unwin Brothers Limited, Old Woking, Surrey