R A Roe

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Contents

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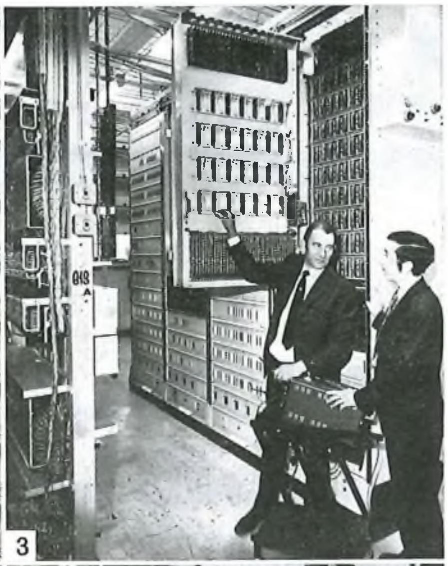
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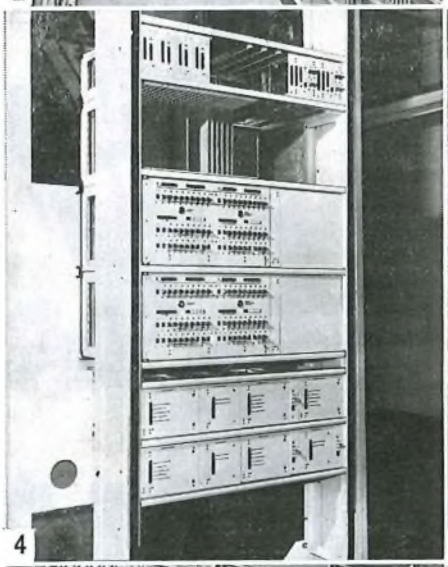
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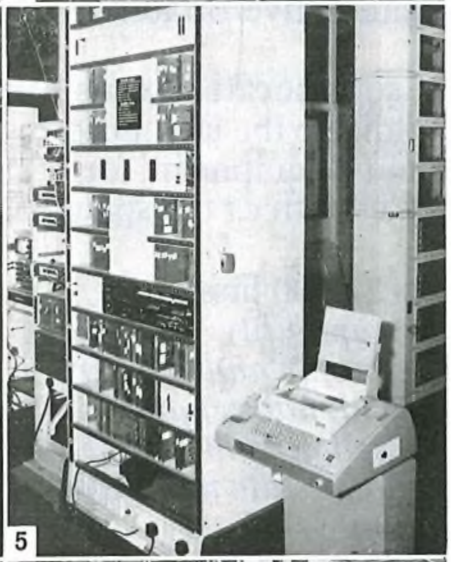
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GEC's ten-year investment in Stored Program Control techniques has an outstanding record of achievement.

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A MK II A processor was installed in the Post Office ISC at Wood Street, London, in 1969 and carried out 'phase A' test, followed by a MK IIB design for 'phase B' tests, of the new CCITT Signalling System No. 6.

A MK IIB processor has been ordered by the South African Post Office for the main control functions of a large trunk exchange.

In 1973, ten years after development started and after an 18 month evaluation of available designs, the UK Post Office has chosen an evolved GEC MK IIB processor, the MK I I BL, to fulfil the control functions for future designs of telephone exchanges for the British network.

This is one of the vitally important decisions affecting switching system concept and design that will have a major influence on telecommunications networks of the future.

ntrol and the CCITT No 6
g System

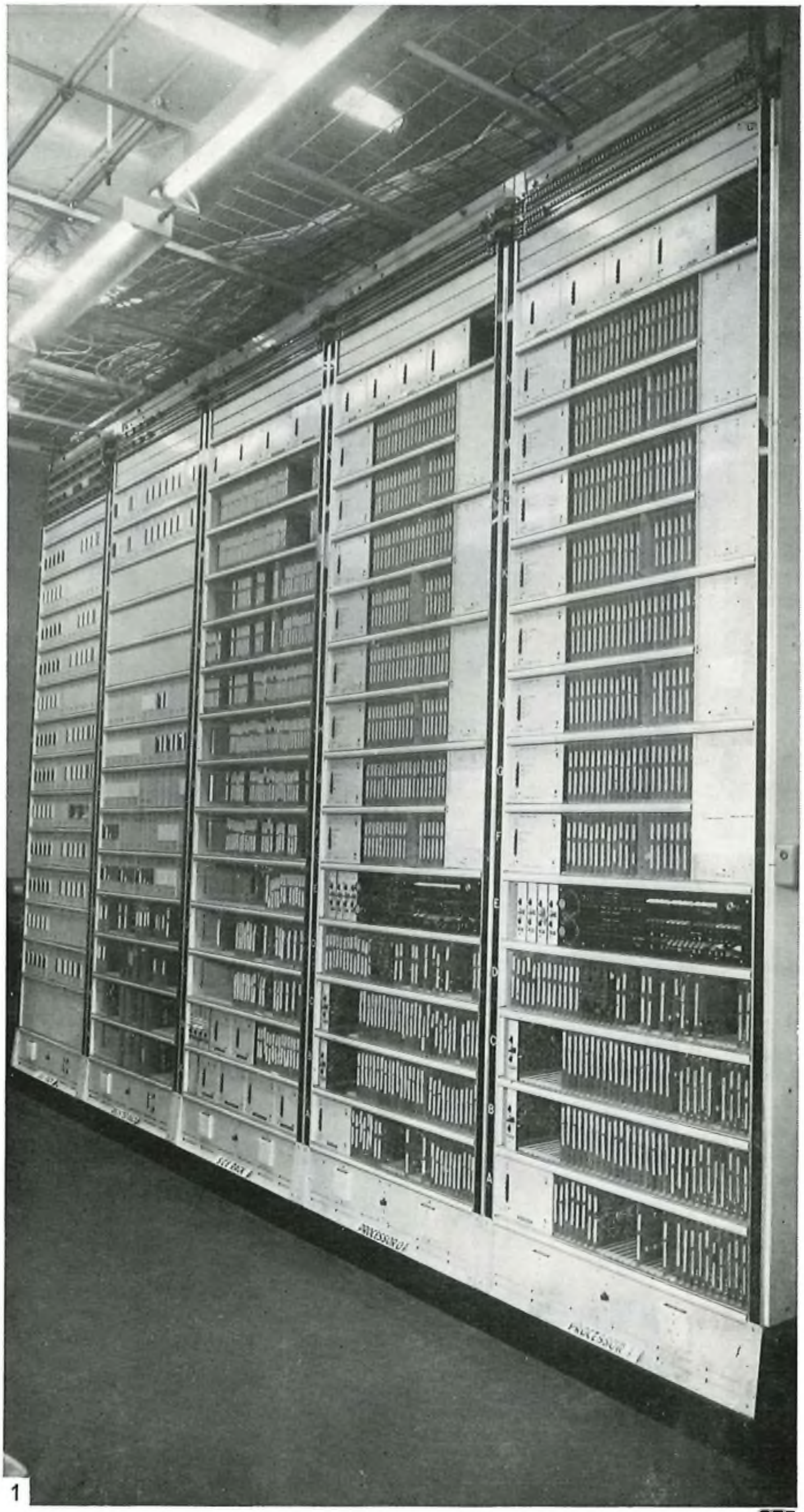
on solid foundations

GEC Stored Program Control installed in the Post Office International Switching Centre at Wood Street, London, successfully controlled the equipment that formed the U.K. terminal of the international field trial of the new and advanced CCITT Signalling System No. 6.

Under contracts awarded by the UK Post Office, GEC Telecommunications Limited developed and supplied all the control and interface equipment, including an adaptation of the GEC MK II B real-time multi-processor, for the U.K. contribution.

Key to photographs.

1. MK IIB processor installed in UK Post Office International Switching Centre, Wood Street, London.
2. MK IC – East Sector Switching Centre, London.
3. MK IC – Johannesburg Central Exchange, South Africa.
4. MK IP (two off) – next generation of MK I range,
5. MK IIA – Wood Street, London. CCITT No. 6 Trials.
6. MK IIB – Wood Street, London. CCITT No. 6 Trials.
7. MK IIB – Extended version for S. African Post Office.



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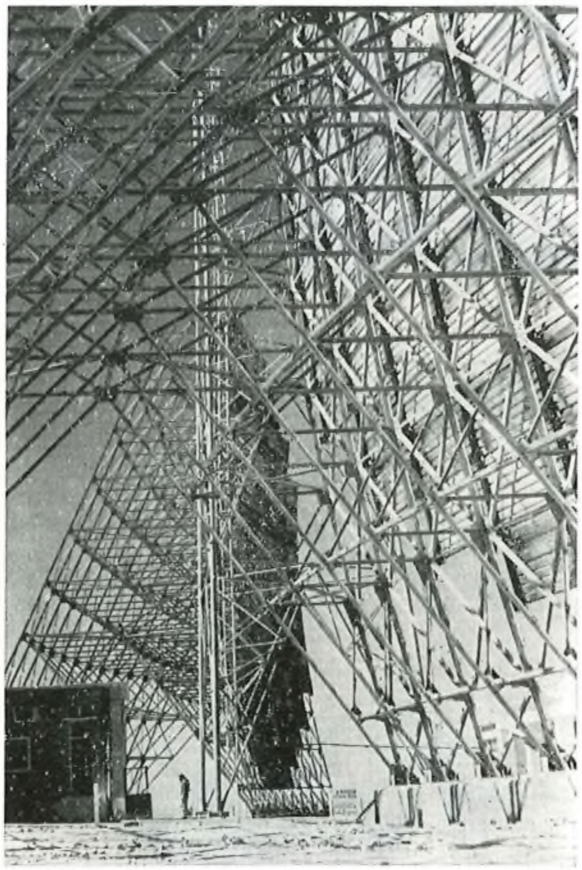

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The Post Office Electrical Engineers' Journal

A sectorization plan as the basis for long-term trunk and junction planning in the London Telecommunications Region was approved by the Post Office General Directorate at the end of 1965, and the work of detailed planning and implementation began. Now, eight years later, we have reached a significant milestone with the first sector switching centre (s.s.c.), at Ilford, due to open in a few months time. More importantly, with six s.s.c. buildings completed and the last, at Croydon, now under construction, accommodation to complete the sectorization plan and to meet growth for the next 15–20 years is assured, and final completion of the plan can be visualized with certainty.

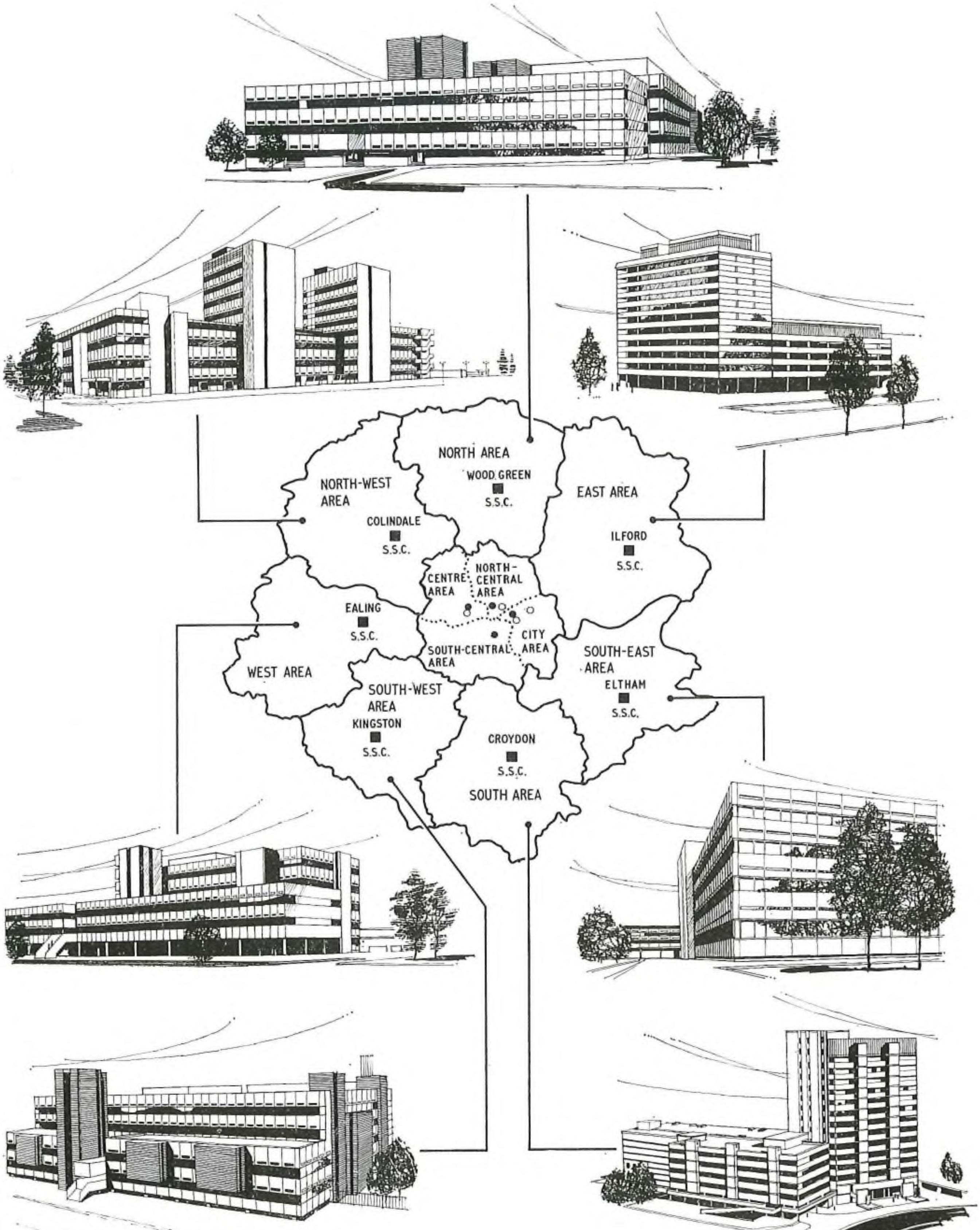
The emphasis has now moved to the plant-provision phases of this £100 million project. Much progress has been made in equipping the buildings with switching and transmission equipment and in reshaping the line network to the sector configuration. Much more detailed work remains to be done, however, before the immense task of decentralizing the switching of some 40 per cent of London's trunk traffic is completed.

A great number of staff in the Post Office and in the Telecommunications and Building Industries have been concerned with this project, and will continue to be so until final completion. For all their efforts, sincere thanks are due and freely given. A particular tribute has been earned by our colleagues in the Property Services Agency of the Department of the Environment, who purchased the sites, designed the buildings and supervised the building work.

A "seal of success" for the project will be affixed on 7 May 1974 when the Chairman of the Post Office, Sir William Ryland, C.B., will unveil a plaque at the Croydon s.s.c.—naming the building *Ryland House.*

E. W. Weaver.

Director, London Telecommunications Region



Artist's impression of s.s.c. buildings

The London Sector Plan: Background and General Principles

A. B. WHERRY, B.SC.(ENG.), C.ENG., M.I.E.E., M.B.I.M., and J. F. BIRT, A.M.B.I.M.†

U.D.C. 621.395.37 : 621.395.74

This article, which introduces the series of four in this issue of the Journal, recapitulates on the background need for the major network changes which are taking place in the London telephone system to establish a foundation sufficiently firm to cope with growth up to the year 2000. It refers to the principles involved and to the major changes which are taking place in the traffic-routing strategy throughout the network.

Planning work for sectorization commenced with the acceptance of the recommendations of the London Trunk and Junction Network Task Force in 1965. With the first sector switching centre due to open early in 1974, it is timely to review overall progress, to draw attention to the problems of implementing such a major project and to highlight some of the features of the equipment which is being used and their impact on the London telephone system as a whole.

INTRODUCTION

An unprecedented expansion and complete reshaping of the London trunk and junction network system has been necessitated by

(*a*) the sustained growth of telephone traffic in London, particularly trunk traffic,

(*b*) the need to improve transmission performance and provide for new facilities, and

(*c*) technical advances.

Four articles in this issue of the *Journal* describe plans which have been evolved to meet these requirements and give an indication of the current stage of their implementation, this article concentrating on the basic need for such a fundamental change in strategy and the consequential changes in the traffic-routing pattern.

The guidelines for routing telephone traffic originating or terminating in the London charging group (L.C.G.) up to the year 2000 were laid down in the mid-1960s following the work of a special team set up for this purpose which was known as the London Trunk and Junction Network Task Force.[1] In essence, the Task Force recommended that there would be considerable advantages in a policy of sectorization in the L.C.G.

At present, the L.C.G. includes all exchanges within about 20 km of Oxford Circus and contains over 350 director exchange units serving some 2·2-million exchange lines. Trunk traffic and indirectly-routed local traffic is now switched at 12 trunk, three toll and seven junction tandem units, all located in central London. In total, these units have an effective capacity of about 70,000 busy-hour erlangs routed over some 250,000 trunk and junction circuits. Under the sector plan, there will be a measure of decentralization, the existing central switching units (c.s.u.s) being retained, but with some change of function. However, they will be supplemented and relieved by seven new telephone switching centres, referred to as sector switching centres (s.s.c.s), located about 13–14 km from the centre of London.

The implementation of the London sector plan, involving the establishment of these major telecommunications centres in the outer Telephone Areas, represents an immense task, not only in terms of the amount of line and switching plant which has to be provided and integrated into a complete working network, but also in the acquisition of suitable sites and the erection of buildings. Some of these buildings are completed, interconnecting line plant is provided and equipment installation is well advanced, while others are in various stages of construction. The scale of these buildings, and their location in relation to each sector is shown in the illustration on the opposite page.

In essence, the sector scheme is being implemented as part of a fully viable and practicable plan for meeting growth in London up to the year 2000. In more detail, it is being adopted to

(*a*) decentralize some trunk and junction tandem switching units and thus avoid the serious site difficulties and high costs of providing accommodation for plant in central London,

(*b*) avoid the practical difficulties and cost of laying telephone cables in central London,

(*c*) decentralize auto-manual centres (a.m.c.s), to group them into larger units in order to improve operational administration, to obtain the best location taking into account staffing, technical and cost considerations, and to enable a.m.c.s in local exchange buildings to be closed down to free space for local exchange equipment,

(*d*) improve transmission performance on trunk and local calls in an economic manner and in accordance with the national transmission standards, and

(*e*) give General Managers in the outer-London areas greater control over their customers' service.

GENERAL

The L.C.G. is divided into eight parts comprising the central area and seven sectors. The central area, a circle of radius 6 km, consists of the four central Telephone Areas and will be served by the existing c.s.u.s, augmented as required. The suburban portion of the L.C.G. is divided into seven sectors whose boundaries are co-terminous with those of the outer Telephone Areas for that part which lies within the L.C.G.

The capital already involved in the scheme for the sites, buildings, initial equipment provision, ducts and cables for the seven s.s.c.s and the London main switching centre (L/m.s.c.) amounts to around £100M. The magnitude of the planning and implementing task and the strength of the arguments to decentralize in London can be judged from the forecast long-term requirements. Switched busy-hour trunk traffic to and from the L.C.G., which in early 1973 was 25,800 erlangs, is expected to rise to 226,000 erlangs by the year

† Trunk Planning Division, London Telecommunications Region.

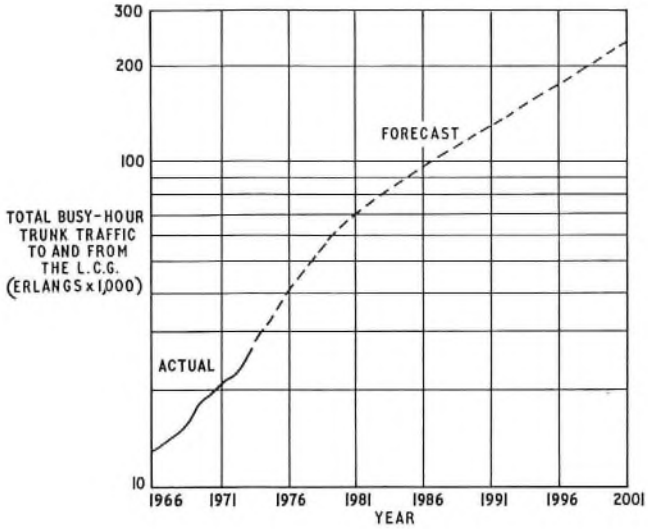


FIG. 1—Achieved and forecast total busy-hour trunk traffic to be switched in London

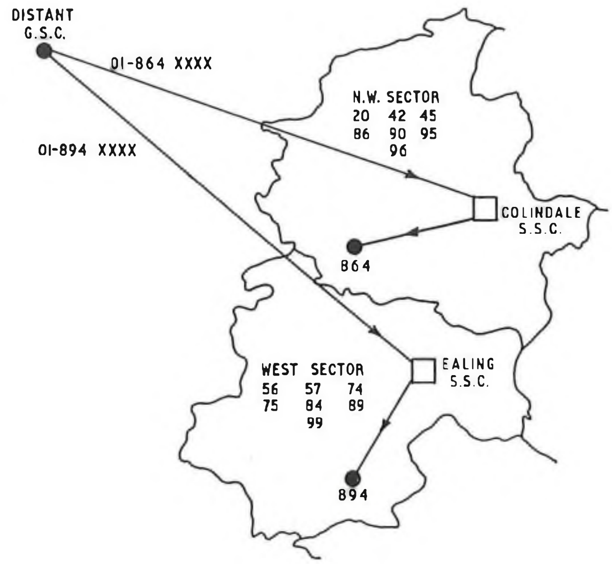


FIG. 2—Example of the routing of incoming trunk and a.c.g. calls to sectors over direct g.s.c.-s.s.c. routes

2001. A graph showing the achieved and forecast trunk traffic to and from the L.C.G. is shown in Fig. 1.

At present, with current space-division switching standards and including junction tandem traffic, 2·7-million square feet of accommodation would be required for L.C.G. trunk and junction switching units at the year 2000, of which 1·1-million square feet would be required at the s.s.c.s located in the suburbs, and 1·6-million square feet in central London. Even with the longer-term accommodation savings offered by electronic switching systems, a formidable requirement will remain and the planned decentralization makes a significant contribution to containing the demand for accommodation in central London.

SECTOR AND CENTRAL-AREA IDENTIFICATION

As a prelude to sectorization, the opportunity was taken, with the changeover to all-figure numbering in the L.C.G., to re-allocate the three-digit codes to individual director exchanges so that the appropriate sector (or the central area) could be identified by the first two digits of the local all-figure numbers. For incoming trunk and adjacent-charging-group (a.c.g.) calls to the L.C.G., which are prefixed by "01", identification of a sector or central area by the controlling register translator (r.t.) at the distant group switching centre (g.s.c.) is given by the three digits following the prefix "0", that is, by "1XX". The routing arrangements are illustrated in Fig. 2 and the codes at present allocated to the sectors are shown in Table 1.

CALL CATEGORIES FOR ROUTING PURPOSES

To understand the full impact of the plans on the L.C.G. network, it is desirable to consider, in some detail, the new routing strategies. For this purpose, it is convenient to consider the L.C.G. telephone traffic under five separate types of call, namely: inland trunk calls, international calls, local a.c.g. calls, local within-L.C.G. calls and operator-handled calls.

Routing of Inland Trunk Calls

At present, all s.t.d. traffic to and from the L.C.G. is controlled and switched at c.s.u.s. Collectively, the c.s.u.s may be considered analogous to a large g.s.c. with routes to and from other g.s.c.s outside the L.C.G. Under the sector plan, the c.s.u.s will perform the same functions for incoming and outgoing calls, but only for those director exchanges located in the 6 km radius circle. The s.s.c.s will serve the director exchanges in their respective sectors. Each s.s.c. is also closely analogous to an independent g.s.c. with routes to and from other g.s.c.s as justified, and with routes to and from all the local director exchanges within the sector served.

The principal effect of the sector plan on the London trunk service will be to decentralize some trunk exchange and transmission equipment and to shorten the junctions between director and trunk exchanges, thereby facilitating the use of cheaper, light-gauge cables. It will also divide the originating and terminating traffic into a larger number of parts, resulting in some increase in the total number of trunk circuits required. In addition, because proportionately less traffic is carried over direct routes, it will involve an additional link circuit and switching centre on more calls than would be required with large central units.

In formulating the sector plan, it was accepted that the quality of service given to customers must not be worsened relative to a centralized scheme and it should preferably be improved. In particular, the plan should facilitate, and in no

TABLE 1

Sector Code Allocation

Sector	Code
Four Central General Managers' Areas	21, 22, 23, 24, 25, 26, 27, 28, 32, 35, 37, 38, 40, 43, 48, 49, 58, 60, 62, 63, 70, 72, 73, 79, 82, 83, 92, 93
North sector	34, 36, 44, 80, 88
East sector	47, 50, 51, 52, 53, 55, 59, 98
South sector	64, 65, 66, 67, 68, 76, 77
South-East sector	29, 30, 31, 46, 69, 85
South-West sector	33, 39, 54, 78, 87, 94, 97
West sector	56, 57, 74, 75, 84, 89, 99
North-West sector	20, 42, 45, 86, 90, 95, 96

way prejudice, the progressive long-term improvement of the London trunk service. Quality of service includes reliability (freedom from plant defects), speed and accuracy of setting up calls, and transmission performance, particularly speech volume, and also freedom from interfering noise. It was concluded that, for L.C.G. trunk traffic, there would be considerable disadvantages in the further extensive use of routing via intermediate provincial centres, namely s.s.c./c.s.u.–g.s.c.–g.s.c. A practical method of avoiding such routing is to provide a 4-wire switching centre in London and it was decided that this should be employed at the outset when s.s.c.s were opened. The initial implications of switching indirectly via the 4-wire switching unit, known as L/m.s.c., or sometimes as a special-purpose unit, can be summarized as follows.

(*a*) The s.s.c./c.s.u.–g.s.c.–g.s.c. routing would necessitate augmenting Strowger equipment at many provincial trunk switching centres, but routing via the L/m.s.c. presents the opportunity of providing a modern trunk network and switching equipment for this block of traffic and making a significant contribution to the improvement of the quality of trunk service.

(*b*) Routing via the 4-wire switched L/m.s.c. gives improved speech transmission, whereas routing via 2-wire switched provincial centres would result in a worsening of transmission performance on some calls.

(*c*) As the L/m.s.c. has the whole of the L.C.G. as a collecting and distributing area and serves all s.s.c.s and c.s.u.s within it, it justifies direct routes to and from a large number of provincial g.s.c.s. It, therefore, minimizes the amount of traffic which needs to be routed via the national transit network, that is, via provincial transit switching centres (t.s.c.s), and the additional costs which would thereby be incurred.

(*d*) Routing via the L/m.s.c. improves signalling arrangements and gives greater reliability by virtue of the repeat-attempt facility. In contrast, s.s.c./c.s.u.–g.s.c.–g.s.c. routing employs two separate voice-frequency signalling circuits in tandem with mainly Strowger equipment between them without repeat-attempt facilities.

(*e*) Routing via the L/m.s.c. will produce administrative advantages since it results in a simple rational routing scheme which can be easily controlled.

(*f*) The use of the L/m.s.c. with its common-control switching system should enable the more economic provision of new facilities and services as required.

Therefore, the inland trunk-routing principles adopted under the London sector plan differ from the present national trunk-routing plan in that all indirectly-routed traffic, including overflow traffic from high-usage direct routes*, will be routed via the L/m.s.c. Unlike provincial m.s.c.s, the L/m.s.c. will only carry traffic to and from the L.C.G. and there will be no through routing between centres outside the L.C.G. This policy also applies to the c.s.u.s and s.s.c.s, thus containing the London switching requirements and permitting a simpler equipment arrangement with separate outgoing and incoming units. The routing principles which will ultimately apply to all inland trunk routing to and from the L.C.G. are shown in Fig. 3. The choice of routing is selected as follows:

First Choice

Traffic is routed over direct high-usage or fully-provided routes between c.s.u.s or s.s.c.s and provincial g.s.c.s, where such routes are justified.

Second Choice

Traffic is routed between c.s.u.s or s.s.c.s and provincial g.s.c.s via the L/m.s.c. where direct high-usage or fully-provided routes are justified between the L/m.s.c. and provincial g.s.c.s. L/m.s.c. direct fully-provided routes will also carry any overflow traffic from the c.s.u./s.s.c. direct high-usage routes.

Third Choice

Traffic is routed via the L/m.s.c. and provincial t.s.c.s, where direct routing is not available. These routings will also carry overflow from L/m.s.c. direct high-usage routes, but it has been arranged that overflow traffic from one high-usage route is always directed to a fully-provided route and not offered to a second high-usage route.

Fig 4 illustrates the way in which inland trunk traffic is distributed between the L.C.G. and objective g.s.c.s. Over 80 per cent of the total originating trunk traffic is to less than 100 g.s.c.s. This is approximately the proportion of the total trunk traffic which will be carried over direct routes from c.s.u.s and s.s.c.s. Whilst each trunk unit has a unique traffic pattern dictated by the catchment area that it serves and the relative community of interest with distant centres, similar distribution curves still apply. In the middle range of traffic levels, direct routes to these g.s.c.s from the L/m.s.c. are justified on the total L.C.G. traffic. At the other end of the range, less than 1 per cent of the total trunk traffic is to about 100 objective g.s.c.s. This small quantity of traffic will be routed via the L/m.s.c. and the transit network to and from these g.s.c.s.

A separate study showed there was no economic advantage

* High-usage routes are deliberately under-provided with circuits to increase circuit loading, and the traffic not carried on the direct route is automatically alternatively routed. Routes provided to normal grade-of-service provision standards are referred to as fully-provided.

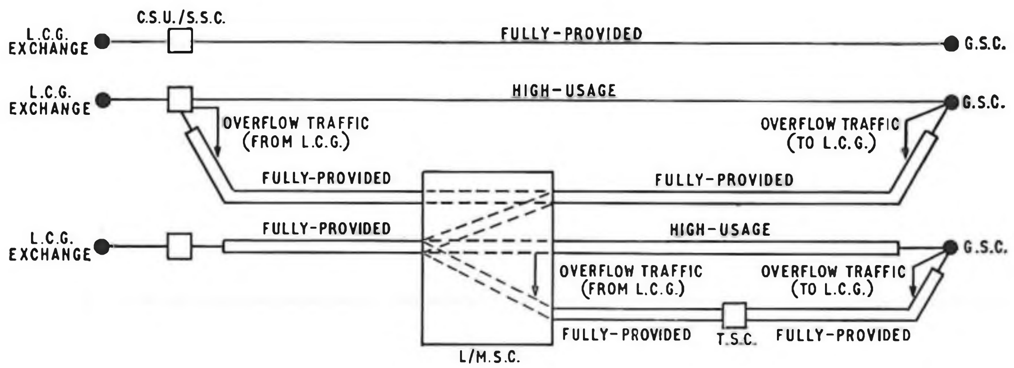


FIG. 3—Routing of inland trunk traffic

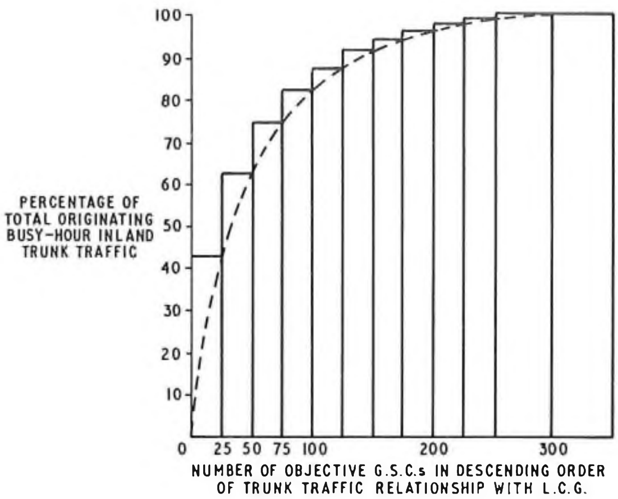


FIG. 4—Inland trunk traffic distribution from the L.C.G.

in using partially-divided main network routes compared with fully-divided routes, and, with the incoming and outgoing trunk units physically separated, there were some practical disadvantages in having a both-way component. All the L.C.G. main network routes are, therefore, unidirectional.

The economic determination of direct-route provision for s.s.c.s and c.s.u.s is further simplified by the decision to route all indirectly-routed traffic via the L/m.s.c. The costs for alternative routing are, therefore, sensibly constant, consisting of a short link between the s.s.c. or c.s.u. and the L/m.s.c., 4-wire switching at the L/m.s.c., and a trunk circuit which is almost equivalent in length to the direct route under consideration. Investigations have shown that high-usage direct routes can be justified in these conditions when the level of traffic exceeds about 3 erlangs. The cost advantage is still present for traffic levels of 10 erlangs and above, but tends to diminish as the route size increases, until there is little economic advantage compared with a fully-provided route. The cost curves for direct routes of 80 km, 160 km, 320 km and 640 km length are of similar form and, for practical purposes, the lower limit is set at 3 erlangs for all distances. To limit the size of high-usage routes and minimize the effect of breakdowns, it is considered desirable to change to a fully-provided route when the level of traffic reaches 10 erlangs. The 3–10 erlang range exploits the economic advantage of direct high-usage routes, yet limits the amount of overflow traffic to more manageable levels. The actual provision of circuits on the direct high-usage routes is on the basis of one circuit per erlang of traffic, or part thereof, offered to the route.

The standards for route justification for L/m.s.c. routes interfacing with the transit network are those used in the transit network namely, direct high-usage routes for traffic levels from 3–5 erlangs and direct fully-provided routes at traffic levels above 5 erlangs, fully-provided routes being mandatory between all other m.s.c.s.

The application of fixed criteria for the justification of direct routes allows the growth of indirectly-routed traffic to be offset by the provision of direct routes. The total of indirectly-routed traffic via the L/m.s.c. to or from any one c.s.u. or s.s.c., with one exception, falls within the range of 230–300 erlangs. This range occurs due to differences in size and the pattern of inland trunk traffic distribution between units, both s.s.c.s and c.s.u.s. Variations in the quantity of traffic via the L/m.s.c. links tend to be smoothed at the L/m.s.c. when the indirect traffic from all of the s.s.c.s and c.s.u.s is combined. At the c.s.u.s/s.s.c.s, the proportion of indirectly-routed traffic reduces as the traffic handled grows because the higher levels of traffic justify more direct routes and the demand on the L/m.s.c. is thus contained.

As the sector plan is introduced, traffic to the incoming L/m.s.c. unit will rise to a maximum, but after completion of the plan, it will remain fairly constant. This is because indirectly-routed traffic to the s.s.c.s will remain steady and since incoming direct routes to central London trunk units will be provided as justified on the total traffic to the central area independent of the capacity of individual c.s.u.s, the traffic to the central areas via the L/m.s.c. will also remain steady. In the outgoing direction, indirectly-routed traffic from the s.s.c.s will remain steady, but each new outgoing c.s.u. introduced will fragment traffic and require its own network of direct routes. Thus, the outgoing L/m.s.c. will grow in steps each time a new outgoing c.s.u. is brought into service. The size of future outgoing c.s.u.s has, therefore, an important bearing on the L/m.s.c. requirements. If developments increase the average unit size and lead to a reduction in the number of outgoing c.s.u.s, the growth of the L/m.s.c. would be reduced. However, the outgoing L/m.s.c. has been designed to permit expansion on the basis of currently-planned c.s.u. design sizes and sufficient accommodation is earmarked for foreseeable requirements up to the year 2001.

As a means of fine control to secure the maximum exploitation of the L/m.s.c. equipment without overload, the criteria for direct-route justification could be adjusted from time to time if traffic via the L/m.s.c. tended to peak.

Routing of International Calls

At present, access to the international switching centres (i.s.c.s) for subscriber-dialled calls is obtained via the central outgoing r.t. units, and access to the international control centres (i.c.c.s) for operator assistance on international calls from the L.C.G. is obtained via the central Toll A unit, or over direct routes.

Access to i.s.c.s from local director exchanges located in the sectors will be obtained via the appropriate s.s.c. outgoing trunk unit, and to i.c.c.s via the appropriate s.s.c. junction tandem unit. International access from local director exchanges located in the central area will continue as at present.

Incoming international access to the L.C.G. will be obtained over direct routes from the i.s.c.s to c.s.u.s for the central area and to s.s.c.s for the sectors, supplemented by direct routes to director exchanges where justified. Exceptionally, as the equipment at Faraday i.s.c. does not permit the segregation of traffic to the sectors, its access to director exchanges in the sectors via Faraday I/C Trunks inland switching unit will be retained. Faraday I/C Trunks will, therefore, continue to give access to all director exchanges in the L.C.G. even after the s.s.c.s are open and until Faraday i.s.c. is closed.

Routing of Calls between Director Exchanges and Exchanges in Adjacent Charging Groups

As each s.s.c. opens, indirectly-routed traffic between director exchanges in the sector and exchanges in a.c.g.s will be transferred from the central Toll A, Toll B and Maxwell units to the s.s.c. After all the s.s.c.s are open, the central toll units and Maxwell will only handle traffic to and from the 6 km radius circle with the possible exception of a small quantity from fringe-type r.t.s to sector exchanges.

The s.s.c. trunk units will handle both trunk and a.c.g. traffic, a.c.g. calls which are national-number dialled from director exchanges located in the sectors being routed over the normal s.t.d. route, and those that are local-code dialled being routed over a separate route.

Direct fully-provided routes between every g.s.c. serving charging groups adjacent to the L.C.G. and every s.s.c. are mandatory so that no a.c.g. calls to or from s.s.c.s will need to be switched in central London. Other auxiliary direct fully-provided routes will be provided as justified. The routing of calls between sectors and a.c.g. exchanges is shown in Fig. 5.

The provision of common-control equipment (for example, TXK1 and TXE2) at local exchanges in the a.c.g.s and electronic, stored-program control, (s.p.c.) directors in the L.C.G., makes it possible to discriminate at the local exchange on national-number-dialled calls and to route traffic over direct routes where this is the more economic arrangement. How best to exploit these new facilities and the future long-term use of the toll and Maxwell units is being studied in the light of these developments.

A simple type of r.t. is employed at some local exchanges on the fringe of London. These examine national-number-dialled calls, discriminate between four categories of calls, and route accordingly. These four routings are

(*a*) to L.C.G. director exchanges over a direct route,

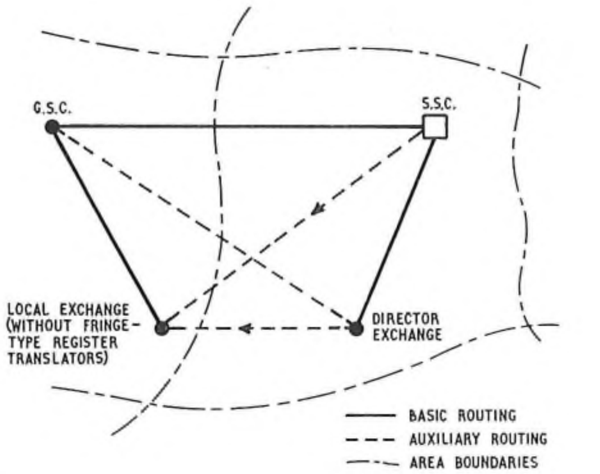


FIG. 5—Routing of calls between sectors and exchanges in a.c.g.s

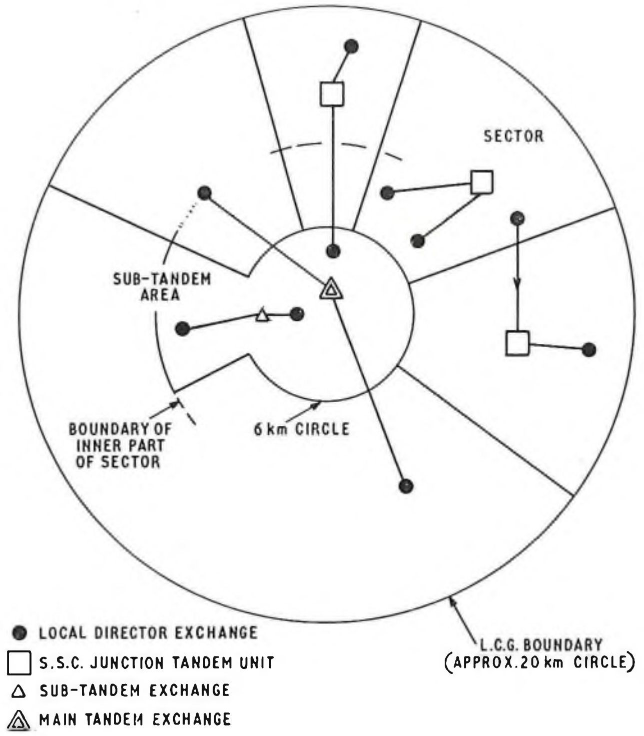


FIG. 6—Within-L.C.G. routing under the sector plan

(*b*) to L.C.G. director exchanges via the g.s.c. over the local route,

(*c*) to the remaining L.C.G. director exchanges via the central Toll B or Maxwell units, and

(*d*) s.t.d. calls to exchanges outside the L.C.G. via the g.s.c. over the s.t.d. route.

Modification of these fringe r.t.s to allow routing via s.s.c.s is practicable and consideration is being given to the use of this facility. In particular, the best timing for any routing changes is being examined having regard to the phased opening of the s.s.c.s and the disposition of existing equipment and line plant.

Routing of Calls within the L.C.G.

Local calls within the L.C.G. which are not carried over direct routes between director exchanges are indirectly routed via junction tandem exchanges. At present, there are two types, main tandems and sub-tandems. Exchanges within the L.C.G. are provided with routes to and from the two main tandem exchanges, Holborn and Museum. Each director exchange has a single outgoing route usually divided between the two exchanges. These main tandem routes carry all calls not carried on direct routes or via the five sub-tandem exchanges. The sub-tandem exchanges provide relief for the main tandem exchanges. Each sub-tandem exchange serves a limited part of the L.C.G. In general, the sub-tandem service areas stop at the 16 km radius circle. The sub-tandem areas overlap and, within an area in central London of approximately 4 km radius from the centre, known as the common sub-tandem (c.s.t.) area, routes are provided to and from each sub-tandem exchange and all local director units within the c.s.t. area. The primary purpose of a sub-tandem exchange is to provide access in both directions between exchanges within, and outside, the c.s.t. area. Additionally, to provide further relief to the main tandems, some routing via sub-tandems has been permitted between exchanges outside the c.s.t. area.

With the s.s.c.s available as locations for junction tandem units, a considerable amount of traffic between central London and the outer parts of London will be routed via the s.s.c. instead of via a sub-tandem exchange. This gives flexibility when planning plant provision and enables the existing congested sub-tandem exchanges to be relieved, so giving a measure of decentralization. Junction tandem units, located at s.s.c.s, will also be well placed to switch indirectly-routed calls between exchanges in sectors and adjacent sectors.

The principal junction tandem routings under sectorization are shown in Fig. 6 and the arrangements are summarized below.

(*a*) Seven new junction tandem exchanges, one at each s.s.c., will be provided to relieve existing main and sub-tandem exchanges.

(*b*) The existing five sub-tandem exchanges will be retained, but the areas they serve will be reduced and overlapping between areas eliminated except for the 6 km radius circle. Within the 6 km radius circle, routes will be provided between all the local director exchanges and all sub-tandem exchanges and s.s.c. junction tandem units. Thus, the c.s.t. area will be enlarged and become co-terminous with the 6 km radius circle.

(*c*) The main tandem exchange function will be retained, but routes to and from local director exchanges within the 6 km radius circle will be ceased. The principal main-tandem function will be to switch indirectly-routed traffic between exchanges in non-adjacent sectors.

Under the sector routing plan, the areas served by the various junction tandem exchanges are clearly defined and no alternative choice of junction tandem exchange is given for any particular routing. Table 2 shows the appropriate junction tandem for most within-L.C.G. indirectly-routed calls.

TABLE 2

Junction Tandem for Main Categories of Indirectly-Routed Sector within-L.C.G. Calls

Type of Indirectly-Routed Call	Junction Tandem Switching point
Between director exchanges in same sector	Home s.s.c.
Between director exchanges in adjacent sectors	Foreign s.s.c.
Between director exchanges in non-adjacent sectors	Main tandem
Between director exchanges in same sub-tandem area, but not in same or adjacent sectors	Home sub-tandem
Between director exchanges in outer part of sector and 6 km radius circle	Home s.s.c.

Note: The proposals for routing traffic within the 6 km radius circle have been omitted for simplicity.

Auto-manual Centres and the Routing of Operator-handled Calls

A study was made of the L.C.G. a.m.c. requirements in relation to the sector plan for routing and switching traffic. Concerning the disposition of a.m.c.s throughout the L.C.G., the following factors were taken into account:

(*a*) The number of relatively-small a.m.c.s which, because of their size, suffered management and service disadvantages, needed to be reduced.

(*b*) There was a rapidly growing need to move a.m.c.s to allow local exchange equipment to be extended into the vacated accommodation.

(*c*) On technical, transmission, and cost grounds, new a.m.c.s of current design should be housed with, or in close proximity to, the trunk switching centre. This requirement may be relaxed when the next generation of a.m.c.s become available with the facility for working from a remote location.

(*d*) Where possible, a.m.c.s should be located in the Telephone Area served so that a General Manager has direct control over the operator service given to his subscribers.

Because of the relevance of these factors to a.m.c. size and siting it was decided to establish at the s.s.c.s one, two or possibly three a.m.c.s, each being a separate managerial unit of 96 positions. The initial provision will be Cordless Switchboard Systems (C.S.S.) No. 1 type, but advantage has been taken of the separate s.p.c. equipment which is being provided for operator use at s.s.c.s to introduce a range of new facilities to help the operator. These additional facilities will also be available to a.m.c.s, both cordless and sleeve-control type, located in the sector. Similar facilities are planned to be provided at a new c.s.u. at North Paddington which is planned to be in service in early 1979 and will serve all a.m.c.s located in central London.[2]

The sector plan requires that trunk and a.c.g. traffic proper to be switched by the s.s.c.s, including operator traffic, should be routed via the s.s.c. Although the operator traffic is only a small proportion of the whole, it is nevertheless significant in total. Distant operators will dial or key via the originating r.t.s as, otherwise, it would be necessary to refer to the visible index file on every London call to identify the appropriate sector and routing. Access via the originating r.t.s will also permit operator calls to be routed over high-usage routes and via the L/m.s.c. where this is the appropriate routing.

Operator trunk and a.c.g. calls, originating in the L.C.G., will be routed via the appropriate s.s.c. or c.s.u. as with subscriber-dialled traffic, although, exceptionally, for special trunk service facilities, central-London operators will have access to the new c.s.u. at North Paddington.

Operator within-L.C.G. calls are usually routed via the associated local-exchange director unit, but the a.m.c.s located at the s.s.c.s will have access to the s.s.c. junction tandem unit where special operator routing will be available to extend access to the whole of the L.C.G.

TRANSMISSION IMPROVEMENTS

In devising the sector plan for routing L.C.G. traffic, special attention was paid to the need to improve transmission standards. Because of the distance between the c.s.u.s and director exchanges in the suburbs, and the difficulty and cost of up-grading the plant, the 4·5 dB standard had been relaxed to 6·0 dB for the L.C.G. The general shortening of these routes which is a feature of the decentralization proposals, and the provision of new line plant or the rearrangement of existing line plant to meet the change in requirements under the sector plan, has, however, provided the opportunity to bring these routes within the national standard maximum loss of 4·5 dB. The provision of 4-wire switching equipment at the L/m.s.c. for indirectly-routed trunk traffic will also permit a significant improvement in transmission performance to be made. The transmission loss from s.s.c. or c.s.u. to the distant g.s.c.s will be 3 dB compared with the 6 dB line loss plus the intermediate switching loss at present encountered on calls routed via intermediate g.s.c.s. Thus, the loss on calls between s.s.c.s or c.s.u.s and distant g.s.c.s will be 3 dB whether the call is routed over a single direct route or indirectly via the L/m.s.c. and, hence, over a direct route to the distant g.s.c. More than 99 per cent of the L.C.G. inland trunk traffic will be routed in this way. The remaining 1 per cent will be routed via the transit network where the s.s.c./c.s.u. to distant g.s.c. transmission loss will be 7 dB.

Local a.c.g. and L.C.G. calls will also benefit from the new routing plan as all new routes will conform to the improved standards which will considerably reduce transmission losses on much of the indirectly-routed traffic.

The transmission loss standards for various circuits are given in Table 3. These losses represent maximum permissible circuit losses and, where amplification is necessary, the standard will be improved to 3 dB wherever possible.

TABLE 3

Transmission Loss Standards

Type of Circuit	Transmission Loss (dB)
Direct junctions between local exchanges	6
Junctions to and from tandem exchanges	4·5
Trunk-junctions	4·5

CONCLUSIONS

The sector plan enables London to keep pace with traffic growth and meet future demand in a manner which would not have been possible by continuing the process of trying to provide more and more units in central London. Not only will it result in a very significant reduction in accommodation requirements in central London where sites are expensive and correctly-located sites are impossible to find, but it also reduces the number of staff which would otherwise be required in the central areas. It will afford a better service to the customer with greater reliability and improved transmission on indirectly-routed calls and provides a high degree of assurance that the system can be developed economically into the longer term.

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The London Sector Plan: Planning for Sector Switching Centres

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U.D.C. 621.395.37:621.395.74:621.395.344.6:621.395.722

This article describes the planning work involved in providing the London sector switching centres (s.s.c.s) as part of the London sectorization project. The difficulties of site acquisition and construction are discussed, and problems arising from the installation of a proprietary switching system are mentioned. The task of providing the line plant necessary to serve the s.s.c.s is described and the design and layout considerations and the basis of provision of the crossbar switching equipment used at the s.s.c.s are discussed. The method of procurement is mentioned. The article outlines the function of the local crossbar tandem exchanges contained within each s.s.c. and how they fit into the revised plan for indirectly routing traffic between exchanges within the London Director Area.

INTRODUCTION

The implementation of the London sector plan constitutes a planning task of very considerable magnitude, involving the acquisition of sites and the provision of buildings, line plant and equipment, on a large scale. This article outlines the progress which has been made and some of the problems which have been encountered in the various fields of activity, and mentions, briefly, the principal design and dimensioning aspects of the crossbar switching system which has been adopted for the sector switching centres (s.s.c.s).

INITIAL PLANNING

Detailed planning work commenced soon after the London sector plan had been formulated in 1965. It was recognized from the outset that the demands on resources, both within and without the British Post Office (B.P.O.), and the time scales for provision were such that the plan could only be introduced gradually, with the work on the seven s.s.c.s being spread over a number of years. An initial planning program was drawn up with target dates for the s.s.c.s to be brought into service at approximately 4-monthly intervals, starting in 1971/72. In the event, the complexity and magnitude of the task has made the achievement of the original target dates unrealizable. There have been site-acquisition difficulties and unforeseen delays in building construction and equipment installation. The result has been that the program has been delayed and extended. However, since detailed planning started, trunk-traffic achievement and forecast levels have reduced from those envisaged in 1965 so that the original plan is largely intact although displaced in time.

Table 1 shows the current target dates for bringing the s.s.c.s into service, including those for the London main switching centre (L/m.s.c.). The L/m.s.c. is accommodated in the major communications building in central London which houses the Rampart outgoing trunk unit, auto-manual centres (a.m.c.s), and local exchanges.

At an early stage in the planning, special project committees were set up in the London Telecommunications Region, one for each s.s.c., under the chairmanship of the Deputy Director/Controller (Planning). The committees meet regularly to progress each project from the site and building stages to the

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TABLE 1

Current Target Dates for Introduction of Service at Switching Centres

Switching Centre	Date for Introduction of Service	
	Incoming Trunk Unit	Outgoing Trunk Unit
Ilford (East) s.s.c.	Mid-1974	Mid-1974
London/m.s.c.	Mid-1974	Mid-1974
Colindale (North-West) s.s.c.	1975	1975
Ealing (West) s.s.c.	1975	1975
Wood Green (North) s.s.c.	1975	1975
Kingston (South-West) s.s.c.	1976	1976
Eltham (South-East) s.s.c.	1976	1976
Croydon (South) s.s.c.	1980	1980

point where the equipment is commissioned. Representatives from the Property Services Agency (P.S.A.) of the Department of the Environment, the nominated architects, Purchasing and Supply Department, Regional Headquarters Planning and Works Divisions, and the Areas, attend as appropriate. Control of each project is assisted by use of a critical-path network.

SYSTEM SIZE

The initial and ultimate equipment quantities provided at each of the s.s.c.s vary according to the requirements of the individual sectors. However, even the smallest combination of incoming trunk, outgoing trunk, and tandem switching units, together with associated repeater station and power equipment, comprise an installation of considerable size. By way of illustration, the main parameters for Ilford (East) s.s.c. are shown in Table 2.

Fig. 1 shows the growth of London-charging-group (L.C.G.) trunk and international-subscriber dialled (i.s.d.) traffic over the next few years and illustrates how demand on the central switching units (c.s.u.s) is progressively reduced as the outgoing trunk units at the s.s.c.s are brought into service.

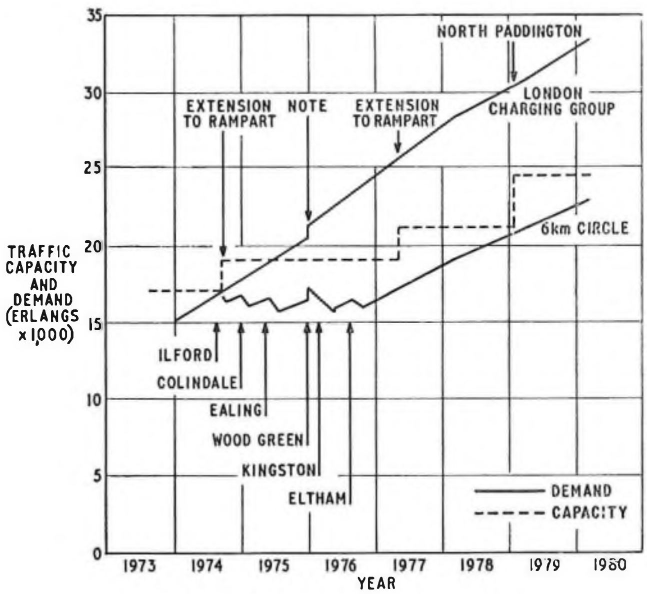
SITES AND BUILDINGS

The need to obtain seven sites, some 13–14 km from the centre of London, of sufficient size to provide for a total of about 1·1 million square feet of accommodation, presented the B.P.O. and P.S.A. with a challenge of some consequence. Not only had the sites to be found and acquired in suitable locations, but seven major buildings had to be planned to satisfy both operational requirements and those of the Local authority. Inevitably this task took longer than was originally anticipated. In fact, in the most difficult case (Croydon), it was not until 1972 that it was possible to obtain a site, that is, some seven years after the decision to go ahead. Sites had to be selected as near as possible to the theoretical centre of the sector concerned, and full regard had to be paid to the existing duct and main-cable routes. The need for the subsequent extension of the initial building to meet long-term needs was also taken into account.

TABLE 2

Initial and Ultimate Equipment Requirements for Ilford (East) Sector Switching Centre

Type of Equipment		Requirements	
		Initial	Ultimate (approx.)
Switching Units	Outgoing Trunk (incoming access junctions)	3,286 circuits 2,150 erlangs	11,000 circuits 7,300 erlangs
	Incoming Trunk (incoming main-network circuits)	3,448 circuits 2,320 erlangs	12,500 circuits 8,200 erlangs
	Tandem	2,900 circuits 1,600 erlangs	5,500 circuits 3,300 erlangs
Trans-mission Systems	24-Channel Pulse-Code-Modulation Systems	91 systems	28,000 circuits
	4 MHz Frequency-Division-Multiplex Systems	9	To be determined
Power Plant	Power Units 225	2	2
	Power Units 130	1	1
	2,000-amp Rectifiers (per Power Unit 225)	3	6
	Batteries 16/14,200 ampere-hour	2	3
	Batteries 16/14,600 ampere-hour	2	3
	Stand-by Generators (500 kW each)	4	4



Note: 6 km radius circle operator traffic via register translators included in demand from end-1975

FIG. 1—Growth of L.C.G. traffic capacity and demand

Apart from their sheer size, for example, some 262,000 square feet of floor area for Ilford (East) s.s.c., the constructional design of the s.s.c.s did not present more than the usual problems expected from any major building project in a large city. However, the largely residential environment of some of the s.s.c.s did present some difficulty in getting planning permission and one case was subjected to a full public enquiry. Planning constraints were also imposed by the local authorities in the form of specified plot ratios and by their insistence on certain elevations, building finishes and site-access arrangements. In most cases, full development on the site at the outset was a planning condition, thus demanding the provision of maximum capacity with a building design period of some 20 years.

Significant delays in actual building work due to difficulties in the construction industry has meant that the s.s.c.s have each taken some 50 per cent longer to build than forecast, and the sectorization program has had to be extended accordingly.

Regarding space utilization and deployment of equipment, care is necessary to

(*a*) satisfy initial needs without jeopardizing the efficient addition of equipment on extensions with little disturbance to other plant, and

(*b*) maintain the functional disposition of equipment.

The need to provide the equivalent of intermediate distribution frames and to allow for their subsequent growth to satisfy ultimate needs has imposed further constraints.

Because the trunk and tandem units at each s.s.c. are being installed concurrently, the equipment contractor has to deploy a large number of men, typically 300, throughout the building during peak periods. With an appropriate proportion of B.P.O. staff engaged on testing, supervisory, and other ancillary work, the provision of staff welfare facilities becomes a major task. Whenever possible, the total planned welfare arrangements have been made available, and supplemented by temporary messing facilities housed in that part of the accommodation not initially required for equipment.

The method for procuring the crossbar switching equipment has had some effect in delaying the availability of detailed information on equipment layouts. In turn, this has resulted in difficulties in formulating ventilation requirements and has also meant, on early s.s.c.s, that cable holes between floors have had to be cut at an undesirably late stage in the building operations. However, experience has now been gained to enable the disposition of the principal equipment items to be established earlier in the planning process, in sufficient time to allow design of ventilating plant to commence, and the majority of the cable holes to be located at an earlier stage of building construction.

LINES

It was anticipated that one of the most complicated problems in establishing seven new s.s.c.s, that is, 21 new switching units, would be their interconnexion with the established London cable and duct network. Experience has confirmed this view, but, nevertheless, the substantial network of new junction cables for the early sectors has been provided on time and many existing cables have been intercepted into the s.s.c.s.

Where new cables are provided to meet audio-circuit requirements, standard 0·63 mm loaded cable pairs are being used. To guard against breakdown, two separate cable routes are used from the s.s.c. to each sector exchange, with one or two exceptions, where existing cable pairs are being used to provide the alternative routing.

Care has been taken to achieve the efficient re-use of those cables into the centre of London which will become spare as each sector is opened. For example, line plant between sector exchanges and the outgoing c.s.u. currently serving them will be re-arranged to provide and augment routes between local and tandem exchanges in central London and those in the outer areas. To facilitate this re-arrangement, the s.s.c. trunk units will be brought into service several months before each tandem unit, and some cables will then be intercepted into the s.s.c. The scale of this exercise can be judged from Table 3 which shows the cables provided for Ilford s.s.c.

Fig. 2 is a block diagram of the 4 MHz coaxial-cable systems which are being provided for the s.s.c.s. In some cases, routes are connected to a main repeater station in central London while, in others, main coaxial-cable routes are intercepted at the s.s.c.s, for example, the Basildon route to central London is intercepted at Ilford s.s.c. The 4 MHz systems may be regarded as links to enable the s.s.c.s to connect with the

TABLE 3

Cable Provision for Ilford (East) Sector Switching Centre

Type of Cable or System	Number Provided or Intercepted
12-pair 1·2/4·4 mm coaxial cable plus interstice pairs	Two cables provided One cable intercepted
Audio cables 1,040 pair/0·63 mm	Ten cables provided wholly for circuits to East Area exchanges Four cables provided for circuits partly to East Area exchanges and partly to adjacent area exchanges
Pulse-code-modulation systems	91 × 24-channel systems provided
4 MHz frequency-division-multiplex systems	Nine systems provided

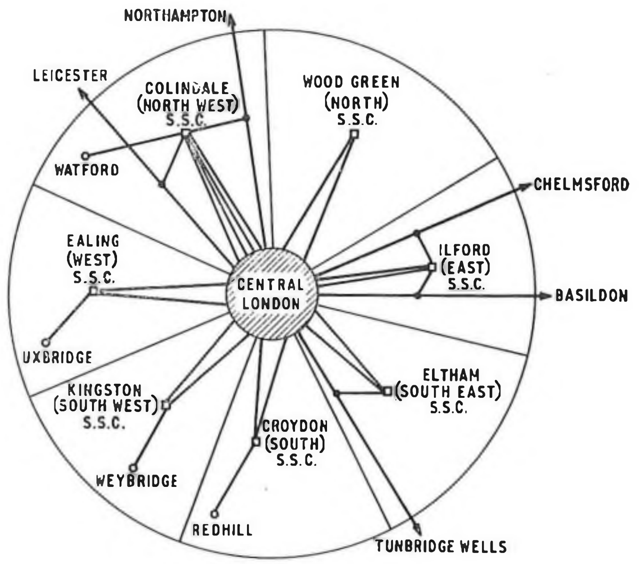


FIG. 2—Block diagram of 4 MHz coaxial systems provided for the s.s.c.s.

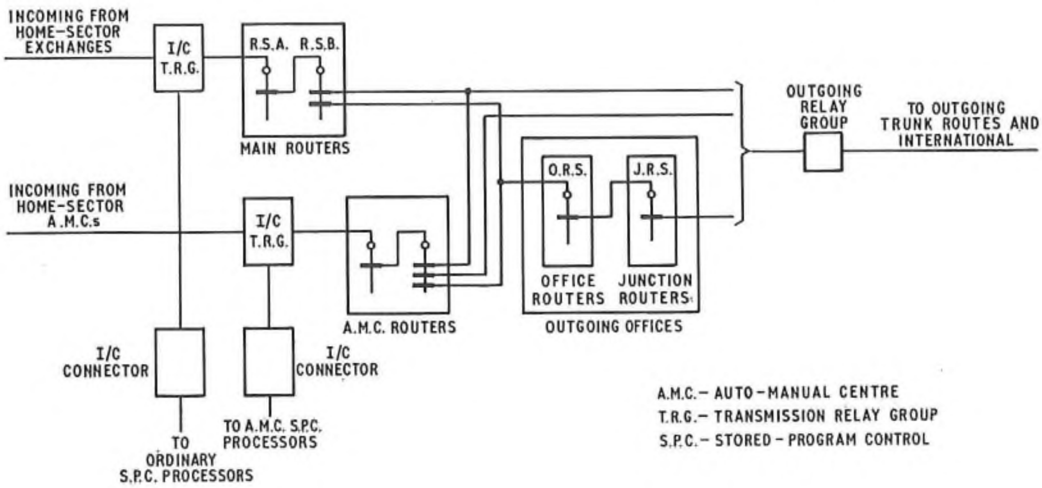


FIG. 3—Typical s.s.c. outgoing trunk unit

main coaxial-cable network, and are combined with other systems to form hypergroup blocks.

Pulse-code-modulation (p.c.m.) systems have been planned for trunk routes from the s.s.c.s to the adjacent charging groups (a.c.g.) and also, in the later sectors to be opened, for adjacent-sector tandem routes.

The introduction of the sector plan provides the opportunity for upgrading L.C.G. transmission standards to meet those set down in the 1960 National Transmission Plan. However, it will take some time to effect improvements throughout the L.C.G. because of the size and complexity of the network. Nevertheless, the junctions between an s.s.c. tandem unit and the local director exchanges served by it, and trunk-junctions between the s.s.c. trunk units and their director exchanges will be provided to the new standards at the outset. The transmission standards adopted are listed in another article[1] and are maximum permissible circuit losses. Where, exceptionally, amplification is necessary, the standard will be improved to 3 dB by using 2-wire negative-impedance amplifiers in preference to the more expensive 2-wire hybrid type. Direct junctions, and tandem junctions not affected by sectorization, will be made to conform with the new transmission plan by loading or by the provision of amplifiers.

In addition to the provision of interconnecting cables in the main and junction network within London and throughout the country, much work also needs to be done at distant exchanges. Corresponding equipment provision and translation changes are required at distant group switching centres (g.s.c.s) and L.C.G. director units to enable routes to and from the s.s.c.s to be brought into service, and very considerable network-planning problems have to be overcome to ensure a smooth changeover to the new units. Even so, equipment installation delays at some distant g.s.c.s may force a small quantity of traffic to remain on existing routings (via the incoming central-London units) for a short period after Ilford s.s.c. is brought into service.

PROCUREMENT OF SWITCHING EQUIPMENT

The s.s.c. exchange contract work is being undertaken by Messrs G.E.C. and P.T.L., while Messrs S.T.C. have supplied and installed the equipment for the L/m.s.c. The TXK1 switching equipment, to be used at all the s.s.c.s, is based on the P.T.L. 5005A crossbar system. The switching matrix is controlled by electronic stored-program control (s.p.c.) equipment developed for this application by G.E.C.

Because of the proprietary nature of the equipment, the Regional contract order gives details of traffic data, trunk and junction circuit quantities, ancillary equipment and signalling requirements in the form of a standard specification. This is translated into a crossbar system design by the equipment contractor, who submits design and dimensioning details to the B.P.O. for approval. Concurrently, preliminary equipment layouts are discussed with the contractor. The B.P.O. ensures that

(*a*) the required overall grade of service is met,

(*b*) the equipment layout utilizes the available accommodation in the most economical way, bearing in mind the requirements for subsequent extensions,

(*c*) the trunking design is sufficiently flexible to permit circuit and route changes to be effected during the design period without incurring unacceptable service interruption, and

(*d*) the exchange can, in due course, be extended with the minimum disturbance, consistent with economy of equipment provision.

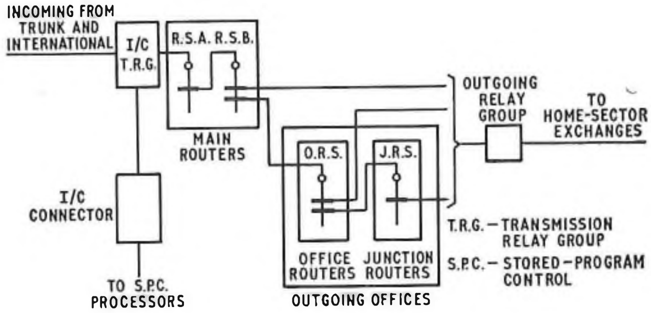


FIG. 4—Typical s.s.c. incoming trunk unit

Sufficient experience has now been acquired within the B.P.O. to enable exchange design to be undertaken and it is probable that some of the later s.s.c. extensions will be dimensioned and specified by the Regional design groups in the usual way.

TRUNKING AND EQUIPMENT PROVISION

The TXK4 system provided at the L/m.s.c. is the same as that used nationally for switching in the transit network, and has been described elsewhere[2]. The following brief description of the main features of trunking and equipment provision is confined to the TXK1 system employed at the s.s.c.s. A description of the system operation is contained in another article.[3]

Typical trunking diagrams of outgoing and incoming trunk units, and of the tandem unit, as provided at each s.s.c., are shown in Figs. 3, 4 and 5.

The switching matrix can consist of three main switching stages which are provided and interconnected according to the traffic to be carried and the number of incoming and outgoing routes between which access is required. The basic switchblock of the first stage is contained in the main router and may be considered as a single stage comprising two component stages of crossbar switches, route switch A and route switch B (r.s.A and r.s.B), interconnected in a fixed pattern to provide 160 r.s.A inlets and 560 r.s.B outlets.

Main routers can carry up to 100 erlangs of traffic each, but somewhat less for the tandem units. They are provided in an exchange in sufficient quantity to terminate incoming trunk and junction routes and to provide access to outgoing routes and subsequent switching stages. In the case of the incoming trunk unit, the r.s.A inlets terminate incoming trunk circuits, via appropriate line-signalling register-access relay-groups. In the outgoing trunk unit, the r.s.A inlets terminate 0-level junctions, via metering-over-junction type register-access relay-sets. The circuits comprising a given route are spread over the inlets of several main routers to ensure even loading of the r.s.A–r.s.B links and to afford security.

The second-stage switchblock is the office-router stage. An office router consists of up to 12 office-router crossbar switches providing a total of 336 outlets. The third-stage switchblock is the junction-router stage, consisting of up to 20 junction-router switches giving access to 560 outlets. Office-router and junction-router stages together form outgoing offices which, when fully equipped with 20 office routers and 15 junction routers, are capable of carrying up to 1,000 erlangs of traffic. In practice, only partially-equipped offices are provided initially, to allow for even and convenient extension as the exchange grows.

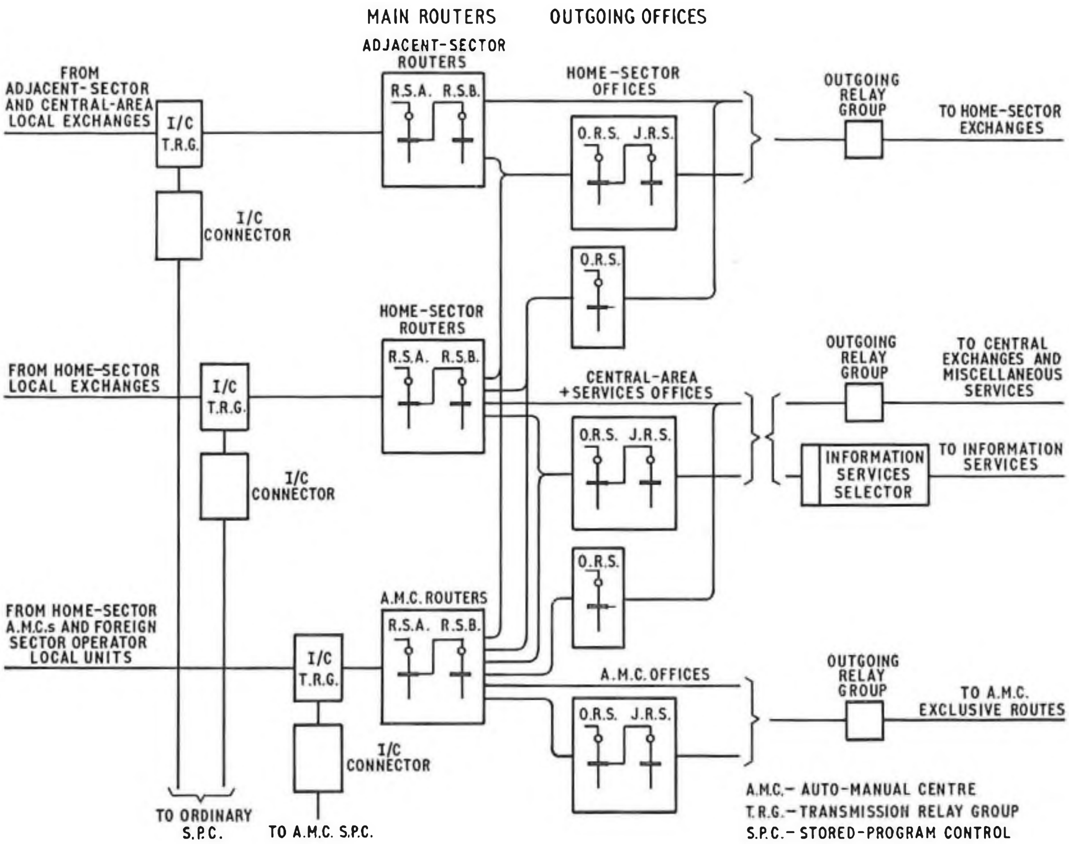


FIG. 5—Typical s.s.c. tandem unit

Outgoing routes are trunked from the first, second, or third stage according to the size of the route and the traffic carried. Large routes are taken from the first stage (that is, r.s.B outlets) or from the second stage (office-router outlets), while small routes are trunked from the junction-router stage. This principle is analogous to that employed in Strowger practice, where larger routes are trunked from early stages to avoid uneconomic provision of switching capacity. However, some r.s.B outlets must be allocated for access to office routers, and some office-router outlets must be allocated for access to junction routers.

Where access to a large number of routes is required, typically 150–200 in the case of the outgoing trunk unit, there will be more offices, but, where access is required to a comparatively small number of large routes, as for the incoming trunk unit, fewer offices will be provided.

The number of r.s.B outlets allocated to give access to a route trunked from the main-router stage, or to the next switching stage, can vary from 30 to 60 depending on the distribution of traffic and routes between the stages, but a typical value is 40. If, therefore, a large route of, say, 200 circuits is trunked from the r.s.B outlets, any one main router will have access to only some of the circuits, that is, it will not have full availability. The grading, or interconnexion pattern, is arranged on the basis that any one circuit appears at several main routers. Thus, as an example, if there are 20 main routers, each with 40 outlets to the route of 200 circuits, there will be a total number of 800 outlets to be graded to 200 circuits, and each circuit will be given four appearances on the outlets of the first switching stage.

The office router, like the main router, can have access to an outgoing route or a subsequent switching stage. In either case, similar limited-availability conditions apply. Each office router has access to all junction routers in the same office.

The junction-router is a single switching stage (unlike the r.s.A–r.s.B matrix in the main router) and the inlets of any single switch in the stage cannot see the outlets of any other. Each junction-router switch must see at least one circuit in a given outgoing route, and so, every circuit in the route must appear on several switches, since the size of route trunked from this stage is small.

As far as the provision of equipment is concerned, terminating relay-sets, in the form of incoming transmission relay groups and outgoing relay groups, are supplied on a per-circuit basis according to the signalling system appropriate to a route. The register connectors and s.p.c. portion of a unit are dimensioned on similar lines to a conventional Strowger register-translator installation, making due allowance for security requirements in the provision of s.p.c. processors.

For the main switchblocks, the provision of equipment to meet the required grade of service (g.o.s.) is not specified on a stage-by-stage basis, as for Strowger systems, because the switching stages are interdependent and the trunking configuration and link loading at one stage reflect into others. The only effective way of determining the g.o.s. afforded by a given configuration is by means of a computer.

The g.o.s. is specified as an overall value in the form L plus x, where L is a figure selected according to the type of unit, that is, outgoing, incoming or tandem and x is a figure determined by the B.P.O. from traffic tables used to dimension outgoing routes.

Specified values of L are

outgoing trunk unit—0·006

incoming trunk unit—0·004

tandem unit —0·006

The g.o.s. referred to is that obtaining under normal conditions. With 10 per cent overload, the g.o.s. should not worsen by more than four times the normal figure and under 20 per cent overload conditions, not more than ten times.

When considering a design, a preliminary configuration is drawn up and traffic distributed in accordance with specified typical parameters of link loading and availability, taking into account

(*a*) the loading of main routers,

(*b*) the number of outlets per main router allocated for access to office routers, junction routers, or outgoing routes,

(*c*) the loading of office routers,

(*d*) the number of outlets per office router allocated for access to junction routers or outgoing routes,

(*e*) the loading of junction-route switches,

(*f*) the traffic carried by outgoing routes,

(*g*) the number of circuits in outgoing routes, and

(*h*) the number of junction-router outlets allocated per outgoing circuit.

Consideration must also be given to the loading of the office and junction markers, since, in some circumstances, the capacity of a switching stage is limited by the traffic-carrying capacity of this equipment.

The g.o.s. of the preliminary design is then determined and adjustments made if the standards are not met, or if the provision is too generous after making due allowance for flexibility to cater for growth. The modified design is then checked, and the process continued until the optimum design is achieved. The dimensioning procedure is thus, to some extent, an iterative process.

TANDEM SWITCHING

The L.C.G. local network is at present served by two main and five sub-tandem exchanges for switching indirectly-routed traffic between local director exchanges, that is, traffic between any two local exchanges which does not justify the provision of a direct route on economic grounds. The additional tandem switching capacity represented by the introduction of tandem units at the s.s.c.s will be used to relieve the existing tandem and sub-tandem exchanges and cater for growth of the network. The introduction of these additional switching nodes has afforded an opportunity to review tandem-routing arrangements and to formulate a new routing plan. Although the established principle of routing through not more than one tandem exchange will be preserved, the routing rules have been simplified by nominating a specific tandem exchange to carry the indirect traffic between two particular exchanges. This obviates the need to determine which of several possible tandem exchanges should be used. Critical traffic values have been derived, with the aid of a computer, to indicate the level of traffic between any two director exchanges at which a direct route should be provided. Even with the more straightforward routing rules, however, the implementation of the new routing plan is a complex process, depending on

(*a*) the timing of the introduction of the s.s.c. tandem units,

(*b*) the forecast traffic growth between director exchanges,

(*c*) the forecast exhaustion dates of existing tandem exchanges, and

(*d*) the disposition and economic utilization of line plant.

For these reasons, the control of tandem routing has been vested in a single group at Regional Headquarters, until sectorization is complete, to ensure the economic utilization of existing line plant and switching equipment in the local network as a whole, and to determine the optimum timing for the provision of additional capacity.

AUTO-MANUAL CENTRES

As part of the forward plan for a.m.c.s in the L.C.G., a class B, Cordless Switchboard System (C.S.S.) No. 1A a.m.c. is being provided with each of the first five s.s.c.s, working in conjunction with the TXK1 crossbar equipment. Typically, East s.s.c. will have two 96-position switchrooms. Some of the exchanges in the sector may remain parented on existing sleeve-control a.m.c.s, but the remainder will be parented on the s.s.c. a.m.c. The provision of the s.s.c. a.m.c. may facilitate the closure of one or more of the class C a.m.c.s, thus effecting operating, maintenance, and other economies. With the exception of certain exclusive operator routes, the s.s.c. a.m.c. shares the outgoing trunk and tandem routes with subscribers, via the crossbar switching equipment. Special a.m.c. routers are provided, however, to allow fast keysending from the C.S.S. positions and also to provide the class C a.m.c.s with access to operator service facilities. The additional facilities, which the introduction of the s.s.c.s has made possible, were described in a previous article.[4]

OUTSTATION WORK

A considerable amount of work is involved at local director exchanges in preparation for bringing an s.s.c. into service. Not only have new routes and terminations to be provided at the exchanges in the sector, but routes to and from central London have to be re-arranged. As an indication of the degree of work and co-ordination required, Table 4 lists the approximate number of circuit advices which were issued for the opening date requirements at East s.s.c.

TABLE 4

Approximate Number of Circuit Advices Issued in Connexion with Opening of Ilford (East) Sector Switching Centre

Type of Circuit		Number of Circuit Advices Issued
Outgoing Trunk Unit	0-level access junctions	2,000
	Outgoing trunks	2,700
Incoming Trunk Unit	Incoming trunks	3,000
	Outgoing junctions	3,200
Tandem Unit	Incoming junctions	3,400
	Outgoing junctions	3,600
Total for all circuits		17,900

ACCEPTANCE TESTING

The s.s.c.s are being installed on a joint B.P.O./contractor testing basis, with various sections of a switching unit being proved for functional operation as installation proceeds.

Final acceptance testing is carried out using B.P.O. call-generating equipment. Simultaneous calls are originated from a number of senders and connected via suitable interface equipment into incoming exchange terminations selected to give an even distribution over the input side of the unit. The calls are directed to answering equipment connected to the output side. Each call failure is held and traced, and details are recorded. Single located faults which cause several failures are counted as single analyzed failures. The decision to accept or reject an installation is based on a statistical sampling plan.

CONCLUSION

The implementation of the London sector plan, with its accompanying national network repercussions, represents probably the largest project so far undertaken by one Region. The normal planning problems have been magnified by the size and the complexity of the London trunk and junction network, and by the fact that a new switching system is being used. Site acquisition, building construction and equipment installation have all been subject to delays which have forced the s.s.c. program to be deferred, but its principal features and staged provision have remained largely intact. The opening of the first s.s.c. in 1974 will mark the beginning of the final implementation process.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of many colleagues in the preparation of this article.

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The London Sector Plan: Design of the Switching System

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U.D.C. 621.395.37:621.395.74:621.395.344.6

Sector switching centres (s.s.c.s) represent a significant milestone towards the increasing use of digital computer techniques to perform telephone-exchange control functions. This article contains a detailed description of the s.s.c. exchange system.

INTRODUCTION

This article describes the apparatus and the call-setting-up procedure used in a sector switching centre (s.s.c.). The reasons for establishing s.s.c.s are detailed in other articles.[1,2]

The main function of an s.s.c. is to switch trunk and tandem traffic for the group of director exchanges within a sector of a director area. The sequence of operations needed to establish a call through the exchange equipment of the s.s.c. preserves the general structure of a 5005A crossbar exchange, designated TXK1 by the British Post Office (B.P.O.).[3,4] However, the common-control apparatus in the s.s.c. includes a G.E.C. Mark Ic processor which utilizes stored-program-control (s.p.c.) techniques to provide the facilities which, in a conventional TXK1 exchange, would be provided by electromechanical registers, coders and translators.

The s.s.c. is divided into three units corresponding to the destination of the traffic switched by the s.s.c. These exchange units, known as *incoming trunk*, *outgoing trunk* and *tandem*, are functionally independent. Operator access to the trunk and local network is gained from the outgoing trunk and tandem units respectively, so giving the five sources of traffic to three destination groups as shown in Fig. 1. Register-translator facilities, required for each of the five sources, are provided by one of the five different processor programs.

SWITCHBLOCK

The trunking of a typical s.s.c. unit is shown in Fig. 2 which represents an outgoing trunk unit. The main difference between this and TXK1 local-exchange trunking is that there are no subscribers' lines terminating at the s.s.c., so that a distributor stage is not required. The switchblock matrix consists of up to four stages of crossbar switches which are interconnected using link-trunking principles. The trunking principles for the s.s.c. are detailed in another article,[2] but a brief description is given here.

Each incoming trunk or junction is terminated on a relay-set known as the transmission relay group (t.r.g.) and this, in turn, is connected directly to an inlet of a register connector and an inlet of a route switch A (r.s.A). The r.s.A, the first of the four switching stages, uses the 10 × 26 crossbar switch, whereas the second, third and fourth stages, known as route switch B (r.s.B), office route switch (o.r.s.), and junction route switch (j.r.s.) respectively, use the 10 × 28 crossbar switch. Outgoing junctions or trunk circuits can be connected to outlets of any of the last three switching stages, an outgoing relay group being associated with each circuit.

The first of the two exchange building blocks, the main router, can consist of 16 r.s.As and 20 r.s.Bs, and be offered 100 erlangs of incoming traffic. One outlet on each r.s.B is used for terminating a test circuit, so that only 25 outlets carry traffic. The outlets of two r.s.As are connected together, thus giving 200 links to the r.s.Bs. The 20 r.s.Bs are divided into two groups of ten, the groups being known as r.s.B X and r.s.B Y.

The main call-setting-up apparatus, the router control, is capable of handling approximately 57 erlangs of incoming traffic. A main router uses two router controls, designated router control X and router control Y. The 100-erlang equipment block consists of up to 160 t.r.g.s, 16 r.s.As, 20 r.s.Bs, the pair of router controls and eight register connectors.

The second and subsequent stages of the switchblock are divided into two halves known as X- and Y-trunking. This division is built into the design of the trunking to provide the following two security-enhancing features:

(*a*) Router control X and router control Y are used to set up paths through X- and Y-trunking respectively. If, owing to congestion, router control X access tests busy, router control Y can be accessed instead, and vice versa. Should one router control fail, the partner router control will continue to serve the main router, although the resultant congestion, especially

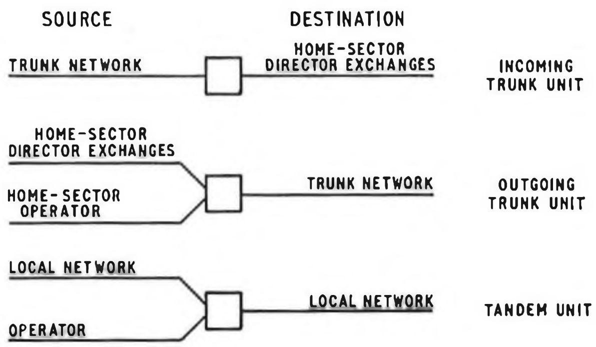

FIG. 1—Source and destination of traffic at an s.s.c.

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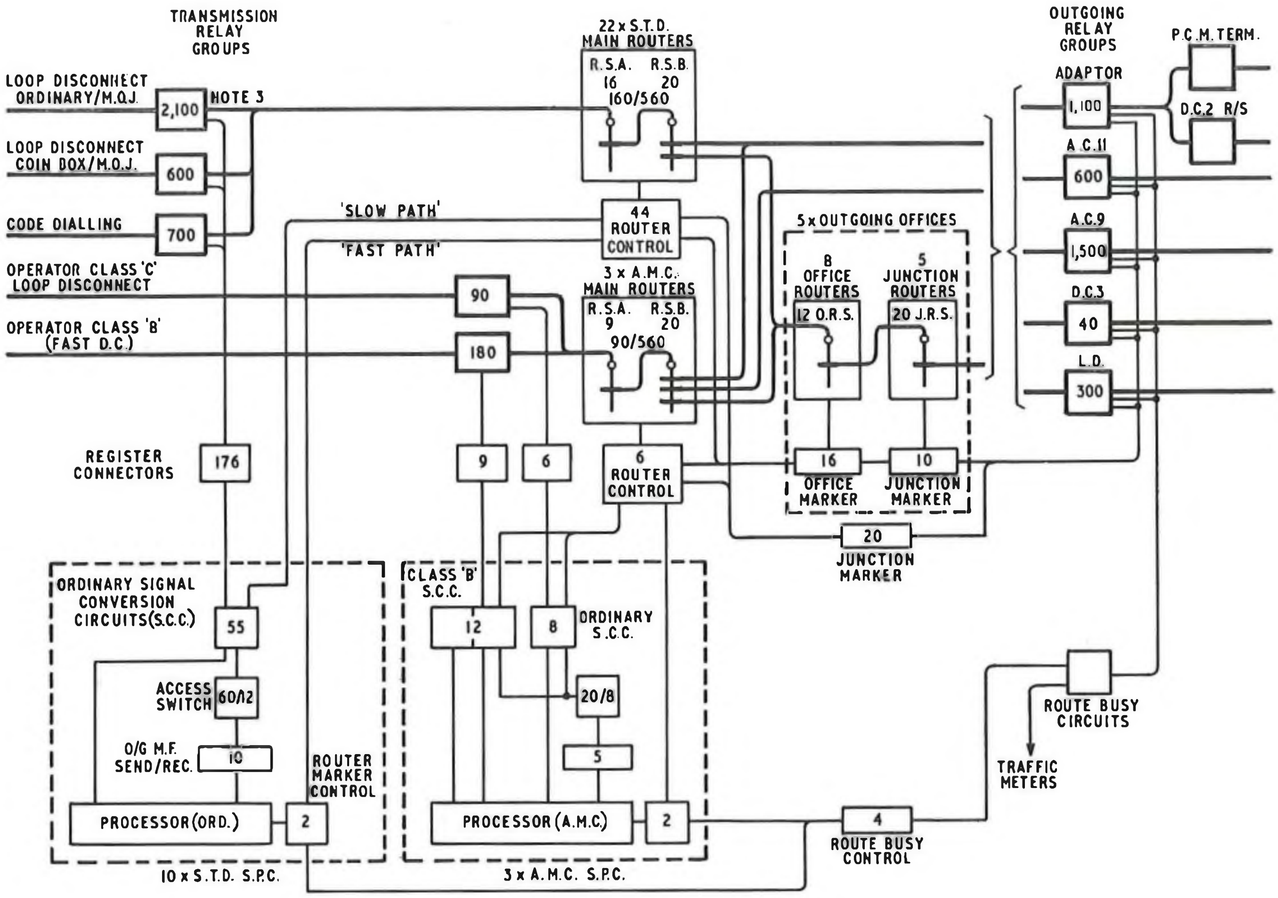


Note 1: Possible speech paths shown in heavier lines
Note 2: X- and Y-trunking not shown
Note 3: Figures denote quantities

FIG. 2—Trunking of a typical outgoing trunk unit at an s.s.c.

in the busy hours, will cause a substantial number of calls to be lost.

(*b*) If a call fails to be set up over X-trunking due to congestion or fault, a repeat attempt at setting up can be made over Y-trunking, and vice versa.

Expansion beyond the main router is provided by office routers and junction routers comprising o.r.s.s and j.r.s.s respectively. Whether a route is trunked off an r.s.B, o.r.s. or a j.r.s. outlet depends on a number of factors such as size of route, and grade of service required.[2] The office routers and the junction routers are grouped to provide the second main exchange building block known as the outgoing office. The fully-equipped outgoing office is composed of 20 office routers each consisting of 12 o.r.s.s and a pair (X and Y) of office markers together with 15 junction routers each consisting of 20 j.r.s.s and a pair (X and Y) of junction markers. The junction markers are used to mass-mark an outgoing route regardless of the stage at which the route is trunked off, while office markers are used to gain access to an appropriate junction marker and to control the o.r.s.s when an office router is involved in routing.

COMMON-CONTROL ACCESS AND INTERFACES

Communication between electromechanical sections of the exchange and the processor takes place via the following interfaces which are part of the processor peripheral hardware:

(*a*) type-A signal conversion circuit (s.c.c.) for loop-disconnect pulsing,

(*b*) type-B s.c.c incorporating a fast d.c. receiver for keying in directly from Cordless Switchboard Systems (C.S.S.) No. 1A auto-manual boards,[5,*]

(*c*) incoming multi-frequency sender/receiver (m.f.s.r.) for association with type-A s.c.c. for incoming m.f. calls,

(*d*) outgoing m.f.s.r. for association with either type-A s.c.c. or type-B s.c.c. for outgoing m.f. calls,

(*e*) router marker control, (r.m.c.), for passing route information from the processor to the router control and the route busy control, and

(*f*) equipment-monitor interface for passing fault information to the equipment monitor.

Incoming information relating to calls requiring a routing through the s.s.c. is passed by the t.r.g. to the processor via an s.c.c., which is the main interface between the crossbar equipment and the processor. The processor uses time-sharing to provide register-translator facilities for 64 s.c.c.s up to 60 of which carry traffic, two being used for test and two being spare.

The holding time of an s.c.c. is determined by the speed of signalling and by the design and speed of the switching system. As its position within the system configuration is similar to that of a register in a conventional TXK1 exchange,

* Specially-developed t.r.g. and fast d.c. receiver obviate the need for the outgoing relay-sets and senders normally associated with the C.S.S. No. 1A auto-manual board.

the s.c.c., with the implied processor back-up, can be referred to as a register.

A 20 × 10 crossbar switch, called the register connector, is used as an access switch between the t.r.g.s and s.c.c.s Since there are 160 t.r.g.s in a main router, eight register connectors are required. The number of s.c.c.s per main router is determined on an on-demand basis by applying Erlang's loss formula to the register traffic. For security reasons, the register traffic from a main router must be handled by a minimum of three processors. In practice, it is spread evenly across all the processors if five or less processors are needed, and across five processors, if more than five are needed.

If the incoming or outgoing information is in the form of m.f. tones, as in Signalling System Multi-Frequency No. 2, the processor associates an m.f.s.r. with the s.c.c. The m.f.s.r. is an interface unit consisting of sending and receiving elements only and, unlike conventional m.f.s.r.s, the logic is not contained within the wiring format, but in the processor program. The s.c.c. accesses an m.f.s.r. through a relay snatch chain known as the m.f. access switch. The basic element of the access switch is a 10 × 4 switch, up to four of which are chained together to provide extra outlets in increments of four to form a 10 × 16 switch. All 60 s.c.c.s can be provided with access to the same m.f.s.r.s to produce a 60 × 16 switch.

The number of m.f.s.r.s per processor is determined on an on-delay basis taking into account the m.f. traffic per processor and the m.f.s.r. holding time. Main routers, handling both loop-disconnect and m.f. incoming traffic, have their register connectors segregated so that all outlets from a particular register connector are jumpered to type-A s.c.c.s, either with or without m.f.s.r. access. Similar segregation is employed in the main routers which handle loop-disconnect and fast d.c. traffic. This arrangement allows efficient utilization of the peripherals.

The processor transfers the route information obtained by translation within the processor to the router control via an r.m.c. Two r.m.c.s are provided per processor, r.m.c. X for router controls X and r.m.c. Y for router controls Y.

Before accessing the router control, the processor determines whether the path is to be set up through X- or Y-trunking and sets up the appropriate fast path and slow path. The processor then passes the route information obtained by translation via the appropriate r.m.c. and fast path to the router control X or Y. Normally, only a fifth of the s.c.c.s (about 2–6) out of those serving a main router are connected to any one processor. Therefore, a processor can serve up to 30 main routers. The router control to be accessed is determined by the s.c.c. involved in setting-up. A router control can be accessed by all the five processors over which the s.c.c.s, numbering up to 30, for the main router are spread. Since up to 30 router-control pairs receive information from a single pair of r.m.c.s, the r.m.c. is a short-holding-time apparatus and the connexion between it and the router control is known as the *fast path*. When the fast path is released, the processor remains connected to the router control via a connexion between the s.c.c. and the router control known as the *slow path*.

The processor directly addresses all 64 s.c.c.s sequentially, using scan decode signals. An m.f.s.r., associated with an s.c.c., is addressed simultaneously in an indirect manner by passing the scan decode signal through the m.f. access switch to the m.f.s.r. so that the processor can check that an m.f.s.r. is associated with the s.c.c. being addressed, although it is not aware which of the 16 m.f.s.r.s has been associated.

PROCESSOR

The processor provides the highest degree of common control in the s.s.c. by controlling the register-translator functions for 60 calling circuits on a time-shared basis. It consists of up to three T 10,000 racks, each 3·2 m high. These are

(*a*) the s.p.c. rack comprising the processor logic circuits and the program, translator and data stores,

(*b*) the s.c.c. rack, and

(*c*) the m.f. rack comprising m.f.s.r.s, if required.

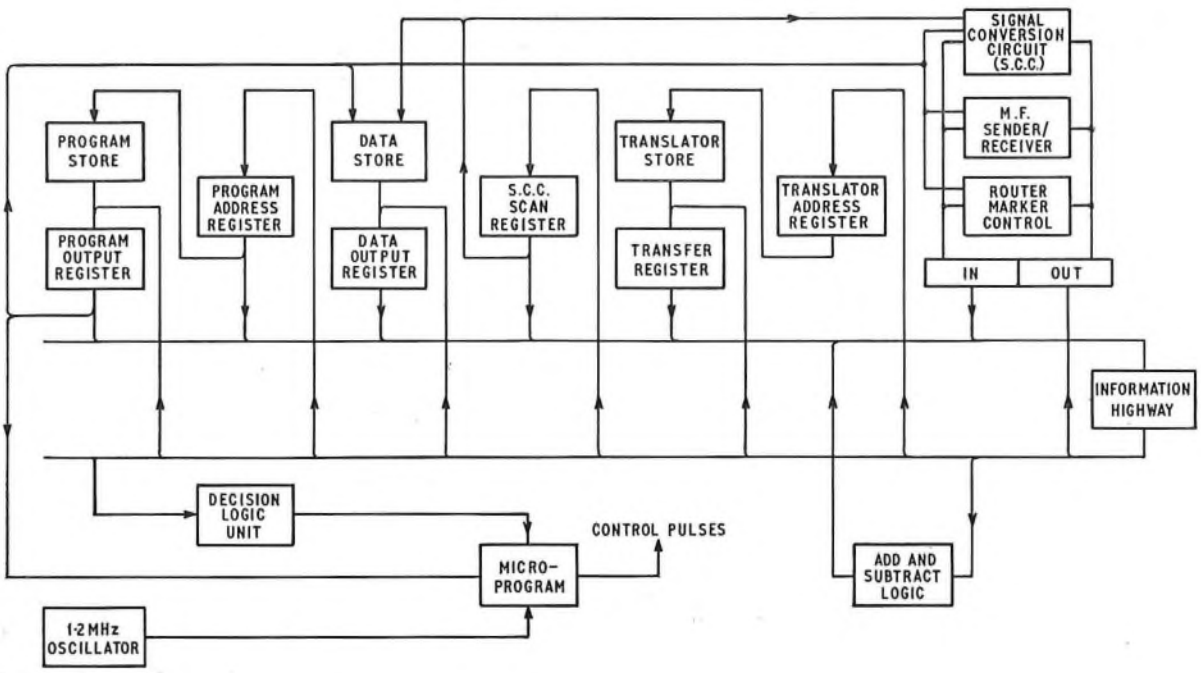
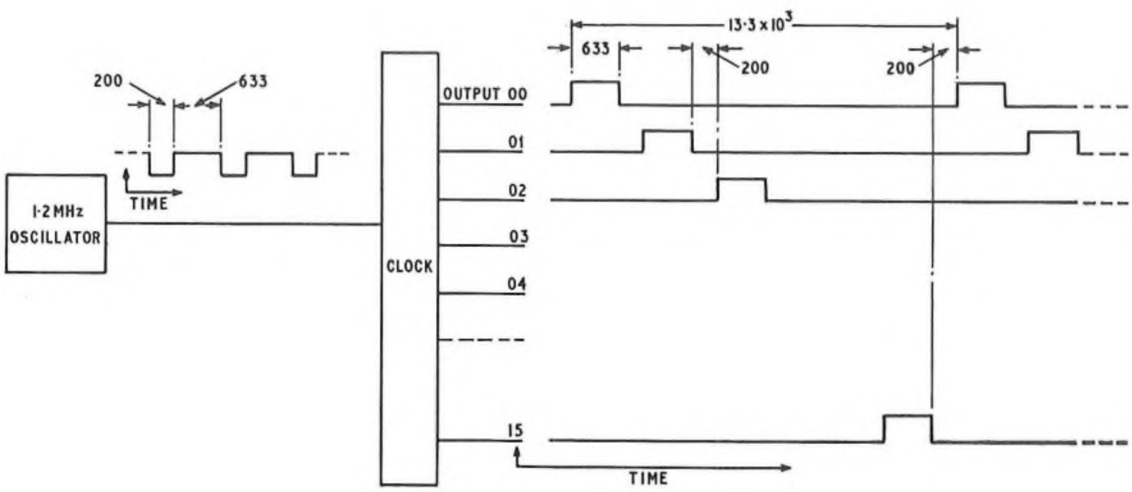


FIG. 3—Simplified block diagram of Mark 1c processor



Waveform timings in nanoseconds

FIG. 4—Clock pulse generator output

Logic circuits, including s.c.c.s and m.f.s.r.s, are mounted on 152 mm high plug-in units and comprise standardized discrete components, including Type-23 relays used in the s.c.c.s and m.f. access switches. The majority of the components are mounted on printed-circuit boards which are assembled on the plug-in units. The 12-volt power supply, needed by the processor, is provided by d.c./d.c. convertors which are also mounted on plug-in units. The program and translator stores are mounted on large panels on opposite faces of the s.p.c. rack. Also mounted on the s.p.c. rack is a monitor console which can be used as a commissioning and maintenance aid.

The processor scans 64 s.c.c.s connected to it every 11·1 ms, spending only a short period at each s.c.c. during which it samples the incoming information and stores it in a working data store for further processing. Processing results in instructions being passed from the processor to the crossbar equipment. Fig. 3 is a simplified block diagram of the processor showing the main functional units.

Timing

The scanning cycle, which begins at s.c.c. No. 00 (i.e. No. 64) and ends at s.c.c. No. 63, is initiated under the control of a 90 Hz oscillator which provides the trigger pulse every 11·1 ms. The sequential stepping to examine all s.c.c.s during the scan is controlled by the processor software. The time spent at an s.c.c. depends on the state of the calling circuit during the scan and is normally different for each s.c.c. The sum of the times spent at all s.c.c.s during a scan is normally much less than 11·1 ms. The processor idles at the end of the scan cycle until the next cycle starts. If the 11·1 ms trigger pulse arrives before the scanning is complete, the pulse is stored to enable the following scan to begin without delay. This event, known as *real-time overrun*, may occur due to either poor programming or a coincidence of unusual conditions and is, therefore, very rare.

The processing rate is defined by a 1·2 MHz crystal-controlled oscillator which generates a 633 ns pulse every 833 ns. These pulses are used to drive a 16-state clock which produces a 633 ns pulse on each of 16 output leads, the pulse on each lead lagging the one on the previous lead by 200 ns, as shown in Fig. 4. The clock, therefore, continuously produces cyclic patterns of 16 pulses of 13·3 μs duration. It is possible to skip to clock pulse (c.p.) 12 from c.p.04 onwards, thereby reducing the duration of a clock cycle.

A program instruction is executed within a single cycle of clock pulses in the following two ways.

(*a*) The pulses are used to control functions which are not dependent on any particular instruction, but constitute basic activities required during all instructions, such as, fetching the instruction to be executed from the program store and incrementing the program address.

(*b*) Functions dependent on the instruction are controlled by the micro-program output pulses obtained by gating the clock output with the instruction. Some instructions do not require all 16 clock pulses in a cycle, so those not needed may be skipped, thus reducing the execution time from 13·3 μs to a minimum of 7·5 μs.

Storage

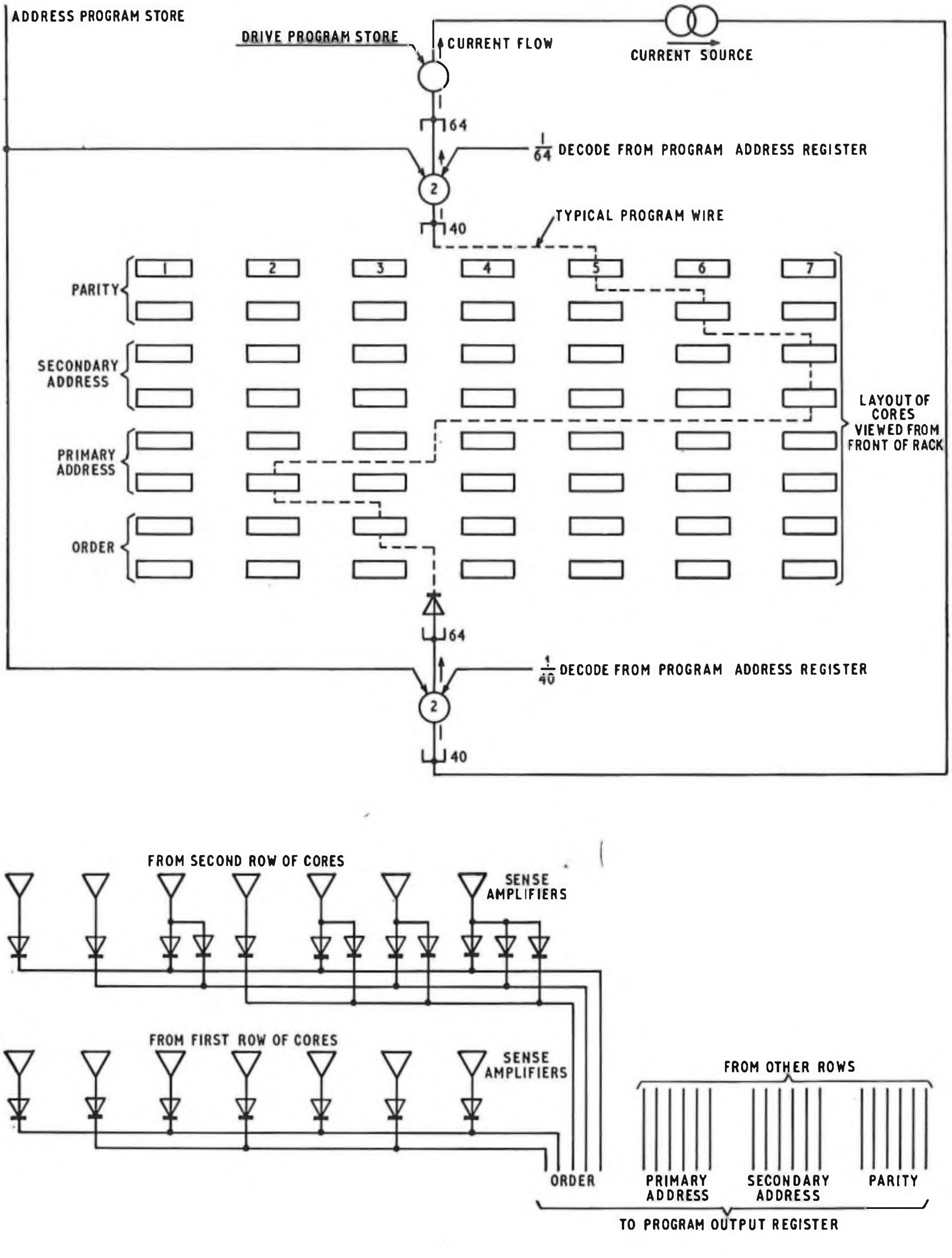
The processor is provided with three separate stores.

The Program Store

The program store consists of up to 2,560 code-wires threaded through a matrix of 56 diamond-ring ferrite cores arranged in eight rows of seven cores each. A program instruction is determined by the threading pattern of a single code-wire, this being threaded through not more than one core in each row, as shown in Fig. 5. Threading through a particular core in a row represents an octal digit. Eight rows, taken two at a time, represent four 2-digit octal numbers which correspond to the four program subwords. A code-wire, having a unique address between 0000 and 2,559, is selected by the 12-bit program address register (p.a.r.). Two groups of 6 bits each of the p.a.r. are decoded to provide 1-out-of-64 and 1-out-of-40 outputs to give 64 × 40 = 2,560 program addresses. Following selection by the p.a.r., the code-wire is driven by a 1·6 μs current pulse. This pulse generates voltages in the windings of the cores and these are detected by sense amplifiers. Not more than one core in each row is energized when the code-wire is driven. The outputs of each sense amplifier represent an octal digit which is converted into a 3-bit binary number, except those from the bottom row which are converted into a 2-bit binary number. The eight rows produce a 23-bit program word which is stored in the program output register (p.o.r.).

The Translator Store

The call-routing information is stored in the translator store in a manner similar to the program store except that



Note: output of first row of cores is modified as shown since only decodes 000, 001, 010 are required, and this facilitates the distribution of program wires.

FIG. 5—Program store

the 2,560 code-wires are addressable by a translator address register. There are two major differences, however.

(*a*) The translator store matrix consists of 168 cores arranged in 18 rows. The output from the bottom four rows is encoded in binary-coded octal form and the rest in binary-coded decimal form.

(*b*) The information represented by the code-wire is not required all at once and so, the outputs of the sense amplifiers are selected by a register called the translator output selector (t.o.s.).

The output is stored in a general-purpose register called the transfer register (t.x.r.).

The Data Store

The data store is a temporary working store which handles call information and uses a standard read/write ferrite core matrix comprising 18 planes of 32 × 32 ferrite cores. A portion of the data store, consisting of 288 cores, is dedicated to each s.c.c. and is made available to it every time the s.c.c. is addressed. Each plane represents a particular bit position in an 18-bit data-store word. Sixteen cores in each plane are required for each of the 16 words allocated to an s.c.c. Two bits of each word are used for parity.

Each s.c.c. is addressed sequentially by the s.c.c. scan register (s.s.r.), which is a 6-bit store capable of addressing the

64 s.c.c.s. Since the portion of the data store dedicated to the s.c.c. is already established, only the word, or part of a word, within that portion need be specified when addressing the data store. During instructions involving the data store, the s.s.r. address is used with part of the program output to address a particular word of the data store.

Every time a data store is addressed, the whole word is destructively read out and stored on the data output register. A new word is written by over-writing the data output register and gating it back into the data store.

Highways

All transfer of data between the internal units, which are not directly connected together, takes place via the information highway which consists of 16 individual highways capable of passing up to 16 bits.

Information transfer between the processor and peripherals takes place via the outside-world highway. This is organized into two separate highways, one of which, the incoming peripheral highway, is gated on to the information highway to transfer information from peripherals, and the other, the outgoing peripheral highway, is gated from the information highway to transfer information to the peripherals.

The reason for separating the outside-world highway from the information highway is that the transfer of information to and from the peripherals requires transmission of signals between adjacent racks, thus giving rise to long-line problems. Information from peripherals is not gated onto the information highway until it has been allowed sufficient settling time, whereas the information to the peripherals is stored on the outside-world highway for a period long enough to ensure successful transmission.

Logic Units

The two main logic units in the processor are the decision logic unit (d.l.u.) and the add and subtract logic (a.s.l.). The d.l.u. is used to interrogate the information highway for the presence of signals. Individual highways, or groups of the information highways, are gated selectively into the d.l.u., causing a change in the state of a decision bistable circuit called the *M-toggle*. The M-toggle is also fed by the output of a sum-modulo two gating tree, which compares two sets of information. The result of the interrogation or comparison, as determined by the final state of the M-toggle, is used to make conditional out-of-sequence program jumps.

The a.s.l. is a simple arithmetic unit used to add or subtract one from a binary number. The logic is normally in the add mode, but may be converted to subtract mode during particular instructions. Associated with the a.s.l. is an increment register to which a word is gated via the information highway prior to an add or subtract operation. This permits the use of the information highway for gating the a.s.l. output back to the source, as it cannot be used for both purposes at once.

Software

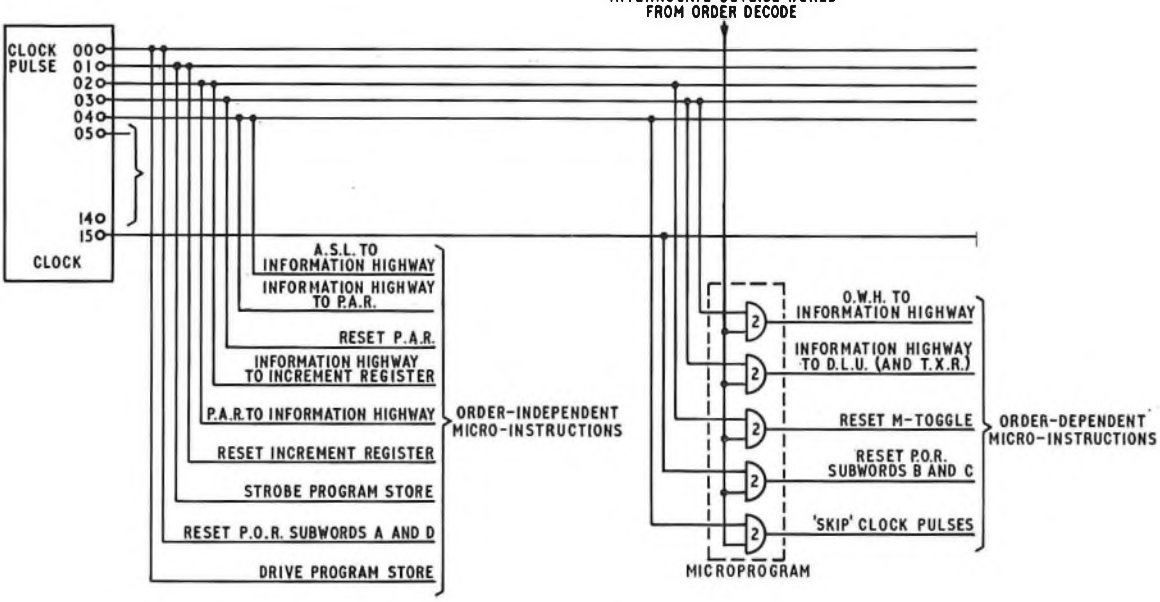
The 23-bit program word, or the program instruction, is divided into four sub-words of six bits each, as shown in Table 1.

TABLE 1

Division of Program Word

Subwords	D	C	B	A
Function	Order	Primary Address	Secondary Address	Parity
Bits	19–23	13–18	7–12	1–6
Example	00101	000100	000110	xxxxxx

Subword D specifies one of the 17 orders which constitute the processor instruction set. The subword is decoded to provide one out of 17 outputs, and this is gated with the clock output in the micro-program to provide a pat...n of micro-instructions within the 16 clock pulses. The micro-instructions switch the various units together to operate on



P.O.R.—program output register
P.A.R.—program address register
A.S.L.—add and subtract logic
O.W.H.—outside world highway
D.L.U.—decision logic unit
T.X.R.—transfer register

FIG. 6—Execution of ORDER 05

the information specified by, or contained in, sub-words C and B of the program word.

An instruction involving the data store requires a word to be specified. This is achieved by using the four most-significant bits of sub-word C, the primary address, in combination with the s.s.r. address. The primary address is also used to address one of 16 different types of peripheral in the instructions involving the outside world.

Sub-word B, the secondary address, is used to select various bits, or groups of bits, involved in processing, thereby restricting the operation to these bits. In certain instructions, it modifies the order function.

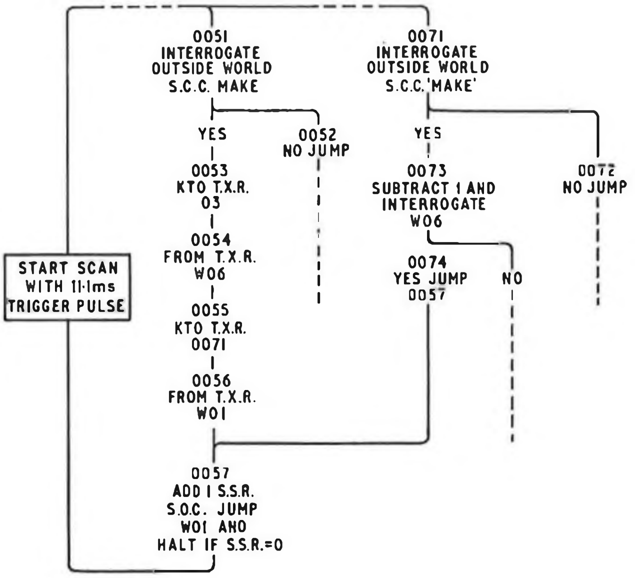
Consider the instruction in Table 1, where ORDER 05 represents *interrogate outside world.* The four most-significant bits of the primary address, 0001, specify that the peripheral is an s.c.c., and the secondary address, 000110, specifies bit 6 of the information highway. Execution of this order is shown in Fig. 6. Micro-instructions executed during the instruction can be considered separately as order-independent and order-dependent. These groups of micro-instructions are executed simultaneously within a single clock cycle.

The order-independent micro-instruction sequence starts at c.p.00 by reading an instruction from the program store. In c.p.00, before receiving the information, c.p.01, the order and parity bits of the p.o.r. are reset. The primary and secondary bits are not reset at this stage, since these are retained for use in those instructions which follow an index instruction.

In c.p.01, the increment register is reset to prepare for receipt of the program address in c.p.02, prior to incrementing it via the a.s.l. in c.p.04. Also in c.p.01, the program word is gated into the p.o.r. In c.p.02, the p.a.r. is gated to the increment register via the information highway. The p.a.r. is reset in c.p.03 and, in c.p.04, the a.s.l. is gated to the p.a.r. with the next program address. To enable skip to be used for those orders which do not need all the clock pulses, c.p.05 to c.p.11 inclusive are not used for order-independent micro-instructions. In c.p.12 to c.p.15, micro-instructions, connected with the self-checking of data, are executed.

The order-dependent micro-instruction sequence starts in c.p.02 with the resetting of the M-toggle in the d.l.u. and the transfer register. In c.p.03, the outside-world highway is gated to the d.l.u. via the information highway to interrogate for the presence of a bit on information highway six. If the secondary address is between 17 and 24, the outside-world highway is also gated to the transfer register. The skip to c.p.12 is initiated by c.p.04. In c.p.15, the primary and secondary addresses of the p.o.r. are reset. This last micro-instruction is not executed if the information in the primary and secondary addresses is to be used in the next instruction.

Four of the 17 orders are described briefly in Table 2. Each order has its own unique micro-instruction sequence as described above for ORDER 05. These orders are joined together to perform various control functions required in register-translation. For example, a 33 ms MAKE time-out, for loop-disconnect pulsing, can be performed from the measurement of the elapsed time by counting the number of 11·1 ms scans using a sub-routine shown in Fig. 7. Assume that the



S.C.C.—signal conversion circuit
T.X.R.—transfer register
S.S.R.—s.c.c. scan register

FIG. 7—MAKE time-out subroutine

s.c.c. under consideration lies somewhere between s.c.c. No. 00 and s.c.c. No. 63. After scanning all the previous s.c.c.s since the arrival of the 11·1 ms trigger pulse, the processor starts scanning the s.c.c. under consideration at program address 0051. If the MAKE is indicated, the transfer register is loaded with a program constant 03 which is transferred to data-store word No. 06. Instructions 0055 and 0056 store the next program address 0071, and the instruction 0057 causes the processor to leave the s.c.c. It then steps on to deal with the next s.c.c., unless it is s.c.c. No. 00, in which case, the processor waits for the 11·1 ms trigger pulse. In the next scan, instruction 0071 is executed to interrogate for MAKE, the presence of which results in data-store word No. 06 being reduced by one. Instructions from 0071 onwards are repeated until data-store word No. 06 is reduced to zero in two further scans. With the time-out expired, the processor can perform other functions on the s.c.c.

The five different programs, one for each section of the s.s.c., are built up using instructions in this manner to provide register-translator facilities. Any one processor is programmed to provide the facilities for one section only as the program capacity is limited to 2,560 words, and the requirement for each section is as shown in Table 3.

TABLE 2

Brief Description of Four Orders

Order	Mnemonic	Function
000001	K to t.x.r.	Information in p.o.r. subwords B and C transferred to transfer register
000010	Yes Jump	Out-of-sequence program jump if M-toggle is set
001011	Translate and Interrogate	Drive translator store and gate transfer register into d.l.u.
001001	Index	Information from data store gated to p.o.r. subwords B and C for operation by the following instruction

TABLE 3

Number of Words Required for each Section

Program	Number of Words
Incoming trunk section	1,910
Outgoing trunk section	2,056
Operator trunk section	2,170
Tandem section	1,540
Operator local section	1,960

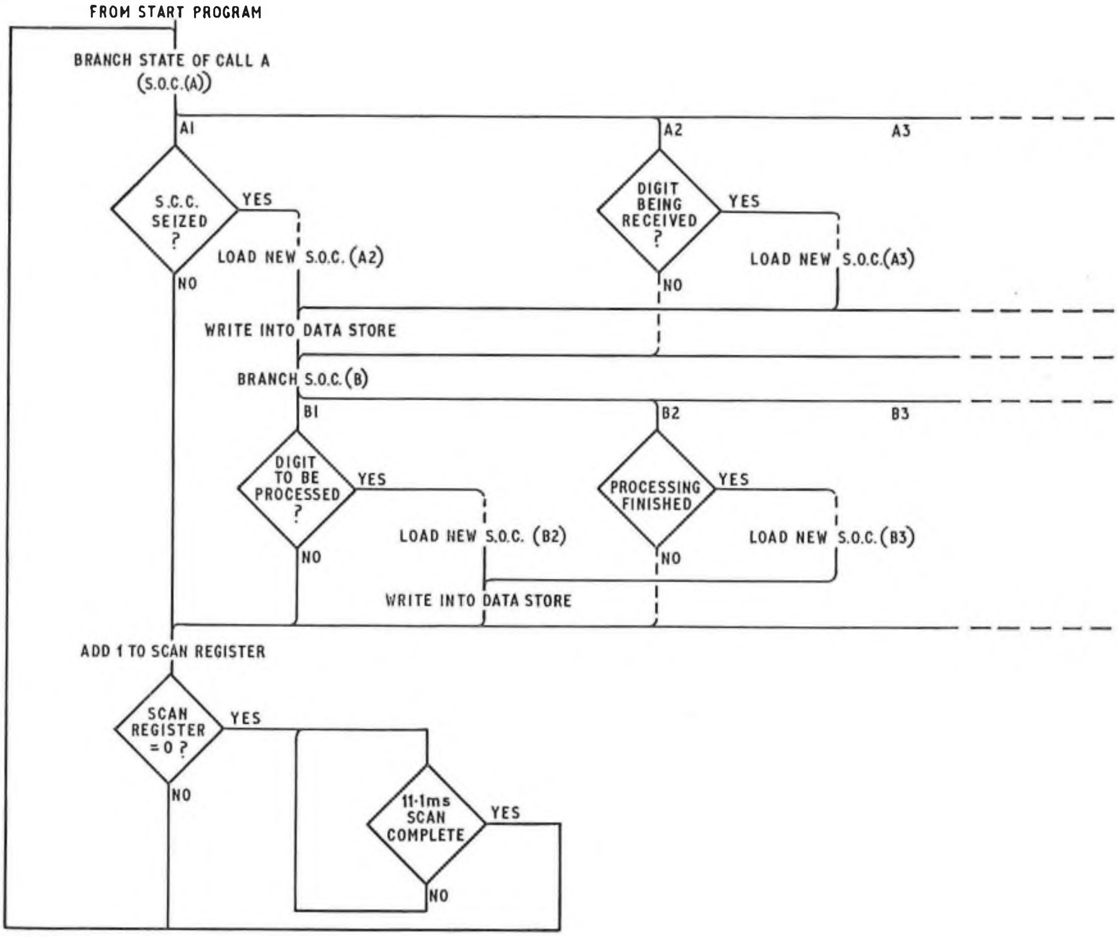


FIG. 8—Program organization

Program Organization

The program is divided into two multi-way branches called state of call A (s.o.c.A) and state of call B (s.o.c.B). The detection of seizure, the receipt of incoming information, the determination of end of signalling-in and the release or forced-release of the call is dealt with by s.o.c.A while s.o.c.B deals with the processing of incoming information to obtain a translation, assists the router control in setting up the call, sends the fee digit to the t.r.g., sends routing digits in either loop-disconnect or m.f. form and informs s.o.c.A of the type of release required.

As shown in Fig. 8, for each s.c.c., one s.o.c.A or one s.o.c.A and one s.o.c.B can be executed during each scan. The s.c.c. is said to be in a particular state of call and the s.o.c. address is stored in the data store during the previous scan. Before leaving an s.c.c., the processor increments the s.s.r. address to step on to the next s.c.c. to permit time-sharing.

The division of the program into s.o.c.A and s.o.c.B is necessary to enable earlier information to be processed while later information is still being received. For example, when routing to a London exchange, ABC xxxx will be received. The digits ABC are processed before all the numericals xxxx have been received to keep the register holding time and the post-dialling delay to a minimum. Also, during earlier and later stages of the call, only s.o.c.A need be used, since these stages are concerned only with seizure and release sequences.

A list-processing technique is used in s.o.c.B to obtain translation. The technique preserves flexibility to deal with a wide variety of routing schemes. When the first digit has been received, it is applied to the translator store using t.o.s. = 1, which selects the outputs from the routing cores. If a translation is not obtained, the digit is applied again to the translator store using t.o.s = 0 to obtain a link address, which is used as a base to which the next received digit is added. The result is applied to the translator store using t.o.s. = 1. This process is repeated until the translation is obtained. Other t.o.s. values are used subsequently to obtain such information as fee digit, omit digits, number length and alternative routing.

Processor Self-Checking

Four mechanisms are used to provide an adequate degree of self-checking within the processor.

(*a*) *Parity check*

Subword A of the program word consists of 6 parity bits which are organized in two groups of 3 bits each. The first group checks the information in subwords B, C and D, while the second group provides a check on the next program address, thus indirectly checking the a.s.l.

(*b*) *Scan check*

In order to ensure that no s.c.c. is missed out or scanned twice during a scan, a secondary s.s.r. is incremented simultaneously with the primary s.s.r. The latter, after being decoded and passed to the s.c.c. for addressing, is re-encoded for comparison with the secondary s.s.r. If the result is negative, a fault in the processor is indicated.

(*c*) *Master/Slave check*

On each processor, s.c.c.s No. 62 and 63 are designated master and slave s.c.c.s respectively. The master of one processor is connected to the slave of the next processor, the slave of the former processor being connected to the master of the previous processor in a chain of three processors, or more if provided. The processor executes a special program for these s.c.c.s which checks continuously the translator store information of one processor against that of the next one in the chain.

(*d*) *S.C.C. check*

As the call proceeds, the s.c.c. is checked under program control and is put through a test program to check relays after an ineffective call.

CALL-SETTING-UP PROCEDURE

A t.r.g. is seized over a junction/trunk from a distant exchange. The t.r.g., in turn, seizes a free s.c.c. via a register connector. The processor recognizes the seizure and prepares the data store for the reception of subsequent information.

The class-of-service signal from the t.r.g. may indicate an m.f. junction, in which case, the processor instructs the s.c.c. to associate an incoming m.f.s.r., or it may indicate that the call has originated from a call office, so that coin-collecting-box metering rates are applicable. Using s.o.c.A, the processor receives the class-of-service signal and the incoming digits. The latter are list-processed by means of s.o.c.B to obtain the translation. Once the translation is obtained, usually after the third digit, the translator store link address cores determine the point in the program where processing must continue. This point is variable and depends on the type of sending program required by the objective exchange.

If the translator store indicates an alternative route, the processor interrogates the route busy control via the r.m.c. to check if the primary route is busy. If at least one junction in the primary route is free, the processor attempts to set up the call to it, otherwise it uses the alternative route.

Having obtained the translation, the processor seizes either router control X or Y and sets up the appropriate fast path. Normally, router controls X and Y are seized alternately, but the priority is overridden if the desired router control is busy.

Establishment of the fast path causes the slow path to be set up between the s.c.c. and the router control. The processor sends the route information in the form of three groups of 4 bits each, and a parity bit.

The router control checks the parity, and acknowledges correct receipt. The processor releases the fast path. The r.m.c. then sends the fee digit to the t.r.g. in the case of a metering-over-junction call and waits for the router control to set up the call, subject to a time-out. If the time-out matures, a second attempt at setting-up is made and if the time-out matures the second time, equipment-engaged tone is returned to the caller.

The router control decodes the route information to determine one out of up to 200 junction markers and seizes it, if necessary via an office marker, and the r.s.A associated with the calling t.r.g. The office and junction markers operate the appropriate route relays to restrict self-steering to the originating main router and the junction marker marks all free outgoing junctions on the required route. As the marks pass through the switching stages, each stage sends a signal to the router control to indicate that the call-setting-up is proceeding satisfactorily. Failure to receive these signals indicates blocking between the stages.

When a path is selected, the router control puts an earth on the P-wire to operate the bridge magnets associated with the path and performs loop-balance and continuity checks on the speech pair. The earth on the P-wire causes an outgoing class-of-service signal to be returned from the outgoing relay group via the junction and office markers, router control and the slow path to the processor. The class-of-service signal may indicate an m.f. junction, in which case the processor instructs the s.c.c. to associate an outgoing m.f.s.r., or it may indicate a bridge-in, bridge-out, or other facility.

When the class-of-service signal has been received, the processor releases the slow path, thereby releasing the router control and the office and junction markers. Using s.o.c.B, the processor now sends the routing and numerical digits while s.o.c.A may still be receiving later digits from the originating exchange. With the sending of the final digit, the processor instructs the t.r.g. to switch through and releases the connexion between the t.r.g. and the s.c.c. The t.r.g. maintains the supervision of the call and the s.c.c. is ready for use on another call.

If at any stage during the setting-up, a fault develops, either in the crossbar equipment or in the processor, the latter associates the equipment monitor[7] depending upon the nature of the fault. If a fault print-out is required, the processor passes the fault information to the equipment-monitor buffer store for printing when a free teleprinter is available.

CONCLUSIONS

Incorporation of Mark Ic processors in TXK1 exchanges, instead of conventional electromechanical registers, coders and translators, simplifies call-establishment procedure and results in considerable savings in floor space and cost and eases maintenance associated with the use of any such electronic equipment. Furthermore, alterations and additions to facilities can be readily achieved for 60 registers simultaneously by simple changes in the processor program.

ACKNOWLEDGEMENTS

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The London Sector Plan: Maintenance of Sector Switching Centres

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U.D.C. 621.395.37 : 621.395.74 : 621.395.344.6–7

The introduction of the sector switching centres into London's public switching network marks a significant change from traditional routing principles, and the new technologies, used for the first time in units of such size, pose challenging problems in the maintenance field. This article examines some of these maintenance aspects, and briefly describes the methods which will be adopted for fault diagnosis and repair.

INTRODUCTION

The opening of sector switching centres (s.s.c.s) in London presents maintenance staff with challenges of new switching and control techniques for which existing maintenance practices are not applicable. New concepts in monitoring of service standards, analysis of fault information, and location of faults will be introduced.

The s.s.c.s will vary in layout and capacity according to the needs of each sector, but each will be a major communication centre of considerable size. Separate stored-program-controlled (s.p.c.) crossbar units will be provided for incoming trunk traffic, outgoing trunk traffic, and the tandem switching of local traffic. The first to be commissioned is located at Ilford in the East Area of the London Telecommunications Region. Where this article makes reference to such factors as quantities, and system size, the Ilford Centre is quoted and may be regarded as typical.

The power equipment, line-transmission facilities and the Cordless Switchboard System No. 1A auto-manual centre (a.m.c.)[1] are of up-to-date, but established design, and maintenance techniques will follow normal modern practice. Any maintenance problems in these fields are likely to be related to the size of the installation rather than the type of equipment. However, the introduction, at s.s.c.s, of crossbar trunk units with s.p.c., high-speed signalling, automatic alternative-routing facilities, diagnostic rooms and computer-aided fault-analysis facilities marks a significant step forward in communications technology, and changes from traditional maintenance philosophies and organization are necessary.

In Strowger exchanges, maintenance effort is primarily directed to the cleaning, adjustment and repair of individual electromechanical devices and is mainly aimed at the prevention of switching failures. Little or no information is available on the cause of individual call failures which have occurred in spite of these preventive measures. In contrast, the switching equipment used at s.s.c.s requires little routine attention, but a great deal of information is available concerning individual call attempts which have failed to find a path through the exchange. Computerized analysis of failure patterns with teleprinter print-out is used to identify points of failure, facilitate fault location, and thus, reduce equipment out-of-service time.

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TRANSMISSION EQUIPMENT

Pulse-code-modulation (p.c.m.) systems will be used extensively for the provision of trunks between s.s.c.s and adjacent charging groups. At Ilford, an initial provision of 2,184 p.c.m. channels is expected to increase, ultimately, to 28,000 channels. The p.c.m. equipment is installed in the switching-apparatus area and maintenance staff will generally restore service in the event of faults by the substitution of digital-section or terminal-equipment cards.

The trunk-circuit requirements of the s.s.c.s are mainly provided on spurs from the main national backbone network of long-haul radio and coaxial-cable systems terminating in major inner-London repeater stations such as Tower and Faraday. The s.s.c.s are connected to these repeater stations by short-haul coaxial-cable systems. Direct coaxial-cable systems are also used to link the s.s.c.s to certain group switching centres (g.s.c.s). Circuits are routed to the s.s.c.s in groups, supergroups and hypergroups, as appropriate. The h.f. equipment is located in the repeater station, which also contains audio transmission equipment for use on junctions, private circuits and networks. At Ilford, there are some 45 racks of audio equipment and 520 racks of h.f. equipment which may be used for 4 MHz, 12 MHz and the proposed 60 MHz coaxial-cable systems.

Modern transistorized transmission equipment requires little preventive maintenance, and the effort in s.s.c. repeater stations will be largely concerned with the clearance of fault conditions indicated by coaxial-cable system-, hypergroup-, supergroup- or group-pilot failure alarms. Many of the faults will be detected simultaneously by pilot-failure indications in several s.s.c. repeater stations and inner-London repeater stations. To avoid duplication of effort and to minimize the effect of failures on service, prompt and close co-operation between the s.s.c.s, the trunk maintenance control centres (t.m.c.c.s), inner-London repeater stations and the regional network co-ordination centre will be essential and, to facilitate rapid intercommunication, omnibus speakers are provided between the various stations concerned.

TRUNK MAINTENANCE CONTROL CENTRE

The t.m.c.c.s will exercise a similar function to those in other major switching units, that is, control of the overall service given by the trunk unit and of localization and clearance of faults on individual circuits. To maintain an acceptable quality of service, the t.m.c.c. must be able to ensure that faulty circuits are removed from service as soon as possible, faults cleared, and circuits restored to service with minimum delay. Trunk and junction routiners are provided, and junction circuits are protected by junction-guard facilities incorporating a route-monitor circuit. The trunk circuits use modern self-alarming signalling systems, which are self busying in the event of failure.

Thus, with facilities for detecting and busying faulty circuits, the t.m.c.c. will become aware of the majority of failures from indications within the s.s.c., and will receive few reports from external sources. Some reports may be expected from the a.m.c. and co-operation will be necessary with distant t.m.c.c.s and local exchange maintenance staff. The s.s.c.s will be the focal point in each sector for circuits associated with the public switched network, and will have a similar function for amplified private circuits. Each s.s.c. will be fully equipped with terminal transmission equipment, test-access facilities and test equipment necessary for the efficient maintenance of private circuits and networks.

The equipment provided in the t.m.c.c. comprises standard test desks, circuit busying frames, test jack frames (t.j.f.s), and duplicate control and display panels associated with the trunk and junction routiners. Test-selector access is provided to pick up the exchange side of the line relay-sets on outgoing trunk circuits, and the line of outgoing junctions. Busying and alarm facilities are provided for all outgoing circuits. A teleprinter and visual-display unit (v.d.u.) is also provided as part of the scheme for computer assistance described later in this article. Reports from trunk-circuit fault recorders are printed-out and the v.d.u. is used to feed back information on faults cleared to the central computer.

The successful integration of the service function of the t.m.c.c. with that of the newly-introduced diagnostic room, will be crucial to the efficient operation of the s.s.c.

SWITCHING UNITS

The functions and detailed descriptions of the outgoing, incoming and tandem switching units in the s.s.c.s are described elsewhere.[2] From a maintenance point of view, each of the switching units may be regarded as separate entities.

In each unit, up to four stages of crossbar switching are used, each stage being a standard 5005-type crossbar switch[3] having 10 inlets and 26 or 28 outlets.

The switches and total quantities in Ilford s.s.c are as follows:

route switches A—1,107
route switches B—1,420
office route switches—1,214
junction route switches—744

There are also 558 crossbar switches used as incoming register connectors making a total of 5,043 crossbar switches to be maintained.

The crossbar switches are relatively simple devices in enclosed cabinets. They do not require routine tests or regular adjustment and cleaning, and preventive maintenance is, therefore, negligible.

At Ilford s.s.c., a total of 21,548 trunks and junctions will be terminated on interfacing relay-sets, designated transmission relay groups (t.r.g.s) and outgoing relay groups. These, together with other all-relay devices such as router controls, office markers and junction markers, will be maintained according to well-established principles for relay equipment.

The s.p.c. processor is time-shared electronic common equipment, which provides the register and translator function for the crossbar switching unit.

To ensure system security, not less than three s.p.c. processors are provided at any installation. At Ilford, the initial provision is of 8, 13 and 9 s.p.c. processors for the incoming, outgoing and tandem units respectively, and system security is adequately provided. The s.p.c. processor consists of discrete-component, solid-state circuits and uses silicon planar semiconductors for the logic circuits, gates, bistable circuits and amplifiers. Standard construction, using printed-circuit boards and plug-in units is used. A signal conversion circuit (s.c.c.) provides the interface between the s.p.c. processor and the electromechanical crossbar switching equipment.

To enable the s.p.c. processors to be continuously tested for correct functioning, a number of processors are linked to form a ring and these in-built, self-checking arrangements

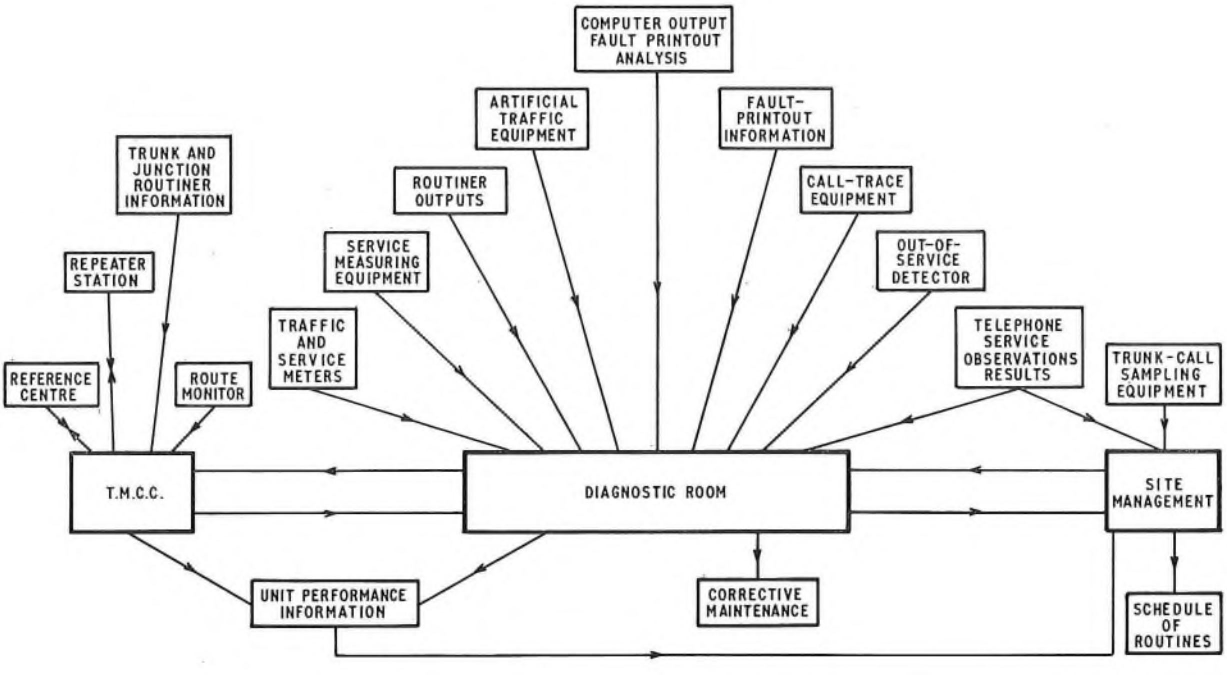

FIG. 1—Information sources of the diagnostic room

reduce routine testing to a minimum. Additionally, parity checks are carried out when information is transferred within the processor. This, and other features, such as scan checks are described elsewhere.[4]

The identification of faults to an s.p.c. processor area follows a simple procedure. The input information to one s.p.c. processor, and the routing information given out, is compared with the equivalent information input and output of another processor. If there is a difference, a fault exists and further automatic comparison with other processors identifies the faulty one. Testers are provided to assist with fault clearance on logic elements and on s.c.c. inlets. Additionally, the inlet tester can be used to check translation changes.

Security within the switching area is improved by the division of the trunking into X- and Y-halves. This also allows two simultaneous calls to be set up through each switchblock and, in the event of a failure, a second attempt is initiated through the other half of the trunking. It should be noted that first-time failures do not, therefore, affect the service given to customers. Identification of each item of equipment involved in a failed attempt is transferred to the equipment monitor, and the state of all items at the time of failure is printed-out and used for further analysis.

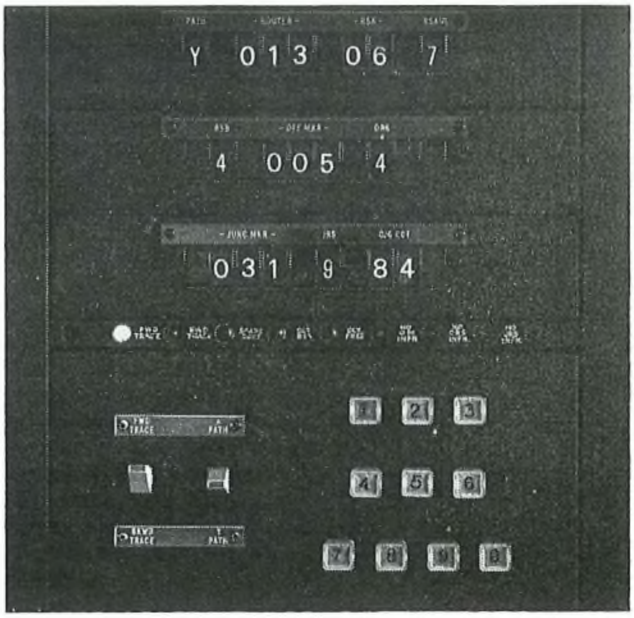

Fig. 2—Call-trace display

DIAGNOSTIC ROOM

The effective and integrated control of the many maintenance aids provided, and the efficient direction of maintenance effort towards providing the required quality of service, are two of the major problems which will face s.s.c. local management. Corrective maintenance will be the logical follow-up of the output from fault print-out analyses, quality-of-service indicators, routiners and automatic detection devices, alarms and customer complaints. All such information is directed centrally to the diagnostic room where results are analysed and any necessary action initiated. Even the busying of equipment for normal maintenance purposes will cause an indication to be given. The diagnostic room will, therefore, become the focal-point of the unit and must exercise overall control of switching-maintenance activities. A separate diagnostic room is provided for each of the incoming, outgoing and tandem units.

The information sources serving the diagnostic room, and the interaction with other functions are shown diagramatically in Fig. 1. The following paragraphs describe some of those inputs to the diagnostic room which have special significance. The remainder follow established British Post Office (B.P.O.) practices.

Telephone Service Observation

As in conventional trunk units, an indication of the quality of service is given by telephone service observations, which are taken at the input to the units, and, at the s.s.c., the arrangements are such that 300 incoming circuits may be observed by a single operator. At an outgoing trunk unit, the observations indicate the total performance of the outgoing trunk unit, the trunk network, and the objective incoming network. Similarly, the observations taken at an incoming trunk unit measure its performance together with that of the objective incoming local network. Any failures observed on the incoming trunk unit of the s.s.c. can only have been caused by malfunction of plant within the sector.

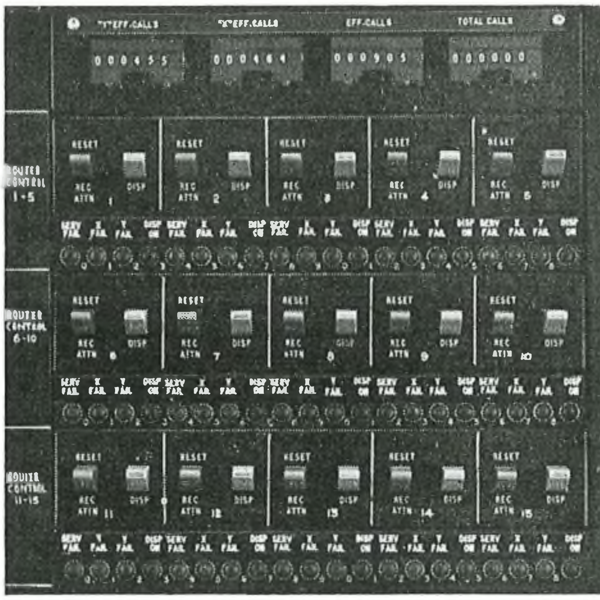

Fig. 3—Service-measurement display

Out-of-Service Detector

The out-of-service detector, which is provided on the basis of one per 200 switches, monitors crossbar switch outlets to check that all working outlets are used in normal traffic service during a period of 24 hours. If they are not used within this period, details of the switch and suspect outlets are printed-out under the control of the equipment monitor. Alternatively, a lamp display is provided. Switches are monitored one at a time and an automatic step-on or camp-on facility is provided. Assuming the minimum rate of usage, each switch will be monitored at least three times per year, but, in practice, the rate of checking will be considerably higher. This should prevent an accumulation of undetected faulty paths leading to exchange internal blocking and a consequent decrease in the grade of service provided.

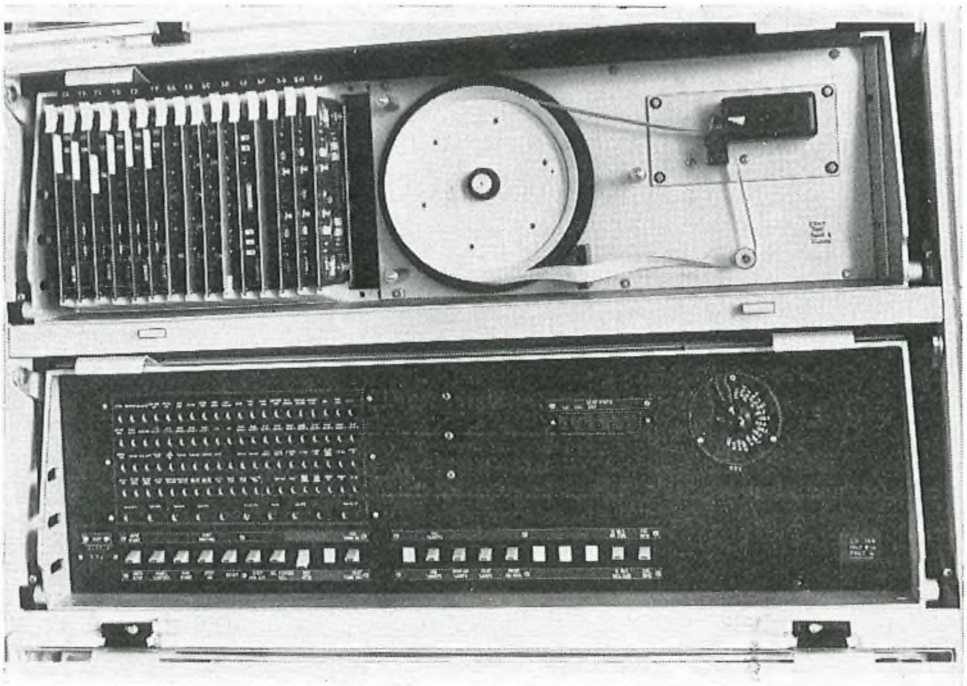

FIG. 4—Incoming metering-over-junction t.r.g. routiner showing tape control

Route Monitor

The purpose of the route monitor, which is provided on all routes, is to give an indication in the t.m.c.c. when a pre-selected number of the circuits on an outgoing trunk or junction route becomes faulty.

Call-trace Equipment

To trace a call, the maintenance officer keys 5 or 6 digits to identify the known outgoing or incoming circuit. The digital indicator display gives the equipment numbers of all the switches, controls and incoming or outgoing circuits used on the call. This call-trace information is displayed in approximately 120 ms. One call trace equipment is provided per unit and a typical display is shown in Fig. 2.

Service-Measuring Equipment

Service-measuring equipment is provided on the basis of one per router in all units of the s.s.c. The display panel is located in the diagnostic room where an alarm is given if the preset quality-of-service limits are exceeded. The limits can be adjusted by means of wire straps within the range 0·03–0·10. In addition, an indication is given if there is imbalance between effective calls X and effective calls Y on any router. The service-measuring equipment is shown in Fig. 3.

Trunk-Call Sampling Equipment

Trunk-call sampling equipment (t.c.s.e.), which samples 1 in *n* trunk calls, is provided in the outgoing trunk unit of the s.s.c.s, on the basis of one t.c.s.e. per 2,000-erlangs capacity. The equipment permits full monitoring of every *n*th call, where *n* is a variable number. Detailed information concerning the call, including the date, time, value of *n*, incoming digits, called-subscriber answer signal, and meter pulses is recorded on paper tape, and later utilized in a computerized analysis of the service given.

A traffic recorder, provided on the basis of one per unit, gives standard B.P.O. records for long- and short-holding-time equipments.

Artificial-Traffic Equipment

Artificial-traffic equipment consisting of a tape-controlled, test-call sender is used to measure quality of service, and provides a *stop-on-a-fault* feature, when required. The equipment can also be used as an automatic routiner for simple checks on loop-disconnect, p.c.m., and Signalling System D.C. No. 2 adaptor t.r.g.s. The results are recorded on meters and faults printed-out.

Automatic Routiners and Print-Out

Routiners will be provided for incoming Signalling System A.C. (S.S.A.C.) Nos. 9 and 11 t.r.g.s, outgoing S.S.A.C. No. 9 and S.S.A.C. No. 11 relay groups, and for incoming metering-over-junction t.r.g.s. These routiners, some of which are paper-tape controlled, can be used in either automatic or manual-start mode. Fig. 4 illustrates the incoming metering-over-junction t.r.g. routiner with tape control. A visual lamp display on the main or auxiliary panels, or fault print-out via the equipment monitor may be selected. A pattern analysis of routiner fault reports is not necessary. They will be stored at the central computer on a 24-hour basis and printed-out in work-load form each morning. Main control panels are located on the appropriate equipment floor with a duplicate in the diagnostic room.

Trolley-mounted portable testers are also provided as back-up fault-location aids to automatic routiners, and for use on t.r.g.s and outgoing relay-sets not tested by automatic routiners. Additionally, standard test equipment for testing such parameters as relay current, pulse speed and ratio checks are provided.

Equipment Monitor

An equipment monitor is provided for each unit of the s.s.c. and is located in the diagnostic room. It accepts fault information from s.p.c. processors, router controls, routiners, and out-of-service detectors, and this fault information is passed forward to the local computer for processing. It can also be seized by the call-trace circuit, but this only uses the switch-identification facility and print-out is inhibited.

There are nine different types of fault print-out messages and the originating sources can be identified by a number between 1 and 9 in accordance with Table 1.

TABLE 1

Types of Fault Print-Out

Number	Originating Source
1	Routiner
2	Out-of-service detector
3	S.P.C. class A
4	S.P.C. plus crossbar class A
5	S.P.C. class B
6	S.P.C. plus crossbar class B
7	S.P.C. class C
8	S.P.C. plus crossbar class C
9	S.P.C. plus crossbar plus routiner linked print-out

The three classes of fault are defined as follows:

class A—definite equipment fault,
class B—probable equipment fault, but may be congestion, and
class C—probable congestion, but may be equipment fault.

The processor seizes the equipment monitor when

(*a*) it detects a fault during the self-checking routine,
(*b*) a fault is detected during call set-up, and
(*c*) it is instructed by a router control which has detected a fault during call set-up.

Fig. 5 indicates the stages before the equipment monitor produces an output on to the data highway, when a fault is detected on a live-traffic call by either the processor or router control.

Processor detects fault
↓
Processor seizes equipment monitor
↓
Equipment monitor receives fault information from processor
↓
Equipment monitor receives fault information from router control
↓
Equipment monitor receives and stores identities of t.r.g.s, switches, markers, etc., used on call
↓
Router control and processor released
↓
Fault information transferred from equipment monitor to data highway for analysis and print-out

Fig. 5—Sequence of operations for fault-incidence analysis

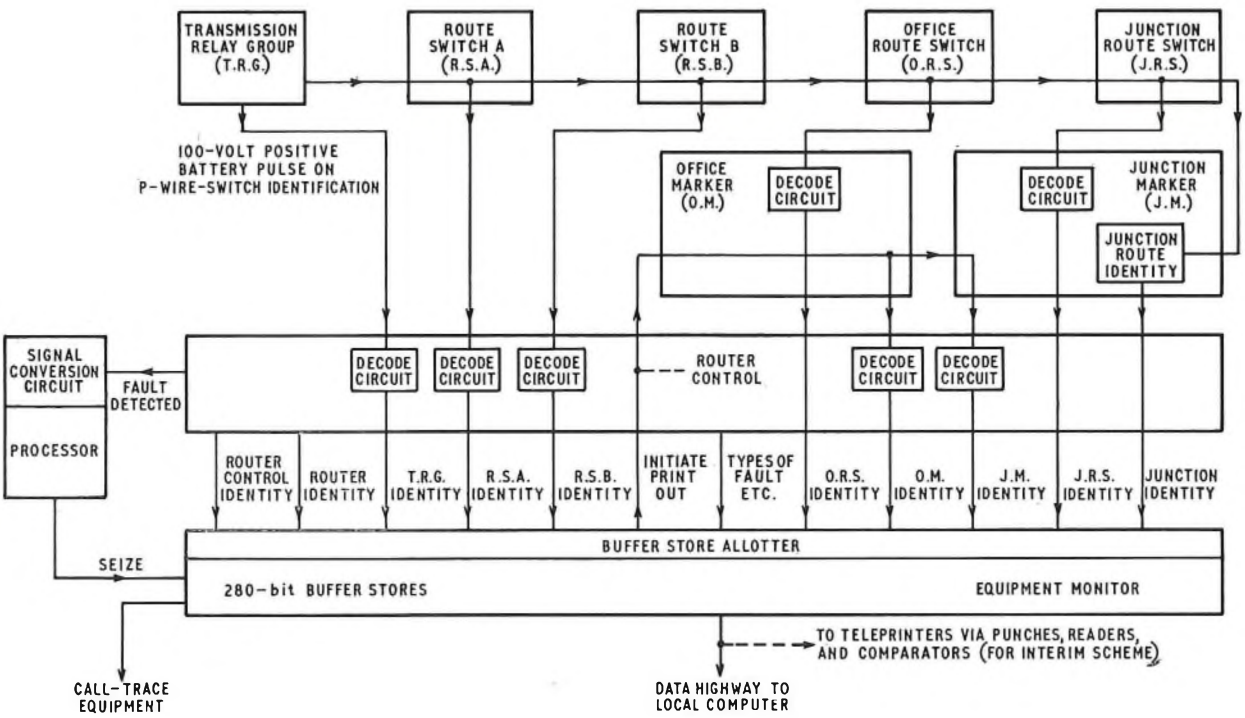

Fig. 6—Simplified block diagram of equipment monitor

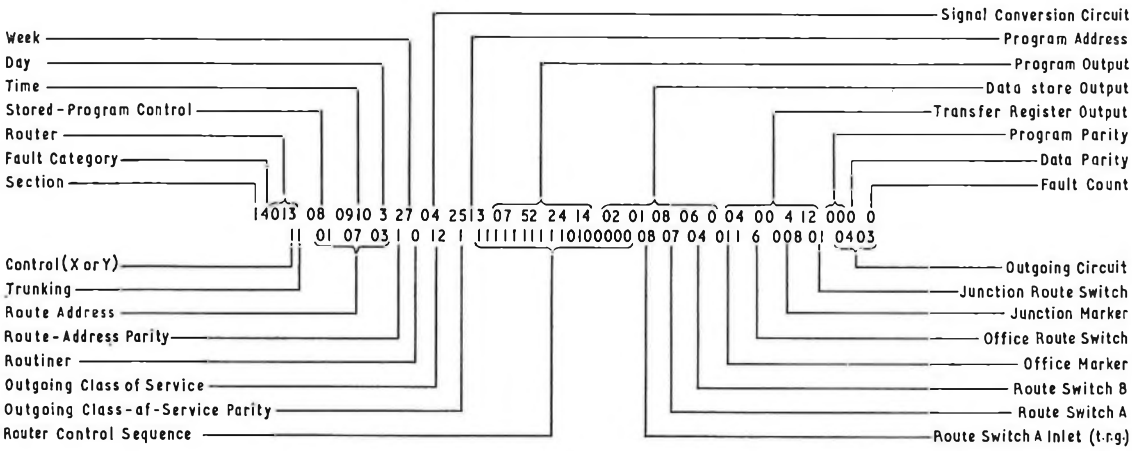

FIG. 7—Typical print-out of fault information

A typical block diagram of the equipment monitor is shown in Fig. 6 and a typical line of print-out for a category No. 4 fault, that is, s.p.c. plus crossbar class A, is illustrated in Fig. 7.

COMPUTER ASSISTANCE

A computer assistance scheme to analyse fault print-out information has already been successfully introduced for TXK1 local non-director exchanges. The use of computerized analysis methods facilitates the early detection of faults and minimizes the need for visual analysis. The latter can be time-consuming, boring and repetitive as there is usually a large volume of print-out containing information which is very similar and may be separated in time and interspersed with other fault information.

The choice of using off-line batch processing or on-line real-time processing methods for computer assistance depends mainly on the volume of print-out, turn-round time required for print-out analysis, size, importance and complexity of the installation.

For TXK1 local non-director exchanges, these criteria can be met effectively by periodic off-line batch processing. However, for s.s.c.s, the volume of print-out will be beyond the limits of batch processing. It is estimated that some 43,000 incident reports per s.s.c. per day will require scrutiny and analysis, and an on-line system with continuous analysis is, therefore, necessary. The system to be introduced uses a small process-control type of computer at each s.s.c., installed in exchange apparatus area, adjacent to an equipment monitor. This feeds into a main computer installation sited at Colindale, North-West Area s.s.c.

The basic features of the computer configuration are shown in Fig. 8. A high order of reliability is required for the system. The local and main computer installations are required to have an operational availability of 98 per cent, that is, 3-hours downtime in 7 days, with 95 per cent of all faults being cleared in less than 3 hours. Local computers will be maintained by B.P.O. staff from the outset, but the main computer will be maintained by the contractor, until sufficient expertise is attained within the B.P.O. All computers will be installed in s.s.c. buildings to give the same security as the

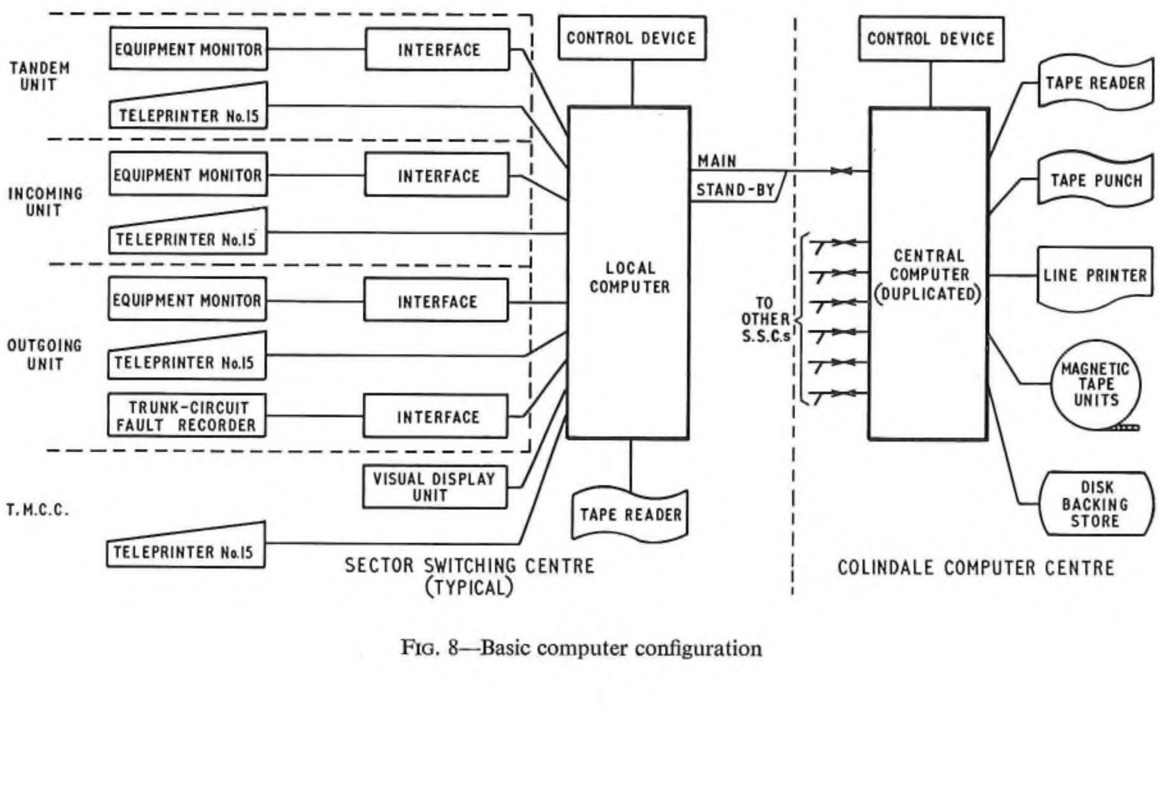

FIG. 8—Basic computer configuration

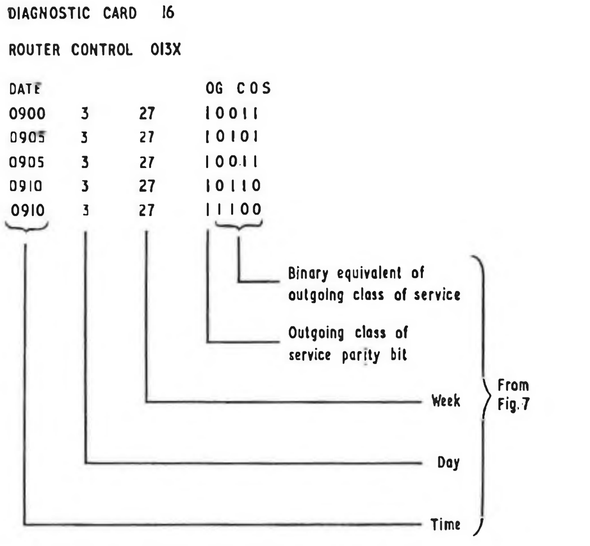

FIG. 9—Typical computer print-out of fault-information analysis

switching equipment they serve. Colindale s.s.c. was chosen for the main-computer site because of the availability of suitable accommodation.

Fault data will be gathered by the local computers from the individual units of the s.s.c.s. An immediate print-out of urgent reports will be given on local teleprinters. Data will be compressed and transmitted as standard messages via a B.P.O. data link to the central computer where it will be analysed immediately to indicate the troublesome area. When the indications exceed a predetermined threshold limit for the area concerned, analysed data will be sent back to the local computer which will print-out an action message at the appropriate diagnostic room.

The on-line computer assistance scheme will not be available by the opening of the incoming unit at Ilford s.s.c. As an interim measure, faults will be printed-out directly on teleprinters and, for the analysis of priority classes of reports only, an off-line daily batch-processing system, using a B.P.O. Data Processing Service computer installation, is available. For the remainder, visual analysis will be used until the on-line scheme is available.

DIAGNOSTIC CARDS

As the computer output becomes available to the diagnostic-room staff, further analysis may be necessary to identify precisely the cause of a particular fault. As an aid for this further analysis, a series of diagnostic cards have been produced dealing with crossbar-switching and s.p.c. processor faults. Fig. 9 gives an example of a computer print-out relating to a failure of outgoing class of service on a call using consistent router and router control. It is an analysis of five print-outs, occurring between 0900–0910 hours, similar to that shown in Fig. 7, and these would be interleaved with any other faults occurring during this period. The print-out indicates the appropriate diagnostic card relating to the particular fault. In the example shown, this is diagnostic card No. 16 which is reproduced in Fig. 10.

CONCLUSIONS

The s.s.c.s will present new challenges to maintenance staff. The introduction of large switching units of advanced, and as yet unproved, design into the outer areas of London will

TXK1 WITH STORED PROGRAM CONTROL — DIAGNOSTIC CARD 16

Outgoing Class of Service Failed

Consistent Router and Router Control

On completion of a successful loop check test, the class of service of the outgoing circuit is passed to the Router Control and checked for odd or even parity. If odd, relay WK (Router Control) operates to indicate that parity is correct, if even, relay FR (Router Control) operates to indicate that parity is wrong. This operation is covered by a Router Control time out.

This fault print out has occurred because the time out period has expired.

As the COS signals are printed with neither WK or FR relays (Router Control) operated, the area most likely to contain the fault is the circuit element shown.

Study the print out to find a possible pattern of the COS signals. This should indicate which of the contacts is the probable cause of the faults.

Operate the Router Control Busy Key (KB) and Inhibit Time Out Key (KTI). Manually operate the relays CSA to CSE as indicated in the print out then check the circuit element shown below for

(a) dis or dirty contacts, or

(b) dis relay coils.

Note that the outgoing Class of Service is printed CSE, CSD, CSC, CSB, CSA from left to right.

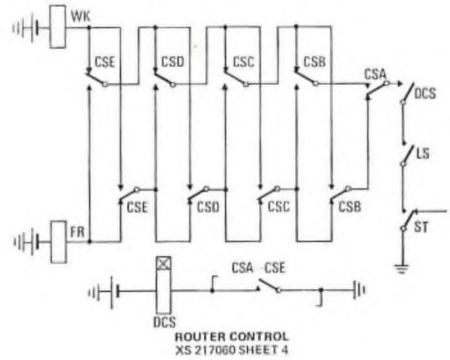

FIG. 10—Typical diagnostic card

require the staff in those areas to acquire new skills. Maintenance organization will need to take account of the change in emphasis from preventive to corrective measures. To take the fullest advantage of computer-aided diagnostic and fault-location techniques, adaptation and refinements of existing maintenance practices will be necessary.

This article is written prior to commissioning of the first of the s.s.c.s and, therefore, has discussed aspects of maintenance as seen at present. There is little doubt that, when practical experience of s.s.c. working has been gained, refinements and developments in both organization and method may well be necessary. The authors have no doubt, however, that the challenges posed by the s.s.c.s will be welcomed and adequately dealt with by maintenance staff.

ACKNOWLEDGMENTS

The authors wish to express appreciation of the considerable help given in the compilation of this article by colleagues in Telecommunications Headquarters and the Regional Headquarters of the London Telecommunications Region.

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Optical-Fibre Telecommunication Transmission Systems

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U.D.C. 621.391.63: 677.521: 621.376

The basic principles are outlined of light propagation in fibres operating in monomode and multimode. Transmission system requirements are discussed with particular reference to modulation and multiplexing methods and possible types of repeater.

INTRODUCTION

This article is the first of a short series which outlines the principles, problems and present state of research and development in a field that now seems likely to yield a new family of telecommunication transmission systems, although, currently, no engineered system has been demonstrated in a form suitable for economic civil telecommunication applications. Considerable research and development effort is now, however, devoted to this field in several countries, including the United Kingdom (U.K.), the United States of America, Germany, Japan and Australia, and confidence is growing that optical-fibre systems will, sooner or later, compete effectively with systems using conventional metal-conductor cables.

Serious interest in the possibility of optical-fibre telecommunications began about 1965 in the U.K., as a result of tentative calculations carried out at the Research Department of the British Post Office (B.P.O.) and at the Signals Research and Development Establishment of the (then) Ministry of Technology. The calculations assumed that very short pulses of light of suitable wavelength could be transmitted with little distortion and acceptable attenuation over long lengths of optical guide, formed by a suitably-cladded glass fibre, as had been demonstrated with long pulses over short lengths by the Standard Telecommunications Laboratories Ltd.[1]

The calculations also assumed, from the limited evidence then available, that the attenuation coefficient of the fibre could be related to the optical properties of the bulk glasses from which the fibre was formed. A considerable act of faith was made that the chemical purity of the glasses could be improved by a factor of 1,000, or more, over that of the best generally-available optical glasses, and that glass compositions could be chosen so that the physical perfection of the glasses in the fibre would approach that in the best bulk glasses. It was also, perhaps naively at the beginning, assumed that a gallium-arsenide laser or light-emitting diode of suitable characteristics would offer no insuperable problems, that a silicon photo-detector would readily meet the detection requirements, and that fibre jointing, termination and formation into cable form would all be achieved within a reasonable time and expenditure of effort.

Many foreseen and unforeseen problems have been met and either overcome, or for the present, circumvented at some cost in performance elsewhere in the system. The system design parameters have been re-optimized as the characteristics likely to be realized for each system element have been seen to change. Existence theorems have been demonstrated, in the U.K. or elsewhere, for each of the main features of an eventual practical system.[2, 3]

LIGHT PROPAGATION IN FIBRES

The guidance of light rays inside thick glass rods, and around bends in such rods, is well known. With reference to Fig 1, if a light ray R1 inside a rod meets the surface of the rod at an angle θ_1, then total internal reflexion of the ray takes place provided that

$$\cos \theta_1 > \cos \theta_c = n_2/n_1,$$

where n_1 is the refractive index of the rod material,

n_2 is the refractive index of the surrounding medium ($\simeq 1$ if the medium is air), and

θ_c is the internal cut-off ray angle.

All the power in ray R1 is then reflected into ray R2. But, if for a given angle θ_1, the ratio n_2/n_1 is increased (for example by immersing the rod in a liquid having a suitably-higher value of n_2) to a value greater than cos θ_1, then total internal reflexion ceases and some of the power in R1 appears in an external refracted ray R3 at an angle θ_2 such that

$$\cos \theta_2/\cos \theta_1 = n_1/n_2.$$

For the given higher value of n_2, total internal reflexion can be restored by reducing the internal angle of incidence θ_1 until cos θ_1 again exceeds n_2/n_1. For a straight rod or fibre, or, as in most practical transmission-line applica-

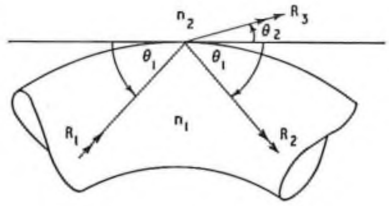

FIG. 1—Internal reflexion of a ray within a fibre

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tions, where the radius of curvature of the fibre is large compared with the fibre diameter, the angle θ_1 is equal, or almost equal, to the angle between the ray and the axis of the fibre (the off-axis angle of the ray).

The propagation time of a light pulse travelling along a ray of off-axis angle θ_1 exceeds that along a ray parallel to the axis by a factor $1/\cos\theta_1$. The intensity of any rays with off-axis angles greater than the cut-off angle θ_c will, however, decrease rapidly in the direction of propagation due to the out-radiation of a significant fraction of its power at every encounter with the fibre wall. Thus, only rays having $\theta_1 < \theta_c$ will survive any considerable distance of travel along the fibre. If a flash of omnidirectional light is produced at the planar near-end face (normal to the axis) of a length L of fibre, a fraction of the light will arrive at the far end of the fibre as an extended pulse with an arrival time spread between Ln_1/c and Ln_1^2/n_2c, where c is the velocity of light in free space.

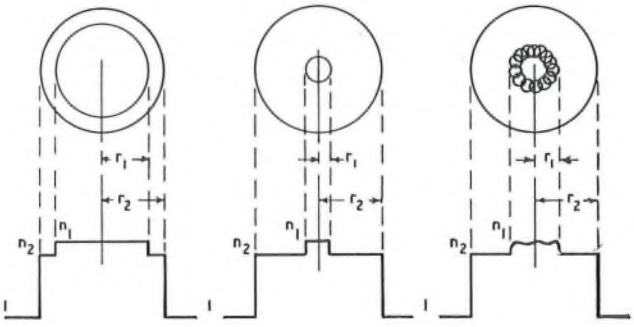
In order to ensure sufficient mechanical flexibility, the fibre, which must be made of a silicate glass or similar material in order to attain the required low optical loss for long-distance transmission purposes, is required to be of small diameter, usually about 0·1 mm or less. Such a fibre can readily be made by drawing-down from a rod at a suitable high temperature. The simple concept of a ray, as a beam of small diameter that propagates in a straight line while maintaining a constant diameter, remains a useful and meaningful one so long as the beam diameter is many times the wavelength of the light.

An additional requirement for usefulness in the present context is that the beam diameter should be small compared with the diameter of the optically-important part of the fibre cross-section. For the simple fibre considered so far, the whole cross-section is relevant. Visible light extends over a wavelength range, in air, of about 0·4 μm–0·7 μm. The wavelengths most likely to be used in fibre telecommunication systems are in the near-infra-red range of about 0·7 μm–1·1 μm. It is, thus, just permissible to make use of the ray concept in considering light propagation in fibres of about 50 μm–100 μm effective diameter, if a ray is regarded as a beam of about 10 μm diameter. A brief consideration of the wave theory of light shows, however, that such a ray will not conserve its diameter over any great propagation distance. Any quantitatively accurate analysis of the propagation properties of these and smaller fibres at such wavelengths must make use of the wave theory. Analyses, supported by experimental data, have appeared in scientific literature.[4]

The wave theory shows that significant optical field penetration occurs to about a wavelength outside the surface of a simple rod or fibre under the conditions of total internal reflexion noted earlier. In the absence of light-scattering or light-absorbing objects close enough to the surface, this phenomenon is of no consequence. But, in practice, the fibre must be mechanically supported and, necessarily, comes into contact with other materials at unpredictable points along its surface. The practical solution to this problem is to construct the fibre with a continuous cladding layer of sufficient thickness (at least several wavelengths) to ensure a negligible optical field at its own outer surface, and of sufficiently low optical loss to make a negligible contribution to the loss of the fibre as a whole. The refractive index n_2 of the cladding material must ensure that the condition for total internal reflexion is met, up to the desired cut-off angle θ_c.

Multimode Fibres

Fig. 2(a) shows schematically the cross-section and refractive index profile of a fibre of the type just described, which is now commonly referred to as the multimode type. This term arises from the wave-theory description of a fibre having a large enough core diameter $2r_1$ to permit, when proper account is taken of the ratio n_1/n_2, many independent wave modes to propagate freely within the fibre. Although there is not a simple one-to-one relationship between wave modes and rays,



(a) Multimode, $r_2 - r_1 \simeq$ 5–10μm.
(b) Monomode, $r_1 \simeq$ 1–5μm.
(c) Graded index, $r_1 \simeq$ 15–20μm.

Note: Typically, $r_2 \simeq$ 25–50μm and $(n_1 - n_2)/n_1 \simeq$ 0.005–0.02.

FIG. 2—Cross-sections and refractive index profiles of three types of optical fibre

a multimode fibre can be considered as capable of carrying rays over a range of off-axis angles up to θ_c. The ray description becomes more meaningful as the number of possible modes becomes higher.

An important attraction of multimode fibre is that it can capture, from an incoherent light source of given radiance B, an optical power $P_1 = BA\Omega$,

where A is the effective cross-sectional area of the fibre,

and Ω is its effective optical capture solid angle.

For a multimode fibre,

$$A \simeq \pi r_1^2,$$

and, if the end of the fibre is immersed in a medium of refractive index n_1, Ω is approximately the solid angle of a cone of half-angle equal to θ_c, that is

$$\Omega \simeq 2\pi(1 - \cos\theta_c) = 2\pi(n_1 - n_2)/n_1 \text{ sterad.}$$

Thus, P_1 increases in proportion to

$$r_1^2(n_1 - n_2)/n_1.$$

A disadvantage of multimode fibre follows from the expressions quoted earlier, which show that a short transmitted pulse is spread out in time t to an overall duration of $\Delta t \simeq L(n_1 - n_2)n_1/n_2c$ after transmission over a fibre of length L. Since, in order to maximize the economic benefit of a fibre transmission system, it may be necessary to maximize the product of the length L between repeater (amplifier) positions and the effective bandwidth or bit-rate of the transmitted information signals per fibre, there may exist an optimum value for the index difference $n_1 - n_2$ if an incoherent optical source and multimode fibre must be used together. The resulting maximum range and bandwidth product may not be sufficient to render the fibre system competitive with other systems. There are at least two ways out of the latter difficulty.

Monomode Fibres

The first, which entails the use of a coherent (laser) light source to provide the necessary high-radiance, requires that the core diameter $2r_1$ of the fibre be reduced until only a single wave mode can propagate, and is known as monomode fibre. The wave theory shows that this is always possible provided that, for fibre of circular cross-section,

$$r_1 < 2{\cdot}405\lambda_0/\{2\pi\sqrt{(n_1^2 - n_2^2)}\},$$

where λ_0 is the wavelength of the light in free space.

The ray description is hardly significant for such a fibre, except in the sense that a single ray is guided along the core by the core–cladding boundary and no other rays can exist in a sustained form. Fig. 2(*b*) shows the cross-section and refractive-index profile for such a fibre. A short pulse of light, transmitted along this type of fibre, suffers no spreading in time due to multimode effects. Small amounts of spreading remain due to

(*a*) the dependence of n_1 and n_2 on λ_0 (commonly known as optical dispersion, and generally different for different materials and different wavelength regions), and

(*b*) the dependence of the optical field distribution between the core and the cladding on λ_0 even if n_1 and n_2 are independent of λ_0 (sometimes known as waveguide dispersion).

Graded-index Fibres

An alternative to the use of monomode fibre, as a way of avoiding the large amount of spreading of signal propagation time that must occur in the simple multimode fibre already described, is to modify the multimode fibre so that a large enough proportion of the rays or modes have end-to-end propagation times that are closely equal to a common value. An almost ideal modification is to replace the sharp step in refractive index between core and cladding by a radial gradation of refractive index according to the parabolic law:

$$n^2 = n_1^2 (1 - Kr^2/r_2^2),$$

where K is a constant.[5]

Given this law, a ray launched into the fibre at not too large an off-axis angle oscillates sinusoidally in distance from the fibre axis as it propagates along the fibre, and the propagation time is almost independent of the angle.

It is physically almost impossible to reduce n below unity in a solid and it is technologically difficult to match the parabolic law closely over smaller, but still wide, ranges of n or r. Nevertheless, both theory and experiment have shown that a considerable reduction in the spread of propagation time can be achieved with rather poor approximations to the ideal parabolic law.[6] It is not even necessary to have a maximum of n on the axis of the fibre.The technology for producing a suitable gradation of n over the radius may be more practicable if the maximum of n can be away from the axis (for example, on a cylindrical surface centred on the axis). Fig. 2(*c*) shows a possible graded-index fibre of this type, in cross-section and in refractive-index profile.

TRANSMISSION SYSTEMS

The ultimate theoretically possible information transmission capacity of a single optical fibre with suitable repeaters is so much greater than that of transmission media using lower carrier frequencies, and so much greater than transmission systems seem likely to require for the foreseeable future, that engineering and economic criteria must play a significant part in guiding research as well as development work in this area. The frequency of an optical wave of about 1 μm wavelength is about 300 THz (= 3×10^{14} Hz), so that a 10 per cent bandwidth in this part of the spectrum, which can be transmitted with an optical loss below 10 dB/km through a single fibre, could in principle carry about 10^{10} telephone channels or over 10^6 high-definition television channels. The last two figures assume analog modulation and closely-packed frequency-division-multiplexing (f.d.m). More realistically foreseeable needs, though perhaps still distant, are at least a factor of 10^4 below these figures, corresponding to, at most, an analog communication bandwidth of about 3 GHz per fibre. This can be compared with the 60 MHz per coaxial pair of the most recently developed coaxial cable system.[7] It must not, however, be assumed that a fibre system could be of practical interest only if the capacity per fibre exceeds that per pathway in existing transmission systems.

The potentials of fibre systems must be explored on their own technical and economic merits. It may well be found that, because of the low fibre attenuations attainable, fibre systems of quite low capacity will become competitive with conventional cable systems because of the smaller number of repeaters (besides the smaller cable duct space) required.

The term repeater is used in this article to designate the arrangement of optical, optical-electronic, electronic and electronic-optical components and devices and their interconnexions, mountings and powering arrangements needed for use at one location along the system with a single operational fibre pathway. In a fibre system, a repeater will normally operate for only one direction of transmission, and will normally include short tail fibres at the input and output, connexions to the main fibre cables being made by suitable fibre-to-fibre connectors.

MODULATION AND MULTIPLEXING METHODS

The general requirements for a repeater depend on the modulation and multiplexing methods used in the fibre transmission system as a whole. In order to minimize the costs of linking fibre systems with existing transmission systems, the modulation and multiplexing methods should have maximum compatibility consistent with giving the maximum benefits for the fibre systems. While almost all trunk cable systems presently carry analog f.d.m channels for telephony,[8] many shorter-distance systems now make use of pulse-code-modulation (p.c.m.) signals with time-division-multiplexing (t.d.m.),[9] and it is likely that p.c.m./t.d.m. systems will extend to cover a broader field in the future. The much reduced stringency of the requirements of p.c.m. transmission systems for amplitude linearity and signal-to-noise ratio (compensated by their greater bandwidth requirements for equal transmission capacity) tend to favour the use of p.c.m in optical systems, where the amplitude linearity and noise characteristics of repeaters will generally be poorer than in lower-frequency systems.

The available transmission bandwidth per pathway will be limited by the properties either of the fibre, or of the repeater components, or by a combination of these. The ultimate noise level will be set by a combination of thermal noise independent of signal level and of quantum noise that increases with (but more slowly than) signal level. Where the available bandwidth is much greater than that needed by the original information signals (such as telephony or television) it is well established[10] that the signal-to-noise ratio requirements within the transmission system can be relaxed by spreading the information signals spectrally so that they occupy the available bandwidth in a way that matches the noise. Suitably-coded p.c.m. methods can provide efficient matching of this sort while using digital signals in the transmission path that can readily be processed without distortion at the repeaters, at system interfaces and at switching points. In principle, analog pulse-time-modulation (p.t.m) could equally avoid the amplitude-linearity restrictions of optical send and receive devices. But, analog p.t.m methods cannot, in general, give as great an advantage as can p.c.m in relaxing the signal-to-noise ratio requirements, nor are they suitable, without demodulation, for interfacing or switching. Nevertheless, there could be some fields, particularly in short systems that will not interface directly with the main digital transmission network, where analog p.t.m transmission may be attractive.

P.C.M. is generally, and naturally, used in conjunction with t.d.m. Nevertheless, it is technically possible to pulse-code-modulate an f.d.m assembly of analog-modulated channels. Similarly, while p.t.m. would generally be used in conjunction with t.d.m if a number of original channels had to be transmitted, it would be possible to drive a pulse-time-modulator from an f.d.m assembly of the analog-modulated original channels.

Optical F.D.M.

Optical f.d.m. might be achieved by modulating several separate-frequency optical-carrier sources with independent information streams, and combining the resultant optical signals by simple superposition and launching into a common optical fibre. In most cases of possible practical interest, the modulation bandwidth is likely to be much smaller than the natural optical frequency spread (linewidth) of likely sources. To permit the optical signals to be separated without significant crosstalk at the receiving end of the fibre, the frequency separation of the optical carriers must be at least several times their linewidths. At the present state of development, a semiconductor laser operating at room temperature under single-mode conditions may have an effective linewidth of about 10^{-5} of its frequency, but a greater width must be allowed for to take account of possible multimode operation and thermal-drift effects. The achievement of acceptable optical filters for the receiving end of such a system, with narrow-enough pass-band, high-enough rejection of other channels, low-enough loss in the pass-band, and compact-enough construction with good-enough temperature compensation is still only a distant possibility. In comparison with optical space-division-multiplexing, optical f.d.m. for fibre systems would seem to have little prospect of finding application.

Optical Space-Division Multiplexing

Optical space-division multiplexing amounts in its basic form to no more than the aggregation into a single cable of several independent and independently repeatered, but identical, optical-fibre systems. Such an aggregation provides all the benefits of optical f.d.m. without any of its disadvantages except that a separate fibre is required for each optical carrier. The multi-fibre space-division system can have greater repeater spacing and simpler repeaters, and can be cheaper than, an optical f.d.m. system because

(*a*) each fibre is small and many fibres can be included in a cable at, eventually, only a small additional cost,
(*b*) all the optical carrier frequencies are equal, and
(*c*) optical filters are unnecessary and their insertion loss can be saved.

A multi-fibre space-division system is analogous to a multi-tube coaxial-cable system, and both have similar capabilities for handling traffic from very large sources.

Fibre-bundle Systems

A distinction must be made between multi-fibre space-division systems and fibre-bundle systems. In a fibre-bundle system, the same signal is transmitted simultaneously through all of a group of fibres between each sending and each receiving device. A greater total signal power can be transmitted in this way and the fibre redundancy provides some security against breakage of individual fibres. Fibre-bundle systems may have applications within equipments, in buildings and over other short distances. The spread in propagation-delay among the component fibres will limit the range of such systems for high communication-rates.

REPEATER PRINCIPLES

Amplifiers of light intensity were known in the form of image intensifiers well before laser action was first demonstrated in 1959. Ultra-sensitive detectors of light were known, in the form of photo-multiplier tubes, much earlier. Modern photomultiplier tubes can have current gains in the region of 10^6–10^8, and can give useful electrical outputs in response to single optical quanta (photons) over a broad range of wavelengths from ultraviolet to near infra-red, with rise-times as short as 1 ns. A more convenient photodetector is the silicon-avalanche photodiode, which, however, has a gain of only about 10^2 and a longer rise-time, but can cover a similar wavelength range.

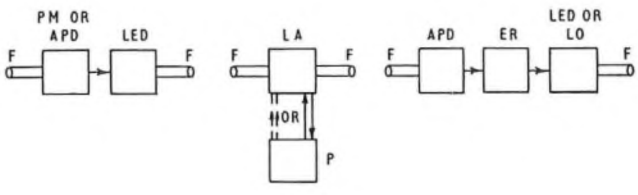
The output section of an image intensifier, like that of a cathode-ray tube, is a screen containing small crystals of a luminescent material which is excited by impinging electrons of sufficient energy. Electro-luminescent materials can be made into similar polycrystalline screens that are excited by the direct passage of transverse electric current. None of these light sources is very efficient or fast in response. Efficient and fast-enough electrically-driven light sources have appeared only with the development of monocrystalline semiconductor p–n junction light-emitting-diodes (l.e.d.s). By suitable choice of the semiconductor material and of its doping impurities, l.e.d.s can be made to emit at wavelengths from the visible to the infra-red.

One of the most efficient l.e.d.s is of gallium arsenide (GaAs) and emits in the near infra-red at about 0·9 μm wavelength. This wavelength, or preferably a slightly shorter one obtainable by a small change in the l.e.d. composition, is suitable both for transmission through a low-loss fibre and for detection in a suitable photomultiplier.

Optical Repeaters

A possible repeater might, therefore, be built around a light amplifier comprising little more than a photomultiplier coupled directly to such an l.e.d. Another possible repeater would make use of the seemingly even simpler amplifier formed by a laser without its optical feedback system (or with insufficient feedback to cause self-oscillation as in a normal laser). It is well-known that a GaAs l.e.d. of suitable geometry can operate as a laser in the 0·9 μm wavelength region when pumped with a sufficient current density. A GaAs laser with one or both of its end reflexion coefficients sufficiently reduced might thus serve as a suitable direct optical amplifier.

Another type of laser which makes use of neodymium (Nd) atoms in a suitable host material, needs to be pumped optically (for example, by means of the 0·9 μm wavelength radiation from a GaAs l.e.d.) and could similarly be arranged to amplify without self-oscillation. Such a Nd light amplifier shows maximum useful gain at about 1·06 μm wavelength, which also happens to be suitable for transmission through low-loss fibres, but is not so suitable for efficient detection. Figs. 3(*a*) and (*b*) show schematically two of the basic arrangements for the optical repeater as outlined.



(*a*) Direct-coupled repeater
(*b*) All-optical repeater
(c) Baseband electronic repeater

Note: PM—photomultiplier, APD—avalanche photodiode, LED—light-emitting diode, LA—laser amplifier, P—pump (optical or electronic), ER—electronic repeater, LD—laser oscillator, F—fibre.

FIG. 3—Basic optical repeaters.

Electronic Repeaters

Fig. 3(*c*) shows what is presently considered to be the more realistic form. This makes provision in the electronic repeater section for all the gain needed to drive the laser or l.e.d. at the output from the avalanche photodiode at the input, and also, to re-shape and/or re-time the final drive signals to compensate, as far as possible, for imperfections due to distortion or (with pulse signals) noise in the received signals.

The scope for such compensation is almost absent in the direct-coupled arrangement of Fig. 3(*a*) and may be very limited in the all-optical arrangement of Fig. 3(*b*), although further long-term developments in the latter form can be expected.

A variant of the arrangement of Fig. 3(*c*) is necessary if the laser oscillator cannot be directly modulated at the required rate. In that event, the laser is allowed to oscillate continuously and its output is gated by means of a suitable electro-optic or similar fast optical switch.[11]

PROSPECTIVE SYSTEM BENEFITS

It was seen from the start of the B.P.O. work on optical-fibre systems that, as the communication rate increased, there would be a cost cross-over point in the comparison between fibre and coaxial-cable systems. Assuming a basic repeater layout as in Fig. 3(*c*), and making reasonable assumptions about the optical input and output devices, approximate repeater cost comparisons are possible.[12] These indicate that the fibre system would be cheaper for bit-rates above about 100 Mbit/s for 20 dB/km fibre loss, and above about 20 Mbit/s for 10 dB/km fibre loss, assuming that the costs of the fibre cable and the 1·2/4·4 mm coaxial tube cable chosen for the comparison were similar and that the cable duct costs were also similar. With fibre losses already reported[6] to be as low as 5–6 dB/km, the prospects for fibre systems becoming economically attractive even in low-capacity, medium- and short-distance systems, as well as in long-distance high-capacity systems, now seem to be good.

CONCLUDING NOTE

It is hoped that articles dealing with particular aspects of optical fibre transmission systems, from more specialist points of view, will appear in coming issues of the *Journal*. A detailed coverage of optical communication systems principles, with particular emphasis on atmospheric-beam systems, has appeared in other literature.[13]

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Book Review

"Techniques of Circuit Analysis." G. W. Carter, and A. Richardson. Cambridge University Press. vii + 548 pp. 302 ill. £5·00.

The authors state that the book is written primarily for undergraduate students of electrical and electronic engineering, although it will also be found useful to physicists. As the title indicates, the emphasis of the book is upon inculcating the technique of circuit analysis rather than upon studying the general theory of circuits.

There are thirteen mains sections, namely, direct-current circuits; ideal circuit elements; alternating-current circuits and the use of phasors; complex numbers in sinusoidal analysis; theory of transients; reduction methods and network theorems; frequency characteristics of elementary circuits; two-port networks; harmonic analysis; transient analysis, Fourier transforms; the complex plane in circuit analysis and synthesis; distributed circuits. At the end of each main section, questions are set and all numerical answers are given at the end of the book. Worked examples are also included in various parts of the text.

This is a high-quality publication with good type-face, excellent layout of text, and extremely good line drawings to illustrate circuit arrangements and elements. The authors' treatment of the subject is of a high standard but this is only to be expected from senior academicians dealing with well-known themes. However, there are sections covering matters omitted from many existing texts, one example being the analysis of distributed circuits and transmission lines under transient as well as steady-state conditions. The only criticism to be offered is that more worked examples should have been included in the text. This would have made the book more appealing to those who may have to study electrical engineering without ready access to a tutor.

The book will be of most use to students on degree or diploma courses in electrical engineering, but there are several sections on basic theory which could also be useful on less advanced courses, such as the National Certificate. In general, however, the book can only be recommended for purchase by those doing degree-level studies.

J. F.

A Long-Term Study of the United Kingdom Trunk Network

Part 2—Network-Layout Studies and General Conclusions

D. BREARY, C.ENG., F.I.E.E.†

U.D.C. 621.395.374.001.1:621.395.31

Part 1 of this article dealt with overall study methodology, described the service, technological and cost-forecasting procedures and described cost studies comparing alternative plant types in given situations. Part 2 describes studies of the network as a whole, dealing first with methodology, then outlining some results and finally drawing attention to some implications on network management and planning.

NETWORK STUDY RATIONALE

A long-term cost study of the layout of a switched telecommunications network should ideally contain all the following steps:

(*a*) the collection of information about the numbers and distribution of various customer terminals and the traffic they originate: this traffic data should be in the form of a matrix showing the traffic between all centres,

(*b*) the processing of the collected data (by computer) to produce a series of matrices showing the forecast traffic at a series of dates over the study period, probably 30 years,

(*c*) the preparation of forecasts of the technologies and plant systems likely to emerge during the study period, their costs estimated and cost trends forecast (at constant prices),

(*d*) the preparation of a range of network futures, each describing a different form that the network could take at the end of the study period,

(*e*) the determination of the theoretically-ideal traffic routing and plant layout for each network future for a series of dates in the study period to obtain a series of theoretically-ideal future layouts,

(*f*) study of the theoretically-ideal future layouts, and plans prepared for the conversion of the existing network to a form near to the ideal: the plans should include details of interworking proposals for the conversion period,

(*g*) comparison of the alternative plans obtained in this way using present-value studies either for the total network or for selected portions of it, and

(*h*) sensitivity testing to check the effects of variations in cost forecasts, traffic forecasts, etc.

The study first derives theoretically-ideal networks appropriate to the new technologies, forecast costs etc. in order to determine a theoretical target, before going on to examine practical plans and costs for converting an existing network to a new form. When studying the long-term network configuration appropriate to a new plant type, it is necessary to assume that all the plant in the network (or a specifically-studied subdivision of it) is of the new type. To do otherwise would result in traffic flows and plant layouts that are largely dictated by transitionary interfacing and interworking arrangements, and there would be real danger of retaining obsolete plant beyond its true economic life. In this part of the study, the technique is to take a series of "snapshots" at given points (using annual charges) rather than to use present-value or discounted-cash-flow methods spread over a study period. This allows the traffic flows, and plant costs and quantities, to be appropriate to the year in question in situations where these change from year to year. However, studies on this basis have an element of idealism which makes it necessary to include practical considerations in their interpretation and to check any deductions by means of present-value studies. Present-value costing of the entire network may not be necessary if costings of parts of the network over a 30-year period indicated that the deductions had been sound. Nevertheless, overall costings of this type may be necessary for financial-control reasons.

FINANCIAL STUDIES

An overall financial study of the entire network is needed to enable a costed plan, with acceptable cash flows, to be described in sufficient detail to permit final management decisions to be taken. Such studies must cover parts of the local as well as the trunk network, although these two ingredients can be studied separately and the results then brought together. In the trunk network, the studies will contain the following two stages beyond those already described:

(*a*) The network plans for the study period must be drawn up in greater detail (especially with regard to the conversion of plant to the new types and the proposals for the interworking between the old and the new).

(*b*) A discounted cash-flow study of the whole of the trunk network over the study period must be carried out.

The amount of work involved in carrying out all these steps in a network as large and varied as that of the United

† Formerly with the United Kingdom Trunk Task Force.

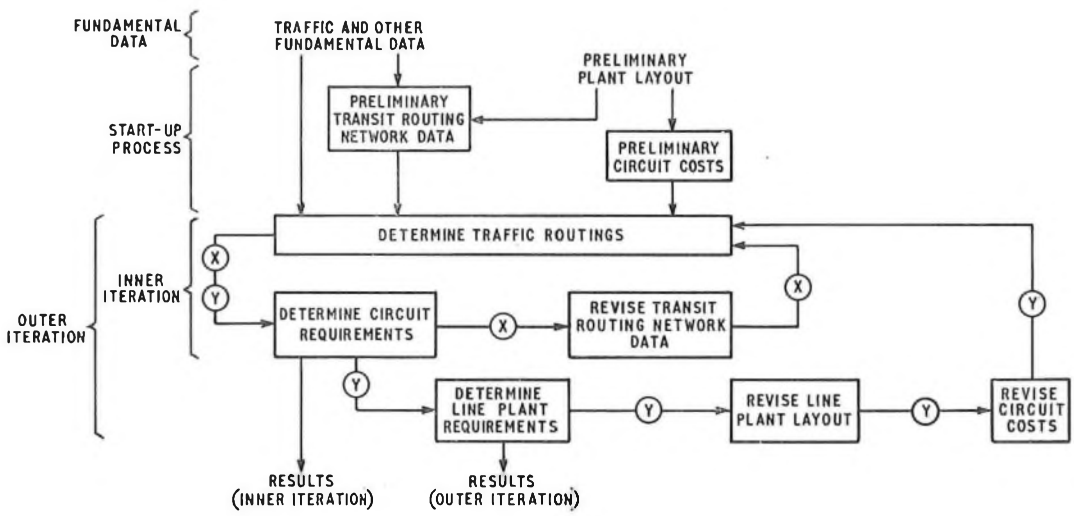


FIG. 14—The self-optimizing network-configuration and costing model

Kingdom (U.K.) is enormous, even with the help of large computers. However, it is doubtful whether total optimization is possible or, indeed, is either desirable or meaningful in view of the imperfect techniques that must, of necessity, be used in the field when determining traffic routing and planning the network. The amount of work involved in the network studies was formidable, even though, as the studies proceeded, the general trend of forthcoming work could be broadly foreseen, thus enabling the next stage of work to be directed into the most profitable areas of investigation and permitting some short cuts.

COMPUTER MODELS

Two basically different types of computer model are required for the evaluation of a switched network. The first is a network-configuration model making use of annual charges to enable traffic routings to be calculated and the consequent quantities of plant to be determined. Such models are almost invariably reiterative or recursive, though it has been suggested that, as an alternative, dynamic programming techniques could be used. The second model is required to cost alternative plant-provision plans using discounted-cash-flow methods. It is possible to conceive a single model incorporating both features, but such a model would be highly complex, and for a large network, probably impracticable. There would be the additional difficulty that the output of the traffic-routing part of the model requires human interpretation and adjustment before it is suitable to form the input to the discounted-cash-flow calculations.

The Network-Configuration Model

Of the two types of model, the network-configuration model presents the more complex problems. The model developed contained two interactive reiterative processes, one optimizing the pattern of traffic flow, and the other the pattern of line-plant layout. This is illustrated in Fig. 14. It will be seen that, using input traffic data, a preliminary transit network is formed which is that part of the total network available to carry multi-link traffic. A preliminary plant layout forms an initial input, and from this, preliminary circuit costs are determined for all potential traffic links and traffic links postulated to exist. After the first iteration, the preliminary circuit costs and preliminary transit network are replaced by revised circuit costs and by a revised transit network. The original data on traffic flow are, however, used throughout all the iterations. The inner iterative process (marked X in Fig. 14) routes the traffic over new routes using the circuit costs supplied and then produces a new network, including that part used for transit routing. The revised network provides new transit routing network data for the next iteration. When traffic routing has been optimized using the preliminary plant layout and preliminary circuit costs, the process moves into the outer iteration (marked Y in Fig. 14). The outer iterative process uses the output of the inner optimizing process to determine the new line-plant requirements and revise the line-plant layout accordingly. Revised circuit costs are determined for the new layout and these are input into the inner iterative process to permit a re-optimization of the traffic routing. Thus, each outer iteration leads to a new inner optimization.

The inner iterative process normally became completely stabilized by the tenth iteration. Subsequent iterations did not alter the routing of any element of traffic or change the total annual charges. However, it was found that the changes between the fifth and tenth iteration were negligible, and, hence, the process was normally stopped after the fourth iteration. The outer iterative process normally stabilized on the fourth iteration and subsequent iterations resulted in no change in line-plant layout or circuit allocation. The outer iteration was, therefore, normally stopped on the completion of the third outer iteration when line plant was being optimized, or on completion of the second iteration, if traffic routing was being optimized, but the optimum line-plant layout was not required.

THE NETWORK FUTURES

Numerous network futures were derived by selecting combinations of the following:

(*a*) transmission systems (analogue or digital),

(*b*) switching systems (analogue/space, analogue/time-division multiplex (t.d.m.), digital/space or digital/t.d.m.),

(*c*) signalling systems (in-band, out-band or separate-channel/addressed), and

(*d*) control (stored-program control (s.p.c.) or distributed control).

By various processes of elimination, three combinations emerged as being of special interest. These will be referred to as:

(*a*) the present network, containing analogue transmission, analogue/space switching, in-band signalling and distributed control, (*b*) the intermediate network, containing digital transmission, analogue/space switching, interprocessor separate channel/addressed signalling and s.p.c., and

(*c*) the digital network, containing digital transmission, digital/t.d.m. switching, interprocessor separate channel/addressed signalling and s.p.c.

Variants of the intermediate and digital networks assumed distributed control and in-band or out-band signalling instead of s.p.c. with separate channel/addressed signalling. Because of the similarity in costs, the present network was considered to be representative of an alternative intermediate network containing analogue transmission and digital/t.d.m. switching. Network futures involving the space switching of digital bit streams, and the use of separate digital/t.d.m. higher-order switching centres in an otherwise analogue/space switching network were eliminated on cost grounds and were not used in network configuration studies.

The traffic routing and network configuration of the network futures selected for study were evaluated for the years 1986 and 2001. The present network was also evaluated for 1975. The evaluation normally assumed that high-usage working would be used where appropriate, that the grades of service would be slightly better than those at present in use, that a high-usage route would not contain more than three basic 30-circuit modules of digital plant, and that fully-provided routes would contain not less than two such 30-circuit modules, although these assumptions were varied in some evaluations, as described later. Some of the results obtained using the network model are discussed in the following paragraphs.

NUMBER OF TRUNK SWITCHING CENTRES

The results for the present, intermediate and digital networks using 1986 parameters are given in Fig. 15. The graphs indicate the total trunk network annual charges for networks containing from 30–420 trunk switching centres which have had their traffic flow and line-plant layout optimized using the network model. With the rather idealized conditions assumed, the optimum number of trunk switching centres in the present network is about 300 and in the intermediate and digital networks, the optimum is rather less than 100. All the curves are relatively flat over a large part of their length and hence, the number of centres is not critical. The introduction of digital transmission plant significantly reduces network annual charges, and the introduction of digital switching and transmission reduces them dramatically.

The present network was also studied only for 1975, and the results indicated that the optimum number of trunk switching centres was about 350 (the exact number was not economically critical). The current network, which is the result of generations of optimization, contains 376 trunk switching centres, and the close correspondence between these two figures provides a useful check on the operation of the network model. In fact, a run of the model based on the present 376 switching centres produced a pattern of routes almost exactly corresponding with that operationally planned for the real network.

The sensitivity of the digital-network curve to variation in the estimates of transmission and switching costs is illustrated for 1986 in Fig. 16. Using upper-limit switching or transmission plant costs does not affect the optimum number of trunk centres although, naturally, they raise the total network annual charges. The foregoing results deal with centres to switch only trunk traffic.

The various ways in which trunk and local tandem switched traffic can be handled are illustrated by four schemes in Table 1. They are:

(*a*) scheme A, having separate trunk and local tandems at each of N centres (N varying from 30–420),

(*b*) scheme B, having separate trunks and local tandems at each of N centres plus sufficient remote local-only tandem centres to bring the total to 420 centres of all types,

(*c*) scheme C, having combined trunk and local tandems at each of N centres, and

(*d*) scheme D, having combined trunk and local tandems at each of N centres plus sufficient remote local-only tandem centres to bring the total to 420 centres of all types.

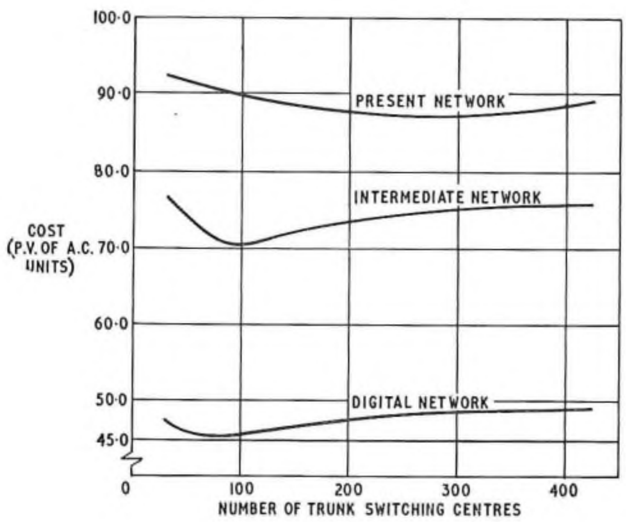
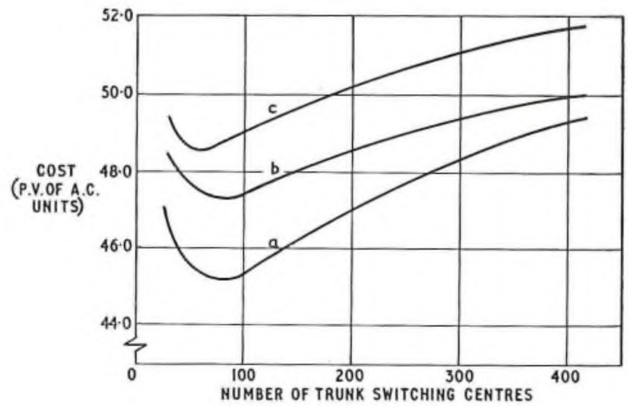


FIG. 15—Comparative trunk-network costs at 1986.



(a) — median costs, switching equipment and line plant
(b) — upper-limit costs line plant, median costs switching equipment
(c) — upper-limit costs switching equipment, median costs line plant

FIG. 16—Comparative wholly-digital trunk-network costs at 1986

TABLE 1

Trunk and Local Tandem Switched Traffic Schemes

Scheme		Type of Switching Centres		
		Trunk switching centres	Remote local switching centres	Co-located local switching centres
A	No. of centres	N	—	N
	Traffic switched	Trunk	—	Local tandem
B	No. of centres	N	420—N	N
	Traffic switched	Trunk	Local tandem	Local tandem
C	No. of centres	N	—	—
	Traffic switched	Trunk + local tandem	—	—
D	No. of centres	N	420—N	—
	Traffic switched	Trunk + local tandem	Local tandem	—

Fig. 17 shows the effect on annual charges of including local tandem switched traffic in the study of the digital network in various ways. The costs are, of course, higher because they include switching and line plant to carry this traffic not included in the previous studies, but the optimum number of switching centres remains unchanged. Schemes, in which trunk and local tandems are combined, proved cheaper than schemes in which they are separate because the digital switching and transmission plant is used more efficiently.

Fig. 17 shows that, at 1986, the optimum number of centres lies between 70 and 90 and that costs rise rapidly if the number is reduced below this optimum, but rise much less steeply if the number is increased above the optimum. In practice, it is expected that there will be a few centres where separate trunk and local tandems would be justified under digital conditions, and others where local tandems (remote from trunk tandems) would be justified. However, individual cases have not been investigated. Fig. 18 shows that, at the year 2001, the minimum is in the region of 150–200 centres, and the curve is much flatter, except below about 70–90 centres. The difference in the shapes of the curve at 1986 and 2001 is partly due to switching costs becoming cheaper relative to line-plant costs as time goes on, and the increasing efficiency with which the rather large basic module of 30 circuits is used as the traffic density on the smaller traffic routes increases.

From the results obtained, it can be deduced that as the amount of digital transmission plant in the network increases, the economically-ideal number of trunk switching centres decreases. But, the economic advantage resulting from reducing the present number is small, and will almost certainly be outweighed by the cost of reorganizing the network, unless this is done at a time convenient to each centre as part of a long-term plan covering the remainder of the present century. However, the practical implications of such a plan need study before any move to reduce the number of switching centres could be undertaken.

LINE-PLANT LAYOUT

Optimization of the line-plant network using the outer iteration of the computer model led to the conclusion that a simple grid containing relatively small numbers of large transmission links was cheaper than a mesh containing a multiplicity of smaller transmission links. The simple grid leads to a less direct routing of circuits, with the attendant penalty of multiplexing equipments at intermediate flexibility points, but nevertheless the large size of the individual main transmission links led to net cost savings compared with the cost of smaller, but more direct, links. This preference for a simple grid would apply, whether there were a large or small number of switching centres, although it will be appreciated that, with a large number of centres, there will be many occasions when the final link from the main grid to a particular centre will be a small spur link. Hence, a small number of centres is favoured. The large cheap-line-plant routes favour the provision of direct traffic routes between centres, and the optimized line plant led to a 1 per cent increase in such routes compared with the present network configuration. It, predictably, led to less through-switched traffic and lower overall costs. Thus, even in a country as small as the U.K., it pays to concentrate on heavy transmission links under digital transmission conditions even though this may involve the use of more multiplex equipment for flexibility at intermediate nodes. There is an added advantage that network protection by alternative transmission links is simpler and cheaper in such a network.

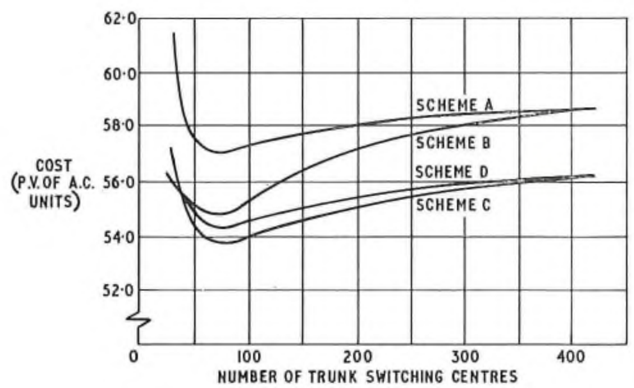


FIG. 17—Comparative wholly-digital trunk-network costs at 1986, including local tandem-switched traffic

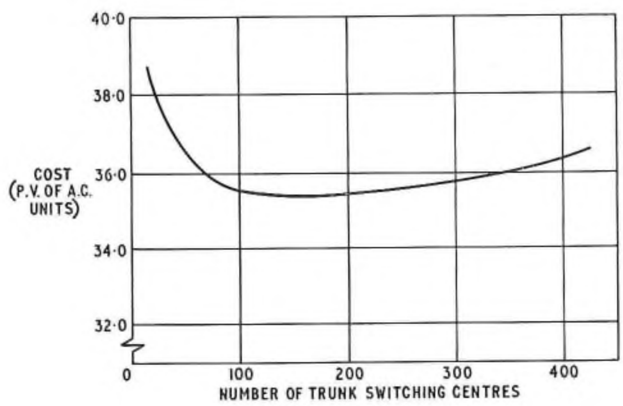


FIG. 18—Comparative wholly-digital trunk-network costs at 2001

SENSITIVITY STUDIES

Numerous evaluations were carried out to test the sensitivity of the network layout to variations in network, cost and other assumptions made. The results of some of these are that:

(*a*) changing the switching or transmission costs to the upper or lower limits estimated had some effect on the slopes of the cost curves, but did not change the position of the minimum,

(*b*) using distributed control, with in-band or out-band signalling at trunk switching centres instead of s.p.c. with inter-processor separate channel/addressed signalling, had no effect on the size and location of switching centres, although it did result in a slight increase in total network costs,

(*c*) making no provision for high-usage working did not alter the size or number of trunk switching centres, but did slightly increase the total network costs,

(*d*) increasing the grades of service from those at present in use to slightly higher grades of service did not affect the number of group switching centres, although it increased the total network costs slightly but significantly, and

(*e*) permitting the minimum number of 30-circuit pulse-code modulation (p.c.m.) modules allowed on a fully-provided route to drop from two to one had no effect on the number of switching centres, although it reduced costs significantly at the expense of some loss in network reliability.

HIGH-USAGE ROUTES

The method used for justifying high-usage routes allowed for the fact that line plant is provided in minimum modules of 30 circuits, and, surprisingly, almost all high-usage routes justified an exact multiple of 30 working circuits. In a typical network containing about 300 trunk switching centres, there were 580 high-usage routes of 30 circuits each, 450 high-usage routes of 60 circuits each, and 350 high-usage routes of 90 circuits each (the largest size allowed) and only 50 routes of other sizes. The total number of high-usage routes was 1,430 and the number of fully-provided routes was 1,200. In the above figures, routes were considered to be the aggregate of their incoming and outgoing components. The studies showed that, in layouts of more than about 200 trunk switching centres, interconnected by p.c.m. digital plant, the smaller centres could justify only a very small number of routes. In the case of a scheme containing 400 trunk switching centres, over 100 justified only one or two routes, and over 200 justified only one to five routes.

IMPLICATIONS OF STUDIES ON PRACTICAL NETWORK PLANNING

From the network studies described, the features of a trunk network to meet the needs of the future have been derived.

The practical implications and cost of moving from the present space/analogue network to a wholly digital switching and transmission network in the future now need to be studied in depth and a discounted-cash-flow study of the whole trunk network over the conversion period will be required. Progressive development and conversion of the network, the practical problems of interworking, the financial implications of changing the configuration of the network and the number of switching centres, all need to be taken into account. This will constitute a major and continuing task for the operational departments in the years ahead.

CONCLUSIONS

The studies of the U.K. trunk network allow a number of broad conclusions to be drawn and the following are significant among them:

(*a*) Under a wide range of circumstances, there are operational, service, and economic benefits to be obtained from the use of digital transmission in the long-distance network irrespective of the switching systems that are adopted, provided that an appropriate repertoire of systems of different capacities is available.

(*b*) When an adequate start has been made on the introduction of digital transmission, there will be considerable advantage from the adoption of digital switching at group switching centres.

(*c*) If the network develops along these lines, the economically preferred alternative will tend towards a network having a smaller number of larger switching centres than is the case today.

(*d*) Optimum network configurations will increasingly tend in the direction of very large backbone routes with some large associated meshes rather than towards proliferation of a mesh structure.

The work has emphasized the importance of the following three factors in the planning of digital trunk networks (i.e. networks containing both digital transmission and digital switching).

(*a*) It is important that the switching and transmission parts of the network should be planned as a single operation, thus cutting across the traditional division between switching engineers and transmission engineers.

(*b*) The increase of the basic size of transmission plant modules from 12 circuits (f.d.m. plant) to 30 circuits (p.c.m. plant) has underlined the importance of justifying high-usage and other auxiliary routes on the basis of 30-circuit line plant module costs rather than per-circuit costs. When routes are justified in this way, high-usage routes need be considered for almost all purposes, only in complete multiples of 30 circuits.

(*c*) Digital transmission plant, and if available, digital switching plant, can most economically be introduced in "digital conversion cells" about 50–100 km in diameter and containing one or more base towns which would form focal points for line plant.

ACKNOWLEDGEMENT

The work described in these two articles is the joint effort of many people in the U.K. Trunk Task Force and elsewhere. The author gratefully acknowledges the contribution they have made.

Single-Channel-per-Carrier, Pulse-Code-Modulation, Multiple-Access, Demand Assignment Equipment—SPADE—for Satellite Communications

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U.D.C. 621.396.946: 621.396.721: 621.376.56

Communication by satellite is rapidly being adopted by many of the developing nations as the prime instrument of their international communications systems. In order to more efficiently provide for the light-traffic requirements of the smaller users, a demand-assignment system, which allocates circuits between earth-stations only when actually required for traffic, has recently been developed and implemented. The installation of the necessary equipment for demand-assignment working has been completed at the United Kingdom earth-station at Goonhilly Downs in Cornwall.

INTRODUCTION

Global coverage by satellites has made communications of all types, between widely scattered points around the world, an accepted feature of this modern age. Conventionally, when two countries wish to establish communications via satellite, it is necessary for each of them to provide the required ground terminals, and for an appropriate amount of satellite capacity, that is, power and bandwidth, to be permanently allocated or pre-assigned for the service. The current INTELSAT IV system utilizes the 6 GHz and 4 GHz bands for the up-links and down-links respectively, and the satellites have 12 transponders, each with a bandwidth of 36 MHz, within the 500 MHz band allocated for fixed-service satellite communications. The earth stations gain access to these transponders using frequency-modulated/frequency-division-multiplexed/frequency-division multiple-access (f.m./f.d.m./f.d.m.a.) carriers of 2·5 MHz, 5 MHz, 7·5 MHz, 10 MHz, 15 MHz, 20 MHz, 25 MHz and 35 MHz bandwidth each, which correspond to capacities ranging from 24 channels to 960 channels when operating in a global-beam mode. Certain transmissions from the satellite can be radiated in a spot-beam mode of operation, that is, a narrow-beam transmission that illuminates only a part of the earth's surface, in which case, the carrier capacities are approximately double that for the global-beam carriers of the same bandwidth. Fig. 1 gives an outline of the INTELSAT IV satellite, and Fig. 2 shows a typical f.m./f.d.m./f.d.m.a. carrier assignment plan.

THE NEED FOR DEMAND ASSIGNMENT

The smallest capacity unit that can be allocated in the pre-assigned carrier system currently adopted, is a 2·5 MHz global-beam 24-channel carrier. Also, the smallest unit of capacity increase that can be effected is 2·5 MHz of bandwidth, which, on an existing carrier, represents a minimum increase in capacity of 36 channels. The actual requirement for a given service may be only three or four circuits during a peak period of less than an hour or two a day, and some of these circuits may actually be idle for several hours a day. It is obvious, therefore, that if capacity for 24 channels has to be permanently assigned to meet this requirement, there is considerable inefficiency in the utilization of satellite capacity, and a large number of such cases could significantly advance the saturation date of a particular satellite.

In addition to possible under-utilization of satellite capacity due to light-traffic routes, a similar situation can arise with high-traffic routes. An earth station may have a traffic peak-hour requirement on a particular route for three or four circuits above the capacity of a standard size global-beam carrier. For example, a requirement for 28 circuits during the peak hour would necessitate the allocation of a 5 MHz, 60-channel carrier rather than a 2·5 MHz, 24-channel carrier, just to accommodate the additional four circuits for perhaps an hour or two a day.

In both the above cases the inefficiency is twofold. Firstly, there is the actual allocation of capacity for 24 channels or more for just a few circuits and, secondly, even these circuits are only active for a few hours a day. A third, related, but not so apparent factor, is that on any two-way circuit, only one channel is normally active, that is, has speech present, at any given time. In fact, if the time for pauses between speaking is taken into account, the resulting activity factor for a two-way circuit is about 40 per cent for each direction of transmission.

In addition to the light traffic and overflow requirements, which nevertheless may still justify the provision of pre-assigned circuits, it is necessary to consider the very light traffic requirements which do not justify provision of pre-assigned circuits. In these cases, the service would probably be provided on an indirect basis by transit switching and, hence, be subject to the availability of facilities outside of the control of the corresponding entities. Obviously, such services would be better provided on a direct basis if this could be done efficiently and economically.

In order to accommodate the requirements of light-traffic routes, provide for overflow traffic from certain pre-assigned routes in a more efficient manner, and provide a means whereby the very light traffic requirements can be economically provided on a directly-routed basis, there is a need for a system that will allocate a circuit only when it is actually required for traffic. To further conserve satellite power, such a system should also take advantage of the 40 per cent activity factor that is inherent in normal two-way voice-circuit operation. The recently-developed INTELSAT demand assignment system known as single-channel-per-carrier, pulse-code-modulation, multiple-access, demand assignment equipment (SPADE) provides these facilities.

UTILIZATION OF SATELLITE CAPACITY

The SPADE system utilizes one of the 36 MHz global-beam transponders of an INTELSAT IV satellite. Like the pre-

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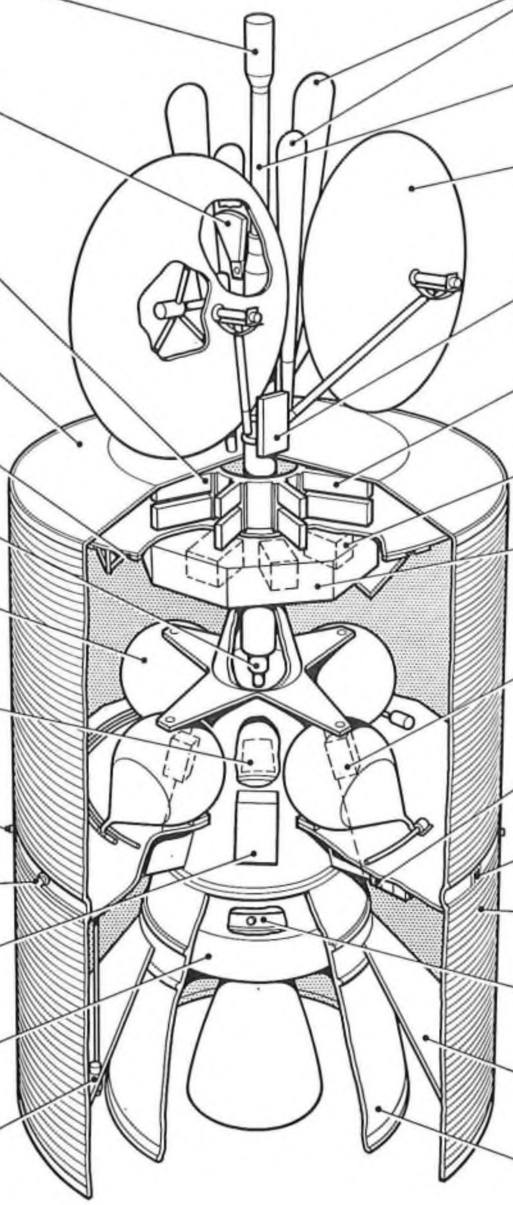
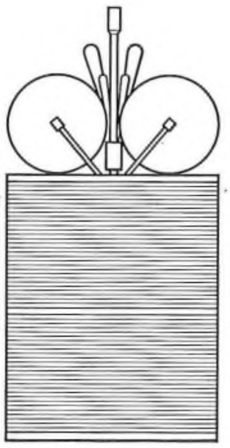
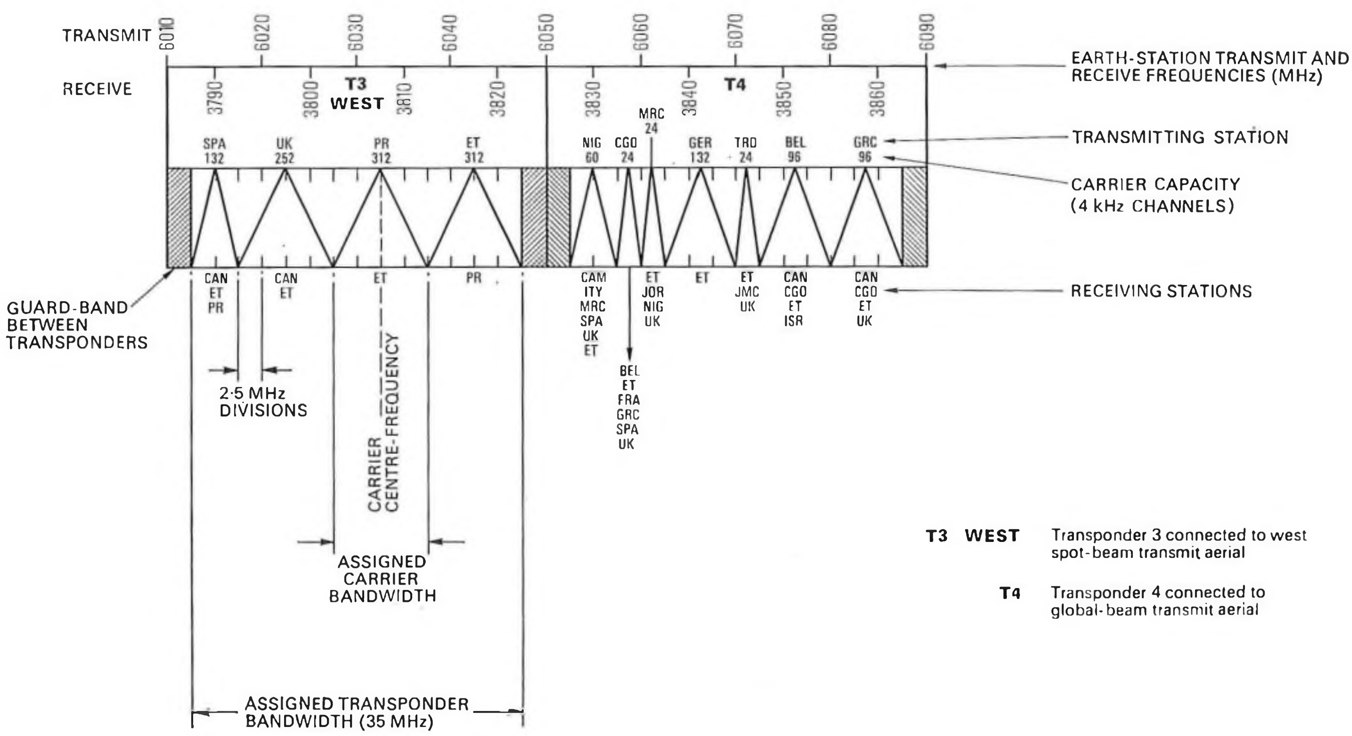




Size	2.38 m diameter 2.82 m solar panel height 5.28 m overall height
Weight	1,387 kg at launch 700 kg after apogee motor fire
Characteristics	Capacity: 3,000 circuits with transponders in earth mode and 9,000 circuits with transponders in spot-beam coverage mode, or 12 television channels or certain combinations thereof. Has 12 transponders, each with a 36 MHz bandwidth. Two global transmit antennas, two global receive antennas, and two steerable spot-beam transmit antennas. Design life: seven years. Multiple access and simultaneous transmission capabilities.
Launch Vehicle	General Dynamics, Convair Division Atlas Centaur.
Spacecraft Contractor	Hughes Aircraft Company.

FIG. 1—INTELSAT IV



EARTH-STATION ABBREVIATIONS

BEL	Belgium	GER	Germany	MRC	Morocco
CAM	Cameroon	GRC	Greece	NIG	Nigeria
CAN	Canada	ISR	Israel	PR	Puerto Rico
CGO	Zaire (Congo)	ITY	Italy	SPA	Spain
ET	Etam (U.S.A.)	JOR	Jordan	TRD	Trinidad
FRA	France	JMC	Jamaica	UK	United Kingdom

FIG. 2—Typical transponder carrier assignment plan

assigned services, SPADE is a f.d.m.a. system. However, unlike the pre-assigned f.m./f.d.m./f.d.m.a. carriers, which transmit channels in conventional groups and supergroups, each SPADE carrier is a single-channel, pulse-code-modulated (p.c.m.), phase-shift-keyed (p.s.k.) transmission.

The power requirement of each of the SPADE single-channel p.c.m. transmissions is such that an INTELSAT IV transponder can support about 400 active single-channel carriers simultaneously. Taking into account the 40 per cent activity factor for two-way circuits, this represents a capacity of about 400 conventional two-way circuits, provided only the active channel in each channel pair is actually transmitted. On this basis, SPADE operation in one INTELSAT IV transponder can be considered as providing the equivalent of 800 pre-assigned channels. This basic capacity compares with that of a minimum of 336 and a maximum of 972 configured channels, which, in practice, relates to an average of about 600 configured channels, for an INTELSAT IV global-beam transponder carrying conventional f.m./f.d.m./f.d.m.a. pre-assigned carriers.

Furthermore, as has already been indicated, the actual requirement for circuits on any given service outside of the peak traffic hours is less than the pre-assigned capacity that would be required to meet the full peak-hour traffic load. Also, because of world time differences, the peak hours on different routes can occur at different times of the day. It is apparent, therefore, that it should be possible for a common pool of satellite capacity to be utilized on a time-sharing basis to meet many of the light-route, overflow and occasional-traffic requirements. The SPADE system, by permitting channels to be allocated on an individual basis and assigning them only when actually required for traffic, provides this capability. The effect of this is that SPADE can handle the same amount of traffic that would require two to two and a half times the number of circuits if it were accommodated on a fully pre-assigned f.m./f.d.m./f.d.m.a. system. The basic 800-channel capacity of the SPADE system can thus be considered as accommodating a traffic configuration that would require the equivalent of about 2,000 pre-assigned channels.

The SPADE system, therefore, fulfils the requirements for the efficient provision of service on light-traffic routes, and for accommodating overflow traffic from pre-assigned routes. It also enables the establishment of new routes, without the need to provide additional pre-assigned equipment at the earth stations and allocate pre-assigned capacity in the satellite, until such time as the service has grown sufficiently to justify this action. Furthermore, it facilitates the establishment of direct service on routes which would not normally justify pre-assigned circuit operation and, thereby, makes possible the provision of services and facilities that otherwise might not be provided at all.

BASIC OPERATION OF SPADE

The 36 MHz bandwidth of the INTELSAT IV transponder is divided into 800 channels, each of 45 kHz bandwidth, which are associated in pairs to provide connexions for up to nearly 400 simultaneous two-way circuits. The actual usable capacity is slightly less than the 400 circuits indicated because

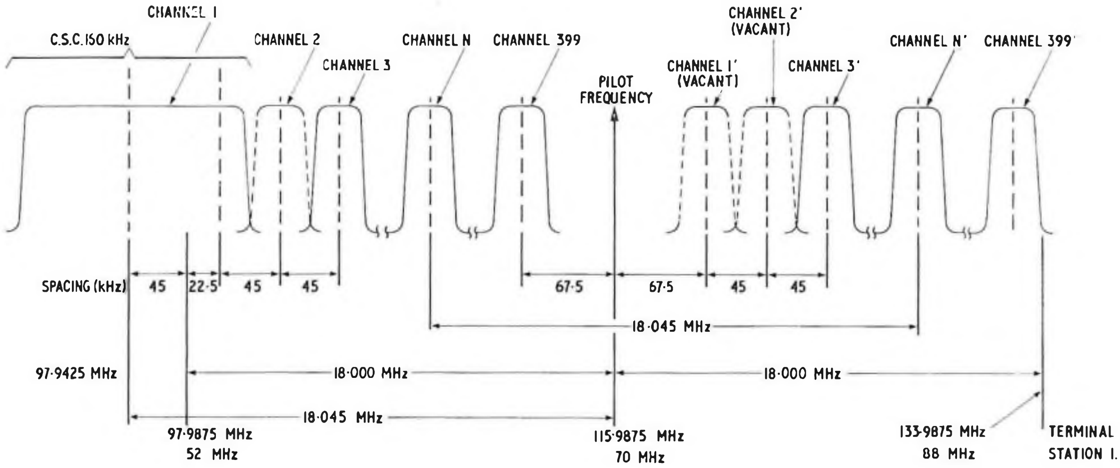


FIG. 3—Transponder frequency allocation

a portion of the transponder bandwidth is allocated for system pilots, and control and signalling channels. The control system, which is not centrally co-ordinated, allows up to 49 terminals to operate into the one SPADE system, one of the terminals being designated to transmit the pilot frequency at any given time. Fig. 3 illustrates the channel arrangement within a transponder.

The access circuits from the national transit centre (c.t.) are linked to the SPADE terminal at voice frequency via a terrestrial interface unit (t.i.u.). The main function of this equipment is to extract the signalling information required to facilitate the systematic initiation, supervision and termination of all calls, and to carry out the conversion between the terrestrial signalling system and the SPADE signalling system.

Demand Assignment Signalling and Switching Unit

The brain of the SPADE system is the demand assignment signalling and switching unit (d.a.s.s.) which controls the setting up of calls in conjunction with similar units at all the other stations. To provide the communication link between the d.a.s.s. units there is a common signalling channel (c.s.c.), which is shared by all the stations on a time-division basis. All signalling information, after extraction and conversion in the t.i.u., is transmitted over this 128 kbit/s, two-phase time-division multiple-access (t.d.m.a.) link, which is also used, on a non-priority basis, for the transmission of management and circuit-status signals. For c.s.c. control purposes, one of the terminals is designated to transmit a reference burst, in addition to its own data burst, with all of the other terminals' bursts being synchronized to this reference.

When a call request is received, the d.a.s.s. unit automatically selects a frequency pair from the pool of available frequencies and informs the destination station, via the c.s.c., of an incoming call and the frequency assignment for response. All d.a.s.s. units utilize the signalling information disseminated over the c.s.c. to update a channel-utilization record so that frequencies already assigned are not available for new calls.

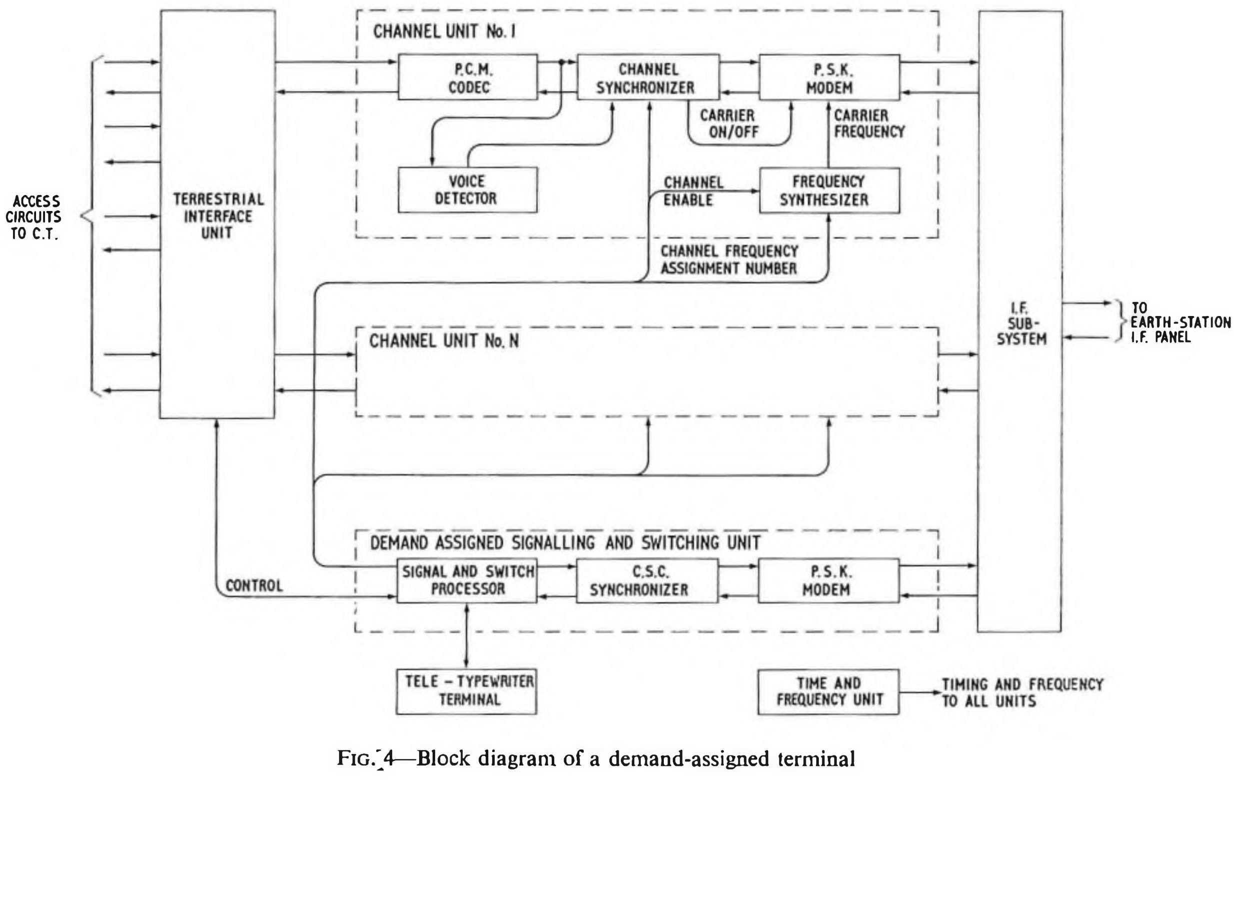


FIG. 4—Block diagram of a demand-assigned terminal

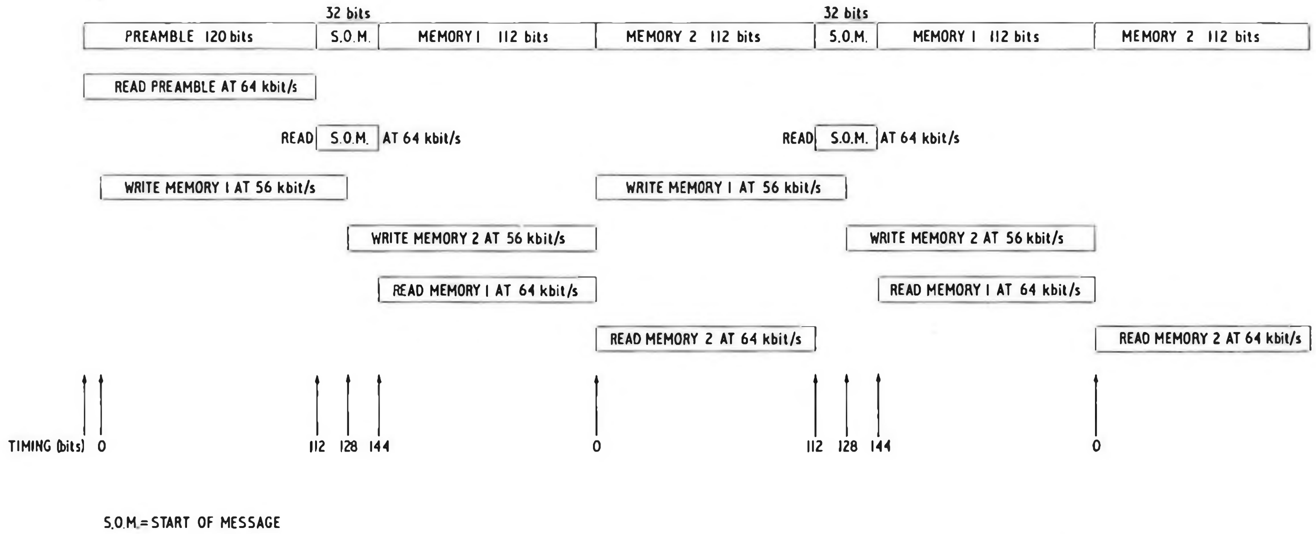


FIG. 5—Voice data burst format

Channel Unit

Each call is passed through the t.i.u. to a SPADE channel unit. The channel unit contains a pulse modulator and p.c.m. coder/decoder (codec), a voice detector, a frequency synthesizer, a channel synchronizer, and a four-phase p.s.k. modulator/demodulator (modem). A block diagram of a SPADE terminal is shown in Fig. 4.

The frequency selected by the d.a.s.s. for a particular call is generated in the channel unit by means of the frequency synthesizer, which is capable of generating any of the 800 discrete pool frequencies using digital codes provided by the d.a.s.s. unit. This frequency is used both for the outgoing carrier and the received-signal local oscillator, channel pairings being based on the common use of the synthesizer frequency for transmit and receive signals. Upon activation of the modem, the d.a.s.s. unit conducts a two-way circuit continuity check and, if successful, the circuit is connected through.

During the conduct of a call, the content of the voice channel arriving at the channel unit from the c.t., is detected by the voice detector. This information is used to gate the channel carrier ON or OFF as a function of talker activity, so that a carrier is only actually transmitted when speech is present on the channel. This feature of voice activation is not to be confused with the time-assignment speech interpolation (t.a.s.i.) system that is used on the transoceanic cable systems. In the t.a.s.i. system, an idle channel is actually re-allocated to another user during pauses in the speech. In

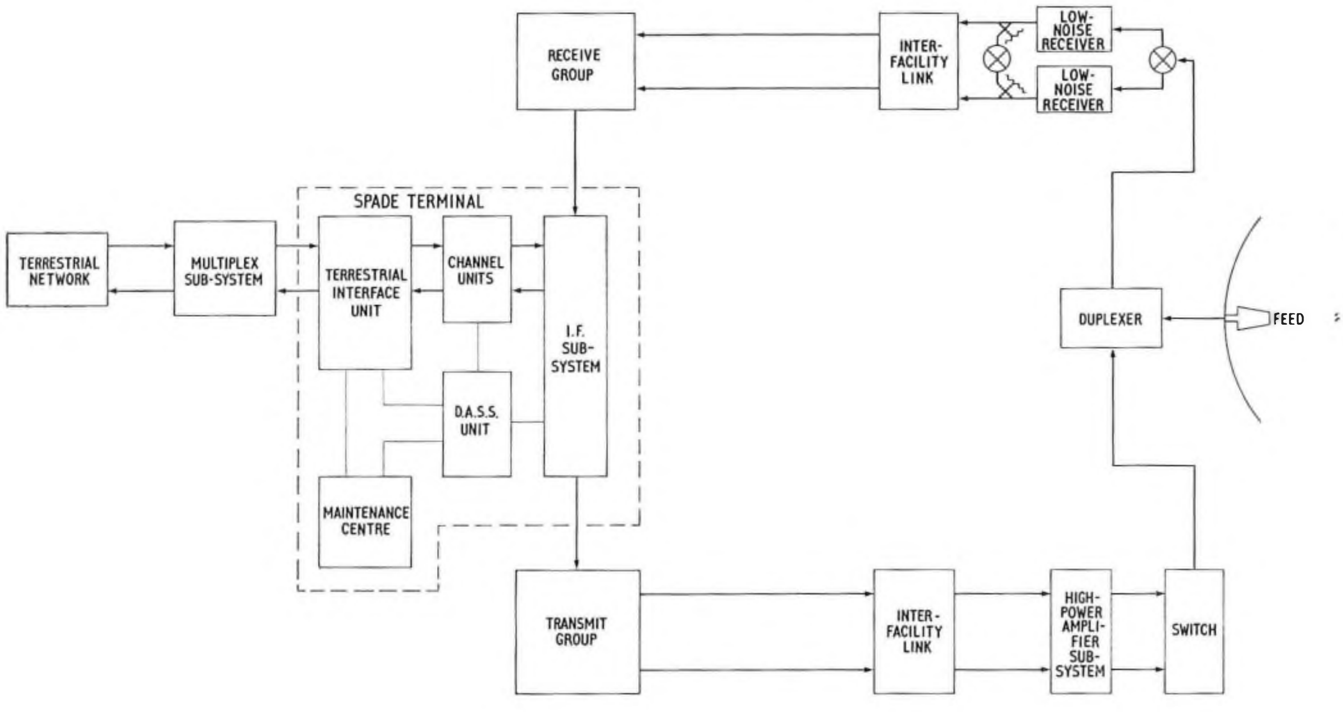


FIG. 6—Earth-station/SPADE terminal interfaces

the SPADE system, the channel allocation remains fixed for the duration of the call, but the assigned satellite carrier is only activated when there is speech on the channel.

The analogue voice signal arriving at the channel unit is sampled 8,000 times a second by the pulse modulator, and the p.c.m. codec encodes each sample into a seven-bit word using non-linear (A-law) encoding.[1]

Synchronizing information is transmitted at the beginning of each speech burst to enable the receiver to acquire word synchronization. This information is inserted many times during a speech burst to ensure that word synchronization is maintained. The timing, buffering and framing functions are performed by the channel synchronizer, and results in the transmitted bit rate being increased to 64 kbit/s from the 56 kbit/s emitted by the p.c.m. codec. Fig. 5 shows the voice data burst format.

The p.s.k. modem modulates the assigned carrier frequency with the outgoing bit stream and coherently demodulates the incoming bursts by recovering carrier and bit-timing information associated with the received signals. The modulated carriers, both incoming and outgoing, are passed through a common intermediate-frequency (i.f.) sub-system, which interfaces with the earth station up- and down-converters at i.f.

Control

The carrier used for the c.s.c. is also passed through the i.f. sub-system. Fig. 6 illustrates the overall connexion from the terrestrial link, through the SPADE terminal, to the earth-station equipment.

When the call is completed, a control signal from the c.t. activates the d.a.s.s. unit to return that circuit to a non-occupied state, and the relinquished frequency pair is returned to the pool and made available for re-assignment. This information is passed to all the other d.a.s.s. units in the system via the c.s.c., to enable their channel-utilization records to be updated.

In addition to the control functions carried out by the d.a.s.s. unit, it can also be programmed to carry out other functions, such as recording of call durations and failures for both traffic-engineering and charging purposes, and automatic checking of channel performance for maintenance purposes.

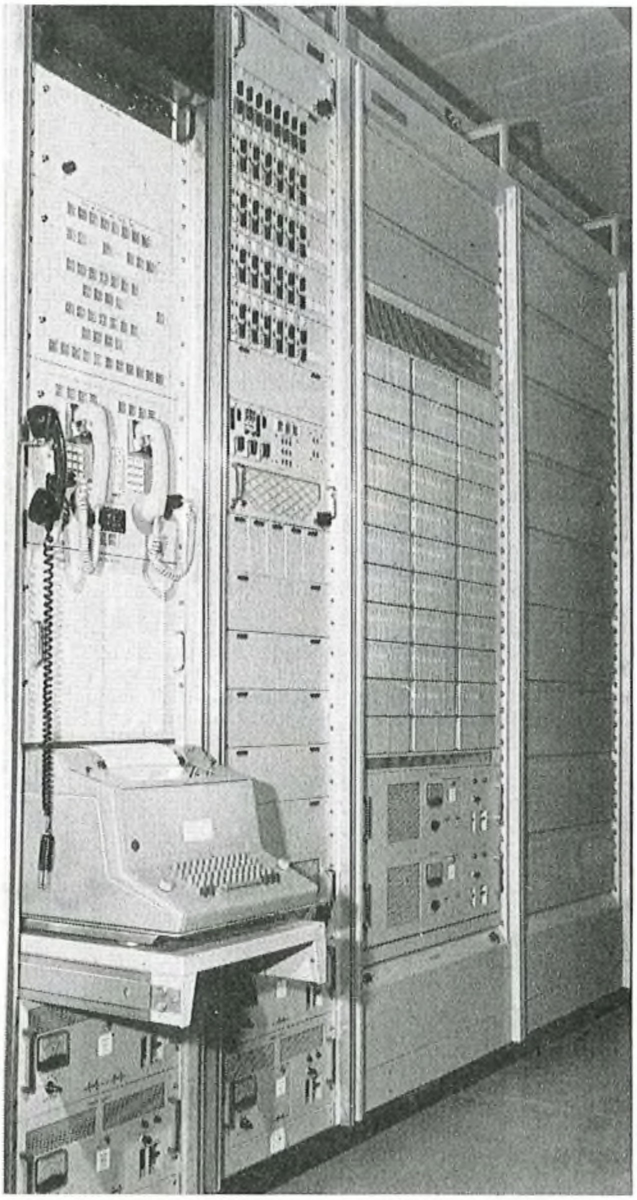


FIG. 7—Maintenance bay and terrestrial interface unit bays

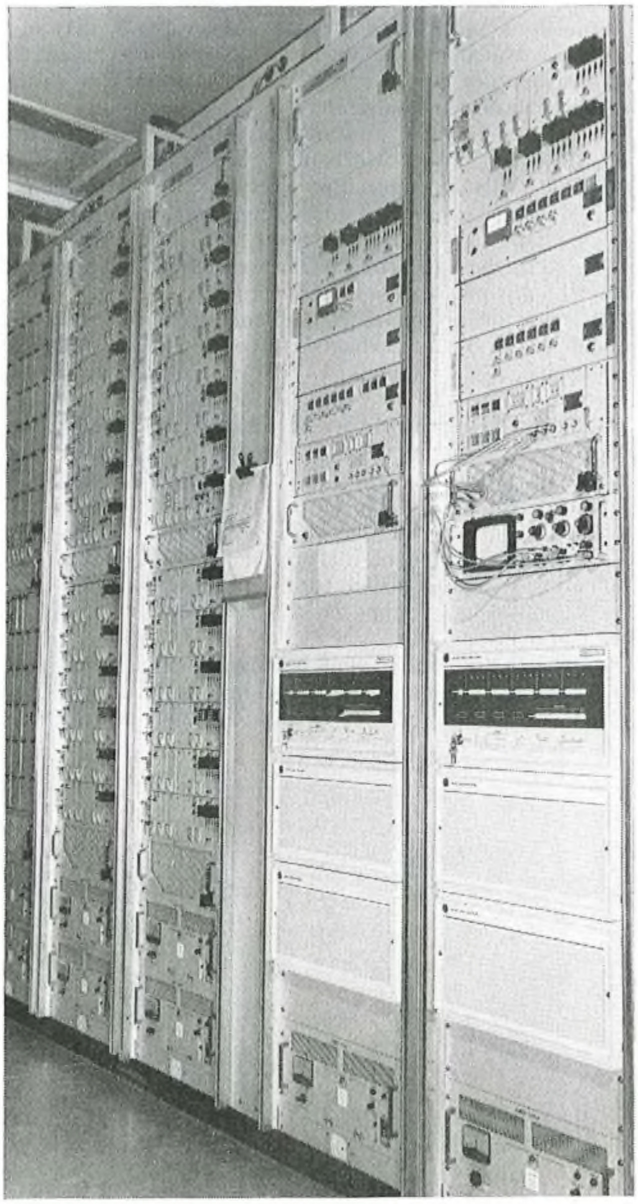


FIG. 8—Channel-unit and common-equipment racks

Goonhilly

The SPADE terminal at Goonhilly[2,3] is accommodated in two suites of racks which face each other with a spacing of about 6 ft between them. One suite contains three terrestrial interface-unit bays and the maintenance bay. The second suite contains two racks of common equipment and two racks of channel units, plus a spare rack for expansion. These suites are shown in Figs. 7 and 8 respectively.

SERVICE ASPECTS OF SPADE

The SPADE system was initially designed to provide demand-assigned two-way voice circuits to facilitate the economic provision of light-traffic requirements. However, the basic equipment can do more than this: for example, narrow-band data, such as conventional record services of 1,200 bit/s, 2,400 bit/s and 4,800 bit/s which may normally be transmitted over 4 kHz telephone circuits, can be processed directly by the standard SPADE channel unit configuration. Also, a two-way voice circuit can be permanently assigned as a 24-channel voice-frequency telegraph bearer.

Both voice and record links can be operated on a demand-assigned basis, or a pair of frequencies can be removed from the pool and permanently assigned to a given service. In some cases, these pre-assigned single-channel-per-carrier transmissions, particularly the data transmissions, may not be voice activated, and care has to be taken in assigning such services in order not to overload the transponder with an excessive increase in the overall channel activity factor.

In addition to these transmissions utilizing the standard SPADE channel unit, wideband, medium-speed data, that would normally be transmitted over a 48 kHz group link, can also be accommodated on one single-channel-per-carrier transmission. In this case, however, the signal cannot be processed by the standard SPADE channel unit and a special channel unit configuration must be provided.

Basically, the medium-speed data channel unit matches the incoming data bit rate, which may be 40·8 kbit/s, 48 kbit/s or 50 kbit/s, to the required 64 kbit/s transmitted bit rate, by a process known as *convolutional encoding* or *bit stuffing*. While this may appear to be wasteful of digital capacity, the processing of the input bit rate, to make it compatible with that required for transmission via the standard single-channel-per-carrier equipment, does make possible the use of the standard equipment for this purpose without modification. The alternative would be the provision of a different non-compatible system specifically for this purpose, which may not be economical for meeting the comparatively small requirements of many cases.

It is worth noting that, while a conventional voice channel on a f.m./f.d.m./f.d.m.a. transmission can be utilized for conveying the equivalent of twenty-four, 50-baud telegraph channels, one standard SPADE voice channel can, by utilizing the medium-speed data channel unit and appropriate multiplexing arrangements, be used to convey the equivalent of several hundred, 50-baud telegraph channels.

As has been indicated, any of these pre-assigned services, that is, voice, narrow-band or medium-speed data, can be provided simultaneously with the demand-assigned services, within the same SPADE system. However, a totally pre-assigned single-channel-per-carrier system can also be provided, quite independently of a SPADE system, in which case the main difference would be the elimination of the d.a.s.s. units.

SPADE PARTICIPATION

By the fourth quarter of 1973, some dozen earth stations in the Atlantic region were already equipped or were being equipped with SPADE terminals, and were either operational or undergoing test, and a further ten or so were on contract for provision of SPADE equipment. The U.K. terminal at Goonhilly commenced limited operations in February 1974 with countries in South America. The current program indicates that 20 earth stations should be operating in the SPADE system by the end of 1974.

In addition to this planned participation in SPADE, several other countries have indicated an intention to participate within the 1974–1975 time frame, and at least three earth-station owners, one being the U.K., are providing equipment for the pre-assigned medium-speed data service to be associated with their SPADE terminals.

CONCLUSION

Despite some initial problems in getting the SPADE system implemented, a good start has now been made and the next two years should see it grow into a fully-operational system. As more and more earth stations become equipped with SPADE, its usefulness will become more apparent to all users of the system. In addition, it provides a valuable introduction to the use of digital techniques in the INTELSAT system as a forerunner to the more complex t.d.m.a.[4] digital systems that are being developed for the future.

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Steel Masts and Towers in the British Post Office

Part 2—Materials, Methods and Applications

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U.D.C. 624.97.014.2 : 621.396.7 : 621.04

Part 1 of this article dealt primarily with the functional requirements for tall structures used for supporting radio aerials, the nature of the loading they have to withstand and the methods of stress analysis used. This part is concerned with the physical construction of masts and towers, and concentrates on the newer or lesser-known aspects. Examples are given of past and present masts and towers of the British Post Office.

MATERIALS

The basic structural materials which are of practical use for aerial-supporting structures are steel, aluminium and reinforced concrete. The lightness of aluminium is an advantage only if frequent manhandling is necessary. This applies to construction equipment, and transportable masts used for propagation testing or temporary radio links. In other situations, aluminium is less competitive; larger members than the equivalent steel sections are likely to be needed, leading to an increase in wind loads. Aluminium has a modulus of elasticity about a third of that of steel, and the deflexion in an aluminium structure could be large enough to make it unsuitable for supporting microwave aerials. There are also problems in combining high strength with weldability.

Reinforced concrete as a construction material is attractive, but the first cost is usually substantially more than that for a steel tower, although maintenance costs are lower. In present circumstances, the costs of a steel tower tend to rise in step with general engineering prices since much of the fabrication is carried out in the factory. Reinforced-concrete construction requires mostly on-site work and is subject to the much greater cost-inflation problems of the building industry. Economically, steel is, in most circumstances, the first choice of material.

* Operational Programming Department, Telecommunications Headquarters.

Two types of structural steel are in common use—mild steel and high-yield-strength (h.y.s.) steel. There is little difference in ultimate tensile strength between the two, but, as the name of the latter suggests, its yield stress is significantly higher and this permits members to be designed for higher working stresses as shown for typical members in tension in Table 4.

It can be seen, then, that h.y.s. steel, although more expensive, permits about 40 per cent increase in tensile stress which, in turn, permits reductions in the sizes of members with a consequent reduction in the area presented to the wind. Unfortunately, the full benefit of large gains in strength is not usually realizable on masts and towers because changes in the strength and speed of wind vary not only the magnitude of forces in members, but also their direction. Therefore, most components have to be designed to withstand tension and compression. In compression, the gains in permissible stress range from some 40 per cent for short stiff members down to zero for long slender ones. The reason for this is that short struts, like tension members, deform in accordance with Hooke's law up to the elastic limit; for long struts, an instability failure due to buckling is likely to occur well before elastic failure. Another point about h.y.s. steel is that the stress at yield is nearer the ultimate-failure stress than for mild steel. It follows that a structure constructed of mild steel has a greater reserve of strength between the point where permanent deformation takes place and final collapse, and it

TABLE 4

Comparison between Mild Steel and High-Yield-Strength Steel

Grade of Steel to BS4360	Ultimate Tensile Strength Range (tonf/in²)	Minimum Yield Stress (tonf/in²)	Range of Ultimate Stress/Yield Stress Ratio	Permissible Tensile Stress from BS449: 1970 (tonf/in²)
43 (Mild)	28–33	16	1·75 : 1–2·06 : 1	10
50 (H.Y.S.)	32–40	22·5	1·42 : 1–1·78 : 1	13·9

also gives an earlier visual warning of structural distress. However, there is one problem common to structural steels—brittle fracture—which could invalidate the normal assumptions of strength discussed above.

Brittle Fracture in Structural Steels

Brittle fracture in steel is a type of fracture which occurs suddenly, with little or no deformation. It is a particularly disturbing form of failure because the fracture often occurs without warning, at stress levels far below those for which the component was designed.

The problem of brittle fracture has been recognized for over 100 years, but it came into prominence in the 1940s with an epidemic of failures in all-welded ships, in particular the American "Liberty" ships, in which structural failures often took place in conditions which one would not expect to be onerous and which were well within the design limits. The seriousness of the problem may be judged from the fact that in the ten-year period 1942–1952, 250 ships were rendered unserviceable or were lost at sea, for reasons attributable to brittle fracture. The phenomenon has not been confined to ships and serious failures have occured on, for example, pipelines, storage tanks, pressure vessels, bridges, building frames, turbo-generators and offshore drilling rigs. Brittle fracture has, then, affected a wide range of structures, and certainly cannot be ignored whenever fracture could endanger the safety or serviceability of a structure.

An important feature of the brittle-fracture phenomenon for the structural engineer is that fractures become much more likely at low temperatures. If a series of impact tests are carried out on samples taken from a structural-steel component over a range of temperatures and the results are plotted, it will be seen that, over a restricted range of temperatures, the material changes from the ductile condition (large amount of energy absorbed) to the brittle condition (little energy absorption). The narrow temperature range over which this change takes place is known as the transition temperature and its value is likely to vary over a wide range in steels conforming otherwise to the same basic specification. Masts and towers are particularly likely to suffer from low temperatures as their locations are often very exposed and the steel frame is not protected from the elements by cladding, as in a building. It is important to use steels which retain their ductility at the lowest operating temperature of the mast or tower, and this restricts the choice of steel quite severely, especially for critical components. The latest British Standard for structural steels, BS4360, includes ranges of mild and h.y.s. steels which have a guaranteed ductility at specified low temperatures. In present supply conditions, however, it is often impossible to obtain such steels, and this places the specifier in the difficult position of accepting steels with less than optimum performance. He has then to consider the degree of risk to the components involved if steels without a suitable guaranteed ductility were to be used.

One alleviating factor is that most cases of failure have resulted from a combination of circumstances in which low-temperature brittleness is but one, even if the most important, factor. By taking extra care in avoiding the other factors in design and fabrication, the risk of failure can be greatly reduced. For example, brittle steel coupled with poor hatch-cover design led to a stress concentration which was the initiation point for the failure of many Liberty ships, and their all-welded construction allowed any crack to travel uninterruptedly through a large part of the structure; poor-quality welds have similarly initiated cracks in many instances. In brief, the risk of brittle fracture is increased by low temperature, high stress level, triaxial stresses, thick sections, sudden changes of cross-section, welding defects, impact loading or severe vibration. Although brittle fracture cannot be predicted and the results are often dramatic, the mast and tower designer can take some heart from the fact that no such failure has been reported on a British Post Office (B.P.O.) structure in service.

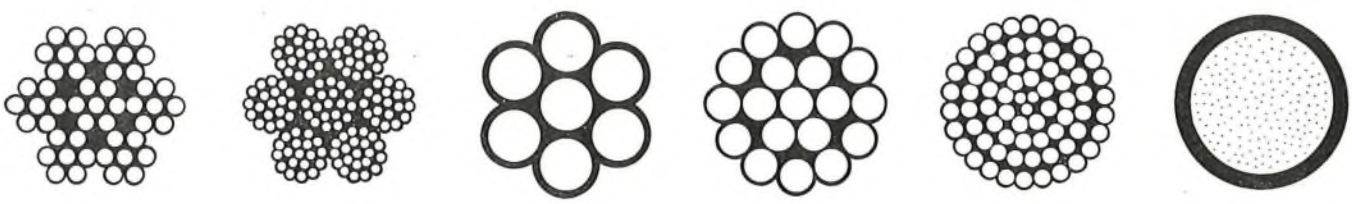
Corrosion Protection

The basic protection now applied to all steelwork for masts and towers is hot-dip galvanizing. This is carried out by immersing the steel in a bath of molten zinc so that a coating of zinc about 0·003 in thick is deposited on the steel. This coating alone can give protection for up to 15 years before further treatment is required, although the life can be much shorter at sites where the atmosphere is salt-laden or highly polluted. Most of the medium and small masts are given no further protection as it is usually more economic to recover the masts for regalvanizing or replacement by new ones than to resort to maintenance painting. For major structures, such as microwave towers or large masts, painting is used to give additional protection. Typically, a zinc-based primer is applied after the galvanized surface has weathered for a few months, followed by two undercoats and one top coat of micaceous iron-oxide paint. Each coat is of a different colour to ensure thorough application.

Connexions between Members

The traditional and most common method of connecting members on masts and towers is to use conventional bolts which transfer forces at the joints by shear and bearing forces on the bolts. Welding is confined to partial prefabrication of structures at the fabricator's works and is not permitted after components have left the works.

High-strength friction-grip (h.s.f.g.) bolts have been used on some of the towers to be described; these combine the convenience of site assembly of ordinary bolted joints with a joint strength approaching that of welding. The basic principle of the h.s.f.g. bolt is that, on tightening, it is highly tensioned and the joint is thereby firmly clamped, so that normal working loads are transferred by the friction devel-



(*a*) 7/7 construction (i.e. 7 strands, each of 7 wires) as used on guys for Mast No. 2A.

(*b*) 7/19 construction

(*c*) 1/7 spiral strand e.g. B.P.O. Wire Suspension 7/12 and 7/14, as used on Mast No. 1.

(*d*) 1/19 spiral strand

(*e*) 1/71 spiral strand

(*f*) Parafil–parallel-lay polyester fibre encased in a polyethylene sheath.

FIG. 11—Cross-sections of typical ropes used for mast guys

FIG. 12—Socket termination on $1\frac{3}{4}$ in diameter spiral-strand mast guy

oped between the surfaces of the joined members. The bolt itself is then subjected to neither shearing nor bearing forces, and changes of external load do not affect the magnitude of the stresses in the bolt. As a result, fewer bolts are required for a joint. It is very important that such bolts are adequately tightened to ensure correct functioning of the joint. Various methods are available to check on this, such as load-indicating bolts or washers which give a visual indication of the tension in the bolt. Manual torque-multiplying or power-operated spanners are needed to apply the necessary high tensions to the bolts.

Guy Ropes for Masts

Steel-wire ropes are manufactured in a wide variety of constructions, but the requirements of ropes for use as mast guys limit the choice. It is necessary for a guy rope to have a high corrosion resistance and this is achieved by using individual strands within the rope of the maximum diameter that will still give sufficient flexibility for handling during transport and erection. The strands are galvanized before making-up into the rope. On smaller masts, the galvanized coating without further protection suffices, and it is usually accepted that replacement of guys when the galvanizing has deteriorated is more economic than employing the regular greasing which is necessary on guys of heavier or higher masts.

It is also necessary that guy ropes have a high and predictable stiffness. This stiffness is the product of the modulus of elasticity and the cross-sectional area. Steel ropes with fibre-rope cores are quite unsatisfactory in this respect because the core crushes under load, leading to high non-elastic and non-linear stretch. The preferred ropes are of simple all-steel construction and Fig. 11 shows some types of rope used on B.P.O. masts. A useful means of achieving a high predictable modulus is to pre-stress, or pre-stretch, the rope. This involves repeatedly tensioning the rope to a high load, often up to 60 per cent of its breaking load, before installation. This eliminates non-elastic stretch which would otherwise be removed over a period in service and which would necessitate subsequent adjustment of the guy tension.

One of the ropes shown in Fig. 11 is unusual as it does not fulfil all the above basic requirements. It is known as Parafil, and is a rope consisting of a tightly-packed bundle of parallel polyester fibres as the load-carrying tendon, with a thick polyethylene sheath protection. This type of synthetic-fibre rope is the only one available which exhibits a linear load/extension characteristic, although the modulus of elasticity is still very low compared with steel. This type of rope is attractive in situations where a steel-wire rope is likely to corrode rapidly, or where it would otherwise be necessary to break up the length of a steel guy with insulators for electrical reasons. In practice, the low modulus value can be partly compensated for by increasing the cross-sectional area, and Parafil has been used successfully on a number of B.P.O. Mast No. 1 installations.

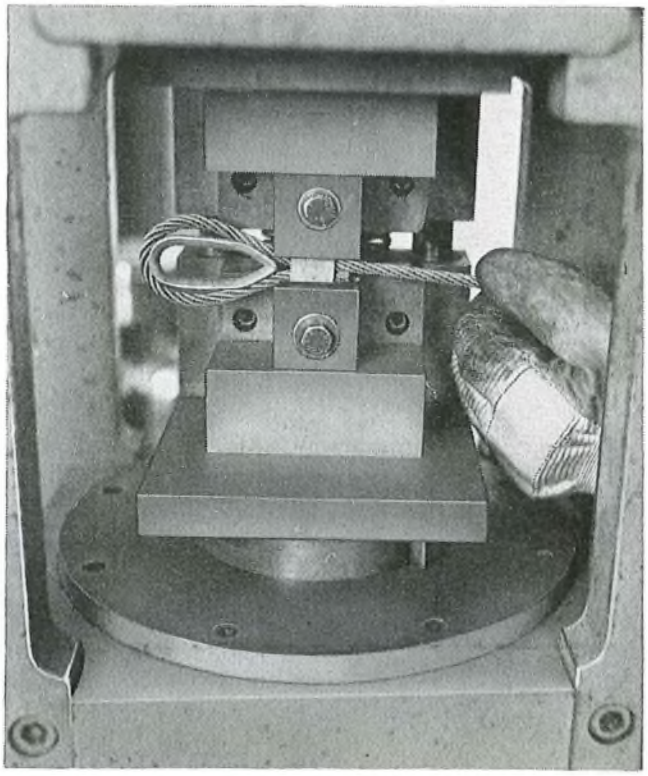


FIG. 13—A Talurit ferrule being positioned between the jaws of an hydraulic press prior to swaging on to the rope

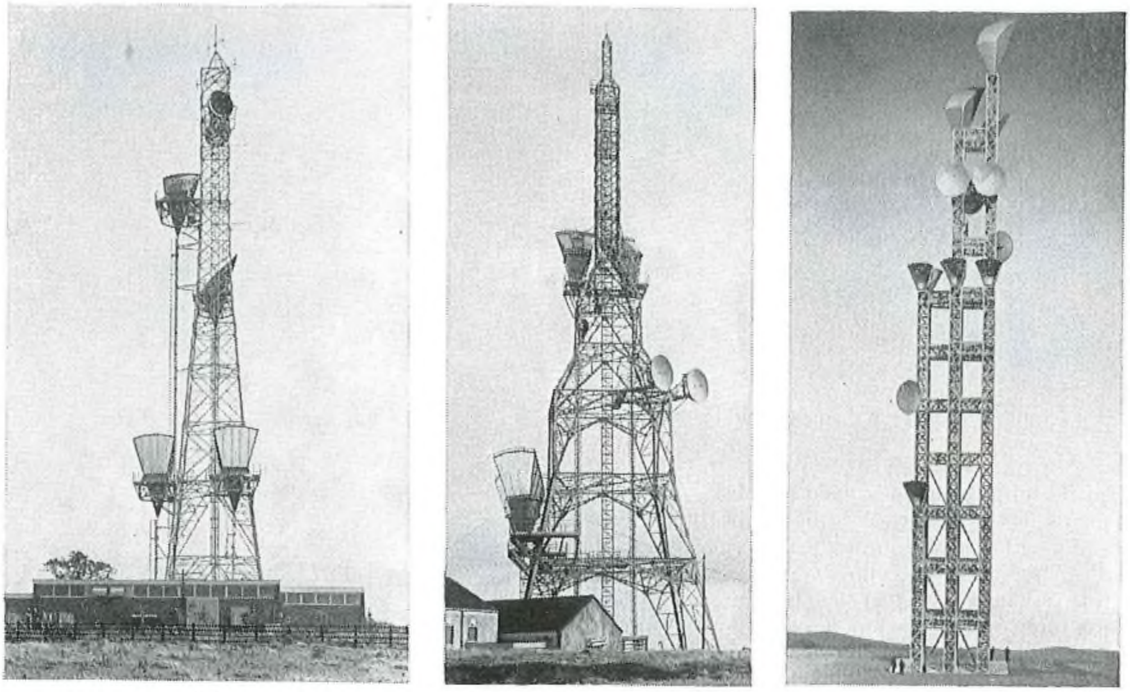
Guy-Rope Terminations

For larger guy ropes, the most common method of terminating is to use steel sockets (Fig.12) with the rope embedded in zinc, white metal or polyester resin. This type of termination is best done in the rope-maker's works. For smaller diameter ropes, socketing is sometimes used, but the standard method used at B.P.O. radio stations is to use the Talurit fitting. This consists of an aluminium-alloy ferrule which is compressed on to the wire rope so that it flows into its interstices giving, usually, a termination equal to the breaking strength of the rope. The ferrules are fitted using a hydraulic press; the portable hand-operated version, shown in Fig. 13, can handle sizes up to the $\frac{5}{8}$ in diameter rope used on the Mast No. 2A. The same machine can terminate Parafil and other synthetic-fibre ropes with equal facility.

SOME MODERN STRUCTURES

Microwave Towers—Past Practice

Most of the earlier B.P.O. towers were variations on the familiar pylon outline, and were fabricated from steel angle-sections with bolted and gussetted connexions. This type of structure was satisfactory when only a few dish aerials were required. The introduction of horn aerials created difficulties which had a disastrous effect on the appearance of this type of tower (Fig. 14(*a*)). One solution was the introduction of a tower with a stepped outline, the horn aerials being mounted at the steps. These towers were designed around a number of standard panels which could be assembled into a structure of the required height and shape to suit particular locations (Fig. 14(*b*)). Another solution was the *daffodil*-type tower, in which the waveguide support was also a structural component. The horn and its stalk-like structural support constituted a unit which could be multiplied as necessary to give a tower of the necessary capacity, as shown in Fig. 14(*c*). One major 200 ft high tower was constructed on this principle. The horn aerial was then discontinued for new work and, as a result, both the stepped tower and the daffodil tower were rendered obsolescent.



(*a*) (*b*) (*c*)

(*a*) A pylon-type tower modified to carry horn aerials
(*b*) A stepped-outline tower with the upper horn aerials mounted at one of the steps
(*c*) A model of the *daffodil*-type tower

FIG. 14—Three older types of tower.

It should be noted that several of the towers illustrated here have been constructed to be adequate to accommodate the aerials likely to be required 20, or more, years ahead, and, as a result, look somewhat out of scale at present with only a few aerials installed.

Tower No. 5A

A feature of the daffodil tower which had considerable attraction was its modular construction based on a few basic components which could be assembled into structures of a wide variety of shapes and sizes. The idea was developed and the Tower No. 5A was the result. It is based on four main structural elements: a prefabricated column unit, rectangular-hollow-section (r.h.s.) horizontal bracing, and solid-rod diagonal and plan bracing. Standard access ladders, platforms, aerial mountings and other ancillary steelwork have also been provided. Such a structural system has the following distinct advantages over the more conventional tower:

(*a*) It is possible to provide a large mounting area for dish aerials by extending sideways rather than upwards. By reducing the height, the structural loads and the overturning moment are reduced, the wind velocity is lower at the lower heights and the tower becomes less conspicuous. Mounting aerials at the minimum necessary height enables feeders to be kept short and this reduces attenuation in the waveguides.

(*b*) It is often not necessary to erect, initially, the full tower required for the ultimate aerial complement as the structure can readily be extended upwards, in depth, or sideways at some later date to accommodate expansion of services.

(*c*) The interchangeability of parts and the small number of different components simplify the provisioning and quality-control procedures, and allow stockpiling of towers against unforeseen demands.

(*d*) Once such a tower system has been designed, it is necessary only to carry out a single overall stress analysis for each tower configuration. No detailed design work is required except for the foundations which, of necessity vary from site to site according to soil conditions.

The Tower No. 5A is suitable for structures up to 150 ft in height. Above this height, the modular system begins to give a less satisfactory load-carrying/structural-weight performance. The type of construction used is not usually optimum in this respect below 150 ft, but its other merits outweigh this disadvantage. The Tower No. 5A and the method of construction are illustrated in Figs. 15 and 16.

The dimensions of the basic module of the tower are 15 ft square in plan and 20 ft in height. To improve the appearance of the tower, care has been taken to use slender members. For example, the solid-rod diagonal-bracing members are designed to carry only tensile forces by allowing the fixing pin at one end to run in an elongated hole so that there is no resistance to compressive forces. Another feature is that the columns are painted in a darker colour than the other components to emphasize the verticality of the complete tower.

The tower is constructed from steels with good low-temperature ductility, especially important because of the large amount of welding and the use of relatively thick rods. Mild steel is used for the column units and horizontal members, and h.y.s. steel for the diagonal bracings.

Tower No. 4A

This type of tower was evolved for the microwave radio sections of the Scottish Highlands and Islands telecommunications scheme. The requirements were different in emphasis to those for towers in the main network. Appearance was of particular importance in view of their locations in areas of considerable natural beauty. The aerial loads were relatively light with up to four 8 ft diameter dish aerials, and the tight criterion of $\pm$ 45 min of arc deflexion, normal for microwave aerials, was relaxed a little. Over 40 towers were required of heights ranging from 45–150 ft, and located in areas where design wind velocities could be up to 140 miles/h. Since many of the sites were very remote, it was desirable to have structures which were easy to handle and transport.

The basic structural element consisted of a parallel-sided panel, 16 ft square in plan and 15 ft in height. For towers over 90 ft, it was advantageous to spread the lower sections, e.g. a 150 ft-high tower would then have a 24 ft square base tapering to 16 ft square at the 60 ft level, and then parallel-sided above that. Seven standard panels were sufficient to cater for all height and loading combinations. The main components are fabricated from h.y.s. steel. The main posts are of circular hollow section (c.h.s.), ranging from $8\frac{5}{8}$ in diameter $\times \frac{1}{2}$ in thick to $5\frac{1}{2}$ in diameter $\times \frac{5}{16}$ in thick with flange joints at the ends. Solid rods of $1\frac{3}{4}$ in or 2 in diameter are used for the cross-bracing, the horizontal and plan bracings being fabricated from tube. The flanges on the post members are connected by h.s.f.g. bolts. These are tensioned after installation to give a pre-tensioned joint in which the total bolt load exceeds the maximum likely service tension in the members. Thereafter, there are only very small changes in bolt tension with fluctuation of external loads; the consequent advantages are that the fatigue life of the bolts ceases to be a problem and the shear force on the joint is carried by the friction between the flange surfaces and not by the bolts.[20]

Two types of the Tower No. 4A are shown in Figs. 17 and 18.

Microwave Towers over 150 ft in Height

For towers over 150 ft, it is generally more economic to resort to the conventional pylon shape for the structure. One recent solution to the problem was a tower, 222 ft high, in

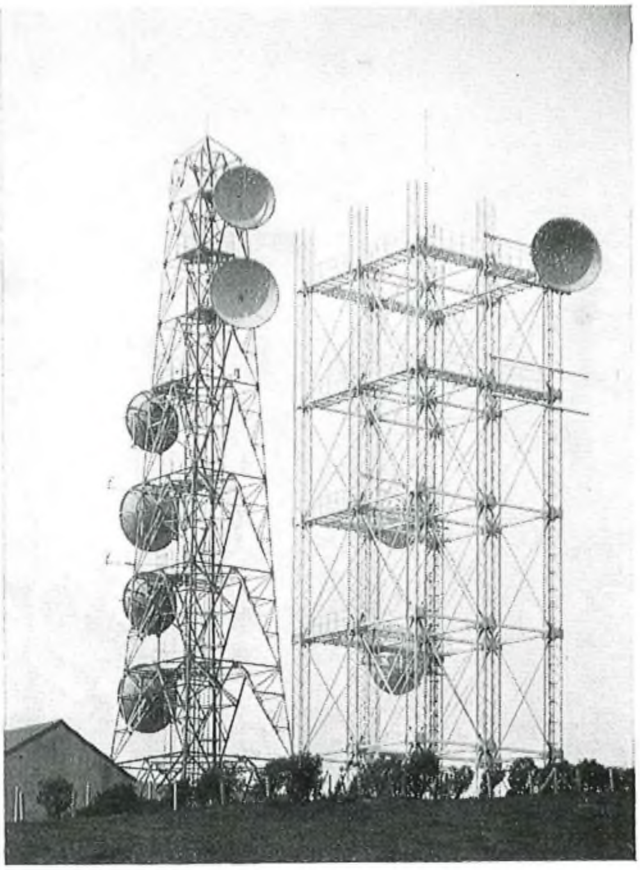


FIG. 15—A Tower No. 5A with the older-type tower it is replacing

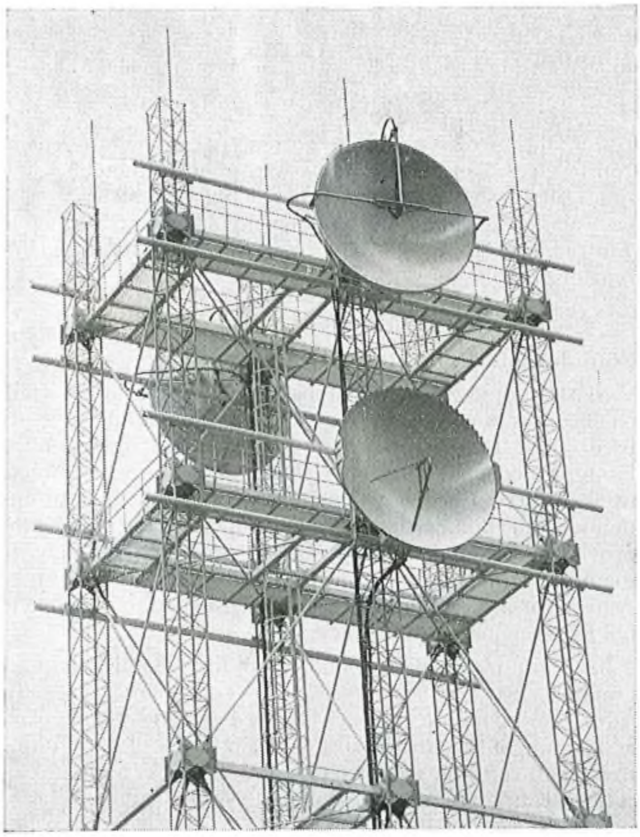


FIG. 16—Detail of a two-module × one-module Tower No. 5A.

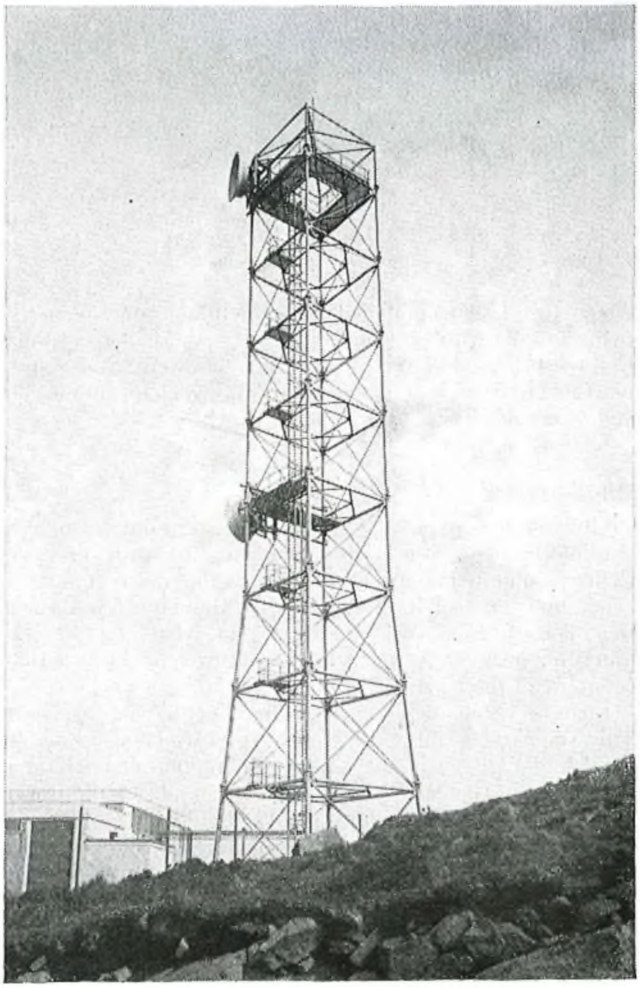


FIG. 17—A 135 ft high Tower No. 4A

FIG. 18—A 45 ft high Tower No. 4A

FIG. 19—A Mast No. 1C being erected using an aluminium hook-on derrick

which the design combined the structural economy of the pylon outline with the convenience of aerial galleries similar to those provided on reinforced-concrete towers. A few guyed masts have been used on microwave links when the numbers of aerials are not large.

Guyed Masts

Unlike a self-supporting tower, there is not much scope for varying the shape of a mast as it consists, basically, of a very slender column supported by guys. The mast column is generally triangular in cross-section, although a few masts in the microwave network are square in section, as ease of mounting dish aerials on such masts outweighs the structural economy of the triangular type.

Mention was made, in Part 1, of the widely-used Mast No. 1. This is illustrated in Fig. 19 where it is shown being erected by a method used when the normal falling-derrick method is impractical. (The derrick shown is an example of the use of aluminium; it is 21 ft 6 in long and weighs about 35 lb. Riveted construction was used to avoid reductions in strength which would result from welding a high-strength alloy.) The Mast No. 1 has a face width of 1 ft $2\frac{3}{8}$ in and can be used with up to 15 sections, each 12 ft 6 in long, giving a maximum height of 187 ft 6 in.

Fig. 20 shows the base of a 300 ft high Mast No. 2A mounted, as most masts are, on a ball-and-socket joint. The mast has a face width of 2 ft 6 in.

For the two very-low frequency (v.l.f.) aerial systems constructed in the 1960s, masts were used in the 600–750 ft range and designed to carry heavy aerial loads. These masts were all of triangular cross-section with post members of up to 7 in diameter in h.y.s. steel. Angle members were used for bracing.

Foundations

Mast and tower foundations follow conventional civil-engineering practice and a variety of foundation types are used; these include mass reinforced-concrete blocks, piles, reinforced-concrete rafts, rock anchors and various combinations of these. For a large microwave tower, the overturning moment due to the design wind condition can require the provision of foundations capable of providing reactions of the order of hundreds of tons to uplift or downthrust forces. A tower or mast foundation can be considered to be liable to fail by three mechanisms, these being

(*a*) uplift, in which the foundation is lifted bodily out of the ground,

(*b*) bearing failure, in which excessive settlement takes place as a result of the downthrust force, both of these resulting from the overturning moment on the structure, and

(*c*) shear failure from the horizontally-applied force.

High factors of safety are also required to guard against inherent uncertainties in the properties of the soil which

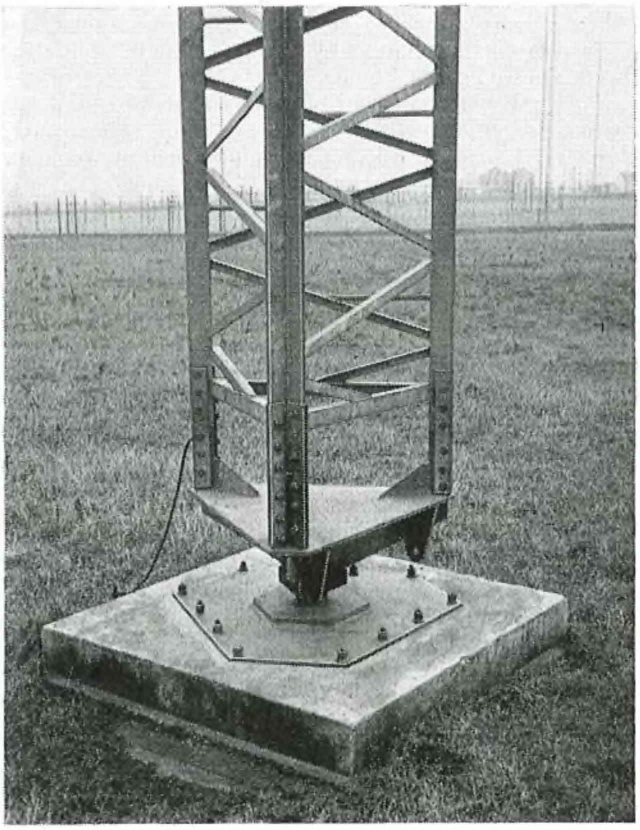


FIG. 20—Base of a Mast No. 2A. The mast sits on a 2 in-diameter ball

exist even when a professional soil investigation has been carried out.

The most common method used for towers is to provide independent concrete blocks for each leg of sufficient base area to give a safe bearing pressure on the soil resulting from the downthrust in the tower leg and the deadweight of the block itself. The uplift on the tower legs is resisted by the mass of the concrete assisted, to some extent, by the soil surrounding it. The tower exerts a horizontal shear force on the blocks, but this type of foundation is usually of such a size as to require no separate provision to resist shear.

Where the tower is located over sound rock, a very attractive method is to use rock anchors which are, in effect, a form of tension pile. The rock-anchor method involves drilling through the overburden into the rock stratum for a sufficient depth. A high-tensile steel tendon, consisting of a multi-strand cable or a solid rod, is inserted and grouted into the rock and then highly-tensioned so that the load on the anchor is constant (*cf.* the pre-tensioned flange connexion described earlier). Rock anchors are usually employed in groups of several anchors which are terminated on the base steelwork of the tower.

When using rock anchors, a sufficiently large capping block has to be provided to distribute to the soil the bearing pressures resulting from the pre-stressing load in the tendon and the downthrust in the tower leg. Resistance to shear force can be provided, to some extent, by raking the rock anchors at an angle to the vertical; the capping block also contributes.

The conventional type of pile is used on occasion when reinforced-concrete-block or rock-anchor foundations are impractical. Unlike rock anchors, piles can be designed to resist tensile and compressive forces. The more common type is the friction pile in which the forces are transferred to

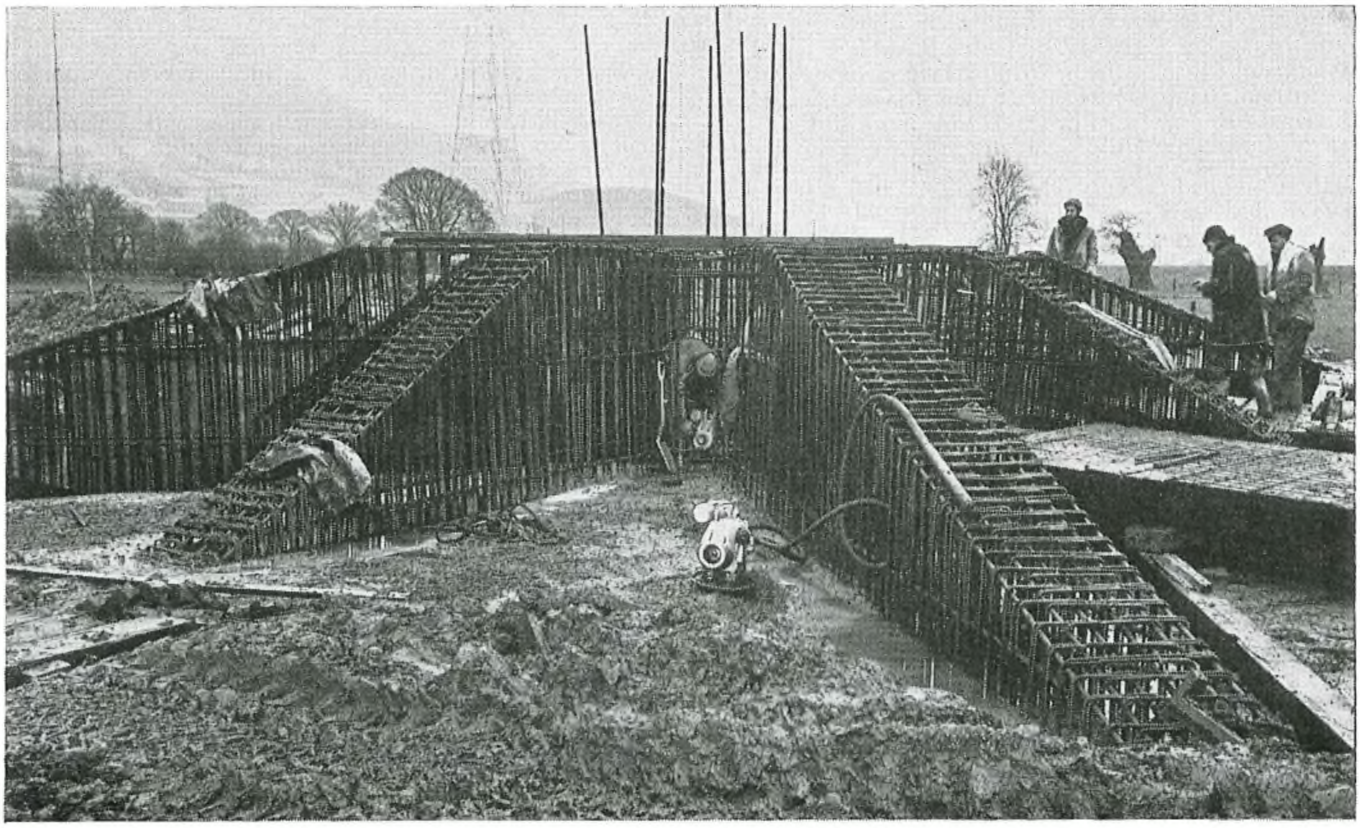


FIG. 21—Foundation for a 700 ft high mast in course of construction

the soil over the length of the pile. The pile is constructed by driving it into the soil to such a depth that sufficient resistance to applied loads is generated.

An example of the use of piles was in providing foundations for three 600 ft high towers in glacial drift for a v.l.f. aerial system in 1942. For the footing for each post of the towers, twelve 18 in diameter piles were driven to various depths up to 93 ft, each capable of sustaining a load of 30 tonf. In addition, eight shorter raking piles per post were driven to provide horizontal shear resistance. It is interesting to note that when the same aerial system was extended, the new 700 ft high masts were provided with reinforced-concrete rafts instead of piles (Fig. 21). The mast-base rafts each had to be 45 ft square to restrict soil pressures.

If rock anchors or piles are proposed, it is most important to carry out an investigation to determine the characteristics of the soil they will depend upon for support. When using the block-type foundation, soil investigation can lead to substantial economies in the amount of concrete required; without an investigation, the design has to be conservative. For lightweight masts, it is customary to specify standard foundation and guy-anchor blocks designed to be adequate for relatively poor soil as it is not usually economic to have individual surveys carried out. A visual observation of an excavation will, in fact, disclose whether or not this conservative design would be adequate.

A soil investigation is not only concerned with the load-bearing properties of the soil. The prevailing ground-water may give rise to construction difficulties, or it may contain sulphates in solution or organic acids which could attack the concrete and its steel reinforcing over a period of time and this will have to be allowed for in the quality and type of concrete used.

CONCLUSION

Part 1 of this series outlined modern design principles; this part has drawn attention to some recent developments in the tall structures themselves. Part 3 will describe some of the work which is carried out to check on the structural performance of masts and towers, and their component parts.

Reference

[20] GILL, P. J. Notes on the Load-carrying Characteristics of Pre-tension Bolts—tensioned joints. *Proceedings, Symposium on High-Strength Bolts.* I.Struct.E., 1959.

Book Review

'Modulation." viii + 108 pp. 67 ill. £1·10. "Noise." viii + 104 pp. 60 ill. £1·10. F. R. Connor, Ph.D., M.Sc., B.Sc. (Eng.) Hons., A.C.G.I., C.Eng., M.I.E.E., M.I.E.R.E., M. Inst. P. Edward Arnold.

These are the last two books in a series of six. The other books, which have already been published and which were reviewed in *P.O.E.E.J.*, Vol. 66, p. 9, Apr. 1973 and p. 173, Oct. 1973, are: Vol. 1—Signals, Vol. 2—Networks, Vol. 3—Wave Transmission and Vol. 4—Antennas. The author's intention is to prepare texts on introductory topics in electronics and telecommunications mainly for students who are preparing for degrees of the London University, and the C.N.A.A. examinations of the C.E.I., and for other qualifications such as H.N.C. and H.N.D.

VOL. 5—MODULATION

The main topics dealt with in this book are: amplitude modulation, frequency modulation, phase modulation, pulse modulation and the various methods of demodulation.

The section on amplitude modulation (a.m.) covers the a.m. spectrum, a.m. modulators, double-sideband suppressed-carrier systems, single-sideband suppressed-carrier systems, independent sideband systems and vestigal transmission. The sections on frequency, phase and pulse modulation are mainly concerned with the frequency spectrums, generation, transmission and demodulation of the respective systems. The level of mathematics required for the treatment given in the book is comparatively low, being mainly basic trigonometry and elementary calculus. Included in the book are 16 worked examples, a list of 30 references for further reading, and six appendices dealing with the more analytical aspects of modulation.

The contents of this book appear in many course syllabuses and, therefore, the book can be recommended to students of electronics and telecommunications of varying standards, roughly equivalent to the 0.2 to A.2 levels of the National Certificate course.

VOL. 6—NOISE

The main topics dealt with in this book are: introduction to the subject of noise, probability and statistics, correlation (statistical regularity) techniques, circuit noise, noise measurements, systems, and six appendices dealing with special aspects of the main subject. Included in the book are 21 worked examples, and a list of 28 references for further reading on the subject of noise. The level of mathematics required for the treatment given in the book is approximately equivalent to the A.1 year of the National Certificate course.

The book is recommended to students of electronics and telecommunications at the level of City and Guilds Telecommunications Course (supplementary studies), H.N.C., and diploma and degree courses; below this level the book would have very limited appeal.

The review of these two books completes the series, and generally, the books should be well received by students on the appropriate courses. The books are low-priced and of a very convenient size for carrying; also, the numerous worked examples and reference material for further studies should prove especially useful.

J. F.

Notes and Comments

Articles on Topics of Current or General Interest

The Board of Editors would like to publish more short articles dealing with current topics related to engineering, or of general interest to engineers in the Post Office.

Engineers have a significant role in modern society, and the *P.O.E.E. Journal* is an instrument whereby themes and ideas may be exchanged.

As a guide, there are, on average, about 750 words to a page, allowing for diagrams. Authors who have contributions are invited to contact the Managing Editor, NP 9.3.4, Room S 08A, River Plate House, Finsbury Circus, London, EC2M 7LY.

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 July issue if they are received before 27 May 1974.

Letters intended for publication should be sent to the Managing Editor, *P.O.E.E. Journal*, NP 9.3.4, Room S 08A, River Plate House, Finsbury Circus, London, EC2M 7LY.

Notes for Authors

Authors are reminded that some notes are available to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal's* 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.

Electricity-consumption Restrictions

The Board of Editors wishes to aplogize for the late distribution of the January 1974 issue of the *Journal*. This was due to printing delays, caused by the Government's restrictions on the consumption of electricity. It is regretted that some delay to the April 1974 issue may also occur.

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).

Supplement

Students studying for City and Guilds of London Institute examinations in telecommunictions are reminded that the Supplement to the *Journal* includes model answers to examination questions set in the subjects of the Telecommunication Technicians' Course. Back numbers of the *Journal* are available in limited quantities only, and students are urged to place a regular order for the *Journal* to ensure that they keep informed of current developments in telecommunications and receive all copies of the Supplement.

Details of subscriptions, and back numbers available, are given on the reverse of page 63.

Syllabuses and Copies of Question Papers for the Telecommunication Technicians' Course

The syllabuses and copies of question papers set for examinations of the Telecommunication Technicians' Course of the City and Guilds of London Institute are not sold by the *Post Office Electrical Engineers' Journal*. They should be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London, W1N 4AA.

Regional Notes

Eastern Region

Brentwood's New Crossbar Exchange

The last manual exchange in the Southend Telephone Area closed on 19 July, 1973, when it was replaced by a crossbar group switching centre (g.s.c.).

The manual exchange was opened in 1932 with five positions, and grew to 98 positions. As a relief, another manual exchange of 37 positions, and two mobile tandem exchange units (m.t.x.s) were installed on the same site, the former in a prefabricated two-storey building.

The new exchange consists of a TXK1 crossbar g.s.c. with an 18,500-subscriber local multiple. The associated assistance centre has 46 Cordless Switchboard System No. 1 positions and 12 directory enquiry positions.

The equipment was installed by Plessey Telecommunications Ltd., the installation commencing in June, 1968. The five-storey building cost £500,000 and the equipment £1,750,000.

Brentwood became the first crossbar g.s.c. to carry live traffic, when the tandem section opened in February, 1973, and progressively handled the traffic diverted to it by the phased closure of the two m.t.x.s, plus the incoming and outgoing traffic for the home charge group (except Brentwood customers). Prior to the conversion of the 14,000 Brentwood customers in July, 1973, the exchange was handling about 300,000 calls a week.

A total of 2,500 main-network and junction circuits were provided, using signalling systems A.C. No. 9 or D.C. No. 2, pulse-code-modulation, or loop-disconnect signalling. On the main network, three high-frequency line-transmission systems with 175, twelve-circuit groups were provided.

Access to the transit network has been provided and international-subscriber-dialling facilities will follow after a local-labour extension, starting this year.

A. TOPSFIELD

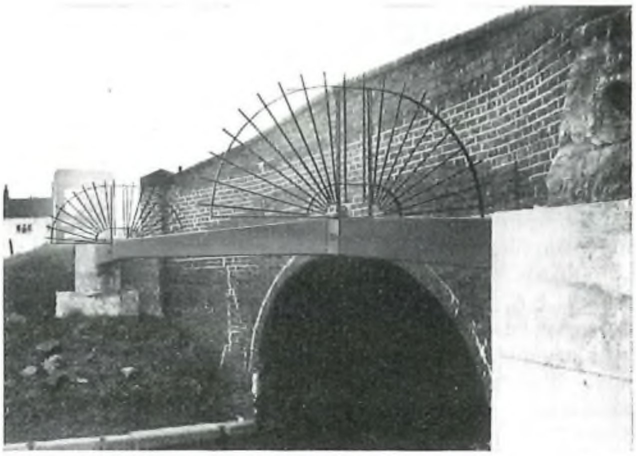
Midland Region

Canal Duct Crossing at Tamworth

Towards the end of 1971, an important four-way duct route had been laid to both ends of a canal bridge at Kettlebrook, Tamworth, Staffs. The bridge, typical of many in the Midlands, had recently been reconstructed and a reinforced-concrete arch inserted. This precluded the placing of connecting ducts within the bridge deck itself. Other constraints were the narrowness of the bridge and its approaches, the large flow of heavy vehicles using the bridge, and the difference in bank heights. Also, to clear the towpath and its access, a pipe slung across the canal would require a relatively long span. A further difficulty was that the road ramp leading to the bridge on the Tamworth side was retained by an old stone wall some 3 m high, which was seriously out of plumb over its height and badly decayed in places.

It was finally decided that a 254 mm square, hollow-section, steel tube, 6·35 mm thick, would provide an ideal carriage for four polyvinyl chloride (p.v.c.) ducts, the ducts passing through the steel section and a reinforced-concrete anchor, and into a joint box in the high bank. Consultation with the Area Works Group revealed an unwillingness to touch the existing stone retaining wall to allow the ducts to pass into the roadway at the Tamworth end. A reinforced-concrete retaining wall was, therefore, designed, into which the hollow steel section could be anchored.

On site, the old stone wall was dismantled, and the stone retained for topping the reinforced-concrete retaining wall, and the new wall was constructed to the level at which the steel section could be lowered into place. The steel section itself



The steel duct-carrying section and concrete anchors

been had made up from two standard production lengths, one of which was carefully cut to provide the two end sections, and to provide the necessary clearance over the canal. The section was held at the high-level (Kettlebrook) end in a reinforced-concrete pad, cast integrally with a surface joint box. The other end of the steel section was cast into the retaining wall. Both ends were seated on, and bolted to, formed beds, and anchored by subsequent casting. It was determined that no special provision would be required to take account of temperature changes, and that the structure would easily withstand the induced stresses.

An expansion joint was, however, provided in the p.v.c. duct by cementing a polythene sleeve (sleeve No. 6) to the outside of the p.v.c. within the steel section, allowing for free movement over the spigot end of the p.v.c. duct cast into the anchor at the Kettlebrook end of the bridge.

The work was completed by adding a stone-built wall to the top of the concrete retaining wall, thus presenting a fair face to all elevations, and restoring some of the original character to the bridge.

Although the requirement was rather unusual, Works Group had little difficulty in ensuring that the work was carried out properly, and the result is an unobtrusive and effective solution to the problem.

R. H. QUAIL
G. J. GOUGH

Northern Ireland

Kilkeel TXE2 Exchange Conversion

At Kilkeel in Co. Down, a new exchange of the TXE2 type was programmed to come into operation on 27 June, 1973 to replace the existing u.a.x. 13. Unfortunately, due to outside electrical interference, the transfer had to be postponed pending the localization and clearance of the interference.

The fault had first been detected on the 4 June, 1973 when the commissioning staff noticed that certain relays in the S.S.D.C. No. 2 supervisory relay sets were vibrating. An inspection of the relay sets at the TXE2 exchange, and also at the associated group switching centre at Newry, failed to reveal any faulty components.

The next step was an examination of the junction circuits, which had one intermediate amplifying stage at Warrenpoint, the mid-point in the junction circuits. This test revealed that an alternating voltage, fluctuating between 8–24 volts, was being induced into the cable pairs. A fault of this type is normally caused by leakage from high-tension power circuits, and radio interference staff, in conjunction with engineers from the Northern Ireland Electricity Service (N.I.E.S.), were asked to investigate the possibilities of a fault in the area. They reported that a fault of this nature did not exist in the area, but the trouble still persisted and further tests revealed that, at certain times, an alternating current peaking to 10 amperes was flowing to earth from the lead sheath of the cable.

Further tests were undertaken in close liaison with the N.I.E.S. engineers and, eventually, the trouble was traced to a new housing estate approximately one mile from Kilkeel on the same road as the cable route. The N.I.E.S. engineers made changes to the high-tension distribution to this area, but still the fault persisted and, therefore, attention was directed at the low-tension supplies, as the possible source of the interference.

During the time that the localization of the possible source of trouble was taking place, the S.S.D.C. No. 2 junction circuits were completely unworkable due to false metering, false signalling on the level-0 metering-over-junction circuits and modulation of the speech frequencies by the induced voltage.

On the 11 June, 1973 a decision was taken to postpone the exchange transfer and the necessary steps were taken by the traffic staff to advise the subscribers of this action.

As the localization of the trouble had the appearance of being a protracted affair, various methods of overcoming the trouble, as detailed in Telecommunications Instruction A2 E3621, were tried, but without success due to the severity of the interference.

The N.I.E.S. engineers located incorrect wiring of electrical appliances in the area due to a local electrician who had reversed the neutral and earth connexions at a number of installations. When these had been corrected the cable-sheath current dropped to a few hundred milliamperes and the induced voltage to 1·5 volts maximum. As these values were inside the tolerances for the satisfactory operation of the junction relay-sets, it was mutually agreed that further maintenance effort would not be expended until the cable sheath current exceeded 1 ampere.

The reason for the fault suddenly appearing was not at first apparent, until it was discovered that a section of iron water-pipe in the area of the housing estate had been replaced with a plastic type, and, therefore, the earth currents had to find alternative routing through the British Post Office cable sheath.

After consultation with the maintenance division, it was decided that precautions should be taken to ensure that similar trouble did not recur, and it was suggested that continuous monitoring of the cable-pair induced voltage should be undertaken.

To this end, a voltage alarm circuit was installed at Kilkeel exchange and connected to a spare cable pair, the alarm to operate if the induced voltage exceeded 2 volts.

After a period of three months, during which time no further trouble was experienced, the exchange was put into service on the 8 October, 1973.

There have been no further problems with the operation of the junction circuits, but, as an additional safeguard, an alarm circuit has now been installed to monitor stray alternating currents flowing in the cable sheath and to give an alarm if the current should exceed 1 ampere at any time.

We have had, in the past, other cases of induced alternating voltage on lines, but this proved to have a most unusual source and was, therefore, the most difficult to cure.

During the whole investigation, the utmost co-operation was given by the N.I.E.S. engineers and the incident once again proved the value of the good relationships which exist between the N.I.E.S. and the Post Office in Northern Ireland.

M. Jones
W. J. M. McKinney

Scotland

Perth–Inverness A9 roadworks

Those of you who have journeyed north to pleasure the beauties and sports of Scotland, only to experience frustrations and delays on the narrow and winding road between Perth and Inverness, will be pleased to know that phase I of the reconstruction in the Dundee area started in November, 1973. However, completion is not expected until spring, 1975.

Simultaneous dispensation of three cables from the hired train.

Temporary interruption of a four-tube coaxial cable, two carrier circuits, two junction circuits and a local cable, over the complete section, was necessary. Provision of interruption cable by aerial means along the line of the new road was impractical due to plantations, undulating ground and the movement of contractors' vehicles. As the railway line ran parallel to the road, it was proposed to lay the cables on the side of the track. At a meeting with British Rail, arrangements were made for the hire of a train and four flat wagons capable of holding three cable-drum trailers and 11 cable drums, allowing three cables to be dispensed simultaneously.

Estimated savings in labour amounted to 700 man-hours.

A similar job was executed the following weekend, to provide 1,500 m of interruption cables on the M90 roadworks at the multi-level interchange at Craigend, but, in this case, the cables were laid through a railway tunnel, which avoided the need for aerial cable over a 60 m hill and very rough ground.

R. C. Donaghy

Relief of Isle of Shapinsay

The Aberdeen and North of Scotland Telephone Area is geographically the largest in the country, occupying some 15,500 square miles of territory. In the northern part of the area are the Orkney Islands, whose main centre of administration and communication is Kirkwall. Four miles across the water, and fed by a 16-pair submarine cable, is the island of Shapinsay, with 75 subscribers served by Balfour u.a.x. 12. Late on Sunday 9 December 1973, this u.a.x. was isolated when the submarine cable developed a fault affecting all pairs. No immediate repair was practicable as the nearest cable ship was berthed at Dover.

On Monday 10 December, arrangements were made to airlift a single-channel v.h.f. radio link (Tranceiver 3A) from Edinburgh by the first commercial flight on Tuesday. In the meantime, Yagi aerials were constructed in Inverness, complete with coaxial feeders, and a pole was erected outside

The Orkney Islands

Balfour u.a.x. to take one of the aerials. All the equipment arrived in Orkney on Tuesday at mid-day and was working later that same day.

Tranceivers 3A, with signalling units, provide standard facilities for a subscriber's line, loop-disconnect signals being converted to out-of-band *tone-on* or *tone-off* signals. Initially, it was decided to establish the link to a nearby public call office, although there would be drawbacks in attempting to contact other subscribers on the island. Further thought showed that much better facilities could be achieved by turning the link back to front. The subscriber terminal was fitted at Kirkwall manual switchboard, and the exchange end was provided as a new number, 300, on Balfour u.a.x. When any Balfour subscriber dialled 300, the resultant ringing condition would be repeated to Kirkwall and speaking conditions established via a switchboard jack. For calls to the island, the operator became Balfour 300, and could dial any number on the u.a.x.

This service was judged to be satisfactory for a few days as the cable ship *Ariel* had made ready for sea, but on Wednesday came the news that the *Ariel* had been forced to turn back. To restore full junction facilities to Balfour, it was then decided to instal a six-channel radio link, complete with interface equipment, working in the u.h.f. range of 450–480 MHz, all signalling being by 3,825 Hz, out-of-band tone. The only available link which was compatible with other Orkney radio systems, was under test at Kirk o' Shotts Radio Station, midway between Edinburgh and Glasgow, and this was dismantled and packed by S.T.B. Headquarters staff. The 1·5-ton weight precluded any conveyance other than by road and, with the diesel fuel crisis at its worst, it seemed a very long 300 miles to the north.

Auxiliary signalling equipment which gives simplified S.S.A.C. No. 8 facilities, to interface the link f.d.m. system with the existing u.a.x. equipment, was located by area staff and, by dawn on Thursday, all items had arrived at Thurso to await the island steamer.

Gales continued to lash the notorious Pentland Firth for a further 48 hours before the sea crossing was possible. The load finally arrived in Kirkwall on Saturday night and by Sunday night one terminal had been installed. A chartered steamer, crossing to Shapinsay next day, enabled the other end to be started, and, although hampered by the snow and gales which had bedevilled the whole operation, all circuits were provided and service restored fully by Thursday 20 December.

The installation, in record time, by area staff, in the face of many difficulties and frustrations, and the help given by S.T.B. Headquarters in the testing of the radio equipment, was a fine example of co-operation in a "fire-brigade" operation which saved the islanders of Shapinsay from a bleak festive season.

J. W. Innes

Book Review

"Fernsehtechnik. Band 1. Grundlagen. (Television Technology. Vol. 1. Principles)." Richard Theile. Springer-Verlag, Berlin/Heidelberg/New York. viii + 160 pp. 126 ill. DM 38·50.

The first volume of a set of three, this book is an introduction to the principles involved in the production of television images. It starts by describing the principles of scanning, follows with an account of the inter-relationship of spot size and line and frame dimensions, and leads to a consideration of the choice of line and frame frequencies, giving a comparison of 405-, 525-, 625- and 819-line standards. After the basic picture formation is established, a further chapter adds the synchronizing signals, interleaving arrangements, integral sound and, finally, the carrier needed for transmission. The spectral structure of the picture signal is analysed, and some indication is given of the effect of interference on various patterns, together with explanations of how it is mitigated. A considerable portion of the book is then devoted to the means of adding colour to the general television picture. Both the optical and electrical bases of colour analysis and synthesis are described in some detail, culminating in an outline of the n.t.s.c. system and its variants. The concluding chapter explains methods of measuring the quality of the television transmission chain and of detecting the presence of disturbances.

The objective throughout is to bring together introductions to the theoretical principles involved without detailed complexity and with no reference to equipment implementation. This aim has been achieved by a clear, straightforward text and ample illustration. In particular, the television picture, as seen by the viewer, has been used as the connecting theme, so that the final relevance of any aspect discussed is immediately understood.

Further theoretical information can be obtained from the publications listed in the bibliography, arranged to correspond with the chapters in the book. The other two volumes in the series are expected to cover applications and new developments. The present volume can be recommended to anyone wishing to gain an insight into television-signal technology, provided that he has the necessary knowledge of basic German and the facility to interpret the technical terms used.

H. B.

Associate Section Notes

Aberdeen Centre

The 1973–74 session began on 19 September with a day visit to the Technology Department of the Royal Scottish Museum in Edinburgh, and, although the party which travelled was small, the members had a most interesting visit. This was followed by a very informative talk in October by Mr. J. W. Robb, D.G.M., Aberdeen, who spoke on submarine systems, covering types of cables, systems, cable-ships and fault-location techniques. An evening visit on 22 November was to a local firm which specializes in spinning synthetic yarns, mainly for carpet manufacture. The December meeting took the form of a quiz competition between the Aberdeen and Inverness Centres. The questions were of a technical nature and the evening was most enjoyable in spite of the fact that Aberdeen was well beaten by Inverness.

J. H. McDonald

Bournemouth Centre

On 5 September, a party of 27 went by coach to the R.A.F. Museum at Hendon. We arrived at about 1100 and, after a short talk given by the officer in charge, we had a very interesting day. We had lunch in the museum restaurant, and left at 1615 to avoid the peak traffic.

Our quiz team, led by Mr. B. W. Fielder, won the first round against Bristol Centre, the second was conceded to us by Swindon and, in the third round, Bournemouth won against Bath. This put Bournemouth into the inter-regional round but unfortunately, after a very close and exciting match, Bournemouth was beaten by Worthing, by 38 points to 36½.

On 12 November, our General Manager, who is also our Centre President, Mr. B. H. Berresford, C.Eng., M.I.E.E., M.B.I.M., gave a very interesting and informative talk on financial reviews.

The Institution of Electrical Engineers kindly invited us to attend their local activities. The November program included:

8 November
Stereoscophy at Bournemouth College of Technology.

14 November
Management of Static Military Communication Projects at the School of Signals, Blandford, Dorset.

20 November
Visit to the P.O. sorting office, Bournemouth.

22 November
Automation in Telecommunication Services at Dorset College.

G. H. Seagroatt

Cambridge Centre

The program for the 1973–74 session of the Cambridge centre is now well under way. A party of 20 members had an afternoon visit to Green King's Brewery at Bury St. Edmunds on 27 November. Following a very interesting tour, the party welcomed the brewery's offer to sample their products.

The program for the future includes the first round of the Regional Land-Line Quiz on January 23, a visit to the local police headquarters on March 6, and the 1974 a.g.m. and film show to be held on April 3. The dates for a lecture on international subscriber dialling by Mr. B. Pierce, and a visit to Lotus Cars Ltd. have yet to be confirmed.

I hope these events will be well attended, particularly the a.g.m., as the centre cannot continue without the support of the membership.

P. Young

Dundee Centre

The recent, rather inclement weather has not prevented the membership supporting, in great style, the first three meetings of the 1973–74 session. A visit to the Gatty Marine Laboratory, St. Andrews, gave us an insight into the research work being carried out there, as well as making us more fully aware of the variety of sea life to be found round our native shores.

An extra visit, which proved a real winner, was a conducted tour round the super-de-luxe Teaching Hospital at Ninewells, Dundee. This multi-million-pound hospital will soon be open to receive patients, and such a comprehensive visit will then become an impossibility.

"TXE Comes to Carnoustie" was the title of a talk by our chairman, Bob Topping, assisted by Frank Sandison. Bob is the T.O. in Carnoustie, and it was there that we were introduced to the intricacies of a TXE2 exchange; a most interesting and informative evening, and well supported. The evening ended on a high note when Mrs. Topping and Mrs. Law served a surprise buffet; thank you, ladies.

It is unfortunate to have to report the cancellation of a coal mine visit—a Coal Board decision—but we still have plenty of good things in store for you during the remainder of the session.

R. T. Lumsden

Edinburgh Centre

On Thursday 17 October, 1973, 17 members visited Messrs. Redpath, Dorman and Long in Buckhaven, Fife. This is a large engineering concern presently building oil rigs for North Sea oil development. No work was in progress during our visit, unfortunately, because of industrial action, but an excellent explanation of the problems to be overcome and the new techniques which had been developed was given by the works manager.

On Wednesday 14 November, a talk on drugs was given by a member of the Edinburgh City Police Dangerous Drugs Department. 14 members attended and were most interested in hearing about the various types of drugs, the different effects they had on people and the difficulties in overcoming the drug problem.

A visit to the National Engineering Laboratories, East Kilbride, on Tuesday 11 December, had to be cancelled because of the power crisis, but will take place at a later date.

M. I. Collins

Motherwell Centre

The 1973–74 session commenced on Thursday 18 October with a talk and demonstration on the No. 4 Jointing Machine. Audience participation was welcomed in operating the machine, to the obvious amusement of the demonstrating jointer. Our thanks to Mr. Dobie, Inspector, Motherwell.

Polkemmet Colliery, Whitburn, was the venue of the November meeting where, with the permission of the N.C.B., the Centre was allowed to visit the coal face and observe the conditions and skills employed in cutting coal.

The meeting for December took the form of a film night, when we had the pleasure of welcoming Mr. Tom Clarke, Scottish National Film Library, who brought along a selection of technical and award-winning films.

D. K. Rainey

Scotland Centres

In 1973, Scotland took part in the National Quiz for the first time, the first round being held on Friday 30 November simultaneously in Glasgow and Londonderry with the aid of an amplified telephone link-up. Although Northern Ireland won by 33 points to 27½ points, the Scottish team gave a very commendable performance for their initial venture and live to fight again. We hope to organize inter-area competitions in Scotland this year in preparation for the next National Quiz, but, for now, my thanks to the many people concerned for all their help, especially our Northern Ireland colleagues and our own team members.

P. B. McBride

The Associate Section National Committee Report

Owing to the present circumstances, the last meeting of the National Committee was cancelled and, as yet, no new date has been chosen for another meeting.

Technical Quiz Competition

The Technical Quiz Competition has got off to a good start and the first round has been completed. These matches were played in different ways; some by the two teams concerned meeting and others over land-lines, but all of which were very successful. The teams through to the second round are Northern Ireland, South East Region, London Telecommunications Region and North West Region.

The next round will be played off soon, so watch for publicity in your region. The teams are playing for the Bray Trophy, which is a superb piece of rock-crystal glass, beautifully engraved with several pictures depicting telecommunications in the modern world. The trophy has been named in honour of the last President of the Associate Section, Dr. P. R. Bray. More news of this trophy will be given in the *National News*, together with a photograph, as soon as possible.

Associate Section Telephone Museum

I have been informed by Mr. Philcox that the Associate Section Telephone Museum is already growing, and that he is very pleased with the response from the members. Please help to save these old items of telecommunications apparatus before they disappear completely.

P. L. HEWLETT

Institution of Post Office Electrical Engineers

Associate Section Papers Annual Awards, 1972–73

The I.P.O.E.E. Council, on the adjudication of the Judging Committee, has awarded a prize of £25 and an Institution Certificate to Mr. I. P. Lightfoot, Technical Officer, Exeter Centre, for his paper "The 5005 Crossbar Exchange".

The Council is indebted to Messrs. T. H. A. Mascall, E. W. Fudge, and B. F. Yeo for kindly undertaking the adjudication of the papers submitted for consideration.

Retired Members

The following members, who retired during 1973, have retained their membership of the Institution under Rule 11(a):

F. Leach, 48 South Park Road, Gatley, Cheadle, Cheshire, SK8 4AN.

S. Watthey, 79 Windermere Road, Kettering, Northants.

W. Rangecroft, 38 Sandy Leaze, Bristol, BS9 3PY.

E. C. Palmer, 6 Silverdale Avenue, Oxshott, Leatherhead, Surrey.

F. F. Feather, 41 West Street, Ewell, Surrey.

F. H. Sturdy, 73 Rawcliffe Lane, York, YO3 6SJ.

A. G. German, 3 Hill Close, London, NW2 6RE.

R. J. Parsons, 55 Cambridge Road, Carshalton, Surrey.

M. Gill, 21 Badgers Walk, Shiplake, Henley-on-Thames, Oxon.

G. Jackson, Cherry Holt, Heol, Punt y Gored, Cardiff, CF4 8NF.

R. N. Hamilton, 3 Acland Avenue, Colchester, Essex.

E. H. Pooley, 47 Hampton Lane, Solihull, Warks.

G. J. Hulcoop, 27 Robinswood Crescent, Penarth, Glamorgan.

C. H. J. Fleetwood, Le Mayals, St. Annes Road. Mountnessing, Brentwood.

E. C. Swain, 86 Vicarage Lane, Kings Langley, Herts.

K. S. Laver, 40 Northey Avenue, Cheam, Surrey, SM2 7HR.

A. B. Cooper, 8 High Corner, Beeton Lane, Barton-on-Sea, New Milton, BH25 7AF.

D. C. Wadeson, 4 Norman Crescent, Pinner, HA5 3QN.

A. B. WHERRY
General Secretary

Book Review

"Microwave Transmission." J. A. Staniforth, B.Eng., Ph.D., C.Eng., M.I.E.E. English Universities Press. xii+243 pp. 115 ill. £2·35 (Unibook), £4·25 (Boards).

This book is a basic guide to the principles underlying wave propagation both in free space and a variety of waveguides. Starting with the two-wire transmission line the author outlines the properties of matched and unmatched lines, introduces standing waves and discusses in some detail the use of a Smith chart. Turning to field theory, Maxwell's equations are stated (without proof) and then used to derive the propagating modes in both rectangular and circular waveguides. Two chapters are devoted to more unusual waveguides, including higher-order modes in coaxial lines. Microwave circuits, cavities and the principles of matching receive a clear and straightforward treatment. The book is completed by two short, descriptive chapters dealing with atmospheric propagation and microwave components.

This work will be useful both for the student and the practising engineer who require an introduction to microwave transmission, and for those whose knowledge has grown rusty and need a compact, lucid book to remind them of the basic ideas. However, there are a number of typographical errors which are confusing, and the bibliography is disappointing. An enquiring reader would have to refer to the bibliography of the books listed to pursue his investigations.

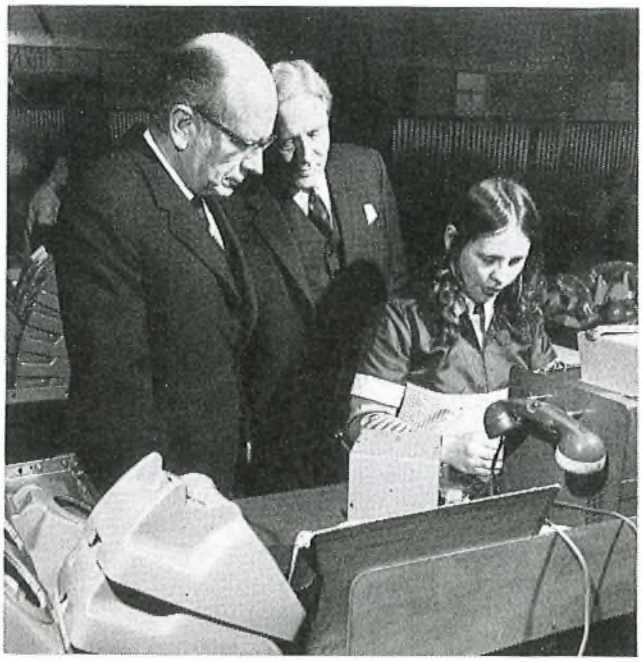
Although the author mentions the uses of microwaves in telecommunications frequently throughout the book, there is not a concrete example illustrating the application of the principles discussed to a simple system. Such an illustration would be more appropriate than the brief descriptions of components and antennas which conclude the book.

C. E. R.

Post Office Press Notices

Telephone Recycling

Mr. Edward Fennessy, Managing Director of Post Office Telecommunications, visits the British Post Office (B.P.O.)



Mr. Edward Fennessy (left) watches the final testing stage

factory at Cwmcarn, South Wales, where more than a million used telephones are rebuilt each year, to go back into service for well under half the cost of buying new ones. The factory, which employs 1,000 people, supplies more than a third of the $3\frac{1}{2}$ million telephones the B.P.O. uses in a year to meet the needs of new customers and to replace old telephones which have become unserviceable.

Datel 4800

The first step towards providing a Datel 4800 service, which will provide for the transmission of computer-data signals over telephone circuits at a rate of 4,800 bit/s, has been taken by the British Post Office (B.P.O.). The rate of 4,800 bit/s is the equivalent of about 6,000 words a minute, with an average of five letters in each word. The B.P.O. has placed a contract with Plessey Telecommunications Research Ltd. for the design and development of a modulator/demodulator (modem) to operate at this data-transmission rate.

The B.P.O. is due to accept prototype modems in 1974, and it will then begin a program of testing and trials, in preparation for the service to start in mid-1975.

There are seven Datel services for transmitting computer data over Britain's telecommunication network, with more than 27,000 Datel terminals in use. The services provide for transmission rates from 50 bit/s, over telegraph circuits, to 48 kbit/s, over rented wideband circuits, but, so far, the highest rate available over the public telephone network is 2,400 bit/s, provided by the Datel 2400 Dial-Up service. A Datel 4800 service will enable a given volume of data, at present sent over the Datel 2400 Dial-Up service, to be transmitted in up to half the time, thereby cutting the cost of the transmission.

Datel 4800 will give alternate two-way, synchronous transmission of serial binary-data at 4,800 bit/s over the public network, or simultaneous transmission over four-wire private circuits, using amplitude modulation with vestigial sideband (a.m.v.s.b.). The modems will also be capable of operating at 2,400 bit/s using a.m.v.s.b. Facilities will be provided for simultaneous, asynchronous transmission at up to 150 bit/s in the reverse direction over a low-rate, backward channel, for supervizing the main transmission.

The seven data-transmission services provided by the B.P.O. are:

(*a*) Datel 100, which provides transmission of serial binary-data, either at up to 50 bit/s, over the public switched telex network, or at up to 110 bit/s, over private telegraph circuits.

(*b*) Datel 200, which provides simultaneous both-way transmission of serial binary-data at an assured rate of up to 200 bit/s, or a non-assured rate of up to 300 bit/s, over the public telephone network or two-wire private circuits.

(*c*) Datel 400, which provides a telemetry, or data-capture service, giving one-way transmission of digital signals at 600 bit/s, or of analogue signals of frequencies up to 300 Hz, and is compatible with the Datel 600 service.

(*d*) Datel 600, which provides transmission of serial binary-data at up to 600 bit/s, or up to 1,200 bit/s, with a simultaneous return supervisory-channel of 75 bit/s.

(*e*) Datel 2400, which provides simultaneous bothway transmission of serial binary-data at 2,400 bit/s over private four-wire, data-quality, telephone circuits. A 75 bit/s supervisory and error-control channel can be provided. The service also provides alternate bothway transmission at 600 bit/s and 1,200 bit/s, with or without the supervisory channel, over the public telephone network.

(*f*) Datel 2400 Dial-Up service, which provides alternate both-way transmission at 2,400 bit/s over the public telephone network.

(*g*) Datel 48K, which provides simultaneous bothway transmission of serial binary-data at speeds of 40·8 kbit/s or 48 kbit/s, over 48 kHz wideband circuits. The service is available on a point-to-point basis.

In addition, the Dataplex services enable Datel users in particular localities to gain access, over a multiplexed long-distance private circuit, to a remote processor, by means of a local-fee telephone call, or by local private telephone and telegraph circuits.

Eurodata to be updated

Eurodata, a massive study of Europe's data-communication needs up to 1985, is to be updated during the next three years. A contract to incorporate extensive fresh information into the original study, completed last year, has been agreed by the 17 telecommunication organizations—including the British Post Office (B.P.O.)—which commissioned the original report.

Eurodata was commissioned to determine future data-communication requirements throughout Europe, and to provide a base from which telecommunication authorities could effectively plan to meet Europe's growing data-communication needs.

The addition of new information over the next three years will provide Europe with its most comprehensive records in this field, containing details of data terminals, computer installations and applications, and the international flow of data traffic.

The move is of particular significance to the British telecommunication service, which will be using Eurodata information as a key input for forward planning and forecasting studies.

The task of updating Eurodata is being undertaken by PA International Management Consultants, in conjunction with Quantum Science Corporation, Italsiel, and Generale de Service Informatique—the group of four which carried out the original £700,000 survey.

Under the updating agreement, PA International Management Consultants are to use some of the original study data for their own commercial use. In return, they will make no charge for updating the study.

The Eurodata study committee is chaired by Mr. F. G. Phillips, head of the B.P.O.'s data communications division, Telecommunications Marketing Department. Other countries taking part are: Belgium, Denmark, Germany, Finland, France, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden and Switzerland.

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Books of model 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.

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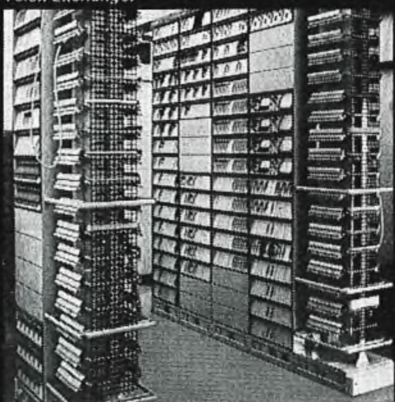

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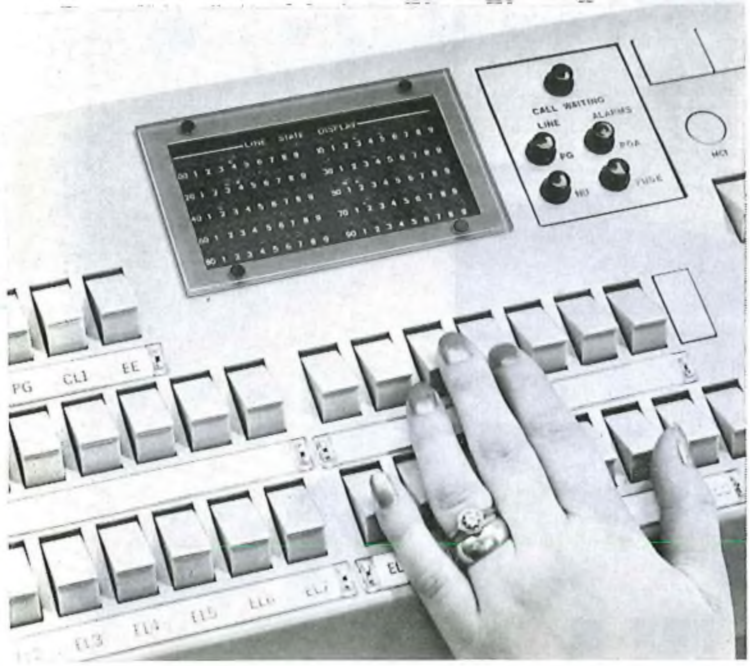

high reliability relays, produces a low-cost yet completely reliable switch. Standardised components streamline stocking and purchasing– for example, there are only six types of miniature relays.

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Wait-on. If an extension finds all trunk lines busy, he dials a special digit and hangs up. The extension can then continue to receive and make calls in the usual way. But, as soon as a trunk line and the extension are both free, his telephone is automatically rung and the extension connected to that free circuit. This benefit also applies to tie-line working.

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Call forwarding. If an extension wants to arrange for incoming calls to be received on another telephone, he simply dials a given digit into the GTEX 100, followed by the number to which he wants calls transferred. All incoming calls are then automatically routed to the second instrument. This feature can also be used to aid staff location. Dialling the same number of the telephone in the empty office puts the call through to the temporary location or the owner of that extension.

Extension group research. By dialling the first number in a group of sequentially numbered extensions, the equipment can be programmed to ring the first free extension in that group.

Line Lock out. If an extension remains off-hook without dialling, or after an incomplete PABX number, that line will be 'parked'. This ensures that registers are available for other calls. The line is released from park when the extension goes on-hook.

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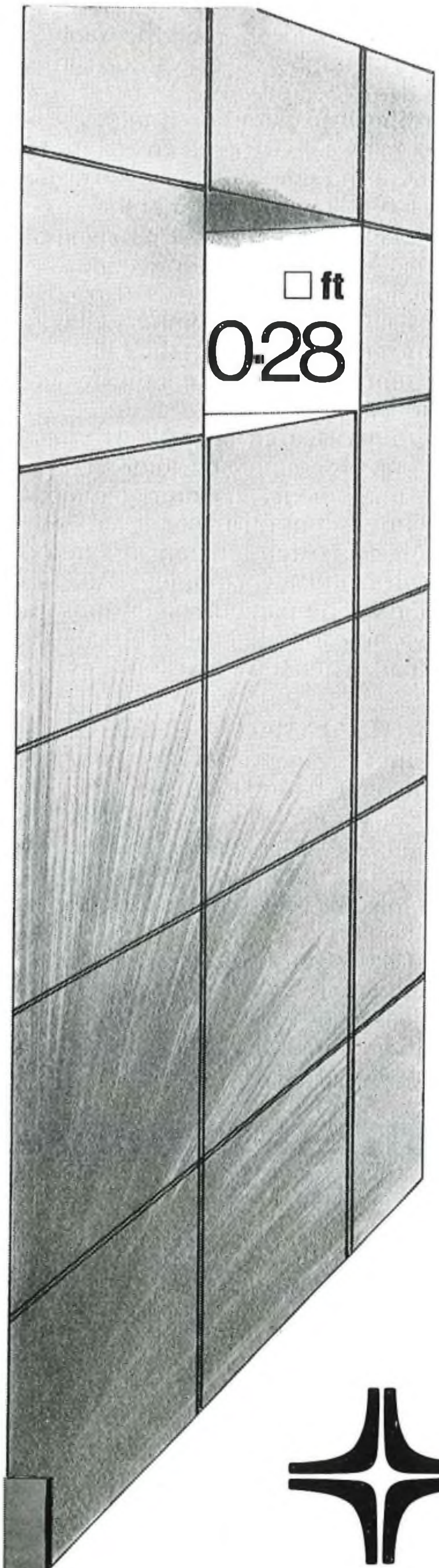

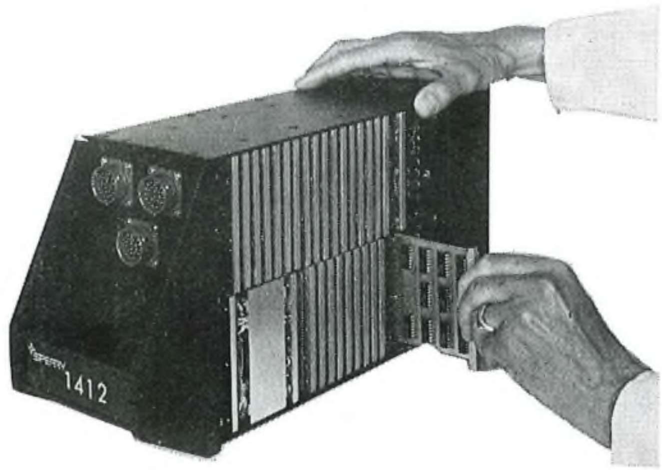

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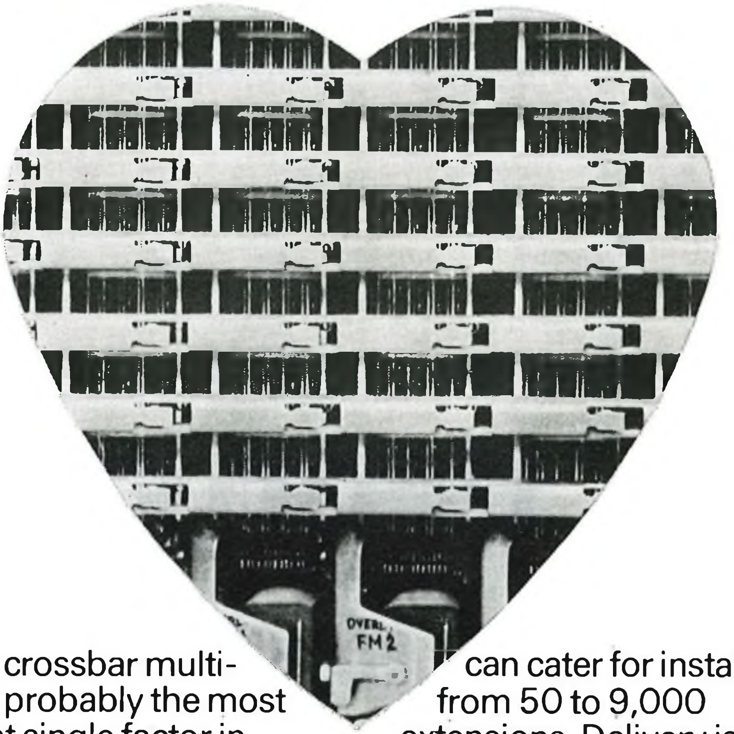

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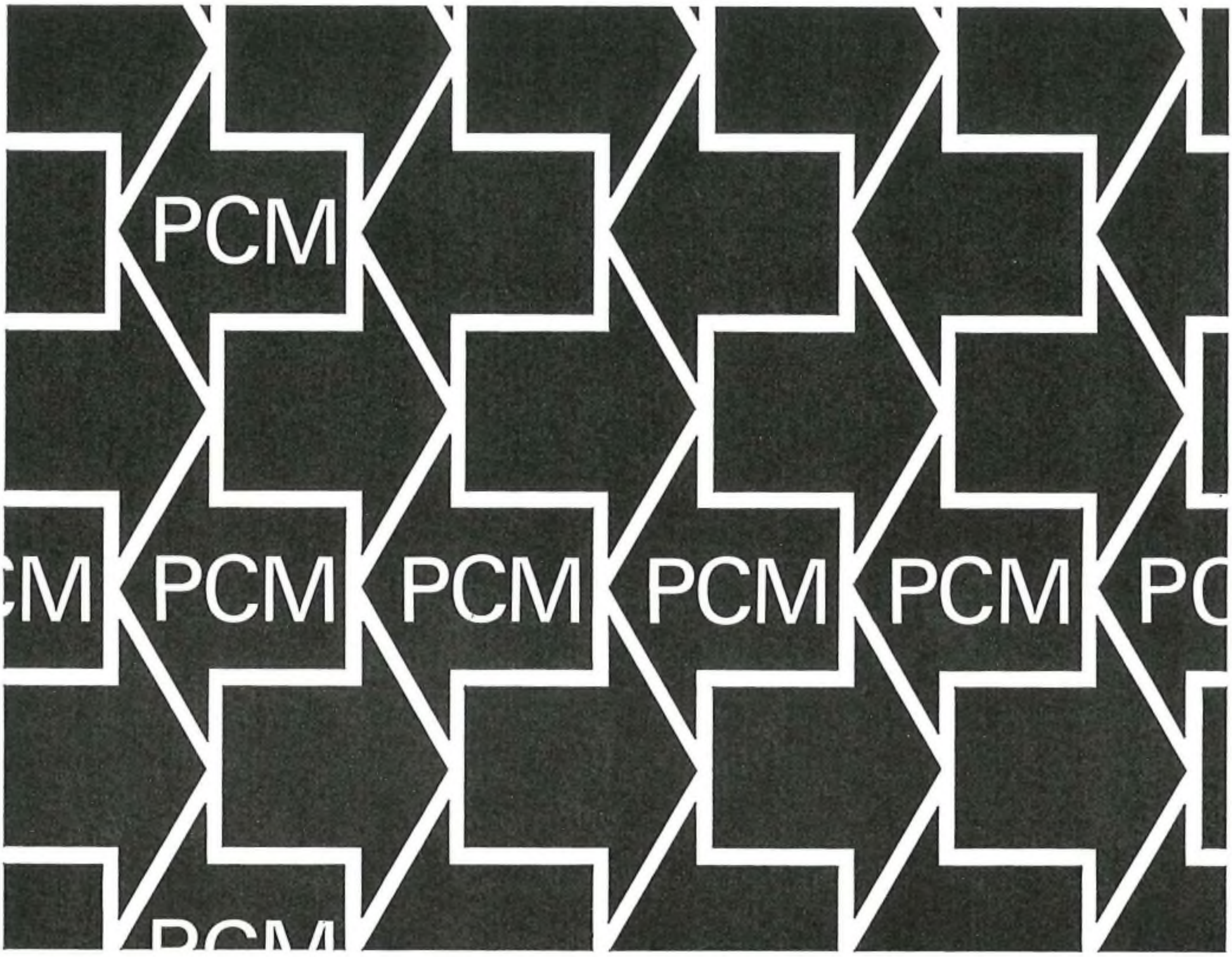
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