R A ROE
PE12

The Post Office Electrical Engineers' Journal

VOL 67 PART 2/JULY 1974

THE · INSTITUTION · OF · POST · OFFICE · ELECTRICAL · ENGINEERS ·
NIL SINE LABORE

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL 67 PART 2 JULY 1974

Contents

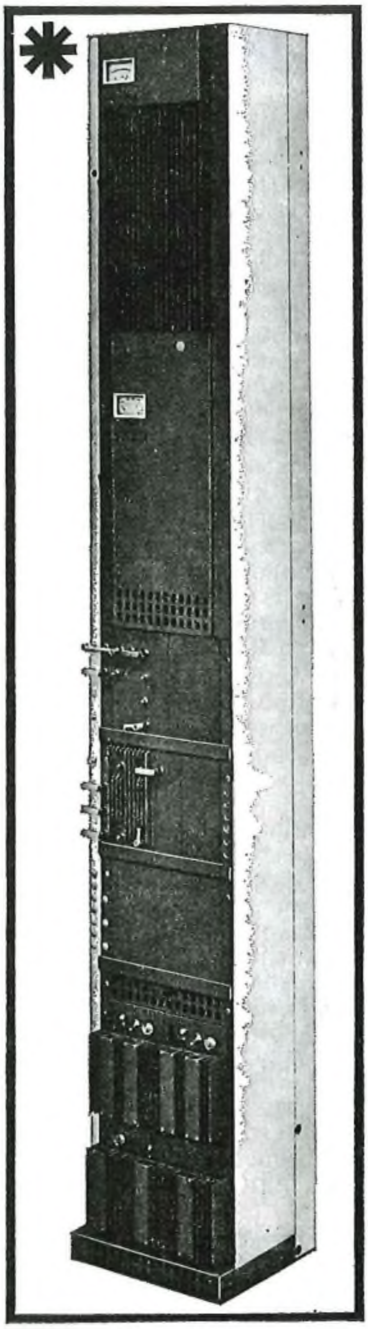
	page
Editorial	65
TXK3 Director-Area Local Exchanges using BXB 1112 Crossbar Equipment Part 1—Trunking and General Operation—R. L. Bell, E. Bloxham and B. F. Callaghan	66
Teletraffic Studies of the TXE2 Electronic Exchange—R. R. Stacey	73
Materials and Fibre for Optical Transmission Systems—K. J. Beales, J. E. Midwinter, G. R. Newns and C. R. Day	80
Experimental Packet-Switched Data-Transmission Service: Network Design and Implementation—D. E. Hadley and D. W. F. Medcraft	88
The Latest Modem for the Datel 600 Service—Datel Modem No. 1F—A. R. Pugh	95
Steel Masts and Towers in the British Post Office Part 3—Structural Testing—D. G. Clow	102
Computer-Aided Design in the British Post Office—A. E. Pullin	109
An Automatic-Frequency-Control System for High-Frequency Radio Receivers—A. St. J. Reynolds	115
Notes and Comments	118
Regional Notes	118
Associate Section Notes	121
The Associate Section National Committee Report	122
Institution of Post Office Electrical Engineers	123
Post Office Press Notices	124
Book Reviews	79, 87, 101

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

Price 26p (36p including postage and packaging). Orders by post only.

Annual Subscription (post paid): Home and Overseas £1.44. (Canada and U.S.A. $3.75.)
Price to Post Office staff: 21p.

H70



- ALL SOLID STATE
- THE LATEST DESIGN IN RADIO EQUIPMENT
- MODULAR CONSTRUCTION
- FLEXIBILITY OF USE
- MAINTENANCE SIMPLIFIED BY ALARMS AND REPLACEABLE MODULES

HIGH CAPACITY
- up to 1800 telephone channels
- 1 TV program + 4 sound channels

MICROWAVE RADIO RELAY SYSTEM

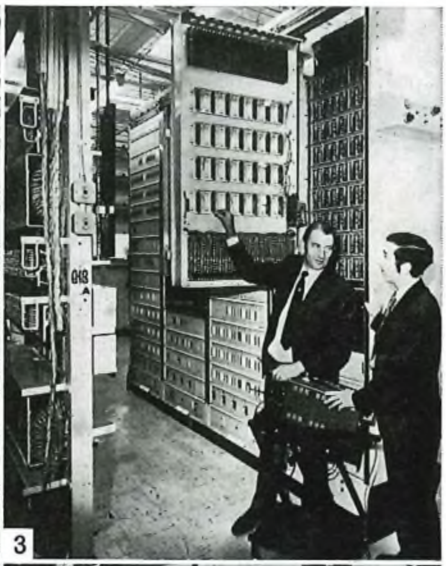
Telettra

TELECOMMUNICATION EQUIPMENT AND INSTALLATIONS

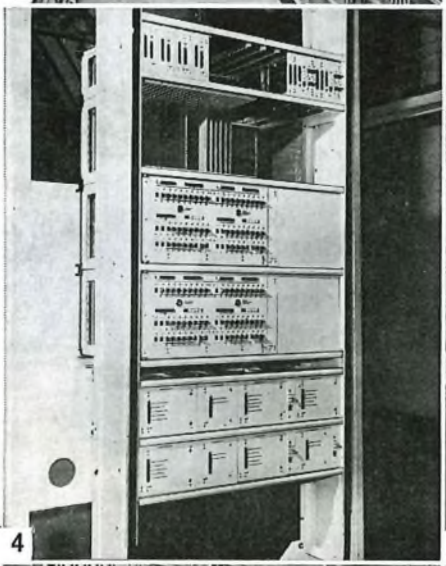
TELETTRA S.p.A. - 20059 VIMERCATE - MILANO - ITALY

GEC Stored Program Co Signallin

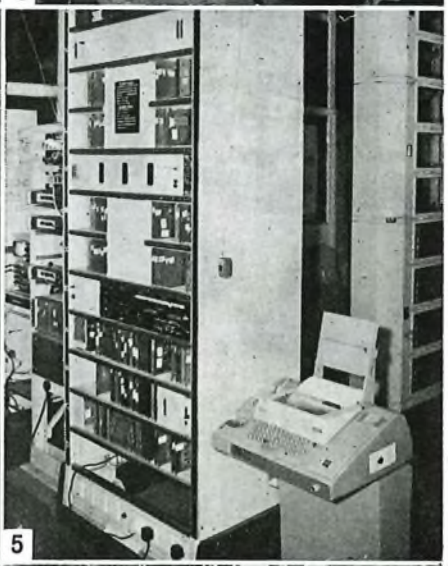
2



3

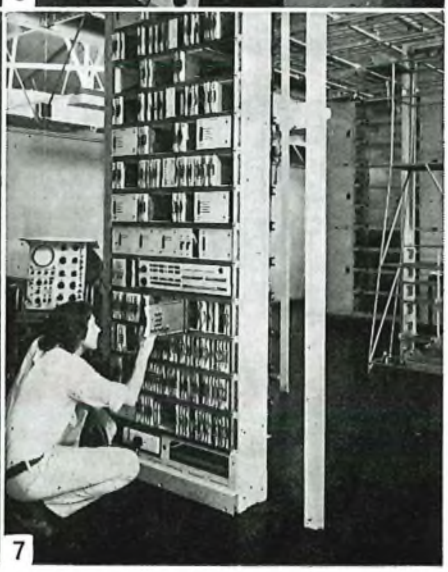


4



5

6



7

GEC SPC Developed

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

The Mark I processor, designed primarily for call-establishment, or register, functions was installed in Belgravia exchange, London in 1966, followed in 1968 by a MK IB.

The experience of 5 years successful operation in public service was incorporated into the Mark IC design which is now in quantity production for, and is operating with:

Strowger Systems.
Electromechanical register translators are being replaced in nearly 100 Director exchanges in the U.K.

Crossbar Systems.
Seven new Sector Switching Centres – huge exchanges that will decentralize London's trunk traffic – are each being equipped with 30 MK IC processors.

Motor-Uniselector Systems.
The first SPC for telecommunications to be exported from the United Kingdom is now operating in Johannesburg in South Africa's STD network.

The MK II processors, which complement the MK I, are more powerful and more versatile real-time multiprocessor computers capable of handling all exchange control functions including network management, exchange misoperation and fault diagnosis.

A MK IIA 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 IIBL, 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

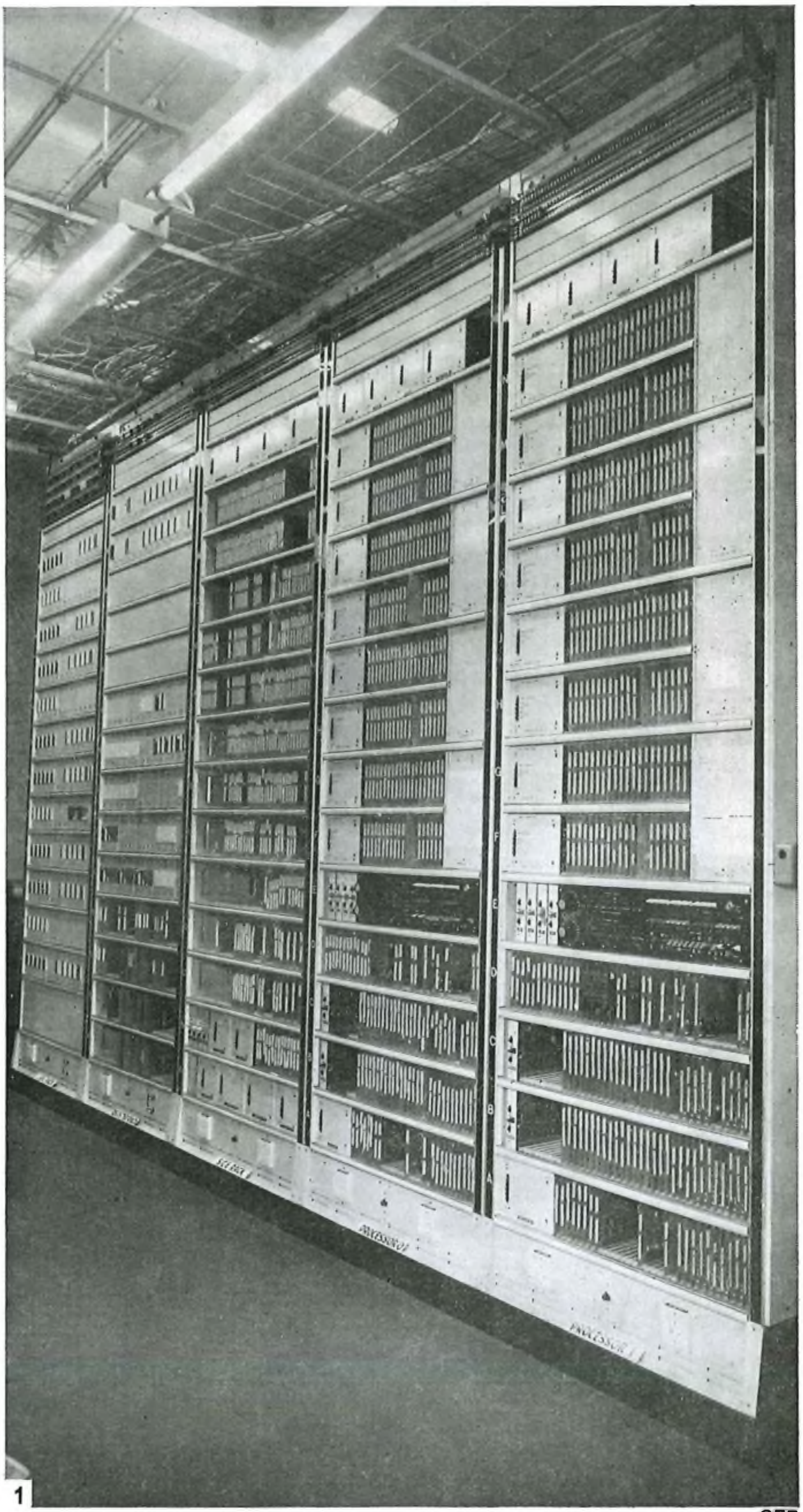
on solid foundations

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 IIB 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.



1

At your fingertip. Two or three telephones on one exchange line and an intercom system all in one.

Press *hold* button and appropriate button for executive required. Secretary confers with executive.

Press appropriate button, *1 or 2* for intercom system.

Executive presses *exchange* button, takes over call.

Press *exchange* button. Secretary answers incoming call.

Press *exchange* button for immediate outgoing call – from any telephone.

The versatile GEC 740 switching telephone.

There's more to the GEC 740 switching telephone than meets the eye....

On one hand it provides independent access to a single exchange line from two telephones (1/2 system) or three telephones (1/3 system).

On the other, it is a separate intercom system–keeping exchange calls secret from internal calls. And it's all in one basic instrument–controlled by push-button switches in front of the hand-set on each 'phone. Neat, simple to use–but extremely versatile.

Dial or pushbutton versions available for all telephones.

GEC manufacture telephones for world markets: table and wall-mounting models in a number of attractive colours, loudspeaking telephones, pushbutton telephones and switching telephone systems....

You couldn't be in better hands.
GEC Telecommunications Ltd.,
Telephone Division, Whinbank Road,
Aycliffe, Co. Durham, England.
A Management Company of
The General Electric
Company Ltd. of England.

GEC

GF1

Latest Micromins widen scope of Hybrid Design

Hybrid circuits with a higher performance and covering a wider range of applications are being made possible by the steadily growing Mullard range of microminiature semiconductor devices.

There are now thirty-eight types available including, not only general purpose devices, but FETs; v.h.f., u.h.f. and microwave transistors; double diodes; high speed switching diodes and zeners.

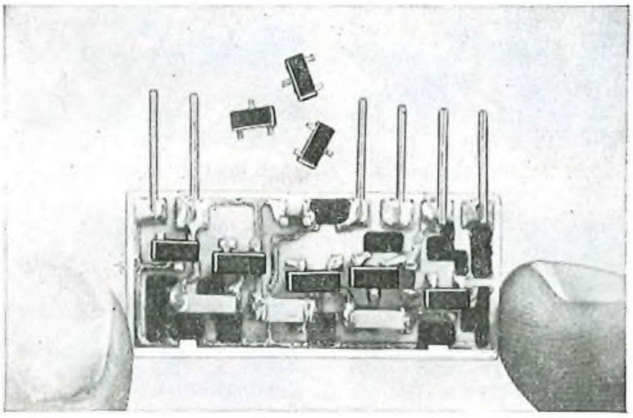
Each is a miniature version of a 'full size' item in the semiconductor catalogue. Ratings are impressively high, the upper limit generally being 200 to 300mW although each device in its plastic encapsulation is smaller than a grain of rice.

A recent addition to the range is a PUT (programmable unijunction transistor) type 555BRY. This is a microminiature counterpart of the BRY39/BRY56 and is a versatile p-n-p-n trigger device which can be used in motor control, oscillator, timer, pulse shaper and triggering circuits, as well as in place of a relay.

Another newcomer is the 565BAY Schottky barrier diode. Comparable with the full-size BA280, it is intended for use either as a u.h.f. mixer or as a fast switching device.

A third recent introduction is a variable capacitance diode, type 574BAY. This is a microminiature version of the BA182 which, in addition to its application in electronically tuned circuits, can be used as a T/R switch in small transmitting and receiving systems.

Full data on the whole range of Mullard microminiature semiconductor devices is available.

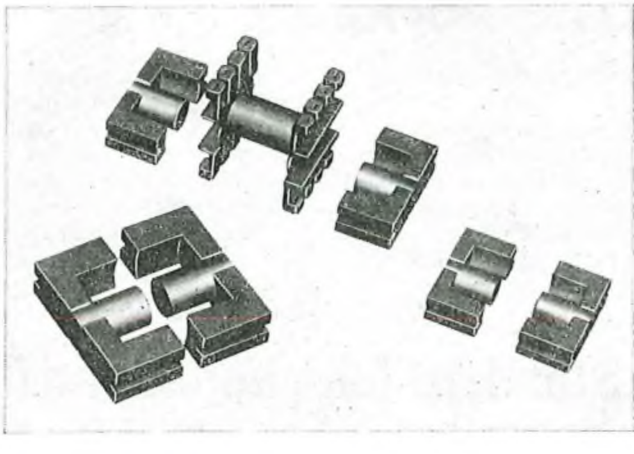


NEW CORES FOR SWITCHED MODE POWER

Designers of switched mode power supplies no longer have to use transformer cores of a material and shape which are meant for quite different applications. A new range of ferrite cores, the FX3700 series, being introduced by Mullard is intended specifically for the job. Insulation and safety, the special stresses of switched mode operation, winding economics, modes of circuit failure, mechanical specifications and BSI requirements have all been given extremely careful attention.

The new cores may be used in units where the input is derived from rectified mains or from batteries, and are suitable for designs covering a wide range of outputs. When used in 25kHz push-pull circuits at the unfavourable end of the application spectrum (supplying low voltage, 5V, output) d.c. output powers from 50W to 500W can be obtained. In more favourable applications, higher outputs can be obtained, and the cores can, of course, also be used in single-ended circuits.

Data is available on the four cores in the series together with an application note (ref. TP1450) which simplifies transformer design and can help save time, money and trouble elsewhere in the circuit.



BETTER COIL FORMERS . . . SAME PRICE

Coil formers for use with Mullard RM inductor and transformer cores are now being made with a high quality electrical grade of glass-loaded phenolic material. It can be readily distinguished from the earlier material by its dark green colour.

Formers made with the new material are interchangeable with their predecessors. Pin configuration, user dimensions and winding space are intended to conform with the IEC specification currently being prepared. As previously, the pins meet the solderability requirements of IEC68 and BS2011 (Part 2, Method 3). The improved material will not result in any price increase.

1954 UK – Norway

1955 Denmark – Norway

1956 Italy – Tunisia

1957 Italy – Sardinia

1958 UK – Belgium

1959 TAT-2B Nova Scotia – Newfoundland

1960 UK – Sweden

1961 CANTAT-1 UK – Canada

1962 COMPAC Fiji – Australia

1963 COMPAC Canada – Fiji

1964 UK – Germany

1965 PENCAN-1 Spain Canary Islands

1966 SEACOM New Guinea – Australia

1967 AFETR Grand Turk Island – San Salvador – Grand Bahama

1968 SAT-1 Portugal – South Africa

1969 Germany – Sweden

1970 MAT-1 Italy – Spain

1971 PENCAN-2 Spain Canary Islands

1972 USA Bahama Islands

1973 BRACAN-1 Brazil Canary Islands

STC has more experience in submarine cable systems than any other company in the world.

From the beginning we've made it our business to be the best.

That's why, back in 1950, we embarked on an intensive programme of research and development to increase the capacity of, and establish the reliability of, repeatered submarine telephone cable systems.

And we've since demonstrated a vigorous capability in overall systems planning, in project management and in system implementation – anywhere in the world.

Over this period we have installed more than 70 systems; providing some 63,000 nautical miles of cable for reliable high quality telephone circuits in a complex network linking 34 countries.

No company in the world can begin to claim this degree of involvement, this degree of experience.

No company, that is, other than Standard Telephones and Cables Ltd., Submarine Systems Division, North Woolwich, London, E.16. Tel: 01-476 1401.

Standard Telephones and Cables Limited

A British Company of ITT

The Post Office Electrical Engineers' Journal

EDITORIAL

The centenary of the birth of Guglielmo Marconi, on 25 April 1974, has been marked in the technical press by many articles and accounts of the early days of wireless telegraphy. These, and the contemporary articles to which they refer, make absorbing reading, particularly to those who have lived their whole lives during a period when radio communication is commonplace.

One aspect of the early work of Marconi, which becomes clear from reading the various accounts, is the degree of help and co-operation given by the Engineering Department of the British Post Office (B.P.O.) and its Engineer-in-Chief at that time, Sir William Preece.

After rejection by the Italian Ministry of Posts and Telegraphs, Marconi outlined some results of his experiments with wireless telegraphy in a letter to Sir William Preece requesting the assistance of the B.P.O. As a result, in June 1896, facilities were provided by the B.P.O. for short-distance tests between buildings in London, and in September of that year, for tests over distances of up to 3·2 km on Salisbury Plain.

Following the satisfactory conclusion of these tests, the B.P.O. made preparations for a further series of tests in South Wales, and in May 1897, successful transmissions over two routes were demonstrated. The first of these was between Lavernock Point and Flatholm Island in the Bristol Channel, a distance of some 5·3 km, and the second across the Bristol Channel from Lavernock to Brean Down, a distance of about 13·9 km. These tests were carried out by B.P.O. staff in close co-operation with Marconi, and the equipment used was supplied jointly by the B.P.O. and Marconi.

The communications system of today owes much to the work of Marconi, and the role played by the B.P.O. during 1896–97, in providing support and co-operation, was of considerable importance to the early development of wireless telegraphy.

TXK3 Director-Area Local Exchanges using BXB 1112 Crossbar Equipment

Part 1—Trunking and General Operation

R. L. BELL, G. BLOXHAM and B. F. CALLAGHAN†

U.D.C. 621.395.344.6: 621.395.722: 621.395.31

Part 1 of this article outlines the history leading up to the introduction of the TXK3 system into the British Post Office public telecommunications network. The salient points of the switching area are discussed, together with system philosophy and trunking arrangements. Part 2 will describe some of the more important features of the system. It will also outline the general maintenance policy and describe various maintenance aids.

INTRODUCTION

In the late 1960s, it became apparent that the British Post Office (B.P.O.) would have to seek an interim solution to the problem of expanding and modernizing telephone-exchange switching. It had been hoped that, by then, electronic switching equipment would be available for all local telephone exchanges. The electronic exchange system which was available at that time, was one developed jointly by the B.P.O. and the British Telecommunications Industry. This system, TXE2,[1] is restricted to use in small, non-director-area exchanges.

The Telecommunications Industry undertook to adapt its own proprietary crossbar systems to meet the needs of the B.P.O. This involved a measure of re-design to reproduce Strowger-exchange facilities and network-interface conditions, so that, generally, the B.P.O. would be able to offer a uniform service to its customers. It was decided that non-director-area, medium-size, local exchanges and large, low-calling-rate, local exchanges, would be served by the TXK1 system, based on the Plessey 5005 crossbar system,[2] now manufactured by Plessey Telecommunications Ltd. and the General Electric Company Ltd. However, director-area local exchanges and large, high-calling-rate, non-director-area local exchanges would be served by an existing crossbar system, following further development by Standard Telephones and Cables Ltd.

BXB 1100 SYSTEM

In the British crossbar (BXB) 1100 series, the design philosophy and equipment practice of the I.T.T. Pentaconta system has been used extensively. Two exchange systems are currently being purchased from the series. The BXB 1121 system (TXK4)[3] is being used in trunk transit switching centres, whilst BXB 1112, designated TXK3, will have a majority use in director areas. In addition to two large non-director-area exchanges, Newcastle-upon-Tyne and Belfast, a number of small exchanges are being purchased for use in Northern Ireland, where the decision to buy the TXK3 system, instead of TXK1, was influenced by the desire to rationalize crossbar maintenance and training.

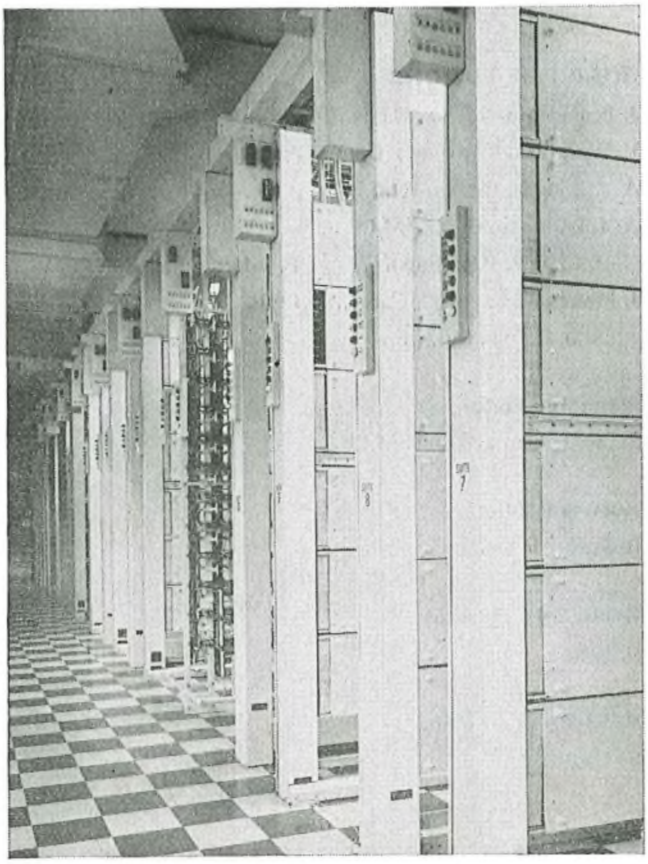


FIG. 1—General view of a TXK3 director-area local telephone exchange

The non-director-area version differs from the director-area version, described in this article, mainly in the facilities given by the register-translator, because of different numbering and routing arrangements.

The physical aspects of the BXB 1100 system, that is, the main components and equipment practice, have been described in a previous article[3] in this *Journal*. Fig. 1 shows a general view of a TXK3 director-area local exchange.

† Mr. Bell and Mr. Callaghan are in the Telecommunications Development Department, Telecommunications Headquarters. Mr. Bloxham is in the Service Department, Telecommunications Headquarters.

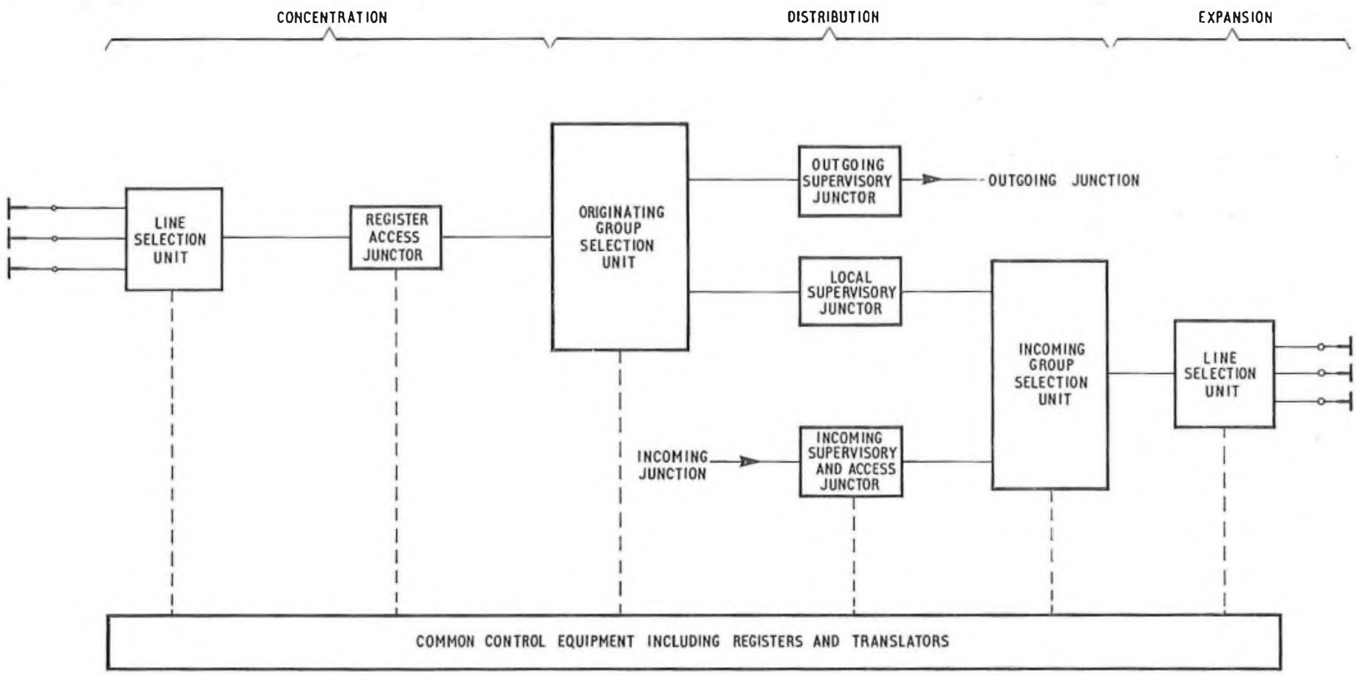


FIG. 2—Simplified trunking diagram for a TXK3 director-area local exchange

CROSSBAR-SYSTEM CONCEPTS

Many large modern crossbar systems available throughout the world have four features in common, namely:

(*a*) the crossbar-switch mechanical action,
(*b*) by-path working (separate control and connecting paths),
(*c*) common control, and
(*d*) link trunking.

The BXB 1100 system has three special features that are noteworthy. These features, which are described in greater detail later in this article, are

(*a*) large-availability switches (14 horizontal bars with up to 22 vertical selectors giving up to 74 outlets from 22 inlets),
(*b*) the by-path information, for use at the various switching stages, is passed over 20-wire d.c. highways, called information paths, which are used on a time-sharing basis, and
(*c*) internal link-blocking is reduced by the use of interaid.

In general, it is the special features of the various crossbar systems that make for incompatibility between equipment of different manufacturers' designs, when considering exchange extensions.

OUTLINE OF THE TXK3 DIRECTOR-AREA LOCAL-EXCHANGE SYSTEM

System Description

The TXK3 system is a register-controlled system having clearly-defined group- and subscriber-selection stages. Marking equipment, incorporated in each selection stage, selects the switching path through that stage, operation of the crossbar selectors being controlled by the register. Each of the selection units comprises a link-trunking network, in which each primary crossbar-switch has access to every secondary crossbar-switch. Internal routing information is transferred using very-short-holding-time common equipment.

In a telephone-switching network serving subscribers, the following three successive operations take place:

(*a*) concentration of calls from subscribers' lines to a restricted number of selectors,
(*b*) distribution of these calls to various groups of desired junction routes and subscribers' lines, and
(*c*) expansion of the distributed calls to subscribers' lines.

In the TXK3 system, concentration of originating traffic from calling-subscribers' lines to the common routing equipment takes place in the line selection unit (l.s.u.), and the uni-directional distribution function takes place in the group selection unit (g.s.u.). The l.s.u.s are used again, in the reverse direction, for the expansion operation.

Fig. 2 shows a simplified trunking diagram for a TXK3 director-area local exchange and indicates the positions of the l.s.u. and g.s.u. in relation to

(*a*) a calling subscriber and a called subscriber, on an own-exchange call,
(*b*) a calling subscriber and an outgoing junction,
(*c*) an incoming junction and a called subscriber, and
(*d*) the common-control equipment.

Numbering Range

In director areas, units of up to 20,000 directory numbers are possible. For units with more than 10,000 directory numbers, two all-figure numbering, 3-digit codes are allocated, discrimination on incoming-junction calls being achieved by the use of a prefix digit included in the incoming information. Any directory number can be allocated to private automatic branch exchange (p.a.b.x.) direct-dialling-in (d.d.i.) extensions. Individual lines in a private branch exchange (p.b.x.) or non-d.d.i. p.a.b.x. group are not normally allocated directory numbers. Each such group is identified by a single directory number, while access to an individual line within the group can be achieved using a by-pass number (similar to night service). This means that an exchange can serve many more lines than it has directory numbers.

GENERAL SWITCHING AREAS

Multiswitch

The basic unit used in the switching areas of this crossbar system is the *multiswitch*. This crossbar switch comprises a range of 8–22 vertical armatures (or selectors) and 14 horizontal bars. Each horizontal bar has two positions, enabling any one of 28 contact assemblies per vertical selector to be controlled. Contact assemblies can be of six, eight, nine or ten springs. Fig. 3(*a*) shows the multiswitch in a configuration capable of switching a maximum of ten wires per crosspoint to any of 28 outlets. The outlets are multipled, by means of rear-commoning wires, across all of the vertical selectors.

A technique of doubling is used to increase the outlet capacity of the multiswitch, at the expense of a reduction in the number of wires switched. The 14th horizontal bar, which becomes the auxiliary (or doubling) bar, is used to divide the inlet wires into two groups. It is necessary to operate both the auxiliary bar and one of the remaining horizontal bars, together with a vertical selector, to select one of 52 outlets. In Fig. 3(*b*), the maximum number of wires switched is five.

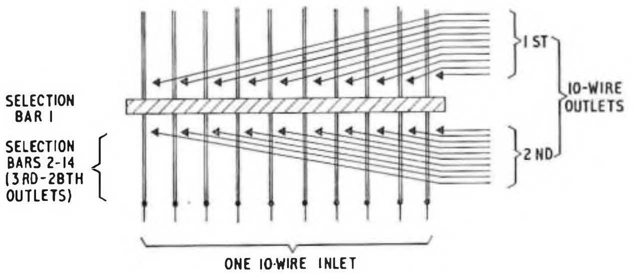
By an extension of the doubling principle, a second auxiliary bar is used to treble the outlet capacity, at the further cost of reducing the number of wires switched. This process, known as trebling, produces a 3-wire, 74-outlet switch, as illustrated in Fig. 3(*c*).

A further configuration is obtained by splitting the horizontal multiple into two halves. This is known as *halved rear-commoning*, and is shown in Fig. 4. With this arrangement, a single multiswitch can be used as

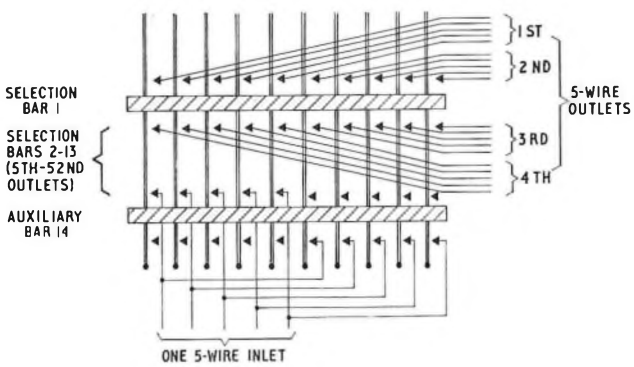
(*a*) two 10-wire switches, each having 11 inlets and 28 outlets,

(*b*) two 5-wire switches, having 11 inlets and 52 outlets, where doubling is also employed, or

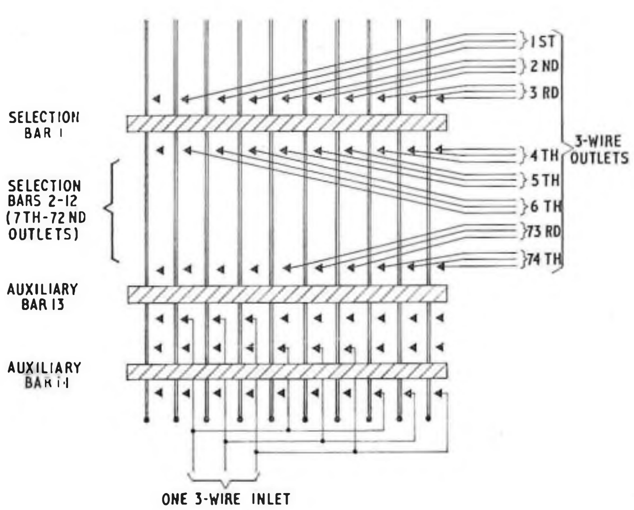
(*c*) an 11-inlet, 28-outlet switch, capable of switching 20 wires, by paralleling the selectors in each half.



(*a*)



(*b*)



(*c*)

(*a*) Simple crossbar switch—28 outlets
(*b*) Doubling—52 outlets
(*c*) Trebling—74 outlets

FIG. 3—Multiswitch configurations

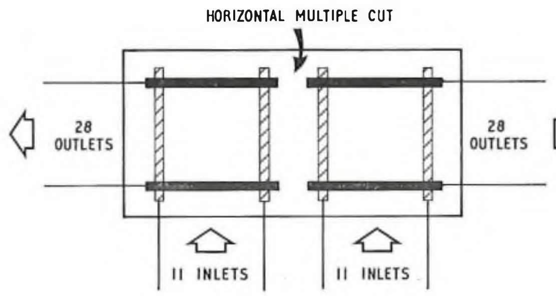


FIG. 4—A basic multiswitch frame divided into two switches by means of halved rear-commoning

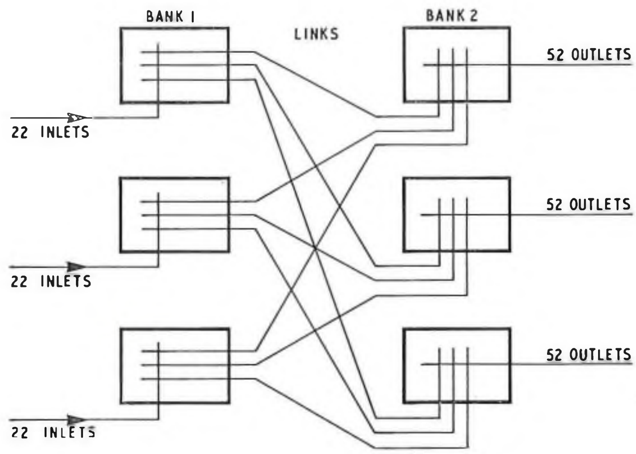


FIG. 5—Interconnexion of multiswitches

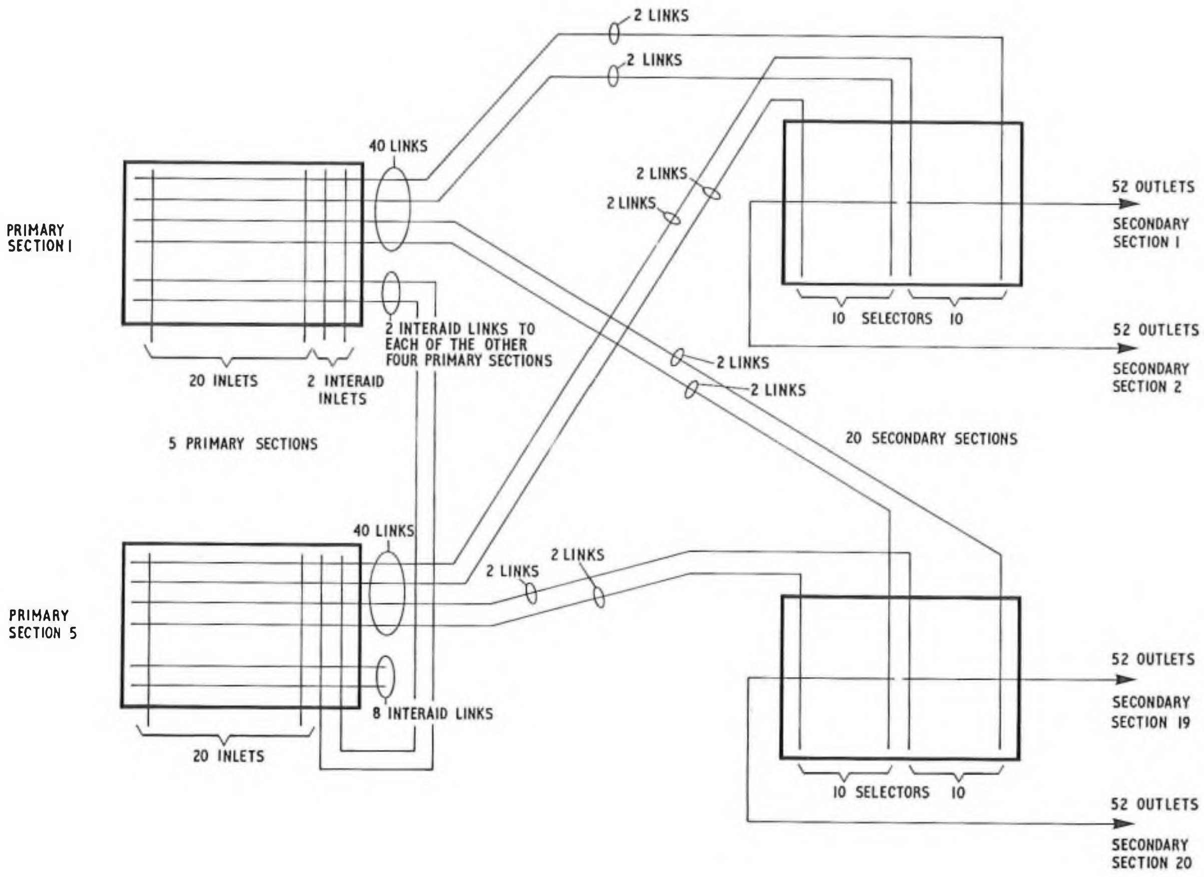


FIG. 6—Formation of a selection unit

Link Trunking

For the main selection units, the number of inlets required is usually far in excess of the maximum provided by a single multiswitch. A single bank of multiswitches would produce the required number of inlets, but with a limited availability, since any particular inlet can have access only to the 52 outlets of the multiswitch of which it is a part. To overcome this limitation, a second bank of multiswitches is provided, the two banks being interconnected as shown in Fig. 5. This is known as *link trunking*, and provides for full accessibility between inlets and outlets.

Each multiswitch in the first bank is connected to every multiswitch in the second bank. Various standard selection-unit configurations are used. The most common arrangement, employed in both the l.s.u. and g.s.u. selection areas, consists of five multiswitches in the first bank and ten in the second bank. The two banks of multiswitches are linked as shown in Fig. 6. In this arrangement, the multiswitches in the first bank are designated as *primary sections*, and those in the second bank are termed *secondary* or *terminal sections*. In certain distribution-switching areas, halved rear-commoning is utilized for the secondary sections, such that one multiswitch forms two sections, and the unit then provides 52 outlets from each of 20 secondary sections.

Although the link principle is economical in the use of multiswitches, it introduces the possibility of link congestion. Referring to Fig. 6, consider the example of a call incoming to primary section 1, which needs to be connected to a free circuit available from an outlet on secondary section 1. If the links between these sections are both busy, a connexion cannot be made and the call would fail, although there is a free circuit in the required route.

The incidence of link congestion is reduced to small proportions by the way in which circuits are allocated to the inlets and outlets. The allocation of incoming circuits to inlets is arranged so that equal amounts of traffic are offered to each primary section. The allocation of outlets to outgoing circuits is arranged so that access to an outgoing route is possible from several secondary sections. For example, a route containing three circuits will require outlet appearances on six secondary sections, that is, each circuit commoned to two sections, while a route of 20 circuits will have one circuit on each secondary section.

Interaid

Link congestion (blocking) can be further reduced by providing an alternative path through additional selectors connected between the existing banks of multiswitches. In the BXB 1100 system, these additional selectors are incorporated into the primary sections of all switching units, the principle being referred to as *interaid*.

Fig. 7 illustrates the use of an interaid connexion from a primary section, which has no free link to the required secondary section, to another primary section which does have a free link.

Group Selection Unit

As previously mentioned, the g.s.u. is the distribution stage of exchange switching, dealing with unidirectional traffic. Three types of g.s.u. are in use at present. Their basic difference is the number of outlets available, and, for this reason,

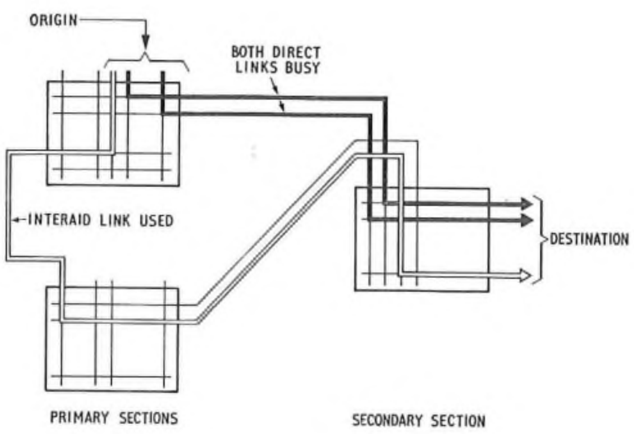


FIG. 7—Use of interaid to overcome link blocking

g.s.u.s are referred to by their maximum outlet capacity; this being 520, 1,040 and 2,080 outlets. An increase in the number of inlets can be obtained by using primary sections made up of more than one multiswitch with the outlets paralleled. The additional multiswitches are termed *auxiliary sections.*

The traffic-handling capacity of a g.s.u. is limited by the traffic-carrying capacity of the 200 available links between the primary and secondary sections, and equates to 140 erlangs, representing a minimum grade-of-service figure for the unit. Normal call-holding times at this traffic level ensure satisfactory operation of the g.s.u. control equipment.

Line Selection Unit

The l.s.u. is also composed of two groups of crossbar switches, primary and secondary sections, which are interconnected by links. Subscribers' lines are directly connected to the outlets of the secondary sections, which are known as *terminal sections*, in the l.s.u. The number of primary sections is variable, depending on the traffic, which is both originating and terminating. The inlets of each primary section are divided into the following three groups:

(*a*) call-finder selectors—connected to register-access equipment and used for traffic originating on the exchange,
(*b*) interaid selectors, and
(*c*) penultimate selectors—connected from the outlets of the incoming g.s.u. for terminating traffic.

The allocation of selectors to these groups can be varied, depending upon the amount of traffic in each direction. The interaid selectors, although accessible to both originating and terminating traffic, are used almost exclusively for terminating calls. This is because a call arriving at a particular penultimate selector must be allowed to gain access to one particular terminal section. However, an originating call only uses interaid when a calling terminal-section has no free link to a primary section having access to a free register.

There are three types of l.s.u.:

(*a*) low-traffic units, the bothway capacity of which is 104 erlangs, for up to 1,000 directory numbers having an average bothway traffic of 0·1 erlang per line,
(*b*) high-traffic units, the bothway capacity of which is also 104 erlangs, but, as a maximum of 500 directory numbers are served, the l.s.u. provides for an average bothway traffic of 0·2 erlang per line, and
(*c*) special-traffic units (special line units), which employ a single multiswitch selection-stage. Each multiswitch serves 52 lines and has a traffic handling capacity of 20 erlangs, giving an average outgoing traffic of approximately 0·4 erlang per line. Incoming traffic to the associated subscribers' lines, mainly high-calling-rate p.b.x. subscribers, is routed directly from the outlets of the g.s.u.

If the average calling rate of lines in the low- or high-traffic units exceeds the permissible rates of 0·1 or 0·2 erlang respectively, blocks of 100 directory numbers can be transferred to other l.s.u.s. Under these conditions, the new address of the transferred block of directory numbers is recorded in the common equipment, which determines the appropriate l.s.u. by examining the early digits of the numerical portion of the called-subscriber's directory number.

TRUNKING ARRANGEMENT OF A DIRECTOR-AREA EXCHANGE

The elements of Fig. 8, which shows the trunking arrangement of a TXK3 director-area local exchange, are described below, broadly in their order of use during the setting up of a call.

Subscribers' Line-Circuits

Incorporated in each l.s.u. terminal section, and associated with each outlet of the terminal section, are the subscribers' line-circuits, which consist of two relays, one for detecting the calling signal and the other performing busying and cut-off functions.

Common Relays

As implied, this equipment is common to all the terminal sections comprising an l.s.u. During pre-selection, which is the association of an originating register, the common relays respond to a signal from the calling terminal-section, and choose a primary section which has a free link to that terminal section and access to a free register. The choice is made with the aid of a distributing device to share the traffic equally over all primary sections.

Register Junctor and Finder

The register junctor is provided on the basis of one per call-finder selector. It serves as a connecting circuit to provide

(*a*) access between the call-finder selector and the register for receipt of dialled information, and between the register and the g.s.u. primary section for setting up the call, and
(*b*) a through connexion between the calling subscriber and line supervisory equipment, after the register function is complete.

Fifty-six register junctors are housed in a multiswitch frame, termed the register finder. Halved rear-commoning is used without doubling, the outlets being connected directly to register junctors, and the vertical selectors to registers.

Line-Unit Markers and Marking Relays

Each l.s.u. has two markers and a common set of marking relays. Each marker can serve the whole of the l.s.u. independently of the other marker. The two markers are provided as security against failure such that, if one of them fails completely, the other will do the work of the two. However, this will probably slow down the line-selection process marginally.

The provision of two markers allows simultaneous processing of two calls up to the point where the marking relays are required. One marker then waits for the other to finish before proceeding. As there is a common set of marking relays, the design incorporates self-checking features for security purposes.

The function of the marker and marking relays is to receive coded signals from the register, and to decode these so that the required line may be marked and seized. Consequently, each available line on the l.s.u. is represented by an individual marking wire.

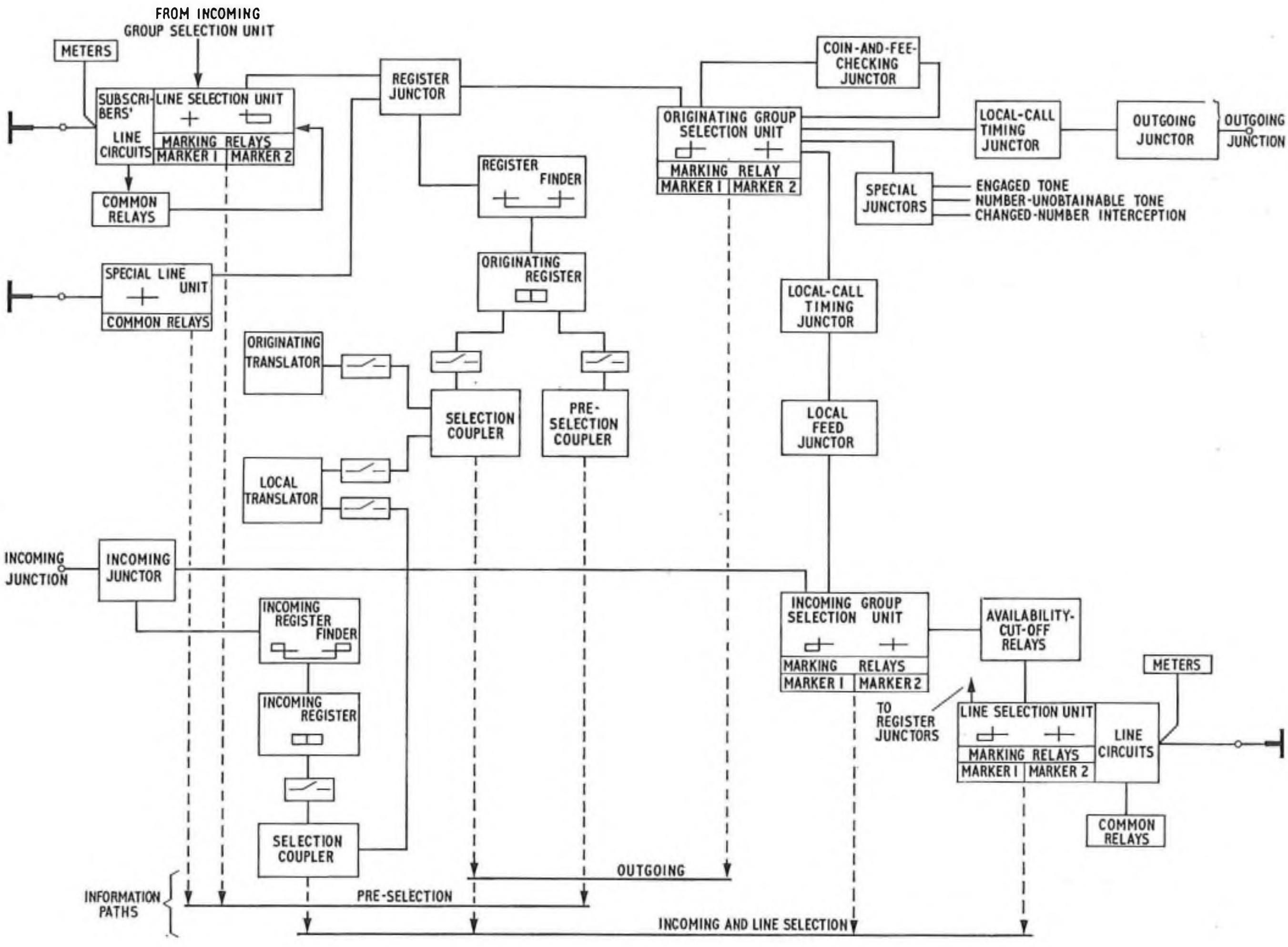


FIG. 8—Trunking arrangement of a TXK3 director-area local exchange

The l.s.u.s have either 520 or 1,036 lines, these being the nearest multiples to 500 and 1,000 of the multiswitch capacity; that is, 10 × 52 and 14 × 74 outlets respectively. In order to mark the 20 and 36 additional outlets for test-access purposes, a two-out-of-six code is sent from the register for the digit representing the specific subscriber. The other numerical digits are sent in two-out-of-five code.

The marking wire represents the directory number of each subscriber, and, to give flexibility, a cross-connexion field is provided between directory numbers and subscribers' line circuits. This allows the association of any directory number with any equipment number within the same l.s.u.

Register

The register is the heart of the control area and has a configuration which may be varied to accommodate the requirements of the particular exchange; for example, d.d.i. and multi-frequency Keyphone facilities. Two types of register are used, originating and incoming. The main functions of the originating register are to

(*a*) return dial tone to the calling subscriber,
(*b*) receive and store, in two-out-of-five code, the dialled or keyed information,
(*c*) receive ancillary information, such as calling-line category (class of service),
(*d*) forward necessary information into both originating and local translators when required,
(*e*) receive and store switching and facility information from the translators,
(*f*) control the functions of all the equipment in the exchange concerned with the setting-up of a call,
(*g*) send digital information on outgoing-junction calls,
(*h*) check the correct operation of the crosspoints, and that supervisory equipment has been seized correctly, and
(*i*) release when all selection and sending processes are complete.

The main functions of the incoming register are to

(*a*) receive and store, in two-out-of-five code, the digital information arriving over an incoming junction,
(*b*) forward the called-subscriber's numerical information into the local translator,
(*c*) associate a loop-disconnect sender when sending to a d.d.i. p.a.b.x.,
(*d*) receive and store switching information from the local translator, and
(*e*) control the switching functions concerned with the setting-up of the call.

Pre-Selection and Selection Couplers

A coupler is a concentration unit and is used as an interface between common-control equipments having different holding times. A group of 10 originating registers is served by two pre-selection couplers, providing access to information paths only, and two selection couplers, providing access to information paths and translators. Both types of coupler are provided in pairs for security reasons. Incoming registers, also in groups of 10, only require selection couplers, as no pre-selection takes place on incoming calls.

Pre-selection couplers are of simple design, having only to connect the register to the information path once during pre-selection when the calling-subscriber's category is returned from the l.s.u.

The more-complex selection coupler is used, during group selection and line selection, to connect the register to both the information path and the translators, for passing routing information, and to the information path only, for the receipt of the outlet category. The routing identity of coin-and-fee-checking equipment used on coin-collecting-box calls is also wired into the selection coupler.

Information Paths

Information paths are common highways linking the registers to the selection-unit markers. Each information path comprises two independent groups of wires (known as channels), either of which may be engaged by a marker. Each channel consists of 20 wires, enabling fast interchange of two-out-of-five coded information in parallel. A sequence of operation, including seizure, signalling and guarding during release, is accomplished in approximately 130 ms. Generally, there are three groups of information paths, one for each of the switching phases: pre-selection, group selection and line selection. In large exchanges, the group-selection information paths may be further divided between the originating and incoming g.s.u.s. A single group can contain up to three information paths (six channels).

Translators

The translator receives coded information from the registers and returns routing and facility information to select the correct line. Two types of translator are employed.

The originating translator normally receives the exchange three-digit code. It may receive some numerical digits if further examination is required to determine the correct routing. Examples of this are calls to mixed seven- and eight-digit exchanges, and own-exchange d.d.i. calls. The facility of eight-digit working has been included in case the existing three-plus-four-digit working become exhausted.

The local translator receives called-subscribers' numerical information, and an exchange prefix digit where two 10,000-line units share common incoming junctions.

Group-Selection-Unit Markers and Marking Relays

Each g.s.u. has two markers and a common set of marking relays. The arrangement is similar to that of the l.s.u., including the security features for the marking relays, which are, in this case, required to mark groups of circuits.

The function of the g.s.u. marker is to receive coded signals from the translator and to mark all free outlets corresponding to the required route, thus determining those available for use. The choice of a suitable secondary section, having both a free outlet in the required route and a free internal link, is made by the marker. To distribute the traffic evenly over the secondary sections, arrangements are made to change the order of selection after each seizure.

The g.s.u. allocation is such that circuits comprising one particular route are evenly distributed over a number of secondary sections, provided that they occupy the same outlet on each secondary section. The g.s.u. marking relays are designed to mark the same outlet in every secondary section to obtain the greatest practical flexibility.

Incoming-Register Finder

A single multiswitch, split into two sections, provides access between 50 incoming junctors and six incoming registers. Interaid is necessary between register finders to increase the availability. An alternative method of providing incoming-register access is to use a two-stage finder, but the fast-access requirement, essential on the incoming side of director-area exchanges, precludes the use of such a finder. A further reduction in access time is achieved, with the existing equipment, by pre-seizure, that is, a register finder associates and seizes an incoming register prior to its own seizure by an incoming junctor.

Junctors

The term *junctor* refers to an assembly of relays, and other components, wired together as a separate entity having a specific function. An equivalent example of a junctor in Strowger terminology is a relay-set. A BXB frame of equipment may contain a number of identical junctors, or it may comprise various different junctors, when it is known as a composite frame. Particular junctors, commonly used in TXK3 exchanges, are

(*a*) local-feed junctor, which provides supervisory functions, transmission, tones and initial metering on own-exchange calls,

(*b*) local-call-timing junctor, which provides subsequent metering on local calls,

(*c*) outgoing junctors, which provide supervisory functions, transmission, junction guard and initial metering on outgoing calls,

(*d*) incoming junctors, which provide supervisory functions, transmission, tones and backward busying on incoming calls,

(*e*) coin-and-fee-checking junctor, which provides similar facilities to the coin-and-fee-checking relay-set used in Strowger exchanges, and

(*f*) special junctors, which is a collective name for equipment providing such facilities as the return of engaged tone, the return of number-unobtainable tone, and changed-number interception.

Availability-Cut-Off Relays

Availability-cut-off relays are provided between selection stages to prevent the premature seizure of inlets to the subsequent stage. Where there is a supervisory junctor, the availability-cut-off relay is included in it.

SUMMARY

TXK3 exchanges have separate switching areas for group- and subscriber-selection stages. Each stage is composed of two ranks of multiswitches, inter-connected by links. Flexibility, both in the number of outlets available from a multiswitch, and in the number of multiswitches used in a selection stage, enables a range of switchblock sizes to be available to meet individual exchange requirements. A call is processed under the control of a register, which instructs marking equipment, associated with each selection stage, to choose a suitable switching path. Internal signalling information is transferred over common information highways.

Some of the facilities of a director-area local exchange will be described in the second part of this article, which will also outline maintenance policy and include descriptions of various maintenance aids.

References

[1] LONG, R. C., and GORRINGE, G. E. Electronic Telephone Exchanges: TXE2—A Small Electronic Exchange System. *P.O.E.E.J.*, Vol. 62, p. 12, Apr. 1969.

[2] CORNER, A. C., and BANHAM, H. The 5005 Crossbar Telephone-Exchange Switching System, Parts 1 and 2. *P.O.E.E.J.*, Vol. 59, pp. 170 and 271, Oct. 1966, and Jan. 1967.

[3] WALKER, N., STALLWORTHY, F. A., and MCLUSKY, R. F. Transit Switching Centres Using BXB 1121 Crossbar Equipment, Parts 1 and 2. *P.O.E.E.J.*, Vol. 60, p. 302, Jan. 1968, and Vol. 61, p. 20, Apr. 1968.

Teletraffic Studies of the TXE2 Electronic Exchange

R. R. STACEY†

U.D.C. 621.395.345: 621.395.31: 621.395.722

By the end of 1973, the British Post Office had 500 TXE2 exchanges in service, with new exchanges opening at the rate of two a week. This article describes the work that has been carried out by the Teletraffic Division of Telecommunications Headquarters to optimize and improve the TXE2 exchange system.

INTRODUCTION

The TXE2 electronic switching system was developed under the auspices of the British Joint Electronic Research Committee formed in 1956 to co-ordinate electronic exchange development between the British Post Office (B.P.O.) and the five principal British manufacturers of telephone switching equipment at that time. It was designed as a local exchange for approximately 200–2,000 subscribers' lines, offering the full range of subscribers' facilities.

Limited traffic studies were carried out during the original development stage and, although these indicated that the traffic-carrying capacity of the links in the subscribers' traffic concentrating stage could possibly be higher, a limit of 7·5 erlangs per 25 A–B links was accepted. When more extensive computer facilities and manpower became available, a more detailed teletraffic study was initiated, including the investigation of proposals for enlarged-capacity TXE2 exchanges as well as a further study of the traffic loading of the A–B links.

For a developed switching system, the main objectives of a teletraffic study, as carried out by the Teletraffic Division of the B.P.O. Telecommunications Headquarters, are to evaluate the traffic-handling capabilities of the system, establish dimensioning standards and procedures for exchange design and management, and, by highlighting those parts of the system which govern its traffic capacity, to offer advice on ways of improving its traffic characteristics.

Teletraffic studies mainly rely on the application of two techniques, namely, mathematical analysis and simulation. To a large extent, they are complementary, but, in some areas of the work, the choice of technique used is determined by such factors as the time available for the study, or the degree of accuracy that is acceptable in a numerical solution. These techniques have recently been discussed more fully in an earlier issue of this *Journal*.[1]

TXE2 SYSTEM DESCRIPTION

The TXE2 system is a small electronic exchange,[2] which employs a multistage switching network of co-ordinate reed-relay switches. Information relating to a particular call is stored in a register during the setting up of a connexion, and all registers have access to a common-control unit which supervises all connexions made in the switching area.

† Telecommunications Development Department, Telecommunications Headquarters.

Switching Area

In the TXE2 switching area, subscribers are connected to three A-switches which have access to five B-switches, three A-switches with their associated B-switches being known as a *major*. The originating route supervisory units (outgoing or own-exchange), which handle calls from subscribers, are connected to the C-switches as shown in Fig. 1. When a subscriber originates a call, the first path allocated to him through the switching area is via the A- B- and C-switches to either a *first-choice* or a *second-choice* supervisory unit. The first-choice supervisory units are connected to the circuits of the most extensively used route, either outgoing or own-exchange. If the own-exchange route is not the first-choice, route, it becomes the second-choice, but, if it is the first-choice route, the most highly used outgoing route is made the second-choice route.

The selected first- or second-choice supervisory unit has access to the register which has been allocated to that subscriber. When the register has sufficient information, it requests the control to carry out a route-change if the dialled digits indicate that the subscriber requires a routing other than the one which has been allocated. If an own-exchange call is required, the subscriber is routed to an own-exchange supervisory unit whose outlet is connected to a D-switch, and, when the wanted-subscriber's number has been received by the register, the call continues as if it were an incoming call.

An incoming call arrives on an incoming supervisory unit, connected directly to a D-switch, which has five C–D links to five C-switches. When the register allocated to the call has received the wanted-subscriber's number, the control can test the paths available and then establish a path through the switching area to the called subscriber.

Control Area

The control area of the TXE2 exchange system contains the calling-number generator (c.n.g.), registers and the call control (see Fig. 2).

In the TXE2 system, the c.n.g. is necessary to identify a subscriber originating a call, or an incoming junction which has been seized by a distant exchange. The c.n.g. consists of an array of pulse transformers threaded with jumpers from the subscribers' line circuits and the incoming-junction supervisory units. After a signal from a calling subscriber, or an incoming junction, the identity of the calling peripheral unit is generated

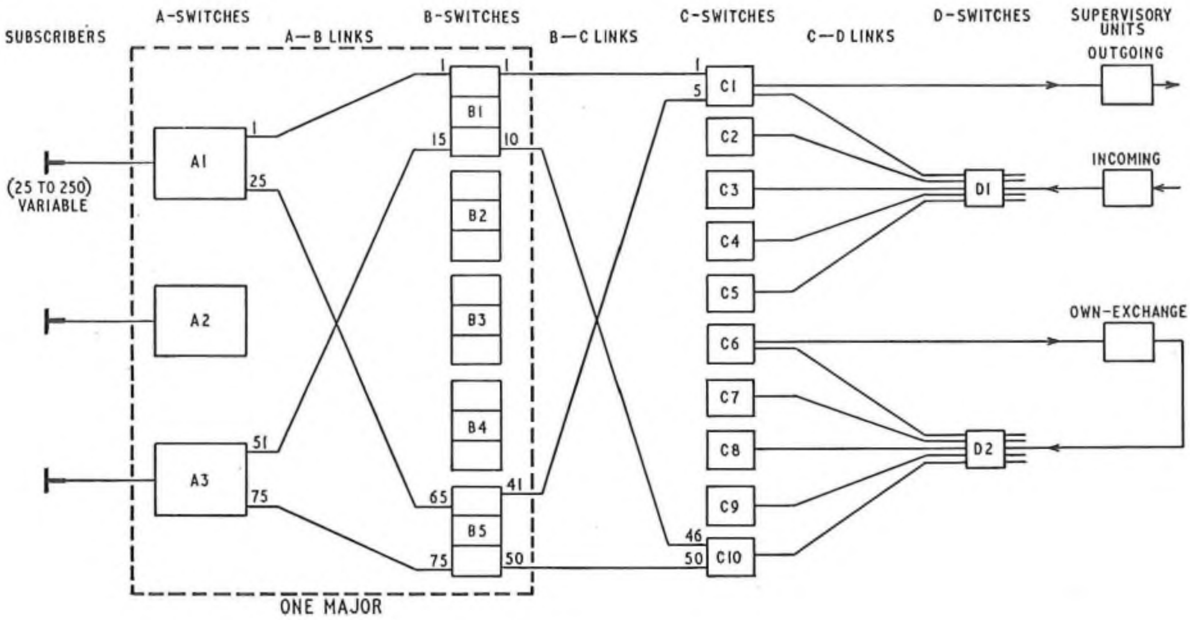


FIG. 1—Block diagram of the TXE2 exchange switching area

in a 2-out-of-5 code. This number is stored temporarily in a high-speed storage device while a free register is selected. Calls which find the temporary storage engaged by a previous call are lost, and equipment-engaged tone is returned to the subscriber.

When a free register has been found, the contents of the store are transferred to it, the register then extending a calling condition to the call control.

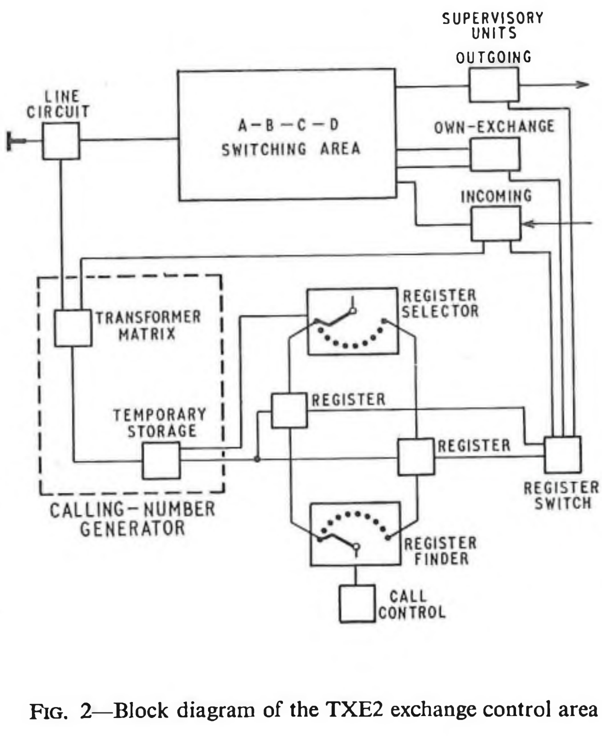


FIG. 2—Block diagram of the TXE2 exchange control area

On detecting the register-calling condition, the control decodes the information stored in the register and selects a path through the switching area, connecting the calling-subscriber's line unit to the first- or second-choice supervisory unit which has access to the register. The register then returns dialling tone. The incoming-call sequence differs slightly, in that the register is connected directly via the register switch to the incoming-junction supervisory unit.

Once the register has been allocated to a call, it inspects the digits dialled into it, recalling the control when it finds that an outgoing supervisory change is necessary, or when connexion to a subscriber on the same exchange is required.

If the control is engaged at any time during the setting-up of a call, the request is queued in accordance with a predetermined priority selected from the following three control-calling priorities used by the register:

(*a*) *priority* 1—incoming call, first application,

(*b*) *priority* 2—all applications requiring action in the inter-digital pause (i.d.p.), and

(*c*) *priority* 3—all other applications.

When the control has received all the information it needs to switch the conversation path through the exchange, the register is released and is then available to accept another call.

STUDY OF EARLY SMALL ELECTRONIC EXCHANGE SYSTEMS

The B.P.O. had two different proposals[3] from the manufacturers for the small electronic exchange system which was to become the TXE2 exchange system, and a limited traffic-evaluation exercise to compare the two proposed systems was carried out by the B.P.O.

With the results of the comparative evaluation of these two proposals to hand, development of the prototype TXE2 system was continued. The early traffic work, which used analytical techniques and the now obsolete electronic traffic analyser,[4,5] concentrated particularly on the A–B link traffic capacity. Although this work indicated that a higher

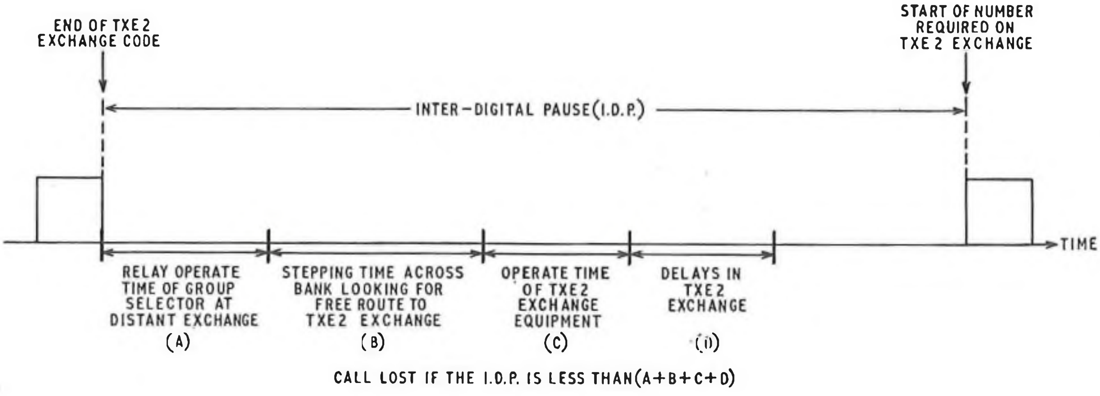


FIG. 3—Timing diagram for a call incoming to a TXE2 exchange

traffic loading of the A–B links might be possible, a limit of 7·5 erlangs per 25 A–B links was accepted.

At first, the prototype TXE2 system had only three stages of switching (A, B and C), and the call losses in these switching stages were found to be excessive. Simulation studies were undertaken to determine the effect of an additional switching stage (D) for both incoming and outgoing calls. No worthwhile advantage accrued from an outgoing-call fourth stage, and the trunking as now standardized was chosen; that is, with a D-switch in the incoming-call and own-exchange-call paths.

The early work showed that there was not an equitable distribution of losses between the control and switching areas. The next series of studies had, therefore, as their objective, the extension of the system designs to a capacity capable of catering for 225 erlangs of total A–B link traffic, that is, 10 majors or approximately 3,000 subscribers, without changes to the control-area design.

ENLARGED-CAPACITY TXE2 EXCHANGE PROPOSALS

More recently, the B.P.O. teletraffic studies have included the evaluation of the manufacturers' proposals for a TXE2 exchange system having an increased capacity. The original TXE2 system, described earlier, had a maximum single-unit capacity of 10 majors. The manufacturers proposed raising this to 20 majors a unit, for both a single-unit exchange and a double-unit exchange, thus effectively doubling the size of the exchange. The proposed single-unit exchange could, therefore, cater for approximately 7,000 subscribers (assuming 125 subscribers per A-switch), but these must be basically low-calling-rate subscribers, because the TXE2 system is limited by its single-processor-per-unit configuration.

It was anticipated by the manufacturers that the increase in traffic capacity would be achieved by enlarging the switching area, leaving the control area as it was on the original TXE2 system, except for providing extra registers. However, the result of the preliminary analytical study showed that the proposal to leave the control area unchanged was questionable. Although the analytical study did not lead to any numerical results, it did indicate that the temporary storage facilities in the c.n.g. were unlikely to be able to handle the extra calls. The waiting time for calls queueing for the control would, therefore, increase and may become critical for the incoming call.

For study-purposes, the B.P.O. considered that a TXE2 exchange system should give incoming calls a grade of service of 0·015 at normal traffic load, 0·030 at 10 per cent overload, and 0·075 at 20 per cent overload. From the original analytical study of the switching area, it was decided to apportion the losses to give 0·013 for the switching area and 0·002 for the control area, with the grades of services with 10 per cent and 20 per cent overloads being two and five times the grade of service at the normal traffic load, respectively.

CONTROL-AREA STUDY

The grade of service of 0·002 for incoming calls in the control area is made up of two parts:

(*a*) calls lost because the first store in the temporary storage of the c.n.g. is engaged by a previous call, and

(*b*) those lost because the setting-up time for the call is greater than the i.d.p. available.

The time taken to set up a call is a combination of the time for circuit selection and seizure at the distant exchange and the TXE2 exchange register connexion time, as shown in Fig. 3. In this study, if a call required greater than 200 ms for TXE2 exchange register association, represented by periods C and D in Fig. 3, it was assumed to have exceeded the i.d.p. available and be lost.

The originating calls in the control area can be lost in attempting to enter the c.n.g. However, delay arising is not so critical because the subscribers are waiting for dialling tone, but it is necessary to limit the delay. The register-calling priorities listed earlier assist the setting-up of incoming calls which require the more stringent standards.

For the control-area study, a simulation program was developed which represented

(*a*) the c.n.g., and
(*b*) the registers and the call control.

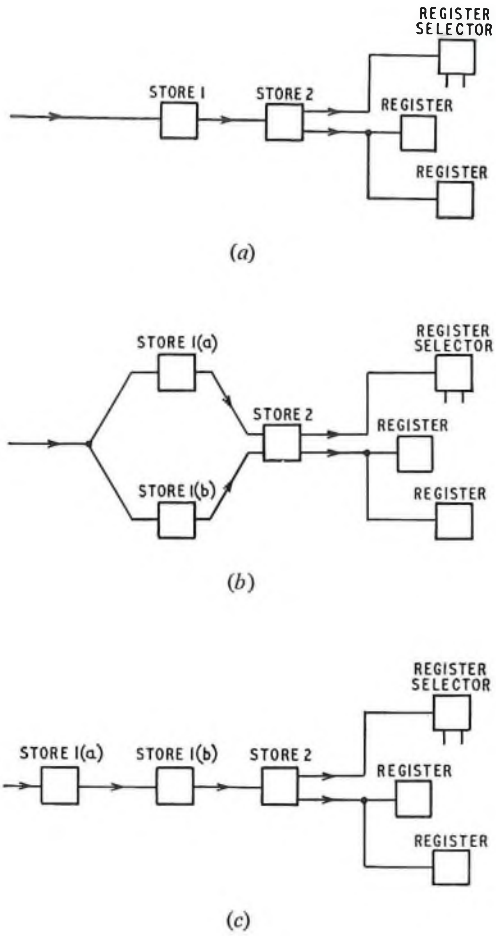
The necessary data relating to equipment operating times and traffic distributions was obtained from other Telecommunications Headquarters Departments, and the two manufacturers concerned.

For ease of comparison of the results, the c.n.g.s studied are referred to here as type A for those from one manufacturer and type B from the other, with numerical suffixes to indicate their order of design.

The temporary storage arrangements of the various types of c.n.g. studied are shown in Fig. 4.

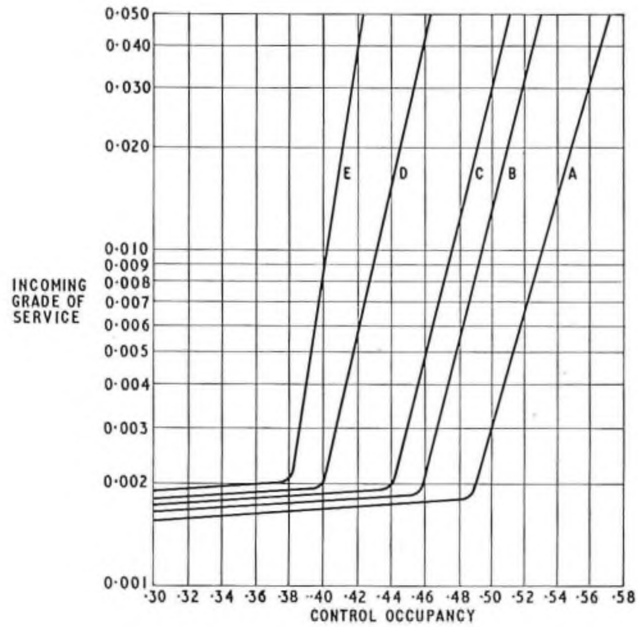
Type-A C.N.G.s

The first c.n.g. simulated was type A2 (see Fig. 4(*a*)) which was the type installed in all but the very early TXE2 exchanges, having a maximum design capacity of 10 majors. This type was considered by its manufacturer to be capable of handling the traffic associated with the increased-capacity switching area.



(*a*) Types A1, A2 and B1
(*b*) Types A3, A4, A5 and A6
(*c*) Types B2 and B3

FIG. 4—C.N.G. temporary storage configurations



Note 1: A, B, C, D and E refer to data given in Table 1
Note 2: As the number of calls offered is kept constant, the deterioration in the grade of service is caused by calls delayed longer than 200 ms

FIG. 5—TXE2 incoming grade of service

TABLE 1

Traffic Distributions

Traffic Mix		Percentages		
	Percentage originating/incoming	Priority 1	Priority 2	Priority 3
A	70/30	15	30	55
B	60/40	21	26	53
C	53/47	24	25	51
D	40/60	30	19·5	50·5
E	30/70	34	16	50

However, the simulation showed that the control area was not capable of handling the heavier traffic. Although the control could handle the extra demands, the operational speed of the c.n.g. temporary storage was too slow and a high proportion of the calls were lost trying to enter it.

The provision of additional registers was studied but, although this did reduce the numbers of calls having to wait for a free register, it did little to alleviate the overall problem.

After discussion of these results, the manufacturer suggested that an extra rank of storage be added to the c.n.g., creating the type A3. From Fig. 4(*b*), it can be seen that this type of c.n.g. had two stores in parallel, each similar to store 1 of the type-A2 c.n.g. However, although the extra rank of storage enabled an extra call to be queued, the operation times and transfer rates were basically those of a type-A2 c.n.g. The revised computer simulation program showed that the type-A3 c.n.g. had a performance which was only marginally better than the type A2 and, consequently, this design was considered unsatisfactory.

During further discussion with the manufacturer, the B.P.O. suggested operation times and transfer rates which, from the simulation results of type A3, would be more appropriate for the c.n.g. temporary storage. From these discussions, the manufacturer developed the type-A4 c.n.g. A simulation study of the control area with a type-A4 c.n.g. proved it was capable of handling the traffic associated with the enlarged TXE2 exchange system, and the manufacturer was notified accordingly. Although the first laboratory version and, later, the production version of the type-A4 c.n.g. (types A5 and A6, respectively) altered the equipment timings slightly, further simulation showed that the improved performance was maintained.

Type-B C.N.G.s

The second manfacturer put forward two proposals for c.n.g.s capable of carrying the traffic associated with the enlarged TXE2 exchange system. These two c.n.g.s, types B2 and B3 (see Fig. 4(*c*)) which differed in operational detail, had a different temporary storage configuration to that of the acceptable type-A c.n.g. It was found that the performance of type-B2 c.n.g. was very similar to that of the type A4, and they would both require the same register-provisioning table. The type B3 had a slightly better performance, however, and this was reflected as a saving in registers on the larger exchanges (approximately two registers on a 20-major exchange, with 55 registers).

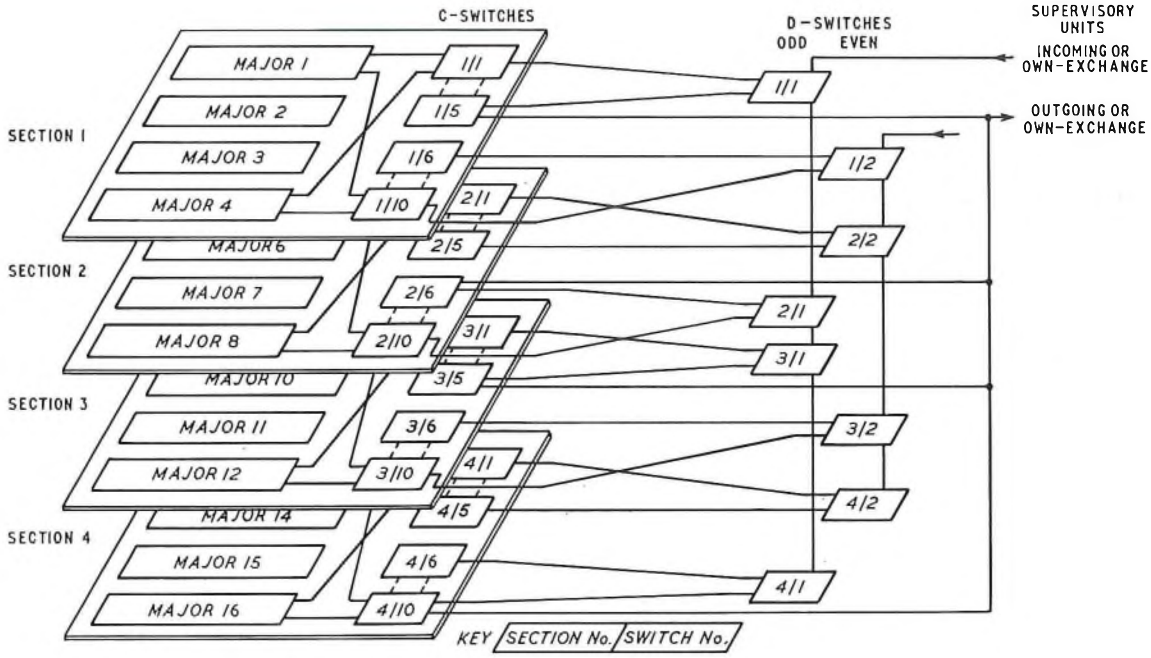


FIG. 6—Block diagram of switching area of a four-section TXE2 exchange

Register Provision

The study continued with an evaluation of those designs of control area in use at that time on the 10-major TXE2 exchange systems. These included c.n.g.s of types A1 and A2, and type B1 from the second manufacturer. The evaluation results showed that the satisfactory operation of these c.n.g.s relied on additional registers, and, consequently, the register-provisioning tables for existing exchanges were amended. However, although the type-A2 and -B1 c.n.g.s were now capable of handling the traffic on a 10-major exchange, the type-A1 c.n.g. was only suitable for exchanges with a total A–B link traffic loading of less than 200 erlangs; that is, approximately 6·7 erlangs per 25 A–B links.

Study Review

The control-area study has recently been updated to generalize the results for a wide variety of traffic distributions, as the first study used average traffic patterns. In addition, this approach showed that the delay which can be expected for each priority queue is a function of the percentage of priority 1 demands in the traffic mix (see Fig. 5 and Table 1). Thus, the performance limits of each part of the TXE2 exchange control area have been determined, and the results will be used in individual exchange design and management.

SWITCHING-AREA STUDY

Sectionalization

The original TXE2 system design allowed up to 10 majors per exchange, each of which had access to all 10 C-switches. Every B–C inlet on a C-switch has to have access to every outlet on that switch. Thus, for larger exchanges with similar trunking, each additional major, over the original ten, would increase the number of cross-points required for each C-switch by uneconomic proportions.

For the enlarged-capacity TXE2 exchange, both manufacturers proposed using sectionalization to increase the switching-area size. In this proposal, the majors were allocated to sections, each section having its own C-switch and part of each D-switch. A typical four-section exchange is illustrated in Fig. 6. With such an arrangement, the size of the C-switch was decreased and, although the D-switch size had to be increased, the expansion up to 20 majors became an economic proposition.

The manufacturers agreed that, ultimately, the 20-major exchange should have four sections with five majors per section. Unfortunately, the way they allocated majors to sections during exchange growth was different. An investigation was, therefore, started to find the growth method which gave the least numbers of cross-points and carried the maximum traffic at each growth step. An analytical approach was used because of the time-scale, and the assumptions made, which were the same for all the schemes, were considered justifiable because only a comparison of the different schemes was required. The answers obtained will be checked by simulation in due course.

Method of Study

The study assumed that the most onerous connexion in the exchange was the one from a D-switch inlet to a called subscriber, this connexion being needed during the setting-up of an incoming call and an own-exchange call. During the study, a grade of service of 0·013 was used for this connexion through the switching area as discussed earlier, and the A–B link loading was assumed to be 7·5 erlangs per 25 links.

A formula was derived which could be used to calculate, for every section configuration, the average inlet occupancy for a D-switch with a specific number of inlets.

Results of Study

A table was produced for each growth proposal giving, at each growth step, the inlet occupancy for D-switches with various numbers of inlets and at a limiting grade of service of 0·013. From these tables, it was possible to derive an optimum section-growth proposal which gave the maximum D-switch inlet occupancy at each growth point. Operational Programming Department then calculated the numbers of cross-points which would be required on a range of typical TXE2 exchanges if the optimum plan were implemented, and those required using the manufacturers' proposals applied to the same exchanges. It was found that the optimum scheme required less cross-points at every growth point except at the lower end (one to four majors). After modification of the lower end of the optimum proposal, this scheme was then presented to both manufacturers for their comments. Although there were no objections on the validity of this scheme, the equipment practices of one of the manufacturers precluded its adoption.

The evaluation, therefore, had to be extended to find an alternative scheme, because any saving that might have accrued due to reduced cross-points would have been offset by implementation difficulties with this manufacturer. Several other growth schemes were investigated and, finally, one which increased the number of sections on a unit from four to five was found to be acceptable to both manufacturers. Although this scheme was not as satisfactory at all points of the growth curve as the one proposed to the manufacturers, nevertheless, it requires less cross-points overall than the manufacturers' proposals. It has, therefore, been adopted by the B.P.O., and Table 2 shows the order of growth of sections and majors, and the range of maximum average occupancy of the D-switch inlets with different numbers of D-switch inlets and outlets if the required standards of blocking are to be maintained.

OTHER STUDIES

Several studies have been carried out by the Teletraffic Division on speculative ideas

(*a*) for using equipment similiar to the TXE2 system for different types of exchanges, and

(*b*) of modified TXE2 system trunking arrangements.

Within the former category, there have been studies on the performance of equipment, similar to the TXE2 system, used as a group switching centre, and on the use of the A–B switching stage as a subscriber's concentration stage for a digitial exchange. Within the latter category, investigations have been carried out on the feasibility of allowing a TXE2

TABLE 2

Growth Scheme Standardized for TXE2 Exchanges

Number of Majors	Number of Sections	Number of Majors on Sections 1 to 5					Maximum Average Occupancy of D-Switch Inlets for Given Numbers of D-Switch Inlets							D-Switch Outlets
		1	2	3	4	5	4	5	6	7	8	9	10	
1	1	1					0·65	0·41	0·28					5
2	1	2					0·65	0·41	0·28					5
3	1	3					0·65	0·41	0·28					5
4	1	4					0·65	0·41	0·28					5
5	2	4	1				0·82	0·51	0·35	0·27				10
6	2	4	2					0·61	0·42	0·33	0·27			10
7	2	4	3					0·71	0·49	0·38	0·31	0·27		10
8	2	4	4					0·82	0·56	0·43	0·36	0·30	0·26	10
9	3	4	4	1				0·92	0·63	0·49	0·40	0·34	0·30	15
10	3	4	4	2					0·70	0·54	0·45	0·38	0·33	15
11	3	4	4	3					0·77	0·60	0·49	0·42	0·36	15
12	3	4	4	4					0·84	0·65	0·54	0·46	0·40	15
13	4	4	4	4	1				0·91	0·71	0·58	0·49	0·43	20
14	4	4	4	4	2					0·76	0·63	0·53	0·46	20
15	4	4	4	4	3					0·81	0·67	0·57	0·49	20
16	4	4	4	4	4					0·87	0·72	0·61	0·53	20
17	5	4	4	4	4	1				0·92	0·76	0·65	0·56	25
18	5	4	4	4	4	2					0·81	0·68	0·59	25
19	5	4	4	4	4	3					0·85	0·72	0·63	25
20	5	4	4	4	4	4					0·90	0·76	0·66	25

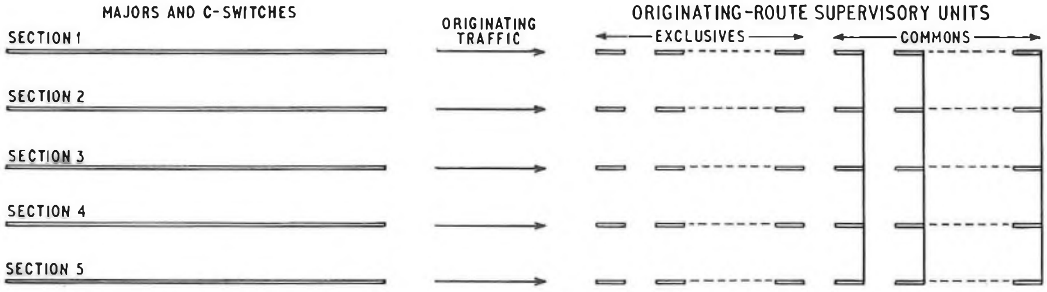


FIG. 7—Arrangement of an originating route split into exclusives and commons

exchange to have direct routes into director areas and of increasing the maximum size of a TXE2 exchange originating route to above 100 circuits, this latter problem resulting from the enlarged TXE2 exchange study, because each C-switch can only accommodate ten appearances from one route.

Thus, if each circuit from a route were commoned across all sections, the maximum route size would be 100 circuits. However, by splitting a route into circuits which are exclusive to a section and others which are commoned across all sections (see Fig. 7), the maximum route size can be greatly increased. When a connexion is required using this route, the control first hunts for a C-switch with a free exclusive circuit, but, if all these are engaged, it then attempts to seize a circuit which is commoned across all sections.

FUTURE WORK

Work is continuing using a simulation model of a complete TXE2 exchange. No other standard B.P.O. public exchange switching system has yet been simulated as a whole. Therefore, besides assisting in standardizing dimensioning rules for TXE2 exchanges, this work is expected to answer several pertinent questions concerned with the philosophy of system study, particularly the effects of splitting systems into smaller segments for teletraffic evaluation. Although the TXE2 exchange system is comparatively small, the work has encountered problems of program size, computer run-time and the time taken to analyse results. Nevertheless, with program refinements, these problems are being overcome and beneficial data has already been accumulated.

CONCLUSIONS

The analytical and simulation studies of the TXE2 exchange system have yielded some important results and provided valuable dimensioning information. The early work quantified the exchange capacity and allowed the TXE2 system to grow to 10 majors. The recently completed work on the control area has effectively doubled its capacity and resolved some anomalies in the register-dimensioning tables for the 10-major exchange, while the work on sectionalization has allowed the switching area to be expanded economically to 20 majors per unit. Furthermore, for the first time since the introduction of TXE2 exchanges, the traffic and connexion capacities will be the same for all manufacturers, thus simplifying the dimensioning standards and rules used for individual exchange design.

ACKNOWLEDGEMENTS

The assistance of the British manufacturers of TXE2 equipment is gratefully acknowledged, as is the help of the author's colleagues.

References

[1] BEASTALL, H., and POVEY, J. A. Teletraffic Studies of TXE4. *P.O.E.E.J.*, Vol. 65, p. 251, Jan. 1973.
[2] LONG, R. C., and GORRINGE, G. E. Electronic Telephone Exchanges: TXE2—A Small Electronic Exchange System. *P.O.E.E.J.*, Vol. 62, p. 12, Apr. 1969.
[3] HILLEN, C. F. J., LONG, R. C., and PORRITT, W. R. A. The Field Trial of Two Small Electronic Exchanges at Leamington and Peterborough. *P.O.E.E.J.*, Vol. 58, p. 1, Apr. 1965.
[4] BROADHURST, S. W., and HARMSTON, A. T. An Electronic Traffic Analyser. *P.O.E.E.J.*, Vol. 42, p. 181, Jan. 1950.
[5] MCGRATH, H. T. The Electronic Traffic Analyser—A Survey of its Use and Limitations. *P.O.E.E.J.*, Vol. 52, p. 19, Apr. 1959.

Book Review

"Reliability Engineering." D. J. Smith, B.Sc. Pitman Publishing. xi + 136 pp. 58 ill. £2·50.

Reliability theory has been dealt with in a number of good books in recent years, mostly of American origin. This book contributes a form of presentation which is concise, based upon practical applications, and, on the whole, lucid. The content is not new and, one feels, borrows fairly freely from other books, but it is likely to provide a good introduction to the subject.

The theoretical basis for reliability engineering is a branch of probability theory. The necessary probability concepts are presented as intuitive ideas rather than rigorous definitions. On the whole, this fits the book's purpose. However, it leaves certain gaps in the understanding which the reader may achieve. The definition of failure rate as a conditional probability occurs late (chapter 5) and, as a tool for the analysis of life-test results, the concept of a variable failure rate is said to be meaningless (chapter 6). This neglects the technique of cumulative hazard plotting which can often be useful in practice. The Weibull model is well introduced, but median ranks are used for plotting a curve in an example without any introduction or explanation. No alternative mathematical models (e.g. lognormal and gamma probability functions) are mentioned. System reliability calculations for components of known constant failure rate connected in series, and active and passive redundancy structures are quite well, but by no means exhaustively, treated. A number of problems are set at the end of each chapter.

The book should be easy to assimilate and provides a useful addition to the range of introductory texts in the subject.

C. J.

Materials and Fibre for Optical Transmission Systems

K. J. BEALES, B.SC., PH.D., A.R.I.C., J. E. MIDWINTER, B.SC., PH.D., C.ENG., M.I.E.E., M.I.E.E.E., M.INST.P.,
G. R. NEWNS, B.SC., B.SC., PH.D., and C. R. DAY, B.SC., D.PHIL.†

U.D.C. 621.391.63: 677.521

Recent advances in glass-making technology have substantially closed the gap between the optical losses obtainable in high-silica materials and in lower-melting-temperature glasses. As a result, several fibre-making processes offer a real possibility of achieving the desired low-optical-loss fibre. The sources of optical loss, and the technology of preparing materials and fibre are discussed in this article.

INTRODUCTION

Optical fibres were first seriously considered for use in telecommunications by Kao[1] and Werts,[2] in 1966, in papers dealing with the electromagnetic theory of propagation in such a dielectric waveguide. This was followed in 1969 by another important paper, also by Kao,[3] in which it was shown that very-low-loss optical materials existed, albeit not in a form readily adaptable to fibre production. This, together with a rapidly growing body of knowledge of coherent optical sources, and particularly solid-state gallium arsenide (GaAs) lasers, led to the promise of an optical-communications system for commercial use.

Optical fibres fall into three main groups, as outlined in a previous article in this *Journal*[4]. These are monomode, multimode step-index and multimode graded-index optical fibres. These are illustrated in Fig. 1. In each case, the guiding core of the fibre has a refractive index approximately 1 per cent greater than the cladding which serves to prevent the electromagnetic field leaking out to the boundary, where it would be rapidly attentuated.

Each type of fibre has its own distinctive characteristics, but they all have many features in common. Typical data rates that the different types of fibre might carry, in bit/s/km are summarized in Table 1. Dispersion, due to different mechanisms, limits the rates and will be discussed in much greater detail in later articles, but the figures are given as an approximate guide. Two light sources are listed, the GaAs laser and the GaAs light-emitting diode (l.e.d.). Since the laser has one tenth the line width of the l.e.d., and about 1,000 times the power per mode, it can efficiently launch into a monomode fibre, whereas the l.e.d. can only usefully be considered in conjunction with the multimode fibres.

TABLE 1

Typical Fibre Bandwith for Different Source/Fibre Combinations

Source	Typical Fibre Bandwidth (km × bit/s)		
	Monomode	Multimode graded-index	Multimode step-index
Gallium-Arsenide Laser	5×10^9	5×10^8	2×10^7
Gallium-Arsenide Light-Emitting Diode	—	10^8	2×10^7

A key element in a viable optical-communications system was recognized, at the outset, to be low-optical-loss fibre. Early work on the development of low-loss materials, appropriate fibre-drawing technologies and new measurement techniques was carried out at several research centres in the U.K., including the British Post Office (B.P.O.) Research Department laboratories. From subsequent work, two distinct material systems have emerged. The first was the one chosen by the U.K. based effort, and involved low-melting-temperature glasses such as the sodium calcium silicates (closely akin to window glass, but ultra pure) and the sodium boro-silicates (of which Pyrex is one well-known composition). These glass systems offer great flexibility in the choice of optical, mechanical and chemical properties, but because they are melted in crucibles from powders, the attainment of very low contamination, and hence low loss, is difficult. The second distinct group includes pure silica, the glass form of quartz, and silica containing a few per cent of various dopants to produce a glass with a slightly different refractive index for either the core or the cladding. Work with these materials has been centred mainly in the U.S.A., and has led, in recent years, to impressively low optical losses.[5] However, the last 12 months have seen the gap start to close again, and there is now good reason to believe that the low-melting-temperature glasses will shortly rival the high-silica group. Since the success of an optical-communications system depends to a large extent on the achievement of low optical loss, much of this article is devoted to a discussion of the various loss mechanisms responsible for the energy decay in fibres, and the main techniques for making glass and fibre are also discussed.

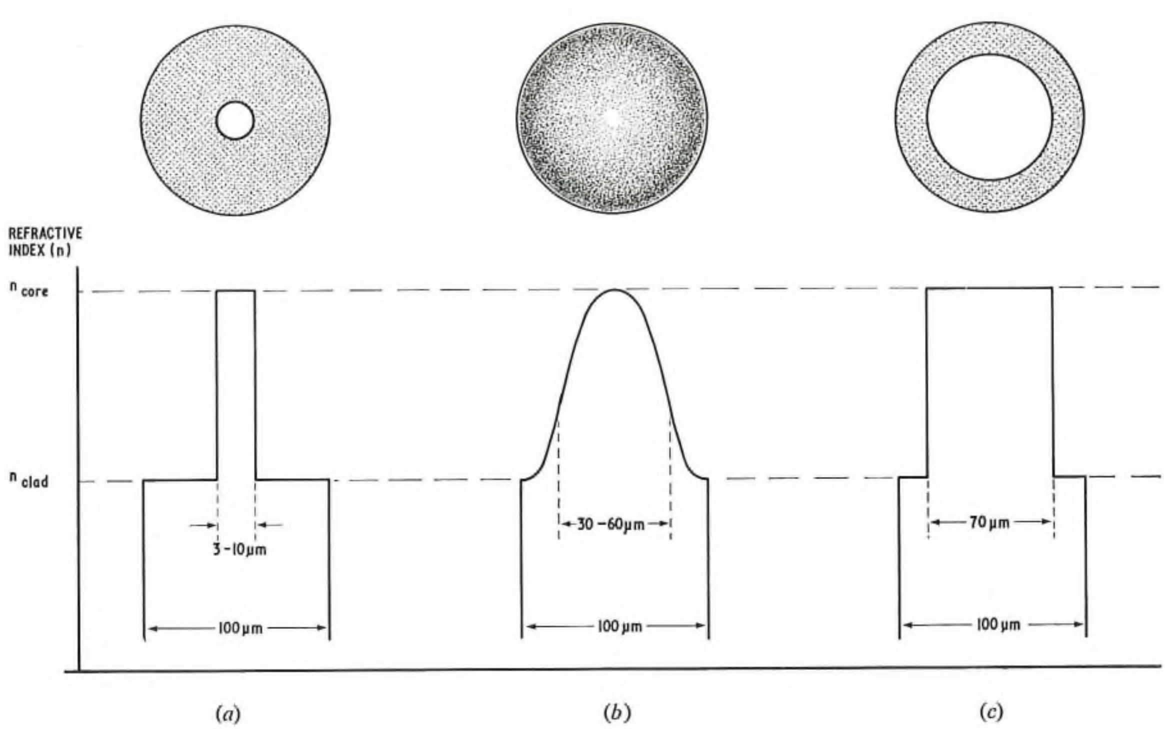
LOSS MECHANISMS

There are many sources of optical loss in glasses and fibres. These depend on the composition of the glass, preparation methods and fibre design, but they fall broadly into two groups, absorptive and radiative.

Absorption Loss

The absorption of light can arise by interaction with either the major glass components, or with impurities. In the infra-red wavelength range (5–15 μm), there are strong absorption

† Research Department, Telecommunications Headquarters.



(a) Monomode
(b) Multimode—graded-index
(c) Multimode—step-index

FIG. 1—Fibre refractive-index profiles

bands due to interaction with the vibrations of the molecular structure of the glass. Electronic transitions are the source of strong absorption bands in the far ultra-violet wavelength range. Between these two extremes, most common oxide glasses have a transmission window in the visible and near infra-red wavelength range, where the absorption loss arises mainly from the presence of trace impurities.

At present, the major cause of loss in the low-melting-temperature glasses in the important wavelength range, 800–900 nm, is due to the presence of transition metal ions.[6] Many of the transition metals in the first row of the periodic table of elements (titanium-copper) can exist in several ionic states in the glass, each ion contributing absorption bands of different intensity, shape and position.[7] The relative proportions of the different ions are influenced by the glass composition, the melting conditions and the techniques used to make the glass. Some typical absorption curves,[6] for the most significant impurities in a sodium calcium silicate glass, are shown in Fig. 2. Qualitatively similar results have been found for other glass systems. The broad absorption bands of copper, iron and nickel, with maxima at wavelengths of 800, 1,100 and 900 nm respectively, are due to the divalent ions. The presence of manganese results in a strong absorption band at a wavelength of 490 nm, with a pronounced low-energy tail extending into the near infra-red wavelength range. The above ions are the dominant impurities in the spectral region of current interest, but other impurities such as chromium, cobalt and nickel are important contributors to the loss at shorter wavelengths. From the intensities of the absorption bands, the maximum acceptable concentrations of such impurities, for an optical attenuation of 10 dB/km, was estimated to be in the range 1–100 parts in 10^9. Considerable progress has been made in reducing the loss, and recent glasses, made in the B.P.O. Research Department laboratories, have losses of about 10–15 dB/km attributable to this source.

Similar behaviour of impurities is found in silica and high-silica glasses, but because of the completely different preparation techniques, which ensure a higher purity material and advantageous transition metal attentuation coefficients,[8] the transition metal impurity problem is less severe.

Water is a common impurity in both glass and silica and is present as hydroxyl groups. The fundamental stretching vibrations of the hydroxyl bond occur between wavelengths

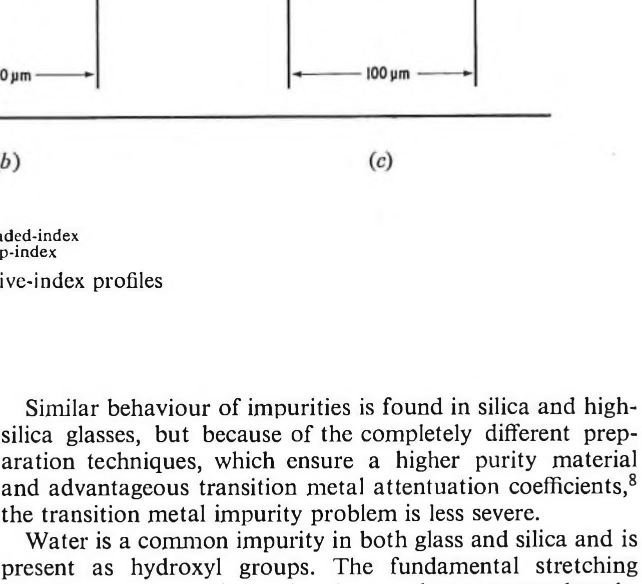


FIG. 2—Absorption coefficients for various impurities in sodium calcium silicate glass

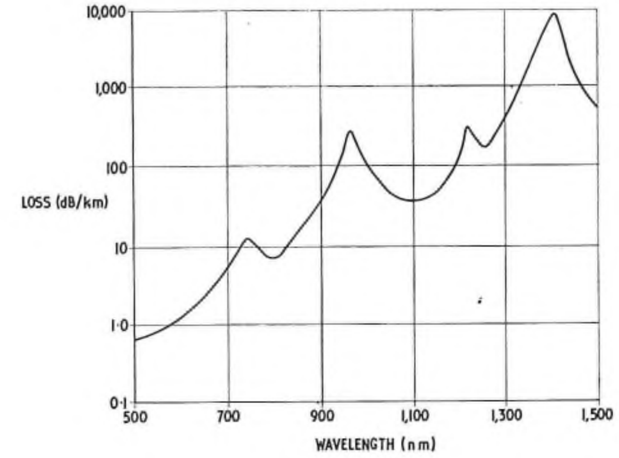


FIG. 3—Absorption in a sodium borosilicate glass due to hydroxyl overtone and combination bands

of 2·7–4·2 μm, depending on the position of the hydroxyl in the glass network.[9] These fundamental bands give rise to a series of overtone (harmonic) and combination bands extending into the visible wavelength region.[10,11] In most glasses and silica, the water content is sufficient to result in substantial attentuation at the absorption peaks, a typical spectrum due to the water in a sodium borosilicate fibre being shown in Fig. 3. Fortunately, the peaks are relatively sharp, and the loss attributable to the high water content in glass, in the region 800–900 nm varies in the range 8–20 dB/km.

Colour centres can be produced in glasses by exposure to ionizing radiations. The induced absorptions are generally observed in the ultra-violet and visible regions and have low-energy tails extending into the near infra-red wavelength range. A typical background dose for a period of 20 years is 2 rd, and this would produce an incremental increase in the loss at 850 nm of about 0·03 dB/km and 0·15 dB/km for silica[12] and sodium borosilicate[13] glasses respectively. Therefore, it does not seem to be a serious problem.

Scatter Loss

The most fundamental loss mechanism in glasses in the visible region is due to light scattering from inhomogeneities smaller than the wavelength of light—Rayleigh scattering. The inhomogeneities arise from density and compositional fluctuations which are frozen in the glass structure on cooling. The density fluctuations increase with increase in freezing temperature and, consequently, the scatter loss due to the density fluctuations will be higher in fused silica than in a glass with a lower glass transition temperature. However, multicomponent glasses have an additional scatter loss due to local fluctuations of composition, but the total scatter loss of some glass compositions and fused silica are comparable,[14] being about 1 dB/km at 900 nm (see Table 2). More recent work[15] has shown that

TABLE 2

Rayleigh Scatter Loss in Bulk Samples of Different Glasses

Glass Type	Scatter Loss (dB/km at 850 nm)	Reference
Silica	1·2	15
Potassium silicate	0·7	15
Sodium borosilicate	2·3	30
Sodium calcium silicate	0·8	14

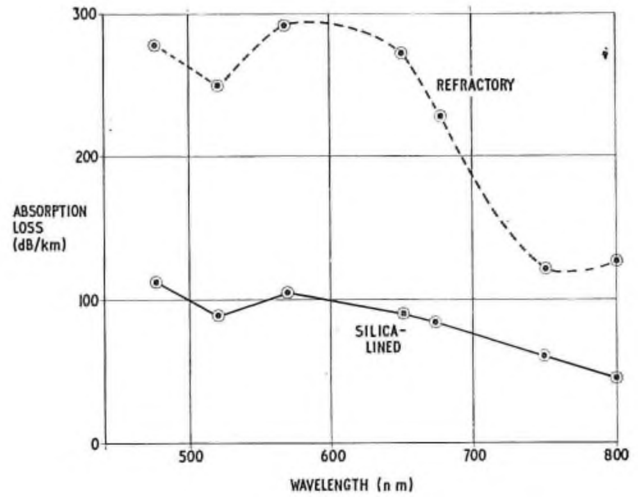


FIG. 4—Change in absorption achieved by lining a refractory furnace with a silica sheath

some glasses have very low compositional fluctuations, and hence, scatter losses which can be half that of fused silica. Rayleigh scatter loss is proportional to (wavelength)$^{-4}$, and consequently, becomes unacceptably high for viable communication systems towards the blue end of the visible spectrum.

Mie scattering is caused by inhomogeneities comparable in size to the wavelength of light, produces mainly forward scatter[16], and is avoidable in principle.

A further scatter loss mechanism peculiar to fibre, arises from any small irregularity of the core–cladding interface.[17] Such fluctuations arise from vibrations or other perturbations during the pulling process, and lead to two effects, one that is beneficial and one that is not. In a multimode fibre waveguide, such undulations scatter energy from one guided mode to another. This mode mixing tends to average out the delay time for energy launched initially into different modes, and hence, helps to increase the usable bandwidth. Unfortunately, the same undulations scatter energy from the guided modes out of the fibre, and thus, increase its loss. In practice, striking a balance between these two mechanisms has proved to be a difficult problem.

Non-linear effects, such as stimulated Raman and Brillouin scattering, have little effect on the loss below a threshold power level. Although, in fibres, the optical power is concentrated on a small cross section, and consequently, high power densities can be obtained at modest total power levels, the threshold levels will not be reached in the systems envisaged at present.

Other more trivial sources of scatter loss are often found in glasses, such as bubbles, incompletely dissolved refractory starting materials, phase-separated regions, or crystals. These are either minimized by changes to the glass-making techniques, or avoided by careful choice of glass composition.

MATERIALS PREPARATION

Optical fibres manufactured from conventional glasses and those made from doped silicas require different experimental approaches.

The glass systems generally used are sodium calcium silicates, sodium borosilicates and sodium or potassium lead silicates. The glasses are prepared by heating premixed, high-purity starting materials (oxides and carbonates) in platinum or refractory crucibles. A sufficiently high temperature

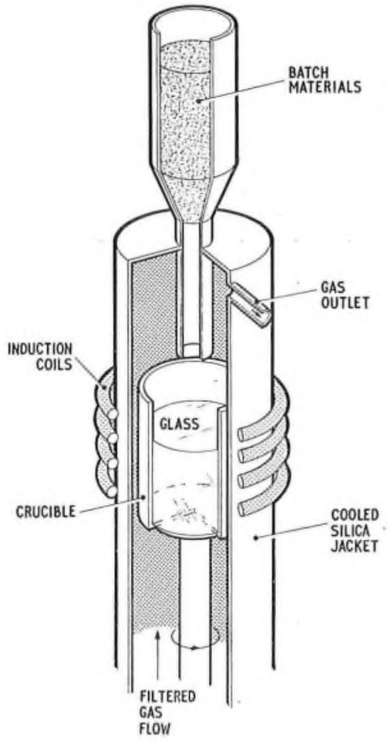


FIG. 5—Diagram of glass-making apparatus

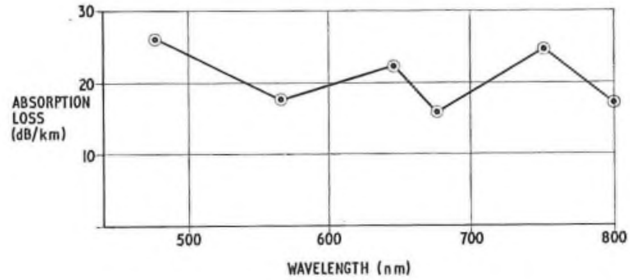


FIG. 6—Absorption loss due to all effects in a glass prepared in a high-purity silica crucible

(1,000–1,400°C) is required to decompose the carbonates and enable the components to react, to form a viscous liquid or melt. Homogenization of the melt is effected by stirring at high temperatures, and at the same time, large bubbles rise to the surface and burst. Residual smaller bubbles (seed) are then dissolved in the melt by slightly reducing the temperature, a process known as refining. The temperature, times and stirring techniques required depend on the glass composition, the impurities present and the desired optical quality. The glass is then either cast into moulds, or pulled into rods from the surface of the melt.

At all stages of glass making, contamination can occur. The three sources of contamination are atmospheric dust, transport of impurities from the furnace[18] and dissolution or diffusion of impurities from the crucible.[6] Hence, all the glass-making operations are usually carried out in clean rooms, where the air is continuously filtered.

Vapour-phase transport of the impurities from the hot-furnace refractories may be minimized by careful choice of furnace materials and liners. Fig. 4 shows the improvement achieved by using high-purity fused silica to line the furnace during glass preparation instead of the usual refractory materials. Contamination by the refractories can be completely eliminated by inductively heating, at a frequency of approximately 0·5 MHz, a platinum crucible within a cool silica enclosure, as shown in Fig. 5.

A third source of contamination is the crucible. If the glasses are made in platinum crucibles, the platinum can dissolve and contaminate the glass. When the platinum is present in an ionic form, it is less important, for its absorption bands are in the ultra-violet wavelength range. If, however, the platinum is precipitated as metallic particles, the loss can be very high. Careful choice of glass compositions and melting atmosphere can practically eliminate platinum contamination.[19] In addition, however, even the purest available platinum crucibles have relatively high iron and copper contents, and these can diffuse into the glass at the high melting temperatures. This contamination can be reduced either by leaching the impurities from the crucibles, or by using a lower temperature for glass making, and thus, reducing the rate of impurity diffusion.

Fused-silica crucibles, with impurity contents similar to those of the starting materials, are commercially available. Sodium borosilicate glasses have been prepared by the B.P.O. in silica crucibles in a conventional resistance-heated furnace lined with silica, the losses of these glasses varying within the range 16–25 dB/km for wavelengths of 450–800 nm (see Fig. 6). These glasses have a lower loss and a wider wavelength window than any low-melting-temperature glasses previously reported. One disadvantage of the above approach is that the molten glass slowly dissolves the crucible, and this can reduce the homogeneity of the final glass.

A novel approach to reducing crucible contamination has recently been described.[18] A radio-frequency (r.f.) field will inductively couple to molten glass. If the electrical conductivity of the glass is sufficiently large, and the frequency is chosen correctly for a given experimental geometry, the induced heat can readily equal, or exceed, the radiative and convective heat losses from the glass at the melting temperature. In practice, the batch materials are heated in a silica crucible using a small graphite susceptor. When sufficient molten glass has been made to sustain the inductive coupling, the susceptor is removed, more glass batch materials are added and the glass volume is increased. The principal advantage of this technique is that the coupling is directly to the molten glass, and not through the crucible. Consequently, the crucible can be kept cool throughout the glass-making process, thus dramatically reducing the interaction with the molten glass. Using this technique, sodium calcium silicate glasses, with losses as low as 27 dB/km at a wavelength of 1,060 nm, have been reported,[20] and sodium borosilicate glasses, with losses under 25 dB/km in the wavelength range 450–800 nm, have been prepared in the B.P.O. Research Department laboratories.

High-purity silica and doped silicas are produced using methods which differ from those employed with conventional glasses, since the very high melting temperatures render high-purity fusion very difficult. In general, silica is prepared either by vapour-phase hydrolysis, or oxidation of silicon tetrachloride ($SiCl_4$)—a volatile liquid easily purified by distillation—in a flame or an r.f. plasma. Both these processes produce materials substantially free from transition metal impurities, but the flame-hydrolysis technique yields a product with a very high concentration of water. Water-free material can be obtained by oxidation in an r.f. plasma. The absorption loss of the best water-free silica is usually below 20 dB/km at wavelengths of 800–850 nm, and some measurements have been reported[21] with losses as low as 3 dB/km. However, bulk silica is not readily adaptable to fibre production, and

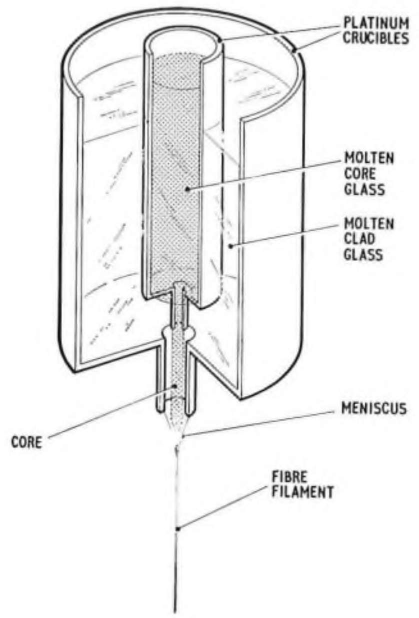


FIG. 7—Diagram of the double-crucible apparatus for fibre production

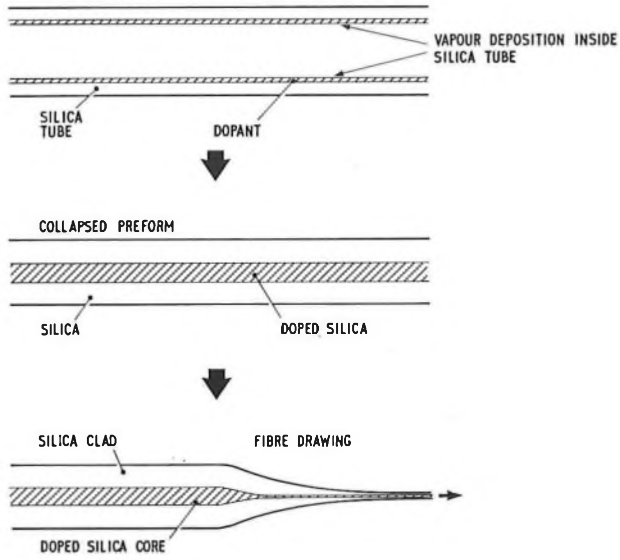


FIG. 8—Diagram of a vapour-deposition process for making silica-based fibre

the technique used to prepare high-silica fibres will be described later.

TECHNIQUES OF FIBRE PULLING

An important characteristic of a glass is the slow transition from the solid to the liquid state with change in temperature. Typically, the viscosity of the glass changes smoothly from 10^{12} to 10^2 Ns/m^2 over a temperature range of several hundred degrees. Use is made of the above property in fibre-drawing technology, where a fine fibre filament of approximately 10^{-4} m diameter, is pulled from the heated glass (viscosity 10^2–10^4 Ns/m^2) and wound on to a drum at speeds in the range 1–40 km/h. The various techniques used for making fibre are described below.

Double Crucible

The double-crucible apparatus is illustrated in Fig. 7. The core glass has the higher refractive index and is loaded into the inner crucible, with a cladding glass in the outer. The crucibles are usually made of high-purity platinum, and may hold from a few hundred grams to several kilograms of glass. Typically, one hundred grams of glass yields about 5 km of fibre. When the crucibles are electrically heated to a temperature corresponding to a glass viscosity of about 10^2 Ns/m^2, the molten glass begins to flow through the concentric nozzles under Poiseuille (viscous) flow. The emergent composite flow is then pulled rapidly, as it cools, into a filament under the action of the winding machine coiling the fibre. Careful control of the temperature distribution and winding speed ensures that the correct diameter for core and cladding is obtained.

To change from monomode fibre, with a core diameter of about 3–10 μm, to multimode fibre, with a core diameter of about 70–100 μm, a larger inner crucible with a larger nozzle diameter is used. This changes the volume ratios of core to cladding glass and gives the required glass flows. Control of the optical loss in the process requires careful attention both in the preparation and loading procedures to minimize unwanted contamination of the glass surfaces, and also in the operation of the apparatus to control the optical properties of the fibre. In the B.P.O. Research Department, the use of sodium borosilicate glass, which can be pulled into the fibre at relatively low temperatures, has markedly reduced contamination from impurities in the crucible.

Graded-index fibre can also be produced by the double-crucible apparatus. By choosing a suitable pair of glasses, sufficient diffusion can be obtained between the core and the cladding, as the core glass flows within the cladding material, but before entering the meniscus outside the cladding nozzle. The inter-diffusion of the two glasses then blurs the boundary[22] between the core and cladding regions. With suitable control, the diffusion process can lead to the formation of a guiding region in the centre of the fibre that has substantially lower mode dispersion, and hence, greater bandwidth than the equivalent rectangular-index fibre. The Japanese *Selfoc* fibre[23] is made in this manner.

Preform Techniques

Under this general heading fall many distinct techniques. All have in common the preparation of a large preform, typically having a diameter up to a few centimetres and a length up to 1 m. This preform is then fed vertically downwards by a precision-feed mechanism into the hot zone of a short furnace, which heats the tip of the preform until it flows. From this molten tip, a fibre filament is pulled and wound on a drum, in a similar manner to the double-crucible process. The distinct technologies differ in the various methods of preform preparation. The preform is a composite rod with a core of higher refractive index material that will subsequently become the guiding core of the dielectric waveguide.

The preform may be produced by sliding a rod of core glass into a tube of cladding glass. This is the *rod-in-tube* technique, but limited success has been achieved, in practice, because of the difficulties of preparing the elements of the preform free of surface contamination.

The preform processes currently attracting the most attention are those in which the guiding materials are deposited from the vapour phase. The best known of these techniques is the *Corning* process, which has currently produced the lowest-loss fibre made. In this process,[24] a tube of

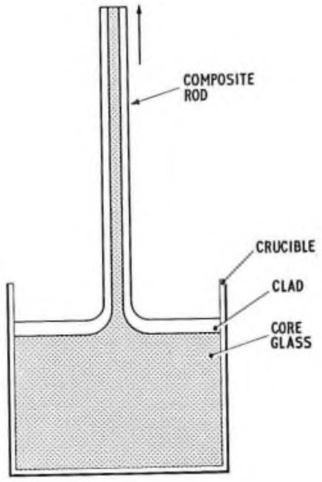


FIG. 9—Preparation of composite rod prior to fibre pulling

silica is used to provide the support structure for the preform. High-purity silica is produced inside this tube by the reaction of $SiCl_4$ and oxygen (O_2) in a gas-oxygen flame. This results in very fine silica particles being produced at the entrance to the tube. The application of a slight vacuum to the other end of the tube draws the particles through the tube, and builds up a uniform deposit on the inside. The powder layer is then sintered at high temperature. A layer of doped silica, typically produced by the reaction of $SiCl_4$, titanium tetrachloride ($TiCl_4$) and O_2, is again produced in like manner and sintered. The resultant preform is then collapsed and pulled into a fibre, with titania-doped silica core and silica cladding. A particular problem with the titania-doped core is to maintain the titanium atoms in the correct oxidation state, and this has involved heat treating the fibre, in an oxygen atmosphere,[25] after pulling. The above problem can be overcome by the use of other dopants, such as germania (Fig. 8).

Numerous variations on this technique are possible and have been tried with varying success. When small amounts of a second oxide are added to silica, the refractive index of the doped material is usually greater than that of the silica. Consequently, the usual preform consists of a doped-silica core and high-purity silica clad. However, if silica is doped with a small amount of boron oxide, the refractive index of the resulting borosilicate glass is less than that of silica. This property has been used to make preforms, and subsequently fibre, which have a high-purity silica core and a borosilicate clad.[26]

A third distinct preform technique is one pioneered by Pilkington Research Laboratories.[27] A crucible containing molten core glass has a layer of cladding glass poured over it (see Fig. 9). A glass rod is then dipped into the melt, and with it, a composite rod with core and cladding is pulled from the two-component melt. This technique, in common with the vapour-deposition techniques outlined above, has the advantage that the core material is never handled in the solid state, so avoiding the problems of contamination that inevitably go with any handling, transfer or machining process.

PRESENT STATUS

Bulk Materials

Precise data on bulk material losses are limited because there are few laboratories in the world that have the measurement capability for the low levels of loss now being achieved.

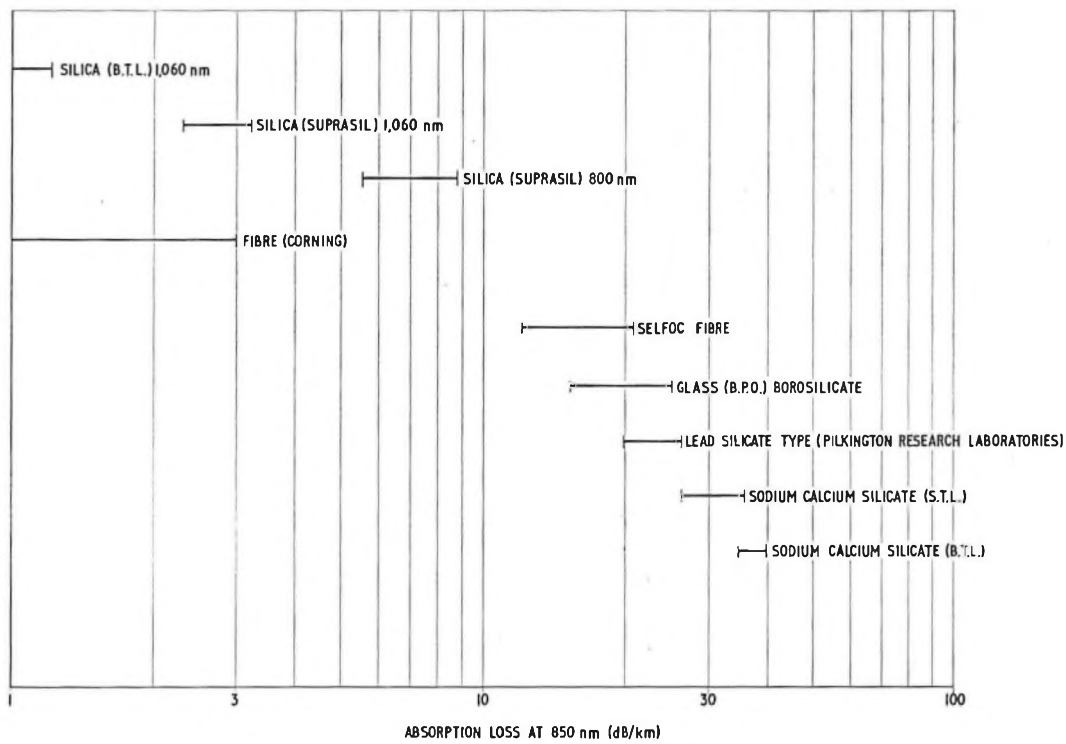


FIG. 10—Absorption of bulk glasses at a wavelength of 850 nm

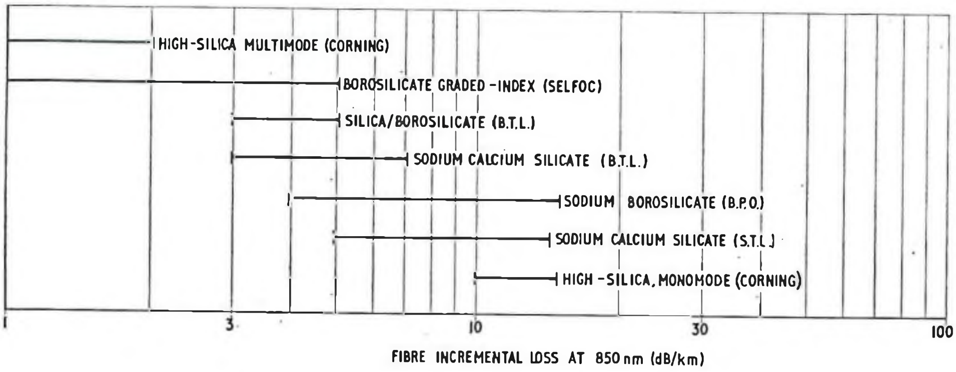


FIG. 11—Incremental losses in converting bulk material to fibre for various fibre-making processes

In addition, it is not possible to quote data on the vapour-deposited films discussed under preform techniques, since the substrates on which the films are deposited are only of secondary importance, and in general, the films cannot be measured until they have been collapsed into fibre. Thus, information is only available on bulk pure silica, and on a range of lower-melting-temperature glasses. The results are summarized in Fig. 10. Silica shows the lowest loss yet achieved, although it is instructive to note that samples of silica chosen range in loss up to values that now overlap the range of the glasses. Of course, glass losses could be shown as ranging up to enormous figures, if ordinary optical glasses were included, and only specially-prepared glasses for optical communications are included.

Scatter losses, listed in Table 2, show a rather smaller variation that is related mainly to composition rather than to the method of preparation. It is worth noting that, in contrast to microwave frequencies, the optical-frequency scatter-loss mechanisms are at least as important as absorption losses. This is because the wavelength is much shorter at optical frequencies, so that all materials and structures do not appear perfectly uniform.

Fibres

The incremental losses achieved in various fibre-pulling techniques are shown in Fig. 11. Incremental loss is defined as the change in loss in going from bulk material to fibre, or in the case of vapour-deposited preform fibres, it is the increase in loss over the limiting loss (due, almost entirely, to scatter in silica). This figure shows that the vapour-deposited fibres have, at present, achieved the best results, but the gap between them and the best achieved by other techniques is now quite small. In particular, the incremental loss achieved by the double-crucible process has come very close to that achieved by the vapour-deposition process in the best runs reported. However, the double-crucible process does not yet appear to be sufficiently well controlled to reproduce this performance every time.

The actual losses in fibre, at this time, cover a wide range, but the best results are as follows. The Corning preform[28] process has yielded multimode fibre with a loss of 4 dB/km, and single-mode fibre having a loss in the range 10–20 dB/km. Other vapour-deposition processes, based on the borosilicate cladding developed by Bell Telephone Laboratories, have yielded a range of fibres having losses of 6–20 dB/km. Another vapour-deposition process developed by Standard Telecommunications Laboratories[29] has yielded a fibre with 15 dB/km loss. Glass fibres made by the double-crucible process are poor by comparison, but this appears to be mainly because the best glass and the best fibre-pulling processes have not yet been brought together controllably. The lowest fibre loss by this technique has been achieved by the Japanese Selfoc fibre with a published figure of 22 dB/km. It would seem only a matter of time before this result is surpassed either in the U.K., the U.S.A., or Japan.

Several quite-distinct fibre production processes now show the capability of yielding fibres with losses well under the 20 dB/km target figure set some years ago. Consequently, there is now no doubt that acceptable fibres will be available on a production scale in due course. However, it is not yet clear which of the many processes will prove to be the best for optical communications, bearing in mind that low optical loss is not the only parameter of significance, but that other factors such as production yield, continuous run length, and hence, cost will be important in the long term.

ACKNOWLEDGEMENTS

The authors wish to thank their staff for generating many of the results quoted here, also Drs. D. Harper of Pilkington Research Laboratories, C. Stewart, and P. Black of Standard Telecommunications Laboratories for supplying some results and materials, and their superiors, Mr. F. F. Roberts, and Mr. J. I. Carasso, for their continued support and encouragement.

REFERENCES

1 KAO, K. C., and HOCKHAM, G. A. Dielectric Fibre Surface Waveguide for Optical Frequencies. *Proc. I.E.E.*, Vol. 113, p. 1,151, 1966.

2 WERTS, A. Propagation de la Lumiere Coherente dans les Fibres Optiques. *L'onde Electrique*, Vol. 474, p. 977, 1966.

3 JONES, M. W., and KAO, K. C. Spectrophotometric Studies of Ultra Low Loss Glass. *J. Sci. Inst.*, Vol. 2, p. 331, 1969.

4 ROBERTS, F. F. Optical-Fibre Telecommunication Transmission Systems. *P.O.E.E.J.*, Vol. 67, p. 32, Apr. 1974.

5 KECK, D. B., MAURER, R. D., and SCHULTZ, P. C. On The Ultimate Lower Limit of Attenuation in Glass Optical Waveguides. *Appl. Phys. Lett.*, Vol. 22, p. 307, 1973.

6 NEWNS, G. R., PANTELIS, P., WILSON, J. L., UFFEN, R. W. J., and WORTHINGTON, R. Absorption Losses in Glasses and Glass Fibre Waveguides. *Opto-electronics*, Vol. 5, p. 289, 1973.

7 SMITH, H. L., and COHEN, A. J. Absorption Spectra of Cations in Alkali-Silicate Glasses of High Ultra-Violet Transmission. *Phys. and Chem. Glasses*, Vol. 4, p. 173, 1963.

8 SCHULTZ, P. C. Preparation of Very Low Loss Optical Waveguides. Amer. Ceram. Soc. Meeting, Apr. 1973.

9 SCHOLZE, H. The Incorporation of Water in Glasses. *Glastech. Ber.*, Vol. 32, p. 81, 1959.

10 ELLIOTT, C. R., and NEWNS, G. R. Near Infra-red Absorption Spectra of Silica: OH Overtones. *App. Spectroscopy*, Vol. 25, p. 378, 1971.

[11] KAISER, P. Spectral Losses of Unclad Fibre Made from High Grade Vitreous Silica. *App. Phys. Lett.*, Vol. 23, p. 45, 1973.
[12] SIGEL G. A., and EVANS, B. D. Effects of Ionizing Radiations on the Transmission of Optical Fibres. *J. Appl. Phys.*, 1974. (To be published.)
[13] WHITE, K. I., BEALES, K. J., MIDWINTER, J. E., and NEWNS, G. R. *Opto-electronics.* (To be published.)
[14] DAGLISH, H. N. Light Scattering in Selected Optical Glasses. *Glass Technol.*, Vol. 11, p. 30, 1970.
[15] SCHROEDER, J., MOHR, R., MACEDO, P, B., and MONTROSE, C. J. Rayleigh and Brillouin Scattering in K_2O-SiO_2 Glasses. *J. Amer. Ceram. Soc.*, Vol. 56, p. 510, 1973.
[16] RAWSON, E. G. Calculations of Mie Scattering by Spherical Particles in Low Loss Glasses for Optical Waveguides. *App. Opt.*, Vol. 10, p. 2,778, 1971.
[17] MARCUSE, D., and DEROSIER, R. M. Mode Conversion Caused by Diameter Changes of a Round Dielectric Waveguide. *B.S.T.J.*, p. 3,217, 1969.
[18] SCOTT, B., and RAWSON, H. Low Loss Glass for Optical Fibre Communications. *Glass Technol.*, Vol. 14, p. 115, 1973.
[19] GINTHER, R. J. The Contamination of Glass by Platinum. *J. Non-Cryst. Solids*, Vol. 6, p. 294, 1971.
[20] STEWART, G. E. E., TYLDLESLEY, D., SCOTT, B., RAWSON, H., and NEWNS, G. R. High Purity Glasses for Optical Communications. *Electronics Letters*, Vol. 9, 1973.
[21] WHITE, K. I., and MIDWINTER, J. E. An Improved Technique for the Measurement of Low Optical Absorptions Losses in Bulk Glass. *Opto-electronics*, Vol. 5, p. 323, 1973.
[22] CHAN, K. B., CLARRICOATS, P. J. B., DYOTT, R. B., NEWNS, G. R., and SAVVA, M. A. Propagation Characteristics of an Optical Waveguide with a Diffused Core Boundary. *Electronics Letters*, Vol. 6, 1970.
[23] KOIZUMI, K., IKEDA, Y., KITANO, I., FURUKAWA, M., and SUMIMOTO, T. New Light-Focusing Fibres Made by a Continuous Process. *App. Opt.*, Vol. 13, p. 255, 1974.
[24] MAURER, R. D. Method of Forming an Economic Waveguide Fibre. U.S. Patent No. 3,737,293, 1973.
[25] MAURER, R. D., and SCHULTZ, P. C. Fused Silica Optical Waveguide. U.S. Patent No. 3,639,915 1972.
[26] FRENCH, W. G., PEARSON, A. D., TASKER, G. W., and MACCHESNEY, J. B. Low Loss Fused Silica Optical Waveguide with Borosilicate Cladding. *App.Phys. Lett.*, Vol. 23, p. 338, 1973.
[27] REID, A. M., HARPER, D. W., and FORBES, A. British Patent No. 50,543, 1969.
[28] KECK, D. B., MAURER, R. D., and SCHULTZ, P. C. *App. Phys. Lett.*, Vol. 22, p. 307, 1973.
[29] BLACK, T. W., and IRVEN, J. Development of High-Silica Optical-Fibre Waveguides. Electro-Optics International Conference, Brighton, Mar. 1974.
[30] WHITE, K. I., and MIDWINTER, J. E. (Unpublished Measurements).

Book Reviews

"Electric Lifts." R. S. Phillips, C.Eng., F.I.E.E. Pitman Publishing. xi+515 pp. 268 ill. £6·50.

All interested in lifts will welcome the appearance of the sixth edition of what is probably the only comprehensive text-book on the subject, but it has to be admitted that the process of piecemeal revision taken to this stage leaves something to be desired. Much material of only historic interest still appears and some inconsistencies arise, particularly from the introduction, in Chapter III, of the 1971 BS 2655 Part 3 standard arrangements and dimensions, which conflict with recommendations elsewhere in the text. A chapter on paternosters has been added, but this is very brief and cannot be regarded as more than an introduction to the subject. The chapter on roping systems and ropes, in particular, contains much obsolete material, and while "equal lay" rope constructions are mentioned, the importance of this feature to fatigue life, by avoiding internal cross-cutting, is not brought out.

The section on solid-state control is reproduced unchanged from the fifth edition except for minor corrections and does not go further than straightforward duplex collective control utilizing Norbit 1 elements. Contrary to some expectations, solid-state control has not yet made great headway in this field, the major manufacturers tending to confine its use to new developments in, for example, supervisory systems for banks of high-speed lifts. However, some makers are now providing lift controllers based on Norbit 2 elements or integrated circuits. While the present text does provide a guide to the principles involved, a wider-ranging treatment of the subject would have been most useful.

It is perhaps inevitable that in a new edition one should look for a solution to a particular current problem. For the reviewer, this is the problem of hand-winding high-speed gearless lifts on power failure, which in times of power rationing can become acute. However, the subject is not even mentioned.

D. M.

"M.O.S.T. Integrated-Circuit Engineering." J. Mavor, B.Sc., Ph.D., M. Inst. P., M.I.E.E.E., C.Eng., M.I.E.R.E., M.I.E.E. Peter Peregrinus Ltd. x + 162 pp. 129 ill. £3·85.

This is a paperback book of about 170 pages, It is based on the I.E.E. vacation school on m.o.s.t. circuit design held at the University of Edinburgh in 1972, and is intended to give information on the design, fabrication and applications of m.o.s.t. integrated circuits.

The approach has an engineering bias and is very practical and non-speculative which, in some respects, is advantageous. It is noted, with relief, that the basic material physics of the key device, often used as an introduction, is omitted. There is only one energy-band diagram to be found in the book. On the other hand, the first chapter on m.o.s.t. analysis includes all that is necessary in electron physics to make a valuable preamble to the more specialized sections of the book which follow.

The two most common processes used today are described, the p-channel-metal and silicon-gate technologies, and examples of process parameters, characteristics and design-layout rules are presented. However, it could have been emphasized that this situation is not static and that the design engineer must be prepared to consider alternatives, particularly those favoured by the manufacturer. The important subject of costs is raised in more than one place. It would have been even more acceptable if other quantitative estimates could have been given, in terms of engineers' time, if not in money, on the lines of the computer-aided-design *versus* engineer-design comparisons in chapter 6.

The sections on design and testing, and the applications described in the final chapter, are particularly useful. There is, however, one activity which has received less than its due share of attention. Apart from the short sections on gate-protection diodes and test transistors, there is no emphasis on methods whereby the customer may ensure adequate reliability for the integrated circuits he purchases. The need for reliability is already of high importance, particularly in telecommunications applications; it can only be satisfied by action at the design, technology and testing stages.

The handbook can, nevertheless, be recommended as a useful view of the present state of the art in m.o.s.t. integrated-circuit design and technology in the United Kingdom.

M. F. H.

Experimental Packet-Switched Data-Transmission Service: Network Design and Implementation

D. E. HADLEY, C.ENG., M.I.E.E., and D. W. F. MEDCRAFT, C.ENG., M.I.E.R.E., M.B.C.S.†

U.D.C. 621.394.4: 681.32: 621.394.742

The concept of packet switching, in relation to data communications, has been covered in a previous article, which also outlined the system defined for the British Post Office experimental service. This article describes the network-design and implementation aspects, and the overall aims of the experimental service.

INTRODUCTION

The experimental packet-switched service (e.p.s.s.) is planned for introduction in 1975. Three packet-switching exchanges (p.s.e.s) are being installed, located at London, Manchester, and Glasgow. In order to achieve the implementation of an experimental service as early as 1975, it has been necessary to reduce the amount of development work involved, and, consequently, the p.s.e.s will be based on a commercial processor, the Ferranti Argus 700E, and the network links and customer connexions will use existing standard Datel equipment.

The fact that commercial processors are being used for the p.s.e.s poses some novel problems in the implementation of the service. So too does the provision of Datel equipment, which is normally installed at customers' premises, but, in the case of the e.p.s.s., also needs to be provided at the p.s.e. sites.

AIMS OF THE EXPERIMENTAL SERVICE

The aims of the experimental service can be summarized as follows:

(*a*) To provide a packet-switching service of sufficient flexibility and geographical extent to establish the usefulness of such a service to customers, and to enable them to assess the overall technical and economic viability of packet switching in relation to their own data-processing systems:

(*b*) To enable a decision to be made, based on the outcome of the experiment, regarding the inclusion or exclusion of packet-switching facilities in future digital-data services:

(*c*) To provide an indication of the likely future demand for a packet-switching service, and to assist in formulating tariff principles, and in establishing traffic-design principles:

(*d*) To enable experience to be gained in hardware and software maintenance.

DETAILS OF THE SERVICE

There are two basic types of customers' data terminals which can be connected to a p.s.e. They are

(*a*) packet terminals, where the customers' data-terminal equipment assembles the data into an agreed packet format before transmission in a synchronous mode to the p.s.e., and

(*b*) character terminals, where the customers' equipment transmits data to the p.s.e. character by character, the p.s.e. then assembling the data into packets for onward transmission.

† Network Planning Department, Telecommunications Headquarters.

Character terminals will operate at speeds of 50 bit/s, 110 bit/s and 300 bit/s, whilst packet terminals will operate at 2,400 bit/s, 4,800 bit/s, 9,600 bit/s and 48 kbit/s, although the 9,600 bit/s facility will not be available initially.

A small number of Telex terminals will also be connected to the service, but these will only be used for in-house tests by the British Post Office (B.P.O.).

Methods of Access to the Service

Customers will access a p.s.e. via direct circuits or via the public switched telephone network (p.s.t.n.).

Customers using speeds of 110 bit/s and 300 bit/s will, normally, access the p.s.e. via the p.s.t.n., but a number of direct circuits are also being provided.

Packet terminals, that is, those operating at 2,400 bit/s, 4,800 bit/s and 48 kbit/s, will be connected to the p.s.e. by direct circuits. A possible future requirement is for 2,400 bit/s and 4,800 bit/s packet terminals to access the p.s.e. via the p.s.t.n.

Size of the System

Table 1 shows the numbers and types of data terminals which can be connected to the p.s.e.s. Initially, the Man-

TABLE 1

Number and Types of Terminals Served at each P.S.E.

Type of Data Terminal	Data Rate (bit/s)	Number of Terminal Connexions		
		London P.S.E.	Manchester P.S.E.	Glasgow P.S.E.
Character:				
Tariff H	50	3	2	2
Telex Dial-Up	50	6*	6*	6*
Tariff J	110	6	4	4
Direct (Modem Interface)	110/300	12	6	6
Dial-Up via P.S.T.N.	110/300	51*	26*	26*
Packet:				
1	2,400/4,800/9,600	24	16	16
2	48,000	6	2	2
Inter-P.S.E. Trunks	48,000	6	6	6

* Figures relate to the number of p.s.e. input-ports. The number of customers accessing these ports will be determined by the customer traffic. Initially, the customer-to-port ratio will be restricted to 2 : 1.

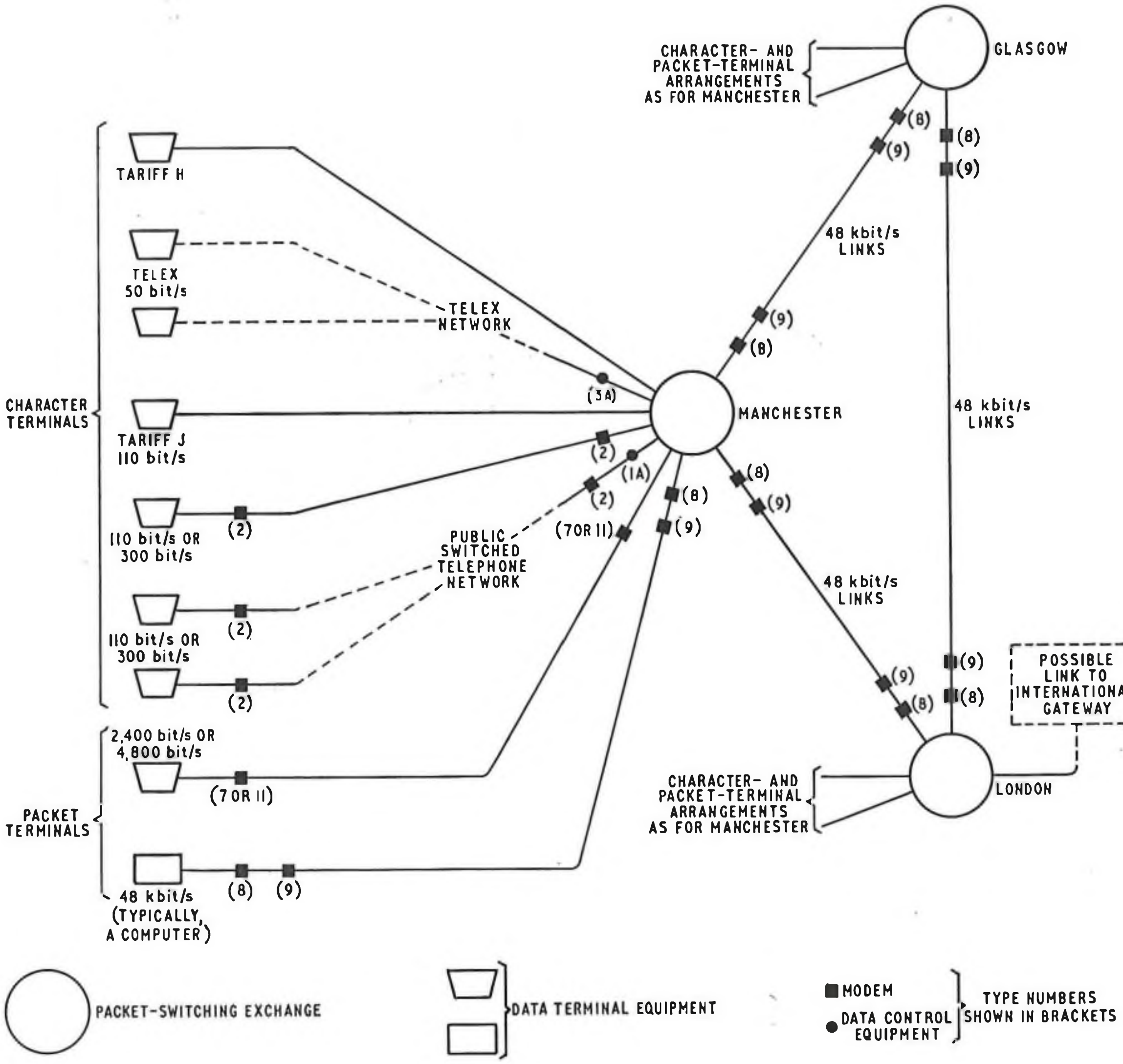


FIG. 1—General network configuration

chester and Glasgow p.s.e.s will accommodate fewer connexions than the London p.s.e., but site plans allow for their extension to the same size as London if this proves to be necessary.

Table 1 also shows the number of inter-p.s.e. link terminations provided at each site. The three p.s.e.s will be fully interconnected by duplicated 48 kbit/s links.

Network Configuration

Fig. 1 shows the general network configuration, and Fig. 2 shows the arrangements at the London p.s.e. in more detail, including the items of Datel equipment.

Numbering Scheme

Ideally, a numbering scheme for a new service should cater for the foreseeable expansion of the service. However, in view of the relatively small number of customers served by the e.p.s.s. and its experimental nature, a simple numbering scheme is also desirable. In order to reduce the need for translation in the billing terminal during processing for billing, traffic recording and other statistical-analysis operations, it may be necessary to include certain special identifiers in each customer's number. For example, depending upon the tariff structure finally proposed for the service, it may be necessary to identify the customer's geographical location, and this could be done by means of an identifier in the number. Also, identification of the speed of operation of a customer's terminal might be required for billing purposes, and would, in any case, be useful for network-management analysis of the traffic flows at various bit rates.

A five-digit numbering scheme is proposed for the e.p.s.s., of the form *AA XYY*, where *AA* identifies the p.s.e. serving the customer, and in addition, may also provide information of the customer's geographical location, *X* could be used to identify the speed of operation of the customer's terminal, and *YY* identifies the particular terminal.

On the e.p.s.s., the called-customer's number will be indicated in the address field of the packet-header associated with call-originating (format 1) packets.[1] The address field occupies bytes* 7–12 inclusive of the header. The actual part

* A byte is an eight-bit character.

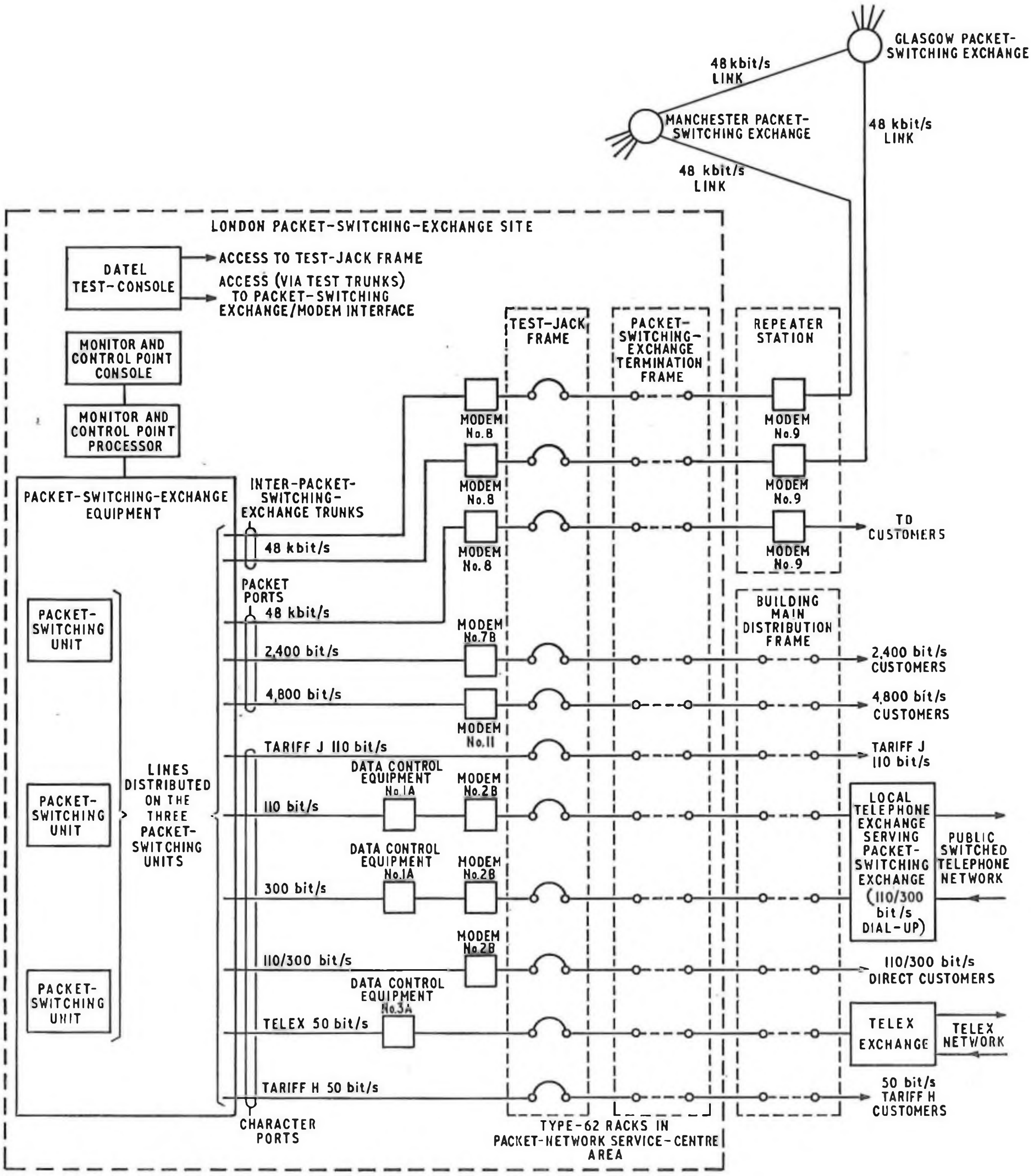


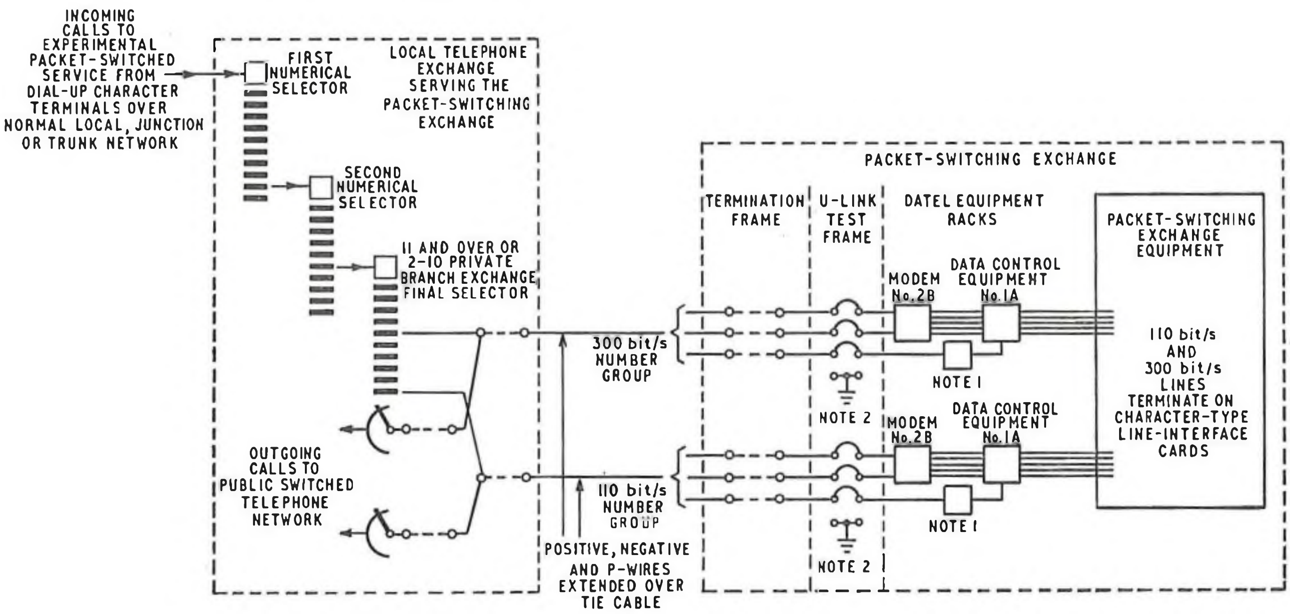
FIG. 2—Details of the London p.s.e.

at present allocated for the customer's number extends over $2\frac{1}{2}$ bytes, that is, five semi-bytes or 20 bits, and will cater for a five-digit number. However, the three semi-bytes preceding this are, at present, unallocated, and could be used to extend the numbering scheme to eight digits, if so required.

The last three semi-bytes in the address field are known as the process field. In the case of packet terminals, three-digit process numbers in the address field of the call-originating packet[1] may be used by a calling terminal to indicate the particular process required at the called terminal. Typically, where the called terminal is a computer, the process number might select access to a particular program facility, or peripheral device, served by the computer. This facility, which is quite separate from the e.p.s.s. numbering scheme, allows identification of up to 1,000 processes by packet terminals.

Access via the P.S.T.N.

To enable character terminals to access the p.s.e. via the p.s.t.n., final-selector numbers on a telephone exchange adjacent to the p.s.e. have been allocated. Separate final-selector numbers are used for customers working at 110 bit/s



Note 1: This modification to Data Control Equipment No. 1A reduces the risk of call-collision between outgoing and incoming calls. It will consist of an additional card for gating circuit 203 to the ON condition when the P-wire is earthed

Note 2: Backward-busying of incoming p.s.t.n. lines is effected by applying an earth to the P-wire at the U-links

FIG. 3—Bothway exchange lines providing access to the p.s.e. from the p.s.t.n. for 110 bit/s and 300 bit/s character terminals

from those working at 300 bit/s. A typical arrangement is shown in Fig. 3.

The method chosen must give full flexibility in the choice of the ultimate tariff structure for the service, since one of the objectives of the experiment is to enable methods of charging for packet switching to be assessed. For the first year of the experimental service, p.s.t.n. access charges will be at the local-call rate, so that it will be necessary to rebate customers accessing from outside the local-call area. A separate system within the p.s.e. will provide information from which the difference between local-call-rate charges and charges recorded on customers' local-exchange meters can be calculated.

The charges to be levied for p.s.t.n. access after the first year of the experiment have not yet been determined, but with the information-gathering facility provided at the p.s.e., it should be possible to cater for any p.s.t.n. access charging requirement, although rebates to customers may still be necessary.

The method of p.s.t.n. access used for the e.p.s.s. has the advantage of being simple to implement. With an expanded packet-switching service, a different method of access may prove more suitable; for example, the use of a special s.t.d. code for the e.p.s.s. However, in determining a different method, account will have to be taken of the eventual tariff structure and the cost of implementation.

EQUIPMENT INSTALLED AT P.S.E. SITES

The equipment to be provided at each p.s.e. site falls into three main categories. They are

(*a*) processors and associated equipment, including packet and character line-cards, interfacing to the Datel equipment,
(*b*) Datel equipment, and
(*c*) packet-switching-network control equipment.

The proposed floor plan for equipment at the London p.s.e. is shown in Fig. 4.

The London p.s.e. equipment comprises three packet switching units (p.s.u.s). Each p.s.u. consists of two processors, duplication being necessary to meet the reliability requirement. At Manchester and Glasgow, only two p.s.u.s are provided, and there is no duplication of processors, although both installations have been designed and planned so that they can be upgraded to the same reliability level as the London p.s.e. should this prove to be necessary. By installing an additional p.s.u. and additional Datel equipment, the Manchester and Glasgow p.s.e.s could be increased in size to have the same capacity as the London p.s.e.

Equipment Accommodation Requirements

The p.s.u.s for the London site each consist of four racks, each rack being 1·8 m high, 600 mm wide and 780 mm deep. The four racks are bolted together to form an assembly 1·8 m high, 2·4 m wide and 780 mm deep, which, after factory testing, will probably be moved to the site as an integral unit. The p.s.u.s for the provincial sites have one rack less than the London p.s.u.s since only one processor is provided. Therefore, they form integral units 1·8 m high, 1·8 m wide and 780 mm deep. The assemblies are totally enclosed in cabinet form, with large doors providing access to each individual rack in the assembly.

The processor equipment would normally be cabled from below floor level, as this would have provided a neater initial layout. However, the use of false floors has been avoided, since problems could be experienced if it was decided to extend the installation. Cables from the bottom of the equipment will be taken up to the normal overhead-rack level on risers in spaces between individual p.s.u.s.

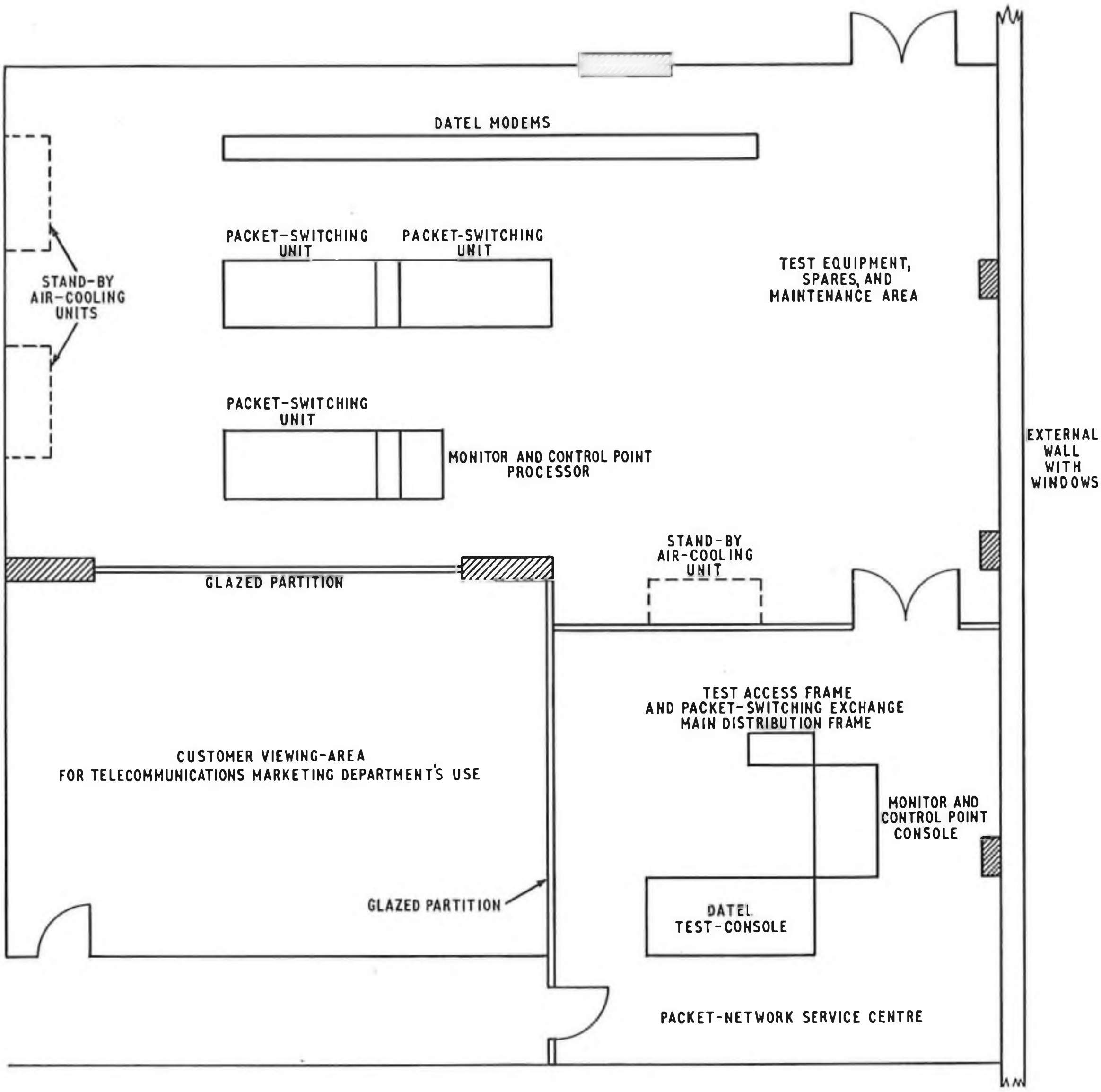


FIG. 4—Floor layout for the London p.s.e.

The B.P.O. Datel equipment will be mounted on standard 62-type racks, 2·74 m high, and overhead cabling will be carried on grids or trunking.

Air Conditioning

The estimated power dissipation at the three sites is shown in Table 2.

Although the existing exchange air-cooling plant can cope with the heat generated, the reliable operation of the p.s.e. equipment at the London site cannot be guaranteed if a failure of the air-cooling plant occurs and gives rise to an excessive increase in the ambient temperature. Stand-by air-cooling plant is, therefore, being provided at London. This will only operate in the event of failure of the main air-cooling plant, and consists of three cooling units on the p.s.e. floor,

TABLE 2

Power Dissipation of P.S.E. Equipment

P.S.E. Site	Power Dissipation (kW)					
	P.S.U.	P.S.E.	Datel Equipment	Monitor and Control Point		Total
				Processor	Console	
London	3·1	3 × 3·1 = 9·3	5·6	1·0	0·4	16·3
Glasgow/Manchester	2·4	2 × 2·4 = 4·8	3·6	1·0	0·4	9·8

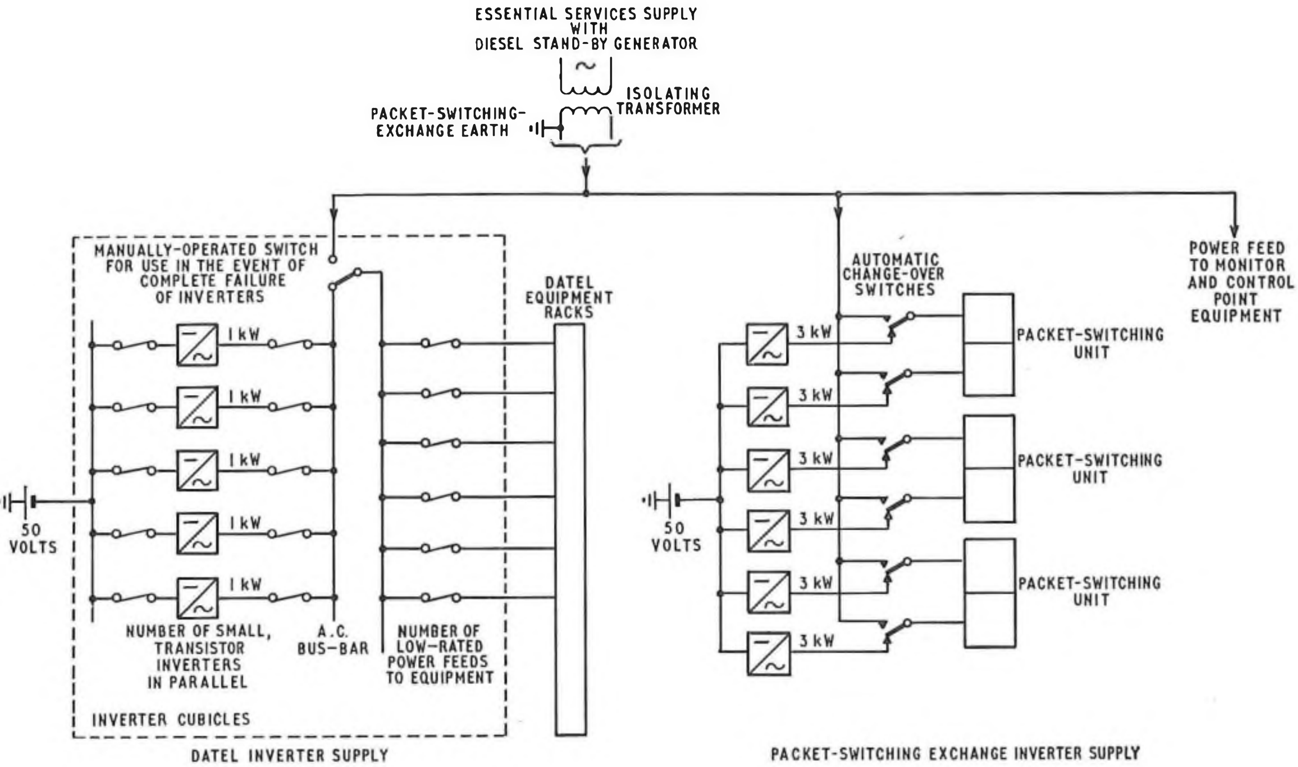


FIG. 5—Power supplies

supplied from a water-chiller on the roof of the building. At Manchester and Glasgow, the heat generated is less, due to the smaller quantity of equipment being installed, and it may be unnecessary to provide stand-by air-cooling plant until the size of these installations is increased.

Power Supplies

The p.s.e. equipment, and the B.P.O. Datel modems, are both designed to operate from 240-volt, a.c., single-phase, 50 Hz supplies.

Due to the importance of the experiment, in particular the fact that it is an operational trial involving customers, the risk of breakdown because of mains failures is unacceptable. To avoid this possibility, the equipment will be powered from the −50-volt exchange battery supply via d.c./a.c. inverters.

The contractor plans to use individual 3 kW thyristor-based inverters to supply each processor, so that, in the event of a failure of one inverter, the p.s.e. would continue to operate.

The B.P.O. inverter system, being developed for the Datel equipment, will use banks of smaller, 1 kW, transistor inverters, feeding a common a.c. bus-bar. Failure of one inverter will not affect the supply, the other inverters maintaining the load. Distribution from the a.c. bus-bar to the Datel equipment racks is via a number of lower-rated, individually-fused cables, thereby ensuring that faults on the load will have minimum surge effects on the inverter supplies.

All inverter equipment will be accommodated in power rooms remote from the p.s.e. This will reduce −50-volt bus-bar lengths and possible interference. If problems arise with the inverter supply, the facility is provided to change-over to the building's essential-services mains supply. This, in turn, is covered by a change-over to a diesel-generator supply, within 20 s, in the event of failure of the public mains supply.

Fig. 5 shows a simplified diagram of the power-supply arrangements. The monitor and control point (m.c.p.), and its associated processor, will be fed directly from the essential-services supply. Test sockets will be powered from the same supply as their associated processor. All power feeds will pass via a single isolating transformer in order to separate the public mains neutral bus-bar from the p.s.e. inverter-earthing arrangement.

Maintenance Equipment

A packet-network service centre (p.n.s.c.) is to be provided at each site as the focal point for the maintenance of the system, and will enable experience of maintenance problems to be gained.

Within the p.n.s.c., a m.c.p. console will be provided, consisting of a visual-display unit, with a conventional keyboard and screen display, and a printer for producing hard copies of screen contents as required. Faults within the p.s.e., or system faults detected by the p.s.e. itself, will be processed by the m.c.p. processor, which is an additional processor located adjacent to the p.s.u.s, and information will be transmitted to the m.c.p. console. Diagnostic functions, and control of the system, will be performed from the m.c.p. keyboard. Normal *urgent* and *non-urgent* alarm conditions, to cover certain faults, will be extendible from the m.c.p. to other floors as required. Testing of Datel lines and equipment will be effected from the Datel test-console located within a p.n.s.c. area.

All lines to the p.s.e. will pass via the p.n.s.c., the tie cables from building main distribution frames and the repeater station terminating on a distribution frame within a

1·8 m high, 62-type rack in the p.n.s.c. This will provide a jumpering flexibility point, enabling any pair to be associated with a particular modem (see Fig. 2). The circuits will then pass through a test-access frame in an adjacent 1·8 m high, 62-type rack, where they can be intercepted for testing or patching purposes, and, from there, will be cabled to the modem racks in the p.s.e. room. Backward busying of incoming p.s.t.n. lines will be effected by means of U-links at the test-access frame.

Four-wire, and 25-way, test trunks will appear on the test-access frame, and on the modem racks in the p.s.e. room. This will enable remote testing of modems from the Datel test-console, or the patching-out of faulty modems, if required. Certain tests require direct access to modems, and for this purpose, portable test equipment will be provided. The 104·08 kHz group-reference pilot alarms on the inter-p.s.e. group-links will be extended to the Datel test-console.

The p.s.e. site will be provided with the following items of test equipment, either mounted on the Datel test-console, or in portable form:

(*a*) a level measuring set and oscillator with variable attenuator,
(*b*) interruption and impulse-noise detectors,
(*c*) Datel testers for Modems Nos. 2 and 7 (one to be rack-mounted and one portable),
(*d*) a Datel tester for Modems Nos. 8 and 9,
(*e*) a digital voltmeter,
(*f*) an oscilloscope,
(*g*) a psophometer,
(*h*) a group-delay measuring set, and
(*i*) a telegraph-distortion measuring set.

BILLING AND NETWORK-MANAGEMENT TERMINAL

The basic data required for the billing of calls, that is, calling- and called-customers' identities, call duration, and number of packets transmitted, for each call, will be stored on magnetic drums at the p.s.e. Information required for traffic analysis and other network-management functions will be similarly stored.

A billing terminal is being provided, situated remotely from the p.s.e. The terminal will gain access to the information stored in the p.s.e. via a 2,400 bit/s packet link. Initially, this data will be processed directly by the billing terminal to produce information in a hard-copy form that can be used by clerical staff to produce customers' bills. If the service expands, it may be necessary to mechanize these processes.

THE FUTURE

If packet switching proves to be technically and economically viable, and if further demand for the service arises, expansion of the network might be called for. However, expansion based on the exchange design adopted for the experimental service may not be the best economic solution for a national public packet-switched service. Recognizing that only limited interconnexion is likely to be required, an interim solution might be to provide a number of networks of the e.p.s.s. type. Each network would be of limited capacity, and would serve terminals dedicated to a particular customer, or shared between a number of customers.

Plans are well advanced for the introduction of digital transmission links which will be used to provide a range of private circuit digital data services. When these facilities become available, it will be possible to interconnect p.s.e.s using digital transmission equipment, and thus eliminate the digital-to-analogue and analogue-to-digital conversion which arises from the use of standard Datel circuits. Economies will result from the use of digital transmission, and improved performance will be achieved. Similar arrangements could be used for the connexions from the customers' premises to the p.s.e.

A number of countries now have plans for providing public packet-switched networks, and the need for international interworking will arise. Connexion to overseas public packet-switched networks could be via a special gateway p.s.e., located in London. Unfortunately, at this point in time, there is little standardization in the procedures and protocols adopted in packet-switched networks, and interworking problems have still to be resolved.

Reference

[1] Belton, R. C., and Smith, M. A. Introduction to the British Post Office Experimental Packet-Switching Service (E.P.S.S.). *P.O.E.E.J.*, Vol. 66, p. 216, Jan. 1974.

The Latest Modem for the Datel 600 Service—Datel Modem No. 1F

A. R. PUGH, B.SC.(ENG.)†

U.D.C. 621.394.4:621.376.3:681.327.8

This article describes the operation and performance of the latest modem for the Datel 600 Service, the Datel Modem No. 1F, and details the interchange circuits between the modem and the data terminal equipment.

INTRODUCTION

The Datel Modem No. 1F provides facilities for the transmission of binary d.c. data signals over the public switched telephone network (p.s.t.n.) or private leased circuits. A modem consists of a modulator and demodulator, from whence the word is derived. The modulator accepts the binary d.c. data signals from the data terminal equipment (d.t.e.) and converts them into voice-frequency (v.f.) signals suitable for transmission over British Post Office (B.P.O.) lines. The demodulator accepts the incoming v.f. signals from line and converts them back into d.c. signals for processing by the d.t.e. The interconnexions between the modem and the d.t.e. are called interchange or interface circuits, and are described in more detail later in this article.

DATEL MODEM NOS. 1A–1F

Since the introduction of the Datel 600 Service using the Datel Modem No. 1A,[1] revision of the facilities required and advances in component technology have necessitated redesign of the modem. Table 1 briefly details the changes incorporated in the different versions.

The Datel Modem No. 1E was a proprietary equipment, a small quantity being purchased to meet a short-term demand for modems which could not be met from B.P.O. stocks.

TABLE 1
Differences in Modem Versions

Modem Version	Differences in Facilities and/or Construction
1B	Same construction as 1A with the additional facility of an indication of the application of ringing current to the modem. This extra facility was provided by using a lamp signalling unit in the associated telephone and providing an additional relay in the modem.
1C	Facilities as for 1B but with the mechanical construction redesigned on to 62-type equipment construction.
1D	Same construction as for 1C with the additional facility of switching from 4-wire-to-2-wire operation under the control of a button on the associated telephone.
1F	Construction as for 1C and 1D, with the interchange circuits conforming to the latest C.C.I.T.T.* Recommendation V23 and redesign of 1D circuitry to use silicon semiconductors.

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

† Telecommunications Development Department, Telecommunications Headquarters.

TRANSMISSION RATES

The Datel Modem No. 1F provides facilities for transmission at rates up to 600 or 1,200 bit/s, the selection of the lower or higher rate being governed by the condition applied to one of the interchange circuits by the d.t.e. The transmission rate is limited by the attenuation/frequency and group-delay/frequency characteristics of the connexion between the transmitter and receiver and by noise and listener echo. The bandwidth required for 600 bit/s operation is approximately 600 Hz and that for 1,200 bit/s, 1,200 Hz, neither of these fully occupying the nominal available bandwidth of 300–3,400 Hz. However, this bandwidth is not fully available for data transmission due to the presence of in-band signalling systems. Some trunk signalling systems use frequencies in the band 450–900 Hz and continuous frequencies must not occur in this band. Other systems use the band 2,130–2,340 Hz, but, in this case, signals can exist in the band provided they are accompanied by other signals not less than 12 dB lower in level, in the band 1,000–2,000 Hz. Therefore, the effective bandwidth available for data transmission is divided up into two bands of 300-450 Hz and 900–2,300 Hz.

Since there are two bands available, it is possible to use two transmission rates simultaneously, one in each of the bands, but, due to the restricted bandwidth, the lower band can only be used for low-speed transmission, in this case, 75 bit/s.

The 600/1,200 bit/s channel is commonly referred to as the forward or data channel and the 75 bit/s channel as the backward or supervisory channel.

MODULATION PROCESS

The modulation process used in the Datel Modem No. 1F is frequency-shift keying (f.s.k.). For the forward channel, a binary 1 condition (−3 to −25 volts d.c.) applied to a particular interchange circuit results in the emission of a line signal of a frequency of 1,300 Hz. This frequency is emitted whether the modem is operating at 600 or 1,200 bit/s. When a binary 0 condition (+3 to +25 volts) is applied, a line signal of frequency 1,700 Hz is emitted when operating at 600 bit/s and 2,100 Hz for 1,200 bit/s operation.

The corresponding frequencies for the backward channel are 390 Hz and 450 Hz for the binary 1 and binary 0 conditions, respectively.

MODEL NUMBERS

To provide the transmission and reception facilities for the two channels, two modulators and two demodulators are required, these being the Data Modulator No. 3 and the Data Demodulator No. 3 for the forward channel and the Data Modulator No. 4 and the Data Demodulator No. 4 for the backward channel.

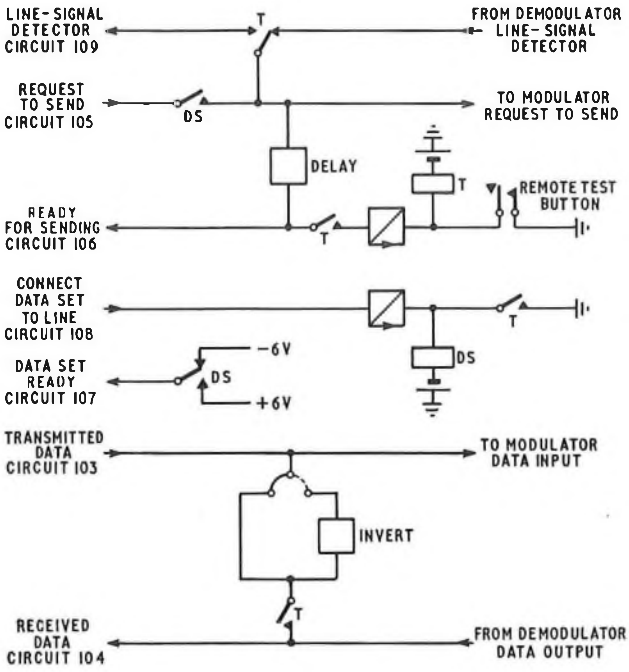


FIG. 1—Control unit—control circuits

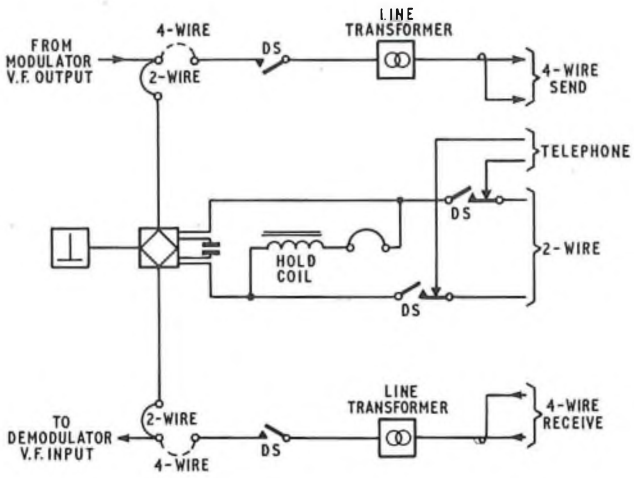


FIG. 2—Control unit—line-switching circuits

The various facilities are provided by using combinations of these modulators and demodulators and are identified by a model number. The model numbers and their facilities are as detailed in Table 2.

The various model numbers are obtained by inserting the appropriate modulator and demodulator into a data main unit, the latter consisting of a case, a power unit and a control unit.

TABLE 2

Model Number	Transmitted Bit Rate	Received Bit Rate
3	600/1,200 bit/s	75 bit/s
4	75 bit/s	600/1,200 bit/s
5	600/1,200 bit/s	600/1,200 bit/s

DESCRIPTION OF UNITS COMPRISING THE MODEM

The various versions of the modem are made up from a data main unit and various combinations of modulators and demodulators. A broad outline description of the methods used to provide the facilities associated with each item is given below.

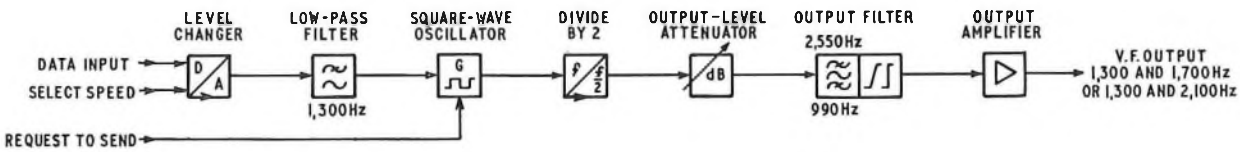


FIG. 3—Block diagram of Data Modulator No. 3A

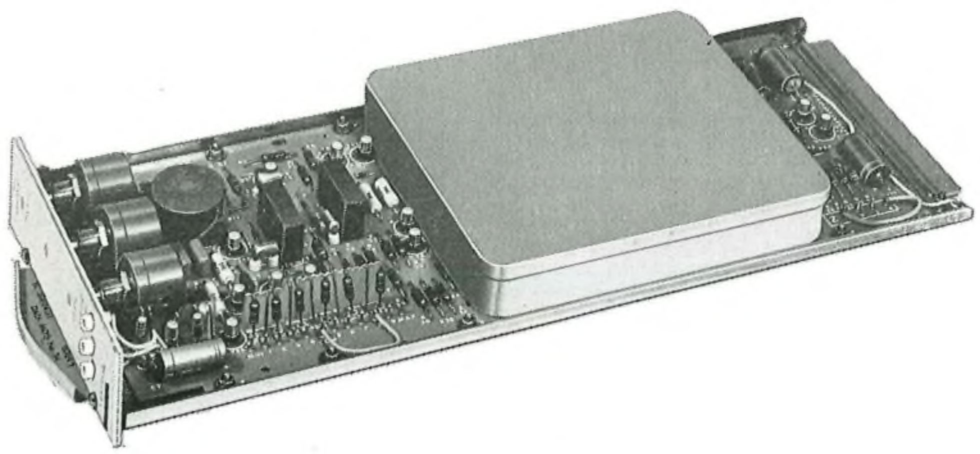


FIG. 4—Data Modulator No. 3A

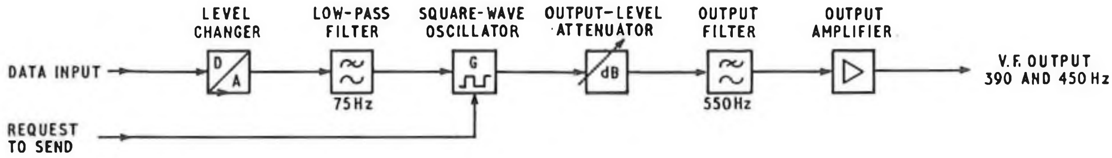


FIG. 5—Block diagram of Data Modulator No. 4A

Data Main Unit

This consists of a power unit, a control unit and a case. The case provides the inter-unit wiring, the terminating blocks for the telephone and line cords and the interface socket.

The power unit provides the d.c. supplies for the other units and a supply for a local-battery telephone when necessary.

The power unit operates from a.c. mains supplies with applied voltages in the range 200–250 volts and frequencies in the range 45–60 Hz.

The control unit, shown in Figs 1 and 2, provides the line-switching and terminating arrangements associated with the 4-wire and 2-wire line connexions and, also, to the control and logic functions associated with the interchange circuits.

Data Modulator No. 3A

The Data Modulator No. 3A (see Figs. 3 and 4) converts the binary data signals from the d.t.e., at rates up to either 600 bit/s or 1,200 bit/s, into v.f. signals for transmission to line.

The three line frequencies are derived from a voltage-controlled multivibrator which runs at twice the desired frequency. The output from this multivibrator is fed to a divide-by-two circuit which reduces the even harmonics and then the signal is fed through a variable attenuator which is used to set the required output level. The output is variable over the range +7 to −13 dBm in 2 dB steps. From the attenuator, the signal passes through a bandpass filter of bandwidth nominally 990–2,550 Hz and, thence, through an amplifier and to line via the control unit.

Data Modulator No. 4A

The Data Modulator No. 4A converts the binary data signals from the d.t.e. at rates up to 75 bit/s, into v.f. signals for transmission to line and a block diagram is shown in Fig. 5.

The line frequencies are derived from a voltage-controlled multivibrator, but, in this case, the multivibrator runs at the desired frequency. The output of the multivibrator passes through a variable attenuator to a 550 Hz low-pass filter and then to an output amplifier.

Data Demodulator No. 3B

The Data Demodulator No. 3B accepts the incoming v.f. signals from the line and converts them back into nominally rectangular binary data signals which are passed to the d.t.e. A block diagram of the demodulator is shown in Fig. 6.

The incoming signals are passed through a 10 dB matching pad to a bandpass filter, nominally 920–2,400 Hz bandwidth, to remove the out-of-band signals and minimize the noise introduced into the demodulator. From this first filter, the received signal is fed through a second stage of filtering, the bandwidth of which is nominally 1,260–1,740 Hz for 600 bit/s operation and nominally 1,160–2,420 Hz for 1,200 bit/s operation. The signal is then amplified, amplitude modulated by a 10 kHz oscillator and the upper sideband selected by means of another band-pass filter of nominal bandwidth 11,130–12,450 Hz.

The signal is then fed into a limiting amplifier from which two outputs are taken. One output is fed to an amplitude-sensing circuit and then to a level-switching circuit to provide the output conditions on circuit 109. The other output is fed to a discriminator which converts the constant-amplitude varying-frequency signal to one having a varying amplitude. The signal is then rectified and passed to a post-discriminator filter (p.d.f.) which removes any residual carrier components. The varying d.c. signal output of the p.d.f. is then squared-up by a high-gain amplifier and passed to the d.t.e. on circuit 104. The output of circuit 109 is also fed into this amplifier so that the optional facility of having the received data clamped to binary 1 when circuit 109 is OFF can be provided.

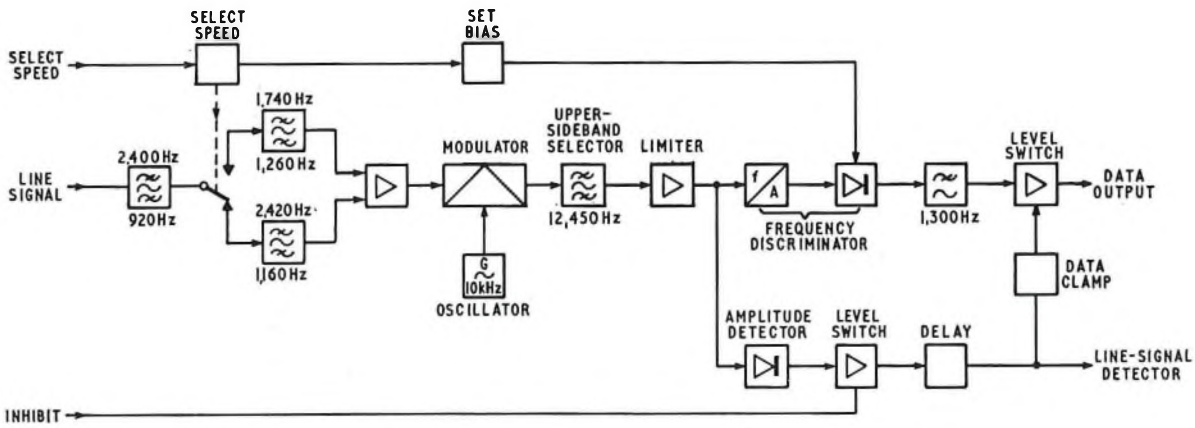


FIG. 6—Block diagram of Data Demodulator No. 3B

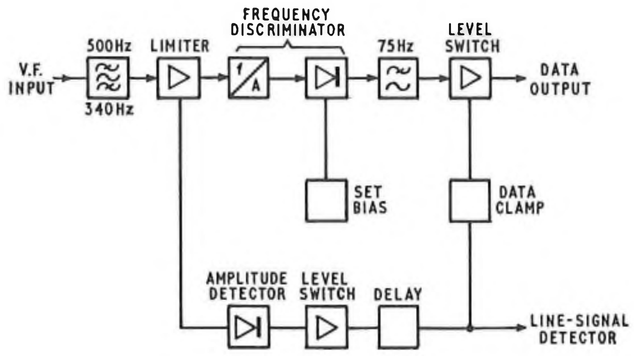


FIG. 7—Block diagram of Data Demodulator No. 4B

Data Demodulator No. 4B

The Data Demodulator No. 4B (see Fig. 7) provides the same facilities as the Data Demodulator No. 3B but operates at 75 bit/s.

The incoming v.f. signals are passed through a 10 dB matching pad and a bandpass filter, having a nominal bandwidth of 340–500 Hz, to a limiting amplifier from which two outputs are taken. One output is taken to an amplitude-detecting circuit and then to a level-switching circuit to provide the output conditions on circuit 122. The other output of the limiter is fed into a discriminator which converts the varying-frequency signal into an amplitude-modulated signal. This signal is then fed to the p.d.f. which removes any v.f. signals and the output is passed to the output amplifier where it is squared-up and connected to the d.t.e. on circuit 119.

INTERCHANGE CIRCUITS

The connexions between the modem and the d.t.e. are called the interchange circuits, these circuits and their characteristics being defined by C.C.I.T.T. Recommendation V23 and are assigned a unique number. The circuits used with the forward and backward channels are detailed in Tables 3 and 4.

The modem can be used on private circuits, 2-wire or 4-wire presented, and over p.s.t.n. circuits. C.C.I.T.T. recommend certain interchange circuits for use on private circuits and the p.s.t.n., these being selected from those detailed in Tables 3 and 4 and the allocation of interchange circuits to model number and type of connexion is shown in Table 5.

The functions of the interchange circuits are detailed below.

Circuit 102—Common Return

This circuit is the reference for all the other circuits.

Circuit 103—Transmitted Data/Circuit 118—Transmitted Backward-Channel Data

The data which are to be transmitted are fed into the modem on this circuit from the d.t.e.

Circuit 104—Received Data/Circuit 119—Received Backward-Channel Data

The data which have been received are fed into the d.t.e. from the modem on this circuit.

Circuit 105—Request To Send/Circuit 120—Transmit Backward-Channel Line Signal

The signals on this circuit control the modulator functions. The ON condition, nominally +6 volts, causes the modulator to be switched on and the OFF condition, nominally −6 volts, causes it to be switched off.

Circuit 106—Ready For Sending/Circuit 121—Backward-Channel Ready

The signals on this circuit indicate whether or not the modem is ready to transmit data. The ON condition indicates that the modem is able to transmit data whilst the OFF condition indicates that the modem is unable to transmit.

Circuit 107—Data-Set Ready

The conditions on this circuit indicate whether or not the modem is connected to line. The ON condition indicates connexion and the OFF condition disconnexion.

Circuit 108/1—Connect Data Set to Line

The signals on this circuit control the switching of the modem to and from line. The ON condition connects the modem to line and the OFF condition disconnects it.

Circuit 108/2—Data-Terminal Ready

The signals on this circuit control the switching of the modem to and from line. The ON condition, which indicates that the data terminal equipment is ready to operate, prepares the modem for connexion to line. When the modem is used with the automatic-answering facility, connexion to line only occurs in response to the combination of the ON condition on this circuit and on circuit 125. When used in the manual-answering mode, connexion only occurs in response to the combination of the ON condition on circuit 108/2 and the connexion of a loop of resistance less than 300 ohms between two of the terminals on the block terminal at the rear of the modem.

The OFF condition causes the modem to be disconnected from line.

TABLE 3

Forward (600/1,200 bit/s) Channel

C.C.I.T.T. Circuit Number	Circuit Title
102	Common Return
103	Transmitted Data
104	Received Data
105	Request to send
106	Ready for Sending
107	Data-Set Ready
108/1 or	Connect Data Set to Line
108/2	Data-Terminal Ready
109	Data Channel Received Line Signal Detector
111	Data-Signalling-Rate Selector
125	Calling Indicator

TABLE 4

Backward (75 bit/s) Channel

C.C.I.T.T. Circuit Number	Circuit Title
102	Common Return
107	Data-Set Ready
108/1 or	Connect Data Set to Line
108/2	Data-Terminal Ready
111	Calling Indicator
118	Transmitted Backward-Channel Data
119	Received Backward-Channel Data
120	Transmit Backward-Channel Line Signal
121	Backward-Channel Ready
122	Backward Channel Received Line Signal Detector
125	Calling Indicator

TABLE 5

Allocation of Interchange Circuit to Model Number and Type of Connexion

Interchange Circuit for Model 3		Interchange Circuit for Model 4		Interchange circuit for Model 5	
Private Circuit	P.S.T.N.	Private Circuit	P.S.T.N.	Private Circuit	P.S.T.N.
102	102	102	102	102	102
103	103	104	104	103	103
105		107	107	104	104
106	106	108/1	108/1 or 108/2	105	105
107	107	109	109	106	106
108/1	108/1 or 108/2	111	111	107	107
111	111	118	118	108/1	108/1 or 108/2
119	119	120	121	109	109
122	122	121	125	111	111
	125				125

Circuit 109—Data Channel Received Line Signal Detector/ Circuit 122—Backward Channel Received Line Signal Detector

The signals on this circuit indicate whether the received data channel signal level is within certain limits, the ON condition indicating that the level is within limits, the OFF condition indicating that it is outside limits. The circuit switches to the OFF condition when the received line signal level falls to −48 dBm and restores to the ON condition before the level has restored to −43 dBm, but with a 2 dB hysteresis on the level at which the circuit switches.

To prevent false operation to short line breaks and noise pulses, this circuit responds to the average level of the received line signal.

Circuit 111—Data-Signalling-Rate Selector

The signals on this circuit control the data signalling rate. The ON condition causes the modem to operate in the 1,200 bit/s mode, and the OFF condition in the 600 bit/s mode.

Circuit 125—Calling Indicator

The signals on this circuit indicate whether a calling signal is being received by the modem. The ON condition indicates the presence, whilst the OFF condition indicates the absence of a calling signal.

The equivalent circuit of the interchange circuits is shown in Fig. 8. The interchange circuits defined by C.C.I.T.T.

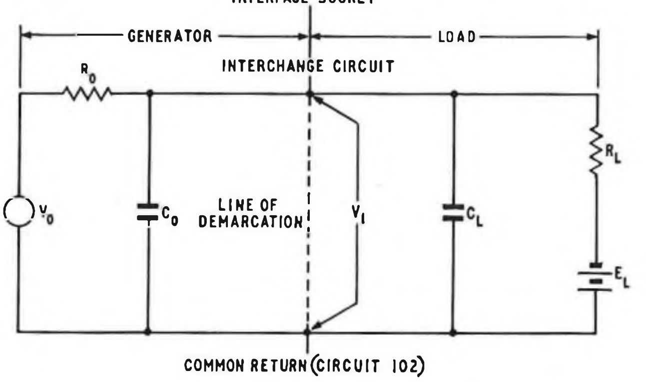


FIG. 8—Equivalent circuit of interchange circuit

Recommendation V24 are operated by nominally ±6 volt signals. On control circuits, +6 volts represents the ON condition and, on the data circuits, it represents the binary 0 condition. On control circuits, −6 volts represents the OFF condition and, on the data circuits, it represents the binary 1 condition. The receiving interchange circuits are designed to respond to input voltages over the range +3 to +25 volts and −3 to −25 volts. The generating interchange circuits are designed to provide a voltage in the ranges +5 to +9 volts and −5 to −9 volts across a receiving circuit whose resistance can be in the range 3,000–7,000 ohms and shunt capacitance in the range 0–4,700 pF.

FACILITIES

As well as providing the interchange circuits between itself and the d.t.e., the modem also provides the following additional facilities:

(*a*) connexion to line via a button on the telephone instead of under the control of the d.t.e.,

(*b*) transmission of data over 2-wire or 4-wire presented circuits,

(*c*) speech path via an associated telephone when the modem is not connected to line, and

(*d*) optional facility to switch from 4-wire to 2-wire operation under the control of a button on an associated telephone.

TYPICAL SEQUENCE OF OPERATION OF A MODEL 3 MODEM ON THE P.S.T.N.

If the calling end, station A, is provided with a model 3 modem and wishes to transfer data to station B, then, clearly, station B must be provided with a model 4 modem. For simplicity, only the operational sequence at station A is considered.

Once the dialled connexion has been established, the modem at either end is connected to line by means of either a button on the associated telephone or the application of an ON condition to circuit 108/1. The condition on circuit 107 then switches from OFF to ON indicating to the d.t.e. that the modem is on line. Circuit 105 is not provided by the d.t.e. and so the ON condition is applied internally within the modem. Hence, as soon as the modem is connected to line, a signal is sent to line. This signal causes circuit 109 to be switched from the OFF to the ON condition after a time delay dependent upon the transmission time of the connexion and the response time of circuit 109 of the modem at station B, provided that the level of the received signal is above the prescribed level. At station A, after the appropriate delay timed from the OFF–ON transition on circuit 107, circuit 106 switches from the OFF to the ON condition, and the d.t.e. then applies the data which are to be transmitted to circuit 103.

The modem at station B also emits a signal as soon as it is connected to line and this switches circuit 122, in the modem at station A, from the OFF to the ON condition. This indicates to the d.t.e. that the conditions appearing on circuit 119 are nominally correct data signals.

At the end of transmission, the operator replaces the handset, or presses a non-locking button which releases the DATA button, or applies the OFF condition to circuit 108/1. Any of these operations disconnects the modem from line.

This operation uses manual answering but the modem can provide automatic-answering, facilities, and the automatic-answering procedures with both circuits 108/1 and 108/2 are described below.

In the *Connect-Data-Set-To-Line* mode, circuit 108/1, the incoming ringing current operates a lamp signalling unit in the telephone associated with the modem which, in turn, applies a d.c. loop to the modem. The application of this loop causes an ON condition to be passed to the d.t.e. on circuit

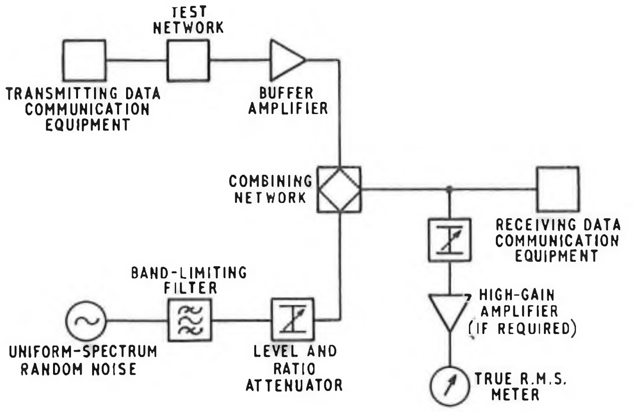


FIG. 9—Block diagram for measurement of error probability

125. If the d.t.e. wishes to answer the incoming call, it applies an ON condition to circuit 108/1 and, at the end of the call, it applies the OFF condition 108/1.

In the *Data-Terminal-Ready* mode the d.t.e. applies the ON condition to circuit 108/2 either before, or during, reception of ringing current. However, connexion to line only occurs when an incoming call is received; that is, coincidence of the ON condition on both circuits 108/2 and 125.

Manual answering is also possible with *Data-Terminal-Ready* operation and, in this case, a non-locking button on the telephone is operated when data transmission is required. If the ON condition exists on circuit 108/2, the modem connects to line, but if the OFF condition exists, it remains off line.

TEST FACILITIES

Since the modem is installed in customers' premises, facilities are provided so that a check can be made from a remote location, a datel test centre (d.t.c.), to ascertain whether or not the modem is faulty.

If the modem is faulty, a call is established from the d.t.c. via the p.s.t.n. to the installation where the suspect modem is located. The modem at the d.t.c. must be compatible with the one to be tested; for example, a model 3 modem to be

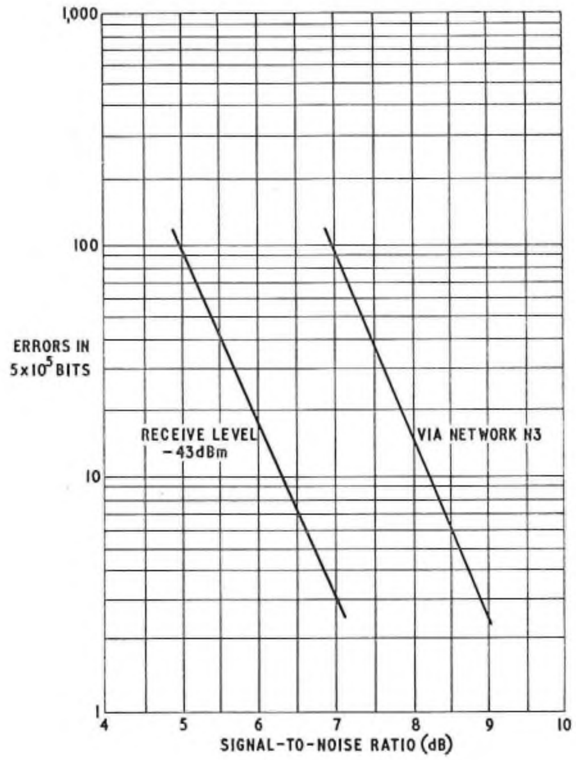


FIG. 11—Error rate for 600 bit/s working

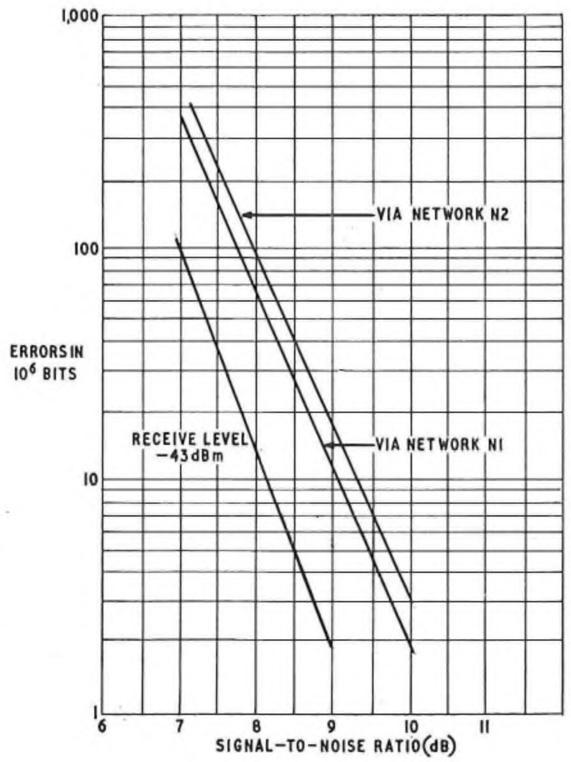


FIG. 10—Error rate for 1,200 bits/s working

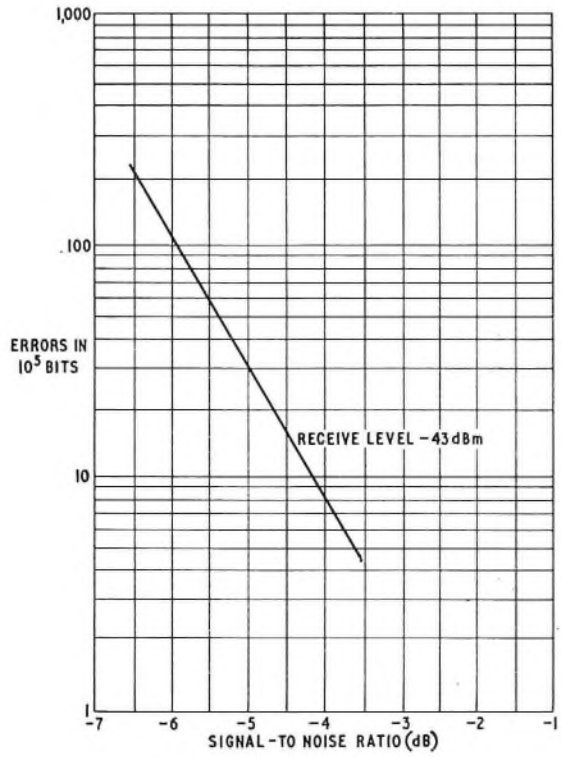


FIG. 12—Error rate for 75 bit/s working

tested requires a model 4 model at the d.t.c. The customer is asked to remove the interface plug from the rear of his modem and, when he hears a tone on the telephone line, to operate a non-locking push button at the rear of the modem. Operation of this button operates relay T, one contact of which operates relay DS, thus connecting the modem to line. The received signal then causes circuit 122 to switch from the OFF to the ON condition. This is then passed via a contact of relay T to the modulator where it is used to condition circuit 105, thus causing the modulator to oscillate. Circuit 119 is connected to circuit 103 via a third contact of relay T, so that the frequency transmitted to line is dependent upon that being received; for example, if the received frequency is 450 Hz, then the transmitted frequency is 1,700 Hz. The ON condition on circuit 106 holds relay T operated via one of the contacts of that relay.

To release the modem from line, the signal from the d.t.c. is removed. Circuit 122 then switches to the OFF condition, causing circuit 106 to be turned OFF and releasing relay T.

When a model 5 installation is tested remotely, the transmitted frequencies are the same as those being received and so a facility is provided such that circuit 104 is connected to circuit 103 via circuitry which inverts the received data. Some of the transmitted signal leaks across the hybrid transformer back into the receiver, and a self-oscillatory state is obtained. The connexion between circuit 106 and the T-relay operate circuit is not, therefore, provided and so the modem remains on line only as long as the test button is held operated. Detection of the self-oscillatory state by the d.t.c. indicates that the modem is functioning.

PERFORMANCE OF MODEM 1F

The two primary parameters of performance of a datel modem are isochronous distortion and error probability.

The degree of isochronous distortion of the forward channel does not exceed 16 per cent when operating at 1,200 bit/s and 8 per cent when operating at 800 bit/s, this performance being met for any received data pattern in the range of receive line signals −5 to −43 dBm. The degree of isochronous distortion of the backward channel does not exceed 5 per cent for the same conditions as the forward channel.

The error probability performance of the modem can be measured under various test conditions which simulate various types of line plant using the test arrangement shown in Fig. 9. The noise level at the input to the receiving modem is set to be the same as that of the signal level so that the signal-to-noise ratio at the input to the modem is 0 dB. The signal-to-noise ratio can then be set directly on the ratio attenuator. Three test networks used are

(*a*) N1, which represents three carrier channels in tandem,
(*b*) N2, which represents 100 miles of standard loaded cable (20/88/1·136), and
(*c*) N3, which represents the nominal characteristics of an extreme connexion involving long junction and trunk circuits on the p.s.t.n.

The error probability is determined over the range of input levels of −5 dBm to −43 dBm by feeding the transmitted signal to the receiving modem via a variable attenuator. Typical results of the error probability tests are shown in Figs 10–12. Fig. 10 shows the results for the forward channel operating at 1,200 bit/s, Fig. 11 shows the forward channel operating at 600 bit/s and Fig. 12 shows the results for the backward channel operating at 75 bit/s.

ACKNOWLEDGEMENT

The units comprising the Datel Modem No. 1F were de-designed by Pye TMC Ltd., and the author wishes to thank them for permission to publish the photograph and the unit descriptions.

References

1 ROBERTS, L. W., and SMITH, N. G. A Modem for the Datel 600 Service. *P.O.E.E.J.*, Vol. 59, p. 108, July 1966.

2 SMITH, N. G., and TRIDGELL, R. H. Performance of the Datel Modem No. 1A. *P.O.E.E.J.*, Vol. 59, p. 250, Jan. 1967.

Book Review

"The Electrical Principles of Telecommunications." R. Lowe, B.Sc., C.Eng., M.I.E.E., M.I.E.R.E., and D. Nave, C.Eng., M.I.E.E. Macmillan. ix + 392 pp. 301 ill. £2·95.

The authors state that this book is intended for three classes of reader: students studying for the City and Guilds of London Institute examinations in Telecommunication Principles B or C, technicians who simply wish to keep themselves up to date, and lecturers of electrical principles with a light-current bias. As so often happens when more than one object is set, none of the objects is satisfactorily achieved.

There are a number of small sections of the Telecommunication Principles B and C syllabuses which have not been covered, and valves and valve amplifiers have not been dealt with at all. Students may find the mixing of the B- and C-year subjects a little confusing, although the beginnings and endings of topics have been marked *B* or *C* for guidance. Overall, the treatment of the subject seems to have been reduced to the bare bones.

The style of writing is easy to read and understand. The figures are well drawn and clearly reproduced. There are many examples, most of which have been taken from City and Guilds of London Institute examinations, and just under half have worked solutions, the others having answers only.

This book, published in paperback form, is unlikely to satisfy those seeking a deep understanding of the subject, but it should prove useful to those preparing to sit the relevant examinations.

R. H.

Steel Masts and Towers in the British Post Office

Part 3—Structural Testing

D. G. CLOW, C.ENG., M.I.MECH.E.†

U.D.C. 624.97.014.2: 624.04.001.41

The final part of this article deals with some of the experimental work which is being carried out on radio masts and towers. The principal object of such work is to verify that structures or their component parts behave as predicted by theory, and as assumed by the designer.

THE NEED FOR STRUCTURAL TESTING

Experimental work is advisable, or even essential, in a number of circumstances, examples being when

(*a*) there is doubt about either the nature of the structural loads, or the structure strength,
(*b*) theoretical methods of analysis cannot be used with confidence, and
(*c*) a practical demonstration of the adequacy of the structure is necessary, especially when a failure could have very serious consequences.

Tests may be carried out on complete structures, on component parts, or on the materials of construction. The principal objective of the work carried out by the British Post Office (B.P.O.) has been to establish the behaviour of actual masts and towers with a view to improving knowledge about the margins of safety, and this, in turn, could lead to useful economies in future designs.

FULL-SCALE TESTING

In view of the objective stated above, full-scale testing is much to be preferred to model testing, the latter being liable to introduce too many variables for the results to be meaningful. Unfortunately, full-scale work is difficult because of the sheer size of the structures involved, difficulties of access for instrumentation, and the problem of finding suitable weather conditions. Usually, it is necessary to have either no-wind conditions, or else a strong wind in a specific direction.

It is rare for suitable structures to become available for tests to destruction, although the prototype of the standard Mast No. 1 was so tested at Rugby Radio Station.[11] All other work has been carried out without the stresses exceeding the permissible values. This restriction has not been a handicap, as recent work has been aimed primarily at determining the behaviour of towers when subjected to dynamic loads such as those imposed by the wind. Effort has been concentrated on measuring the natural frequencies of oscillation of towers, the first mode usually being sufficient, and the determination of the damping present.

There are a number of methods of calculating the natural frequencies of towers, ranging from simple approximations to those requiring expensive computer analyses. The experimental work which has been carried out facilitated the choice, for future work, of the simplest analytical method consonant with acceptable accuracy.

There is no way of predicting structural damping, and published data gave such widely-varying results that the only method available was to test typical structures at B.P.O. radio stations. The damping is measured by exciting the structure, and then recording the decay of vibration. A common method of initiating oscillation is to use a rocket attached to the structure. The B.P.O. have used a motor-driven exciter which enables damping to be measured from a steady-state vibration and permits a much closer control over the energy input to the structure, so eliminating any risk of damage.

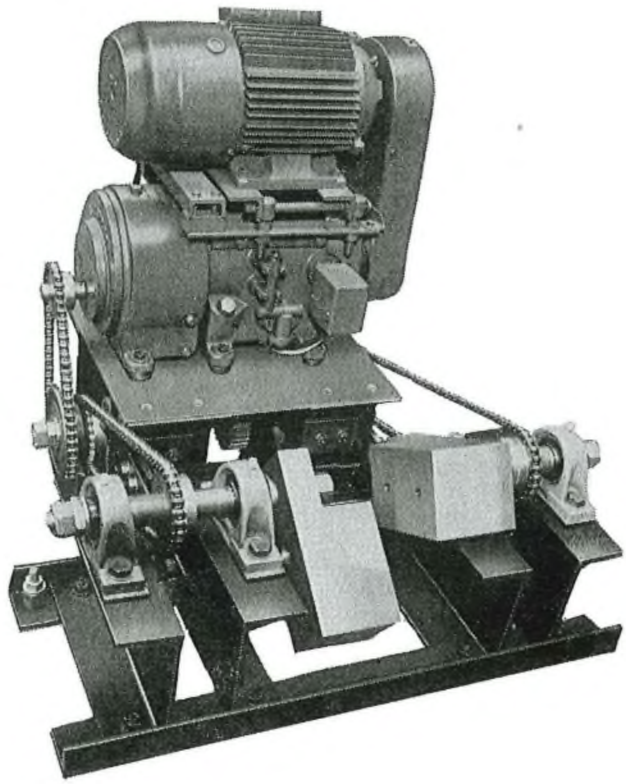


FIG. 22—Vibrator unit

The vibrator is shown in Fig. 22, and consists of a 1·5 h.p. single-phase electric motor, driving contra-rotating weights though a remotely-controlled, variable-speed gearbox. A variety of weights are available to give control over the energy output. The machine weighs 500 lb, and occupies a space 3 foot square in plan and 2·5 ft in height. It can, therefore, be fitted readily to most structures. A pair of contra-rotating weights are positioned such that only a horizontal force is produced, with vertical resultants cancelling out. The maximum centrifugal force which can be applied to the tower is about 300 lbf ft, this being generated at the upper end of the two speed ranges available, namely 0–3·5 Hz and 3·5–10 Hz.

† Operational Programming Department, Telecommunications Headquarters.

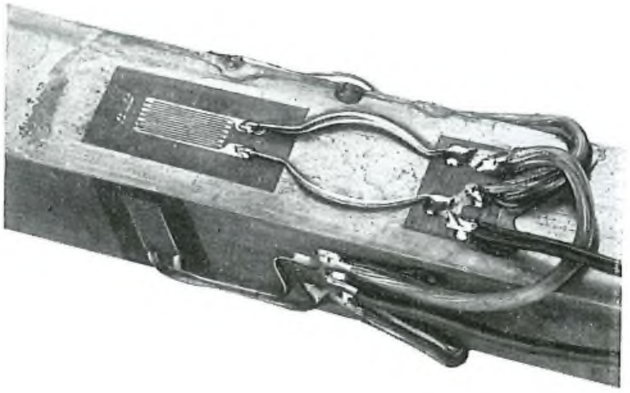


FIG. 23—Electrical-resistance foil strain gauges on ½ in square bar

The damping in a mechanical system is expressed by one, or other, of two non-dimensional quantities, the critical damping ratio β, or the logarithmic decrement δ. The logarithmic decrement is used here and is equal to the natural logarithm of the ratio between two successive amplitudes of the decay of oscillation. When the damping is very small, as is usual on tall structures, then $\delta = 2\pi \times \beta$.

At the time of writing, four towers have been subjected to dynamic-load tests and two of these have also undergone static-load tests. Effort has been concentrated on the dynamic work because of the paucity of information on this aspect.

The ready availability in recent years of two types of transducer has made structural testing much simpler, these being the strain gauge and the accelerometer. From the measurement of strain, stress can be deduced and from acceleration, velocity and displacement can be determined.

Strain Gauges

Various forms of strain gauge exist, but the most generally useful is the electrical-resistance strain gauge which consists of a length of wire or, more commonly, metal foil bonded on to a non-conducting backing. The wire, or foil, is folded back on itself several times in order to increase the sensitivity of the gauge by permitting the use of a long length of conductor within the small overall dimensions of the gauge. The gauge is bonded by a special cement to the surface of the component under test, such that the gauge is strained in the same manner as the test piece (see Fig. 23). The change of length of the test piece under load changes the gauge length, and hence, the resistance of the wire or foil. The change of resistance then gives an indication of the strain according to the relationship

$$\text{strain}\left(\frac{\Delta l}{l}\right) = \text{change of resistance}\left(\frac{\Delta R}{R}\right) \times \text{constant } (K).$$

The constant K is called the gauge factor, and this is quoted for a particular type of gauge by the manufacturer. A Wheatstone bridge circuit is used to measure the resistance change in the gauge. The sensitivity of strain gauges can be very high, with a maximum obtainable with equipment suitable for use in field conditions of a few tens of microstrains.*

Strain gauges cannot normally be used to predict stresses to an accuracy better than ± 5 per cent, even in laboratory conditions, because of variations from the assumed Young's Modulus (E) of the test piece (stress = strain $\times E$), and variability of the gauge performance at the manufacturing and installation stages. Very high accuracy is usually of little practical interest.

Accelerometers

This type of transducer is used in the measurement of vibration and, as the name suggests, it is sensitive to acceleration. There are two types in common use, the inductive and the piezo-electric types. The inductive accelerometer is most

* 1 microstrain = a change in length of 1 millionth part of the original length.

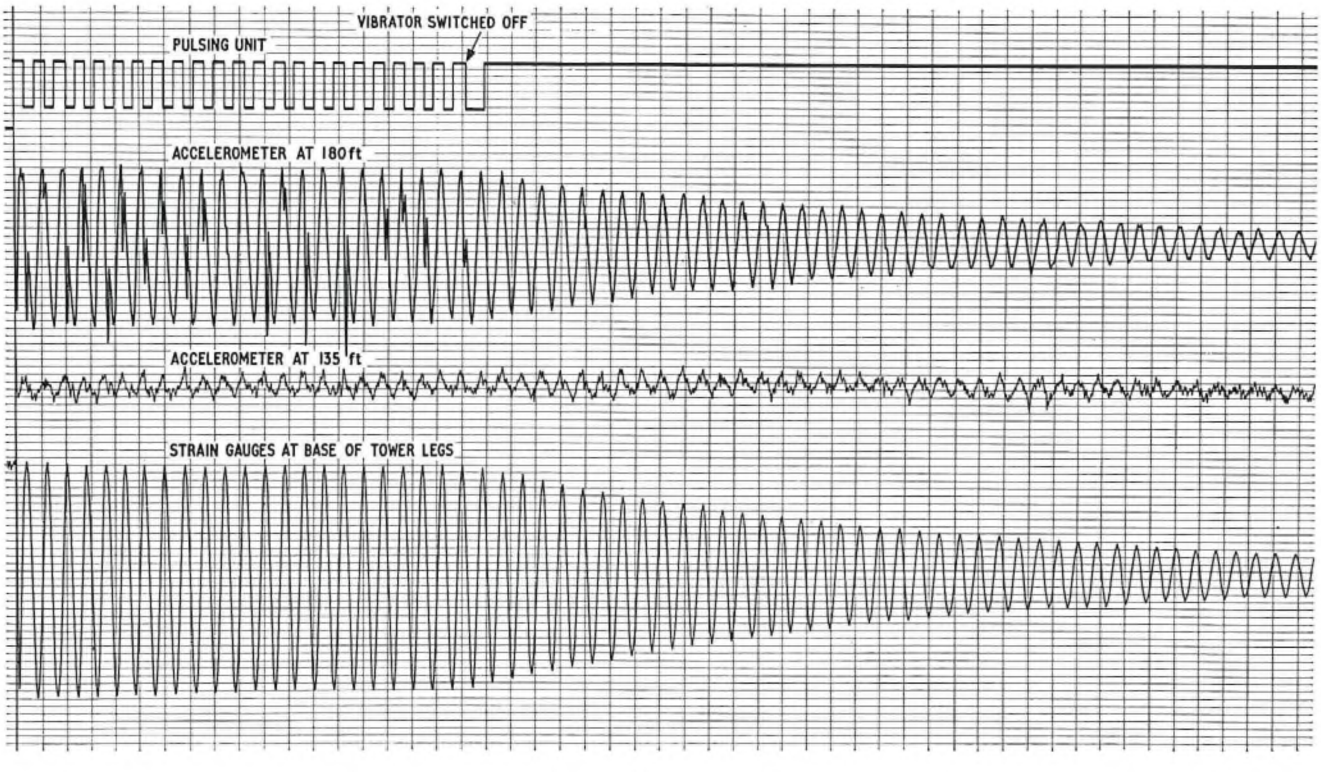


FIG. 24—Typical test recording

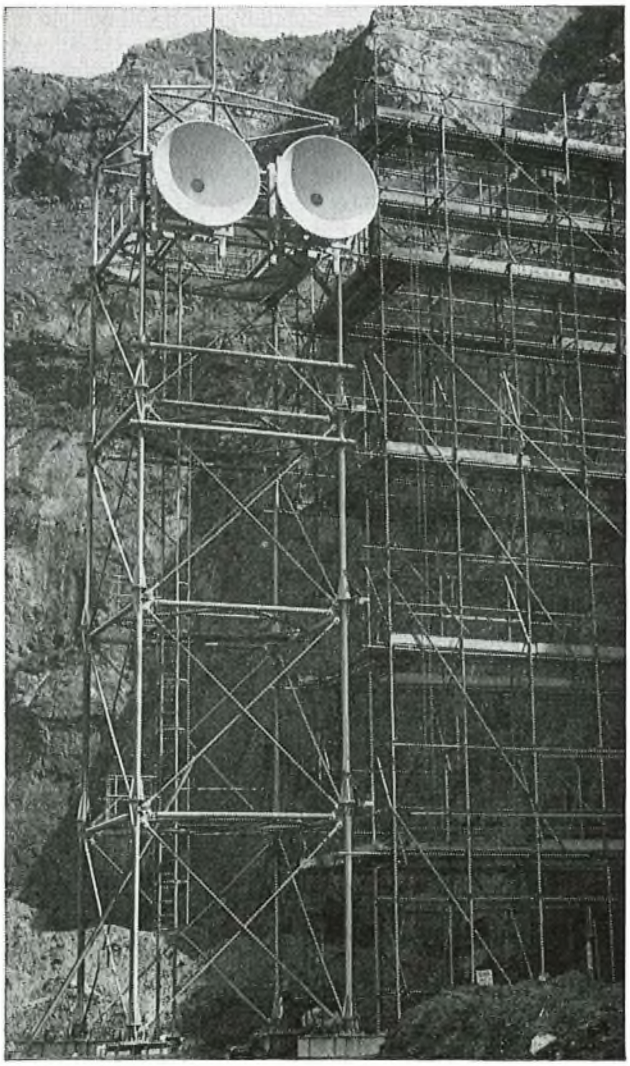


FIG. 25—Tower No. 4A under test

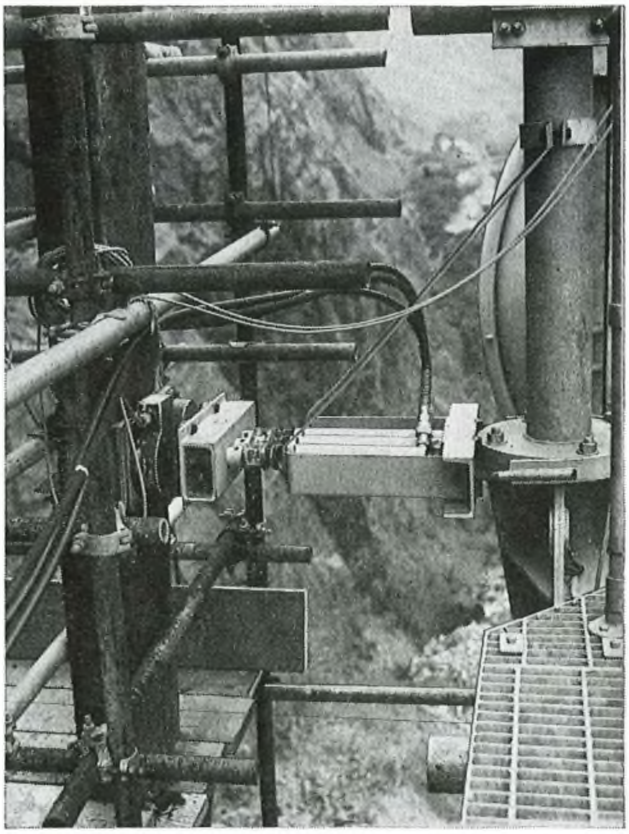


FIG. 26—Hydraulic jacks and load cells between tower and scaffold

suitable for the low-frequency range and has a response down to zero hertz, while the piezo-electric accelerometer is suitable for applications in which very-low-frequency oscillations are not measured.

The inductive accelerometer is a passive device in which the vibration of a suspended mass causes variations in the reluctance of a magnetic circuit. A carrier frequency of several kilohertz is fed into the coils in the device and is amplitude-modulated by any reluctance variation.

The piezo-electric accelerometer has a mass supported on a piezo-electric element and any vibration of the mass produces an electric charge in the element, proportional to the applied acceleration.

An example of the output of accelerometers and strain gauges on a tower undergoing a vibration test is shown in Fig. 24. The exponential decay of oscillation after the vibrator has been switched off is clearly visible. The pulses on the top trace show the speed of rotation of the weights.

TOWER TESTING

Tower No. 4A

A 75 ft high example of the Tower No.4A was not required for immediate use, and the opportunity was taken to subject it to a program of static- and dynamic-load tests. The specification for this work was written such that, firstly, the tower was thoroughly tested for adequacy in view of its unorthodox construction, and secondly, to produce design guidance for the analysis of towers of similar construction.

The work was carried out by consultants, and the tower was erected on the floor of an old quarry outside Edinburgh. The test site is shown in Fig. 25. The large scaffold was provided to transfer the horizontal pushing forces back to the rock face. These forces were applied by the hydraulic jacks to supply loads during the static-load tests. Fig. 26 shows the jacks in position with load cells interposed between the jacks and the scaffold to enable the applied forces to be recorded remotely.

One feature was initially found to be puzzling and is typical of the sort of problem which arises when dealing with practical structures. This was that, on all of the plots of the deflected shape of the tower for a given load, there was a sudden change in slope, indicating a change in tower stiffness (see measured results in Fig. 27). This behaviour was finally attributed to a single bracing member being in compression under no-load conditions, when, in fact, it should never have carried a compressive load under any loading condition. When the results were corrected to allow for this bracing, the corrected curve of Fig. 27 resulted, which gave a deflected shape for the tower very close to that predicted by computer analysis.

It had been thought that this type of tower might have been dynamically sensitive because of the extensive use of welding and friction-grip bolts, but the tower proved to be very stable. The results of the dynamic tests are summarized in Table 5. A dynamic test was then carried out on one of the taller versions of this type of tower illustrated in Fig. 17. The results from this are included in Table 5.

180 ft High Tower

A tower, formerly used for supporting high-frequency aerials at Criggion Radio Station, became redundant and was

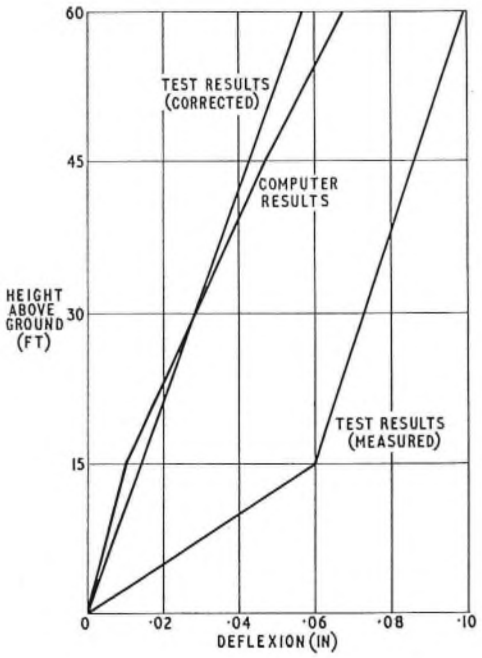


FIG. 27—Theoretical and measured deflected shape of tower

scheduled for demolition. In 1972, a series of tests was carried out on this tower, this time by B.P.O. staff. Unlike the Tower No. 4A, this structure (Fig. 28) was of conventional bolted-joint, angle-member construction, and, as such, the results would complement those of the less-orthodox tower. The Criggion tower was used as a test-bed for the development of test equipment and procedures prior to investigations which were to be conducted on towers in the microwave network. These towers would be carrying working circuits and so any testing would have to be conducted without causing any interference to services.

Figs. 29(*a*) and (*b*) show predicted and measured deflexions and strains. The measured strains are slightly higher, and the measured deflexions slightly lower than the calculated values. The most probable reason for this was that the computer analysis assumed perfectly-pinned frictionless joints, whereas,

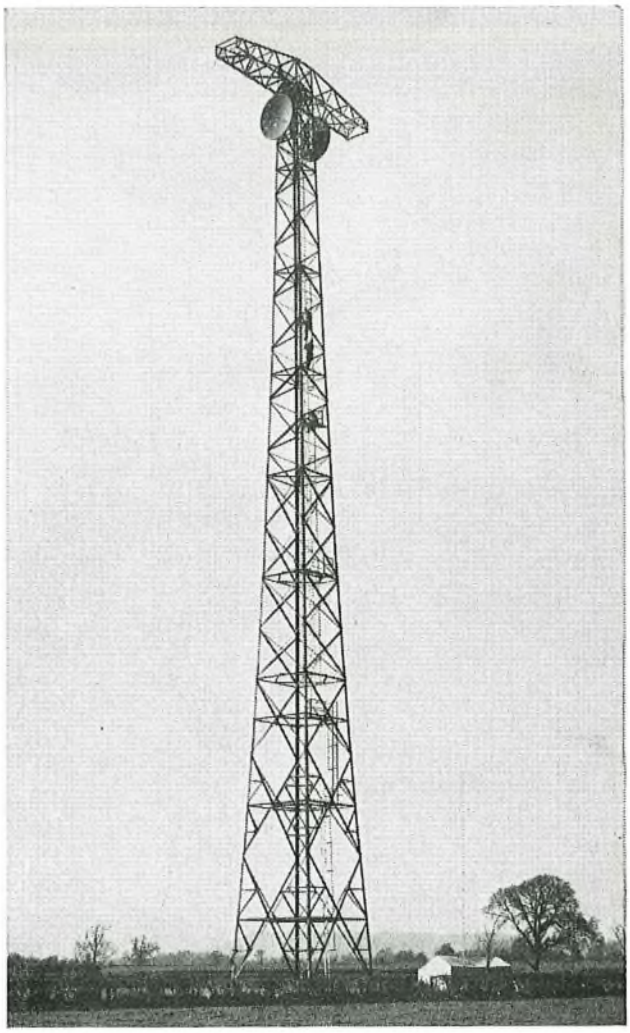


FIG. 28—180 ft tower at Criggion under test with dish aerials fitted

in practice, the joint stiffness would be somewhere between the pinned and the fully-rigid cases.

The results from the dynamic-load tests using the vibrator, described earlier, are summarized in Table 5. One interesting feature was that there was an appreciable difference in both first-mode frequency and damping between dry summer conditions and wet winter conditions. The foundations were in poor alluvial soil, and when water-logged, the concrete blocks could move more, thus increasing the apparent length of the tower and also affecting the energy dissipation in the foundations.

TABLE 5

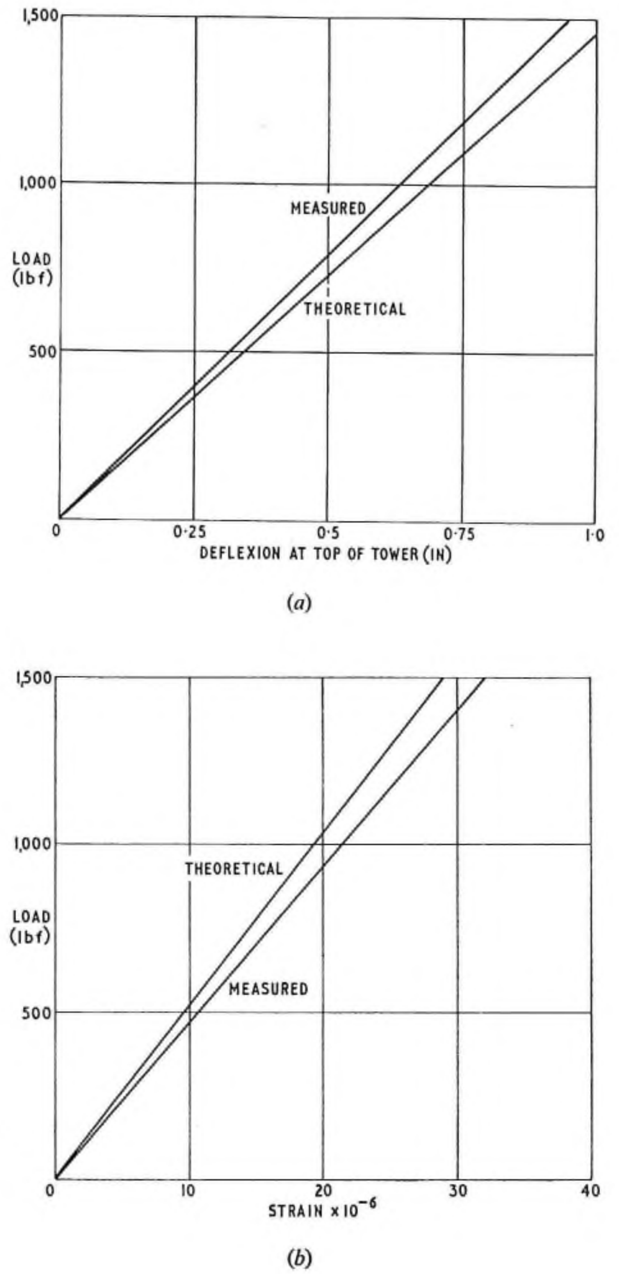
Typical Dynamic Test Results

Structure	Calculated Natural Frequency (Hz)	Measured Natural Frequency (Hz)	Logarithmic Decrement	Remarks
Tower No. 4A				
75 ft high	3·61	3·5	0·151	no wind
137 ft high	3·54	3·65	0·189	no wind
Criggion tower				
no dish aerials	1·29	1·26	0·141	dry soil, no wind
no dish aerials	—	1·25	0·061	wet soil, no wind
two dish aerials	—	1·20	0·061	wet soil, no wind
Farley old tower	—	2·1	0·030	no wind
	—	2·1	0·047	30 miles/h wind
Farley new tower	—	1·42	0·040	no wind

Farley Towers

The experience gained during the Criggion tests enabled tests to be carried out on working towers without fear of causing excessive deflexions of the structure. The equipment had been designed for investigating structures which appeared to be excessively flexible, or to provide data for use at the design stage of new towers. Both uses applied at Farley Radio Station. The tower on the left of Fig. 30 was one of an older type, which was said to be excessively flexible by staff, working on the upper 8 ft square, parallel-sided section. As a result of these reports, a loading limitation had been placed on the tower until the problem could be investigated more thoroughly.

The tests showed that it was indeed easy to get this structure into vibration in low wind-speed conditions, but the frequency of oscillation was relatively high. As was discussed in Part 1,



(*a*) Deflexion of tower
(*b*) Strains in leg post at the base of the tower

FIG. 29—Theoretical and measured strains and deflexions on tower

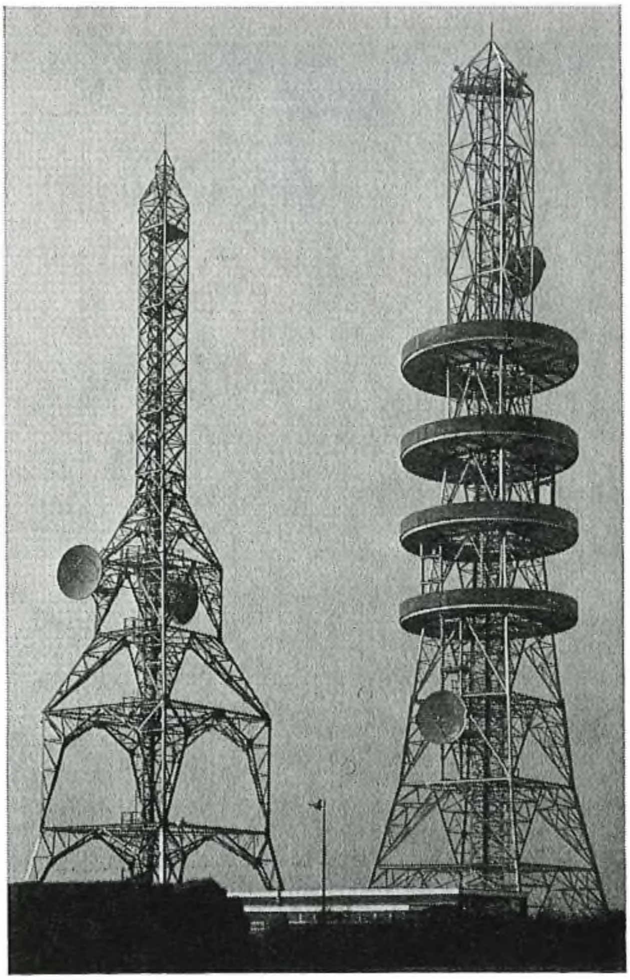


FIG. 30—Farley towers

low damping coupled with a low resonant frequency is the case when gust excitation could be a serious problem, and fortunately, the first-mode frequency of this tower was quite high. It was also noted that, when the tower was vibrated during strong wind conditions, it was much more difficult to get the tower to oscillate. It is likely that the static component of the wind takes up all the slack in the bolted joints, and a considerable increase in structural damping results. There would also be an increase in aerodynamic damping at high wind speeds. The results obtained are summarized in Table 5.

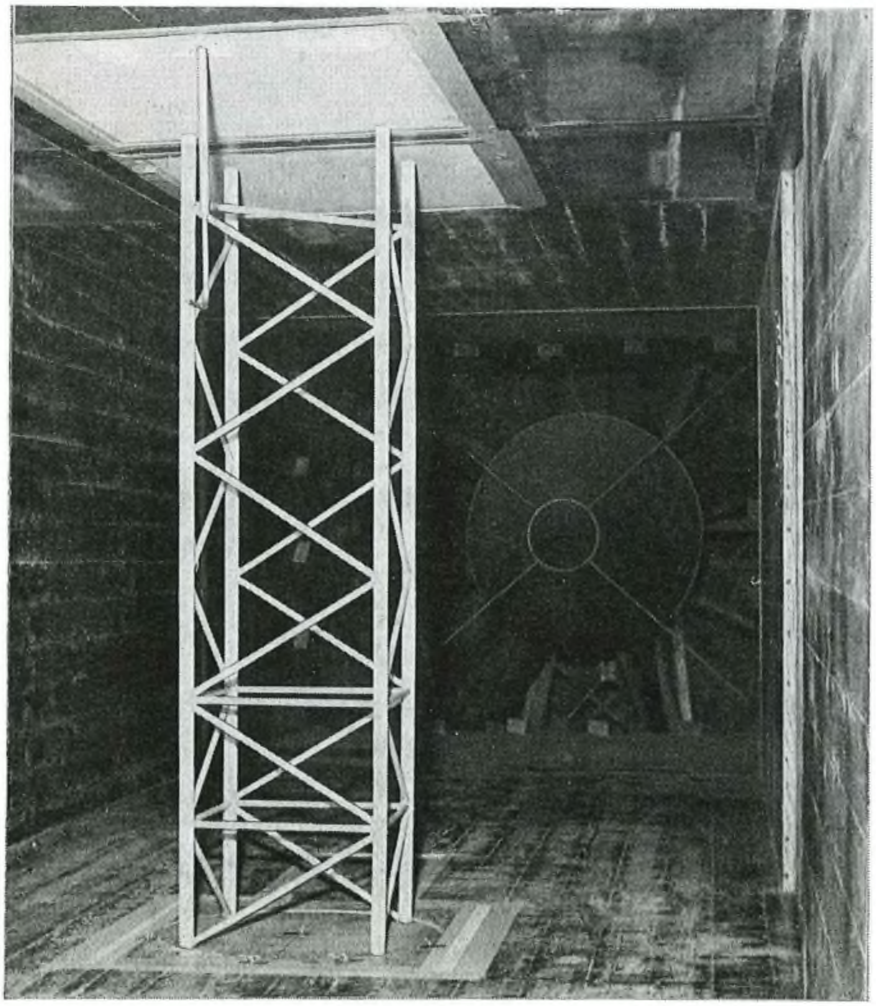
The tower illustrated on the right of Fig. 30 is a new structure which will replace the older tower discussed above. This galleried tower has been investigated by the same techniques, this time to give design data for future designs, as this type of construction could have further application in situations where a modular tower would not be suitable. The test results are included in Table 5. It should be emphasized that this table does not indicate the flexural stiffness of the structures concerned. The stiffness has considerable effect on the response of the towers to the wind, but it can be predicted theoretically, with sufficient accuracy. The new Farley tower is much stiffer than the older one, and this, combined with higher damping, has led to a very stable structure.

It is evident from the structures so far tested that the dynamic performance of structures is rather more complex than published references would indicate. However, sufficient data has been gained to give confidence that, in general, B.P.O. towers are relatively insensitive to dynamic excitation.

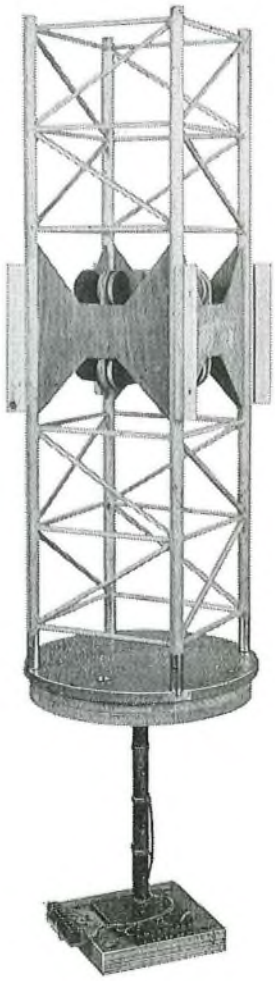
WIND-TUNNEL TESTS

There is an appreciable area of uncertainty in the process of calculating drag on skeletal structures. For example, there are three distinct methods of computing wind loads in the British Standard[17] and when comparing results from the various methods, significantly different answers are often noted. When these differences are translated into costs of structures, in terms of steel and concrete to resist the wind loads, there is good justification for resorting to wind-tunnel testing to obtain realistic drag values.

Wind-tunnel work can be considered under two headings, tests on full-scale components and tests on scale models. Full-scale or large-scale model testing is relatively straightforward, provided that care is taken. The testing of small-scale models of complete structures is much more difficult if valid results



(a)



(b)

(a) Model under test in wind tunnel
(b) Detail of model showing *sting*

FIG. 31—Wind-tunnel tests

are to be obtained, and such work requires the services of experienced aerodynamicists.

The principal problem in wind-tunnel testing of small-scale models is to ensure that the Reynolds number is the same for both the full-scale structure and the model. The Reynolds number (R_e) is the ratio of the inertia forces to the viscous forces in the air-flow; that is,

$$R_e = \frac{\text{wind speed} \times \text{linear dimension of the body}}{\text{kinematic viscosity}},$$

and the kinematic viscosity is the ratio of the fluid viscosity to its density. The Reynolds number can then be adjusted, when a small-scale model is under test, by varying the wind speed or the air density (by using a compressed-air tunnel). Such methods are not usually convenient, and the aerodynamicist often resorts to other methods of adjusting the Reynolds number.

Fig. 31(*a*) shows a half-scale model, in wood, of part of a column unit of a Tower No.5A in a 5 ft by 4 ft wind tunnel. The model is mounted on a base-board flush with the tunnel floor. This board is, in turn, mounted on a *sting*, which is a thin-wall, steel tube, the bottom end of which is fixed to the building floor. The sting is fitted with strain gauges permitting the bending and torsional strains on the tube to be measured, from which the drag may be derived. A model showing the sting is shown in Fig. 31(*b*). Table 6 compares the aerodynamic drag as calculated by the British Standard methods, and as measured for the structure shown in Fig. 31(*a*).

TABLE 6

Comparison of Calculated and Theoretical Drag on a Tower Component

Method	Wind Force in a 50 miles/h wind (lbf)	
	Wind on face	Wind at 45° to face
British Standard CP3 Overall force coefficient	12·08	14·5
British Standard CP3 Multiple-frame calculation	14·25	—
Using force coefficients for individual members from British Standard CP3	13·35	—
Wind-tunnel test	10·9	12·49 (maximum drag occurred at 30° to face

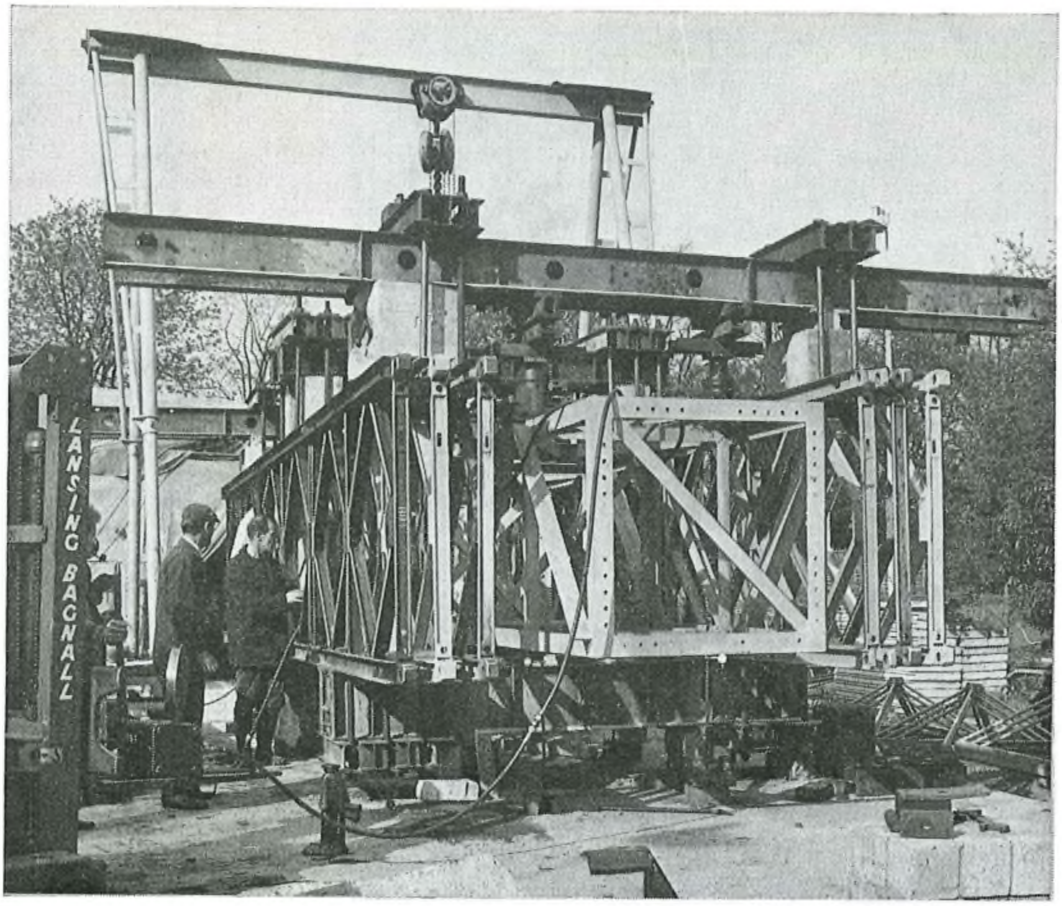


FIG. 32—Tower units under test

TEST ON TOWER COMPONENTS

An example of another useful feature of structural testing is shown in Fig. 32, in which some doubt about the flexural and torsional stiffness of the principal components of the daffodil tower (Fig. 14(*c*)) was resolved by full-scale load tests on production components. The illustration shows a 32 ft length of lattice box section undergoing a bending test with an 80-ton load applied at mid-section by a special test-rig.

Strain gauges and accelerometers have been used for a wide variety of tasks other than those already described. These range from the investigation of the vibration of aerials on concrete towers to the continuous recording of stresses in lifting equipment, such as construction derricks and safety gear. Modern compact battery-operated instrumentation has proved to be as powerful a tool in field work as the computer has been for design, and it is quite often cheaper to carry out measurements than to attempt to produce an adequate theoretical model which can be analysed.

CONCLUSION

It is 43 years since Walmsley reviewed radio tower design in this *Journal*[21], and it is interesting to read his comments in the light of present-day knowledge. The greatest change since then has been the advent of the computer; for example, the analysis of a tower such as the Tower No. 5A in its more complex assemblies would be impractical without powerful computers. It is a little disturbing to note that, until very recently, little progress had been made in the very important fields of realistic wind-speed prediction, and the estimation of drag resulting from the action of the wind on masts and towers. Much work remains to be done on these aspects. No major failure has occurred on a B.P.O. structure and this gives the assurance that the assumptions made in design are adequate. However, it is very difficult to decide whether the structures are being over-designed and, therefore, being provided uneconomically. This is a further aspect which requires more work.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in Telecommunications Headquarters and the Regions for the help given during the preparation of this article. The author is grateful to Tall Structures Research Consultants Ltd. for permission to reproduce Figs. 24 and 25 and the R. H. Harry Stanger Laboratory for Fig. 32.

Reference

21 WALMSLEY, T. Principles of Radio Tower Design. *P.O.E.E.J.*, Vol. 24, p. 231, Oct. 1931.

Computer-Aided Design in the British Post Office

A. E. PULLIN, M.SC., C.ENG., M.I.E.R.E.†

U.D.C. 681.31

This article describes the present state-of-art of computer-aided design applications in the British Post Office. The present situation and applications in the fields of computer-aided circuit and system design is reviewed and the application of computer graphics systems in design is described.

INTRODUCTION

Many engineers do not realize how easy it can be to apply the problem-solving power of a computer to the solution of design problems. The days of the computer as a simple "arithmetic unit" with difficulties of access are long past. Once the designer has formulated his basic design concept, it is now quite feasible to perform a wide range of engineering design tasks very efficiently through the use of a computer. The designer only requires access to a teleprinter, usually a teletype (costing about £600) connected via a rented modem unit and an ordinary telephone line to the appropriate computer.

The design engineer is able to select a program to assist him from a range covering the fields of electrical, civil, structural and mechanical engineering, in addition to more familiar applications.

The user need know nothing about computer programming to obtain the desired results from the many available design programs held ready for use in computer program libraries. Simple instruction in the use of the particular program is all that is required. For example, to obtain the frequency response of an electrical circuit it is only necessary to dial up the computer from the teleprinter terminal, type and send the name of the program required for use, describe, in a prescribed way, the electrical circuit to the program in terms of components (values and interconnexions) and give the frequencies at which the response is to be calculated. There is no need to do anything more to obtain the required results which are returned to the teletype by the computer.

As in the example above, many programs available today can be used by design engineers after a few hours of study to give results which may save hours of slide-rule calculation and of prototype testing.

Given more advanced equipment than the simple teleprinter, the designer can also enlist the aid of computers to perform tasks such as printed-circuit-board (p.c.b.) design, microcircuit design and technical diagram production.

The title computer-aided design (c.a.d.) covers a wide range of applications. However, the British Post Office (B.P.O.) is, at present, mainly concerned with the development of computer techniques to aid in the design of p.c.b.s, integrated circuits and automatic draughting generally.

COMPUTER-AIDED CIRCUIT AND SYSTEM DESIGN

Computer techniques used to aid circuit and systems design fall into two main fields, namely computer analysis and computer synthesis.

By computer analysis is meant the use of a computer to ascertain the performance of a designed circuit, and by computer synthesis, the use of a computer to design the circuit or system automatically from a given specification of the electrical input/output conditions.

Except for a few well-defined forms of electrical circuits, such as filters, it is generally uneconomical with present-day technology and mathematical methods to use computers for large-scale circuit or system synthesis. Computer analysis, however, is a much more profitable proposition.

COMPUTER ANALYSIS

With computer analysis, the designer still has to design his circuit, or system, in the ordinary way and it may at first appear to be pointless to analyse the design by computer instead of testing it in the laboratory. However, it is in this very matter of enabling the time-consuming, costly and laborious laboratory-testing stage to be performed more efficiently that computer application is most valuable. Savings in both time and cost of the order of at least five to one are possible.

Manual Method

Consider first the following typical manual or non-computer procedure for designing an electrical analogue circuit.

A specification of the electrical performance required is used to choose a configuration which should provide the required performance. This is done from the engineer's experience and design knowledge.

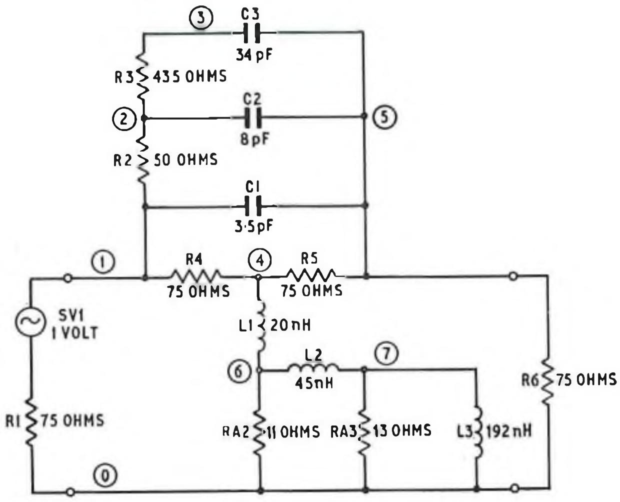
Active devices, such as transistors, are modelled (described) for linear (small-signal) circuits by an equivalent circuit and for non-linear (large-signal) circuits by a series of equivalent linear circuits which each represent small straight lines approximating to part of the curved characteristic. A set of equations describing the behaviour of the configuration is then formulated.

Generally, the analysis equations, which describe the circuit accurately, are complex and design engineers frequently simplify them by neglecting second-order effects. The equations are solved for the variables of interest and, if the output quantities satisfy the specification, the design is complete. Otherwise, key-element values are modified and the analysis is repeated. This interactive procedure, leading to the optimum solution, depends for success upon the original choice of an appropriate configuration.

It may, sometimes, be necessary to select a different configuration and repeat the analysis for an acceptable theoretical solution to be obtained.

A laboratory breadboard hardware model of the circuit is then constructed for testing and, usually, trial-and-error adjustments of the component values are necessary to achieve the required practical performance. The trial-and-error stage

† Telecommunications Development Department, Telecommunications Headquarters.



Note: Interconnexion points in circuit called nodes have numbers abitrarily assigned and are shown encircled

FIG. 1—Equalizer Circuit

becomes necessary because of the approximations resulting from the simplified equations.

Computer Method

Although, in many practical applications, approximations are acceptable, for critical design work, more accurate device modelling and analysis equations are required, which lead to very tedious calculations. By using a computer, the designer can specify configurations and element values, allowing the computer to formulate and solve the analysis equations. Generally, the choice of configuration is made as in the manual method of design.

Many circuit-analysis programs are available, some commercially and some which have been developed by the B.P.O.

To use any of these programs, the designer first has to code his electrical circuit design in a form required by the particular program. For example, consider the computer analysis of the electrical circuit in Fig. 1. The circuit coding required by a B.P.O. analysis program, available for use on the B.P.O. Burroughs B5500 computer service, is shown in Fig. 2. This coding contains the circuit topology (interconnexions) and all

```
"15DB EQUALISER CIRCUIT"
SV1, Ø, 1, 1, 75
R2, 1, 2, 5Ø
R3, 2, 3, 435
R4, 1, 4, 75
R5, 4, 5, 75
R6, Ø, 5, 75
RA2, Ø, 6, 11Ø
RA3, Ø, 7, 13
C1, 1, 5, 3.5E—12
C2, 2, 5, 8E—12
C3, 3, 5, 34E—12
L1, 4, 6, Ø.Ø2E—6
L2, 6, 7, Ø.Ø45E—6
L3, Ø, 7, Ø.192E—6
PRINT, 1, 5
FREQUENCY, 5E6, 5E6, 1ØE6, 145E6
SENTITIVITY, 1, 5, DBS, 40, 35E6
EXECUTE
```

FIG. 2—Circuit Coding

the component values, and is typical of the type of coding required by this, and other, analysis programs.

The coding is fed into the computer by typing it out on the teleprinter, together with extra commands which activate the computer into translating the circuit description code, performing the required analysis and printing-out the results on the teleprinter. Fig. 3 shows the results.

Many circuit-analysis programs have very useful facilities for the designer, e.g., a sensitivity facility in one B.P.O. program enables each of the components forming the circuit to be increased or decreased in value one at a time, by any required percentage. An analysis of the circuit is performed after each component value variation and the corresponding results are printed out on the teleprinter. A histogram diagram for the component can be printed (see Fig. 4) which provides a quick indication of the most sensitive components; that is, those causing the largest changes in the operating conditions of the circuit when their values are changed. This information enables a designer to modify a circuit quickly to meet a specification.

Specific programs impose particular constraints in the analysis of circuits containing active components. Some programs require the user to design the required equivalent circuits manually and to code and insert them in the complete circuit coding. Other programs have one or two fixed-configuration equivalent circuits and only the element values for each

"15DB EQUALIZER CIRCUIT" 11:18 TUESDAY Ø7/Ø8/73

FREQUENCY (HZ)	NODE	GAIN(DBS) (REF. NODE 1)	VOLTS RATIO	PHASE	NODAL VOLTAGE REAL COMP	IMAG COMP	MAGNITUDE
5.ØØE Ø6	5	—2.Ø68E Ø1	9.242E—Ø2	63.9	2.Ø31E—Ø2	4.151E—Ø2	4.622E—Ø2
1.5ØE Ø7	5	—1.57ØE Ø1	1.64ØE—Ø1	43.7	5.933E—Ø2	5.662E—Ø2	8.2Ø1E—Ø2
2.5ØE Ø7	5	—1.427E Ø1	1.934E—Ø1	41.1	7.287E—Ø2	6.361E—Ø2	9.673E—Ø2
3.5ØE Ø7	5	—1.317E Ø1	2.196E—Ø1	42.1	8.146E—Ø2	7.364E—Ø2	1.Ø98E—Ø1
4.5ØE Ø7	5	—1.216E Ø1	2.467E—Ø1	43.4	8.96ØE—Ø2	8.483E—Ø2	1.234E—Ø1
5.5ØE Ø7	5	—1.122E Ø1	2.747E—Ø1	315.7	9.825E—Ø2	9.6Ø1E—Ø2	1.374E—Ø1
6.5ØE Ø7	5	—1.Ø38E Ø1	3.Ø28E—Ø1	315.3	1.Ø76E—Ø1	1.Ø66E—Ø1	1.514E—Ø1
7.5ØE Ø7	5	—9.617E ØØ	3.3Ø5E—Ø1	315.3	1.175E—Ø1	1.163E—Ø1	1.653E—Ø1
8.5ØE Ø7	5	—8.939E ØØ	3.573E—Ø1	315.6	1.278E—Ø1	1.249E—Ø1	1.787E—Ø1
9.5ØE Ø7	5	—8.337E ØØ	3.829E—Ø1	316.2	1.383E—Ø1	1.325E—Ø1	1.915E—Ø1
1.Ø5E Ø8	5	—7.8Ø3E ØØ	4.Ø72E—Ø1	317.Ø	1.49ØE—Ø1	1.389E—Ø1	2.Ø37E—Ø1
1.15E Ø8	5	—7.329E ØØ	4.3Ø1E—Ø1	317.9	1.595E—Ø1	1.443E—Ø1	2.151E—Ø1
1.25E Ø8	5	—6.9Ø8E ØØ	4.514E—Ø1	318.8	1.699E—Ø1	1.487E—Ø1	2.258E—Ø1
1.35E Ø8	5	—6.533E ØØ	4.714E—Ø1	319.8	1.8Ø1E—Ø1	1.522E—Ø1	2.357E—Ø1
1.45E Ø8	5	—6.199E ØØ	4.898E—Ø1	32Ø.8	1.898E—Ø1	1.549E—Ø1	2.45ØE—Ø1

FIG. 3—Results

active component need be entered manually, instead of the complete equivalent-circuit topology.

More recent programs enable the user to store the different types of equivalent-circuit configuration that he may wish to use. The element values only, together perhaps with the name of the required type of equivalent circuit, need then be entered at the circuit-coding stage.

Also, some programs maintain a library of equivalent circuit, for different active components. To use a library component, the designer specifies the library name of the particular component he requires in the circuit-description code. The computer automatically inserts the equivalent circuit for this component in the complete circuit coding and then performs an analysis in the normal way.

At first sight, it may appear that the use of a computer should eliminate all necessity for approximations in design. However, this does not always apply because of the storage and speed constraint of the particular computer. For example, to analyse accurately a circuit containing many different types of transistor over a wide operating frequency range would necessitate many equivalent circuits and, in turn, a large amount of input data. Several equivalent circuits might be necessary for each transistor with each equivalent circuit covering a small part of the frequency range. This can lead to large computer storage requirements and excessive computer processing time and cost. Therefore, even using computer analysis, approximations are needed, although to a much lesser degree than usually occurs in manual design.

Automatic optimization of designs can often be accomplished by computer, although it is sometimes costly and requires a lot of data preparation. Instead, if the results from a computer analysis of a large circuit are unsatisfactory, it is preferable to make modifications to the circuit and perform a new analysis.

To ensure efficient use of the computer system, care should be taken when using it for analysis purposes. The inclusion of non-linear elements which do not greatly affect the overall circuit performance, or the inclusion of high-frequency elements when only mid-band, or low-frequency performance is desired, and vice versa, should be avoided if costs are to be kept down.

Another trap for the unwary user may be the modelling of active devices by constant parameter elements appropriate to small-signal operations only (leading to minimum computer analysis time) and then forgetting to check for non-linear operation. For example, whilst the small-signal circuit model will predict an undistorted output, a large enough input signal may cause a highly-distorted output.

LOGIC-CIRCUIT ANALYSIS

The manual method of logic-circuit design is similar to that for analogue circuits and the procedure can also be improved by using computer techniques. The art of computer analysis for logic circuits is more precise than for analogue circuits. Programs are available which formulate accurately from the circuit coding the boolean equations necessary for the computer analysis, and there is no need for approximations as in the analogue circuit case. A logic-circuit analysis program has been developed by the B.P.O., based on work done by the United Kingdom Atomic Energy Authority. This program can analyse up to 1,000 logic elements where an element can consist of a single gate or a group of gates.

When manually testing logic circuits, it is usually possible to monitor only a limited number of output states at a time. With computer analysis, it is possible to monitor all the output states concurrently and to show the order of logic switching. The B.P.O. program has advanced facilities, such as, a fault-simulation facility which enables each of the gates in a circuit to be switched on or off, in turn, and an analysis to be performed automatically on the complete circuit at each setting.

COMMUNICATION-SYSTEM DESIGN

Another type of c.a.d. analysis program being developed in the B.P.O., based on work done at the Signals Research Development Establishment, will aid in the design of communications systems.

Faced with the design of a new communications system, the designer may first attempt to choose the method of modulation and the response of the critical filters in the main signal path. These, and many other equally important parameters, must be manipulated to achieve the final design. The solution must satisfy rigid constraints, such as the bandwidth allocated for each channel of a radio system, for example, or the peak power available from an individual transmitter.

In the past, if computers were used to aid this process at all, special-purpose programs were written for some relatively

"15DB EQUALIZER CIRCUIT"

SENSITIVITY ANALYSIS FOR INCREASED COMPONENT VALUES

FREQUENCY=3.5000000E 07 HZ   REF=1.317E 01 DBS GN
PERCENTAGE CHANGE IN COMPONENT VALUES=40.0

		VALUE		OUTPUT	PERCENTAGE
ITEM	NAME	ORIGINAL	MODIFIED	DBS GN	DIFFERENCE
1	RS25	7.500E 01	1.050E 01	1.317E 01	8.840E—10
2	R2	5.000E 01	7.000E 01	1.334E 01	1.335E 00*
3	R3	4.350E 02	6.090E 02	1.370E 01	4.008E 00****
4	R4	7.500E 01	1.050E 02	1.411E 01	7.123E 00*******
5	R5	7.500E 01	1.050E 02	1.317E 01	7.687E—03
6	R6	7.500E 01	1.050E 02	1.184E 01	—1.012E 01**********
7	RA2	1.100E 02	1.540E 02	1.306E 01	—8.274E—01*
8	RA3	1.300E 01	1.820E 01	1.279E 01	—2.870E 00***
9	C1	3.500E—12	4.900E—12	1.285E 01	—2.396E 00**
10	C2	8.000E—12	1.120E—11	1.252E 01	—4.899E 00*****
11	C3	3.400E—11	4.760E—11	1.328E 01	8.681E—01*
12	L1	2.000E—08	1.429E—08	1.336E 01	1.480E 00*
13	L2	4.500E—08	3.214E—08	1.355E 01	2.872E 00***
14	L3	1.920E—07	1.371E—07	1.304E 01	—1.008E 00*

FIG. 4—Sensitivity analysis results

FIG. 5—Tektronix Storage Tube Terminal

FIG. 6—D.E.C. GT40 Terminal

narrow aspects of the problem. The advent of the fast Fourier transform algorithm (which transforms waveforms from the time domain to the frequency domain and vice-versa) and the increasing power of computers available, means that it is now realistic to develop general-purpose programs which can be used at a very early stage in the design process.

The B.P.O. program enables designers to assemble proposed communications systems from a library of standard building blocks such as filters and modulators. The resulting system can then be analysed by extracting the waveforms and signal spectra at the outputs of the modules. Provision is also made for deriving conventional measurement values at any required point and printing-out the information such as r.m.s. voltage, peak power and occupied bandwidth.

COMPUTER SYNTHESIS

Although computer circuit synthesis is not generally economical for designing most types of circuit, it is so for electrical filters. The B.P.O. has implemented a suite of easy-to-use filter synthesis programs for the design of simple filters using the B.P.O. B5500 computers. For example, to design a bandpass filter, the designer simply types the following specification data on a teleprinter:

(*a*) the type of filter i.e. bandpass,
(*b*) the filter order,
(*c*) Q-factor,
(*d*) passband ripple,
(*e*) centre frequency,
(*f*) bandwidth, and
(*g*) input and output impedance.

From this information, the computer calculates the network configuration and component values of the filter to meet the specification, and prints them out on the teleprinter. In addition to the B.P.O. filter design programs, there are others available commercially which design more sophisticated filters. These programs are, however, more complicated to use.

For complex filter design, it is still usually necessary to resort to computer analysis for the final design. The designer first obtains a basic design from computer synthesis and then continues the design by manual modifications and computer analysis.

COMPUTER GRAPHICS

The speed of interaction between the teleprinter user and the computer is slow since the designer must prepare his data in alphanumeric characters and enter this into the computer by typing on the teleprinter keyboard. The output from the computer, again alphanumeric characters, has to be interpreted. By the use of computer graphics, the interaction time between the user and the computer can be considerably reduced for applications involving graphical data and/or results. Also, certain computer applications, such as the design of p.c.b.s, are economical only when designed on a graphics system.

The B.P.O. is undertaking computer graphics in two ways for design work. The first is by the use of graphical terminals linked via ordinary telephone lines to a computer in the same way as for a teleprinter. The second is in the *stand-alone* system, where the computer processor and display are associated together as one unit. Both the graphics terminals and the stand-alone systems have alphanumeric and graphical display facilities.

COMPUTER GRAPHICS TERMINALS

Basically there are two types of computer graphics terminal, the direct-view storage tube and the refresh graphics display. Both use cathode-ray tubes. In the case of the storage tube, once an image has been created on the tube's screen phospher, by the electron high-energy beam, it remains visible without being refreshed by the beam. This is achieved by having additional electron guns which flood the tube face with low-energy electrons, and utilize the phenomenon of secondary emission to give a persistent image. In the case of a refresh graphics display, the image has to be refreshed at least 20 times per second in a manner similar to that of an ordinary television set.

Storage-Tube Terminals

The B.P.O. is using Tektronix storage-tube terminals connected via the Datel 600 service to commercially-available bureaux. Such a terminal is essentially a graphical output device only, since no selective erasure is possible and the unwanted elements of a picture can only be removed by erasing and redrawing the whole picture. For large pictures, this can be a relatively slow process and the display of moving pictures is not possible. The storage-tube terminals are being used very successfully for producing graphs from tables of values.

Refresh-Graphics Terminals

With a refresh-graphics terminal, it is necessary to maintain a data file which describes the picture. The scanning hardware obtains its refresh instructions from this file, which is held in

FIG. 7—D.E.C. PDP 15/76 Computer Graphics System

the core store of a computer processor dedicated to displaying the picture. Because of the high data transfer rate required for refreshing, i.e., data transfer from core store to the display, the latter must be located relatively close to the computer.

In the past, the use of refresh-graphics terminals has been inhibited by the high cost of the associated local dedicated computers. However, with the falling cost of hardware and particularly that of mini-computers, it is now possible to purchase a refresh-graphics terminal at an economical price. The B.P.O. has recently obtained a Digital Equipment Corporation (D.E.C.) GT40 refresh-graphics terminal which consists of a graphical display and a PDP 11/10 mini-computer. The latter operates at a speed of 900 ns cycle-time and its core store consists of 8,000 words each 16-bits long.

The terminal operates on a random-scan image-generation basis refreshed from data held in the main memory of the PDP 11/10 computer.

The terminal has a light pen, which gives the user a graphical interaction facility with application programs. This a device which records the co-ordinates on a displayed picture and transmits them to the display control computer. This is done by placing the pen on the screen at the required position, and pressing a button on the pen. Hardware and software instructions, in association with the co-ordinate points registered by the light pen, provide facilities, such as the ability to draw and delete lines or symbols on a displayed picture. Program options can be displayed on the screen in an alphanumeric or other form of graphical list such as a list of symbols. The user can choose the option he requires by placing the light pen anywhere on the particular option's alphanumeric or graphical display symbol and pressing the light-pen button.

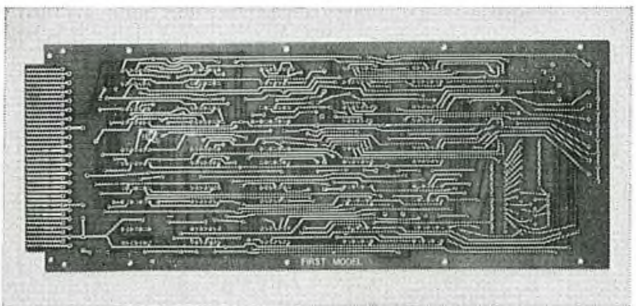


FIG. 8—Printed-circuit board

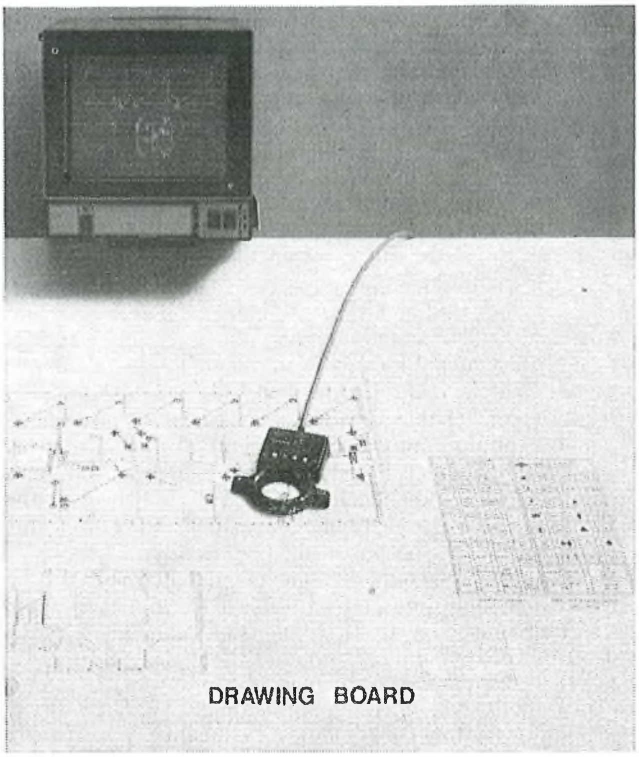


FIG. 9—Ferranti Automated Draughting System

The GT40 terminal is able to receive data from a remote commercial-bureau computer over a telephone line and, by means of the PDP 11/10 local computer, expand the data into instructions forming the display file. It can also be used for applications involving small moving pictures.

The B.P.O. will use the GT40 terminal for input and output to circuit-analysis and filter-synthesis programs to reduce considerably the interaction time between the user and computer. This will reduce the overall design time.

Hard-copy prints of a displayed picture can be made from both the storage-tube and refresh-graphics terminals by photographing them with a Polaroid camera. In the case of the storage-tube terminal, a more suitable hard-copy print can be made using an additional unit which, by a thermal printing process, produces, on request, a printed copy of the displayed picture. However, in time, the print from the thermal process fades. A more permanent and larger-scale plot can be made by programming the PDP 11/10 computer inside the GT40 to produce paper tapes suitable for driving an automatic printer/plotter.

The cost of storage tube displays is in the range £2,000–£7,000 and the cost of the GT40 is £7,500. Fig. 5 shows the Tektronix storage-tube and Fig. 6 the D.E.C. GT40 terminals.

STAND-ALONE COMPUTER-GRAPHICS SYSTEMS

The largest computer-graphics system the B.P.O. is using is a stand-alone refresh-graphics system using a D.E.C. PDP 15/76 computer. The computer system has a 16-bit word, 800 ns cycle-time and 32K core store, together with a refresh-graphics display and light pen. The system has been purchased primarily for the design of p.c.b.s. In addition, the machine will be used for the design of integrated circuits (i.c.s.) and the development of other graphics applications. Fig. 7 shows a picture of the system.

The software necessary for designing p.c.b.s and i.c.s has been developed by Redac Software Ltd.

The use of p.c.b.s in the construction of electronic circuits has become extensive throughout the electronics industry. Fig. 8 shows a typical p.c.b. Each year, the B.P.O. designs approximately 500 new p.c.b.s and, in the past, these have been designed by laying out the interconnexions by hand in the drawing office or contracting the work outside the B.P.O. Manual p.c.b. layout can be a very long and tedious task, and indeed, for very complex circuits, almost impossible. By utilizing the automatic aids of a computer system with an efficient link to the designer to enable him to control and direct the design in the direction his experience knows is best, large reductions in design times, often as high as 85 per cent, can be achieved. Using a computer system, complex circuits can be readily catered for relative to manual design methods.

To design a p.c.b., the designer codes his electrical design in a way similar to that for the circuit-analysis programs, together with information such as the size of the board. This information is punched on paper tape and fed into the computer which automatically processes it and displays the p.c.b. with all the electrical interconnexions and components contained within the outline of the board.

With the use of the light pen, the final design is achieved by a series of modifications to the displayed layout. When the designer is satisfied with the design, a command is typed which causes the computer to output the design on to paper tape. The paper tape is then fed into an automatic plotter which draws the design on photographic material using a light beam. The drawing is developed and subsequently used as a mask for placing the track layout photographically on the unetched p.c.b. The board then undergoes a chemical process which retains the copper tracks on the board where it has been exposed to light in the photographic process.

In the B.P.O. the actual design of p.c.b.s will be carried out on a bureau basis by drawing-office staff, i.e., a draughtsman will use the computer graphics system to design p.c.b.s for engineers, although for particular problems, the design engineer may use the system himself.

Similarily i.c.s are designed using the computer graphics system. The designer codes his component and interconnexion shapes for each layer on the surface of the chip. The computer processes this information and displays a layout solution on the screen. By the use of the light pen, the designer achieves the final design by a series of modifications to the displayed layout. A set of rules entered as data prevent the designer from making unacceptable modifications, e.g., placing component-shapes too close to each other.

In the same way as for p.c.b. design, the final design is output on punched paper-tape and used for driving an automatic plotter which produces the photographic i.c. masks.

The approximate cost of the stand-alone refresh computer graphics hardware is £63,000 and the software £37,000 making a total of £100,000 for the complete system.

AUTOMATED DRAFTING

Another type of computer graphics system soon to be used in the B.P.O. on a one year field-trial basis is the Ferranti automated draughting system. An earlier process was described in a previous article[1]. This system will consist of a digitizer, control computer, graphical display and a plotter. The digitizer is a tool used to record the co-ordinates and other data at selected points on a drawing. A drawing can be described by digitizing a sufficient number of co-ordinates and relevant data.

The system is designed to aid the draughtsman in making complex drawings, especially those which use standard symbols, e.g. electrical symbols in circuit drawings. All basic symbols e.g. solid line, circle, arc, necessary for drawing are stored in the system. To digitize a drawing using this system, the draughtsman places the digitizer graticule over the symbol required in the tabulated list on the side of the drawing board, and presses the digitizer's button. He then moves the digitizer graticule to the co-ordinates on the drawing board where the symbol is to be drawn and again presses the button. The symbol is immediately displayed on the screen at the co-ordinate position together with any previously digitized symbols. In a similar manner, symbols can be deleted from the displayed drawing (see Fig. 9).

When the draughtsman is satisfied with his displayed drawing, he types a command which causes the computer to plot his drawing automatically on a plotter. Alternatively, a punched paper-tape record of the drawing can be made and held separately. Any later amendements can then be made by feeding the paper-tape data into the computer, which will re-display the drawing on the screen ready for modification work in the same way as before.

The system has advanced facilities such as automatic dimensioning; that is, dimensions are calculated and drawn automatically by the computer.

Any spare time available on either of these stand-alone computer graphics systems will be used for the developing of other potentially economical computer-graphics applications.

CONCLUSIONS

Rapid computer synthesis and analysis with the ability to simulate proven sub-circuits in many different configurations, together with simple modification facilities, all provide a powerful tool for the designer. Perhaps the greatest advantage of c.a.d. circuit design is the ability to check a manufacturer's proposed circuit designs thoroughly, but cheaply, under many different working conditions. Indeed, it should become possible for the B.P.O. to write specifications calling for stated results when the design is analysed by a particular c.a.d. program.

Computer graphics provides a very powerful interaction facility between the designer and the computer giving large savings in design time and cost. The use of computer-graphics is already economical in some applications. To prove the economic justification for many other potential applications, it is necessary to have the use of computer-graphics facilities for exploratory development work. The B.P.O. has met this development need by introducing four different types of computer graphics facility. Each of these has been economically justified on its own for already proven computer-graphics applications.

Reference

[1] Walker, G. S. Computer-Aided Drawing Equipment for Integrated-Circuit Manufacturere. *P.O.E.E.J.*, Vol 64, p. 260, Jan. 1972.

An Automatic-Frequency-Control System for High-Frequency Radio Receivers

A. ST. J. REYNOLDS†

U.D.C. 621.396.62.029 : 621.316.726 : 681.323

A new automatic-frequency-control system, using digital techniques, has been developed to replace the servo-motor system used in high-frequency radio receivers. The principal advantages of the new system are reliability and simplicity, with only one frequency-setting control to be adjusted on installation.

INTRODUCTION

Most high-frequency, independent-sideband receivers continue to use automatic frequency control (a.f.c.) to compensate for drifts in oscillator frequency, both in the transmitter and receiver. The purpose of these controls is to reduce the frequency errors of the baseband signal at the receiver output to a few hertz, by processing the reduced-level carrier forming part of the radio signal. Such systems have, hitherto, invariably been complex, costly and vulnerable to signal contamination by noise and interference. The system described in this article has been developed for application to any modern high-frequency receiver employing a carrier filter. It is novel in that digital techniques are used in place of the electromechanical approach, which has almost invariably been adopted previously.[1,2] The new system shows major advantages in reliability, cost and operational simplicity. A block diagram of the basic a.f.c. arrangement is shown in Fig. 1.

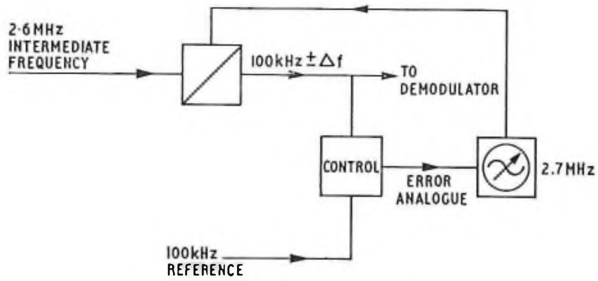


FIG. 1—Basic a.f.c. arrangement

DESCRIPTION OF THE SYSTEM

The signal derived from the incoming reduced-level carrier is compared with a highly-stable reference frequency in a comparator consisting of two identical eight-bit synchronous binary counters (see Fig. 2). No attempt is made to measure the error between the two signals, the only decision required of the comparator being the sense of the error.

Each counter has an eight-input NAND gate associated with it to indicate a full state, and the gate associated with the first counter to fill up causes both input signals to be blocked at the inputs to the two counters. The sense of the frequency error can be determined by the logic of the outputs of the eight-input gates at the end of each count, and these signals are used to control the frequency-correcting section of the system.

The heart of the frequency-correcting part of the system is a reversible ten-bit synchronous binary counter. The count state is either increased, or decreased, depending on the instruction from the comparator, and so this counter replaces the function of the servo-motor. The correction to the controlled local-oscillator tuning is carried out by varactor (variable-capitance) diodes, the controlling analogue voltage being derived, via a converter, from the ten-bit output of the reversible counter.

The interval between successive corrections is controlled by the clock-pulse rate, which resets the comparator counters,

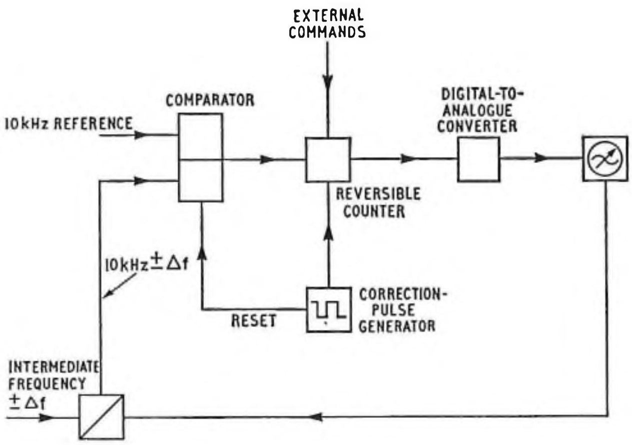


FIG. 2—Block diagram of digital a.f.c. system

and at the same time, adds or subtracts one count from the reversible counter. Every clock pulse fed into the reversible counter produces a 1 Hz change in the frequency of tuning, so that with a 1 Hz pulse-repetition rate, the rate of correction is 1 Hz/s. The ten-bit counter gives a tuning capability of 1,023 Hz, or approximately ± 500 Hz, which meets the normal requirement for modern receivers.

The relatively-slow correction rate of 1 Hz/s is chosen so that small, short-duration and reversible changes—*jitter*—in the incoming carrier are not followed. Rapid correction would

† Radio Engineering Services Division, External Telecommunications Executive.

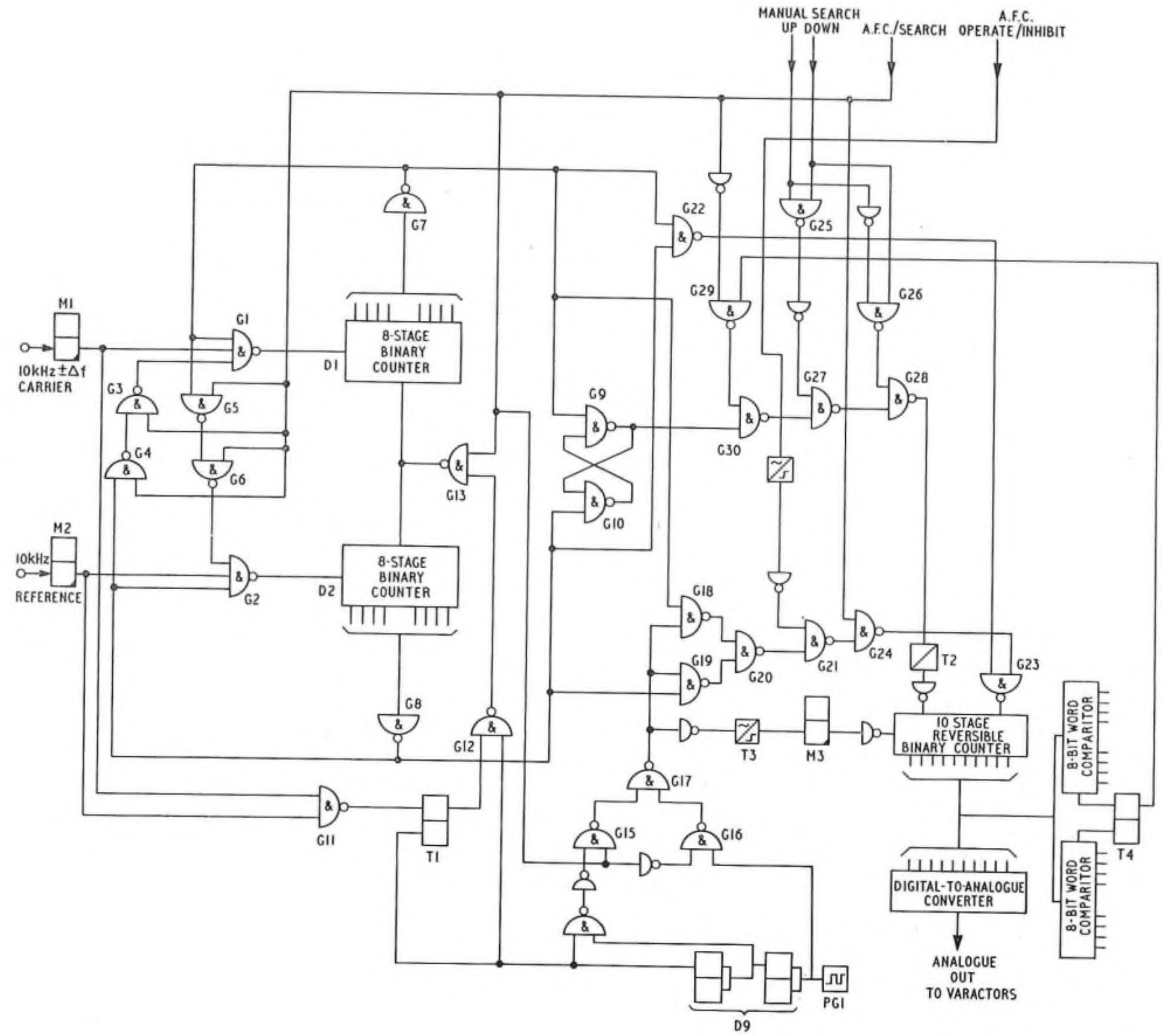


FIG. 3—Logic diagram of digital a.f.c. system

produce frequency modulation of the controlled oscillator frequency, the unwanted sidebands of which would be within the audio-frequency range and, therefore, appear in the final audio output from the receiver.

A comparison error would occur if the comparator counters were started without regard to the phase relationship between the input signals. Therefore, a coincidence gate is used to hold-off the reset pulse until the input signals are in phase. If this precaution were not taken, an area of indecision of up to ± 40 Hz would occur.

In addition to a.f.c., a signal-search facility is included, so that when the receiver is switched to a new frequency, the tuned oscillator is swept over a frequency range of ± 300 Hz at a rate of 10 Hz/s. During search, the comparator counters are allowed to fill, and do not exercise any control over the counting direction of the reversible counter. This control is exercised by a tuning-limit flip-flop circuit, switched by two eight-bit word comparators, these being programmed to recognize when the reversible counter reaches each count state corresponding to either the +300 Hz or the −300 Hz frequency limit. Of the ten bits available from the reversible counter, only the eight most-significant bits are used. This affords an economy in the word comparator and only degrades the recognition accuracy by 3 Hz or 1 per cent. Gates are included in the automatic-search control line to permit manual-search commands to be injected from the central control position so that the operator can assume a searching control if necessary.

DETAILED CIRCUIT DESCRIPTION

A detailed description of the circuit, a diagram of which is shown in Fig. 3, is given below.

The Comparator

The 10 kHz reference signal and the nominal 10 kHz carrier signal are processed by the monostable circuits M1 and M2 to produce 1 μs pulses at the respective pulse-repetition frequencies. These pulses are then applied to the inputs of the comparator counters D1 and D2 via the three-input NAND gates G1 and G2. The four cross-coupled two-input NAND gates G3–G6 are all opened by the a.f.c. command from the receiver, and allow the logic signal from each eight-input NAND gate G7 and G8, connected to the comparator counters, to control the three-input NAND gates G1 and G2. Whichever counter fills first produces a logic 0 at the output of the associated eight-input gate, and blocks both 10 kHz input pulse trains by closing the gates G1 and G2. Therefore, the counter receiving the higher frequency produces a logic 0 at this point and exercises control over both three-input gates. The output logic from the eight-input gates is also applied to a toggle G9 and G10 to control the counting direction of the reversible counter D3.

The Reversible Counter

The counter is a ten-bit synchronous up/down counter, with an inhibit facility and a single up/down control line. The up/down control signal, derived from the comparator, is filtered to remove any noise and is reconditioned by the Schmidt trigger circuit T2. The clock input, which changes the count state of the reversible counter, is the correction pulse in the system. This is derived from the correction pulse generator PG1, via the decade divider D9, and is selected by gates G15–G17. These gates form a change-over switch with the 1 Hz pulse rate selected for a.f.c., and the 10 Hz pulse rate for signal search. The pulse trains are filtered to remove noise and processed by the Schmidt trigger circuit T3 and the monostable circuit M3.

To protect the count state, the reversible counter can be automatically inhibited

(*a*) when the carrier-to-noise ratio is less than 10 dB, by means of a signal from the receiver automatic inhibit circuit in a signal assessor applied via the gates G21 and G22,

(*b*) during the actual comparison period, via the gates G22 and G23,

(*c*) when there is no frequency error between the two input signals, via the gates G18, G19, G20, G24, G21 and G22, and

(*d*) in the absence of the correction pulse, also via the gates G18, G19, G20, G24, G21 and G22.

In this way, the reversible counter is protected by being inhibited for much of the time, and operated only when the carrier signal is of sufficient quality to render it useful and when correction is necessary.

A number of gates are included in the up/down line to facilitate automatic search and to allow manual search in addition to the a.f.c. function. The gates G25 and G26, with the associated inverters and diodes, ensure that logic 0 signals, applied to the manual search lines, override the automatic signal search. This is achieved by disabling the gate G27 and allowing the gate G28 to control the count direction. Under automatic search, logic 1 signals are connected to the inputs of the gates G27 and G28 from the manual search lines. The gates G27 and G28 then pass signals from the gate G9 for the a.f.c. mode, or from the gate G29 for the signal-search mode. The automatic search requirement is for the receiver to explore a frequency range of ±300 Hz for the required carrier. For this purpose, two binary word comparators are connected to the outputs of the reversible counter to recognize when the count state reaches the points corresponding to the ±300 Hz frequency limits of the controlled oscillator. Each word comparator is made up of three integrated circuits.

Two eight-bit words (A and B) are compared in the circuits (each one capable of four-bit comparisons) and a final comparison made in a third circuit. Three unique output states are available depending on whether word A is greater than word B, less than word B, or equal to word B. The output states are used to trigger a two-input bistable circuit T4 which, in turn, provides the counting-direction control for the reversible counter via the gates G29, G30, G27 and G28. Reed relays, which are compatible with transistor-transistor logic, are also operated to energize lamp alarms at the central control position, to indicate when the search reaches the limits. The word comparators are also operative under a.f.c. conditions, so that lamp alarms indicate when a.f.c. action has varied the controlled oscillator by either +300 Hz or −300 Hz, and warns the operator that remaining correction capability is, at the most, 200 Hz.

The Digital-To-Analogue Converter

A ten-bit digital-to-analogue converter is used to provide a unipolar output of 0 to −10 volts from a natural binary input which is compatible with transistor-transistor logic. The converter has a self-contained voltage reference and output amplifier. The digital logic inputs operate gates to switch binary-weighted current sources to a summing bus-bar connected to the output amplifier.

Tuning the Controlled Local Oscillator

The local oscillator, that is tuned for the purposes of a.f.c. and search, is crystal-controlled and tuned over the small frequency range required by variable-capacitance diodes. These are silicon diodes used in the reverse-bias condition, in which the diode junction capacitance varies with the bias applied from the output voltage of the digital-to-analogue converter.

A variation in capacitance of about 25–75 pF is required for a ±300 Hz tuning range, and this is achieved by a bias voltage variation of about 6 volts applied to two varactor diodes connected back-to-back. A change of about 9 volts provides the full a.f.c. range of ±500 Hz.

SYSTEM PERFORMANCE

Table 1 gives the main parameters for the system taken from measurements of the prototype unit.

TABLE 1

Measured Performance of Prototype Unit

Parameter	Performance
Correction speed of the a.f.c.	1 Hz/s
Sweep speed on signal search	13 Hz/s
Residual error after correction	± 1 Hz
Signal-search range	± 300 Hz
Follow range of the a.f.c.	± 400 Hz
Capture range of the a.f.c.	± 70 Hz

CONCLUSION

The automatic-frequency-control system, using digital integrated circuits, has been developed for use in high-frequency communications receivers. The system is suitable for application to any independent-sideband receiver, and offers high reliability and a precise operation which is superior to that achieved by servo-motor systems.

References

[1] LOWRY, W. R. H., and GENNA, W. N. Single-Sideband Multi-Channel Operation of Short-Wave Point-to-Point Radio Links, Part 3—An Independent-Sideband Short-Wave Radio Receiver. *P.O.E.E.J.*, Vol. 46, p. 19, Apr. 1953.

[2] PERKINS, K. G., and DAVIES, W. M. The PVR 800 High-Frequency (3–30 MHz) Radio Receiver. *P.O.E.E.J.*, Vol. 60, p. 204, Oct. 1967.

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 October issue if they are received before 23 August 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. Articles, and contributions for Regional Notes, must be approved for publication at General Manager/Head of Division level.

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.

Regional Notes

London Telecommunications Region

The Lost Cords

The invitation to submit copy for this section of the *Journal* enjoins us to ". . . return this slip even if nothing worthy of comment has transpired."! It set me thinking that, since the contributions are so few, it must be either a very stable or even dull organization for which we work, if so little happens that is worthy of comment. It may be, of course, that we are bashful, or feel that our small problems and excitements could not possibly interest anyone else, and that to write about them in so august a journal would be singularly inappropriate. Perhaps, too, the experiences of other Telephone Areas are so similar to one's own, that we do not feel the need to tell one another about them. Common-place difficulties we cope with all the time; it is only the bizarre, the improbable, or the herculean tasks that deserve to be shared.

Now, the installation of a cordless auto-manual centre surely does not fall into any of these categories, and yet it was a fairly shattering experience for the North-West Telephone Area. Its coming had been eagerly awaited, the lads were keen to get on with it, and the operators ogled the close-carpeting and found the prospects exciting, but the South Harrow Cordless Switchboard System No. 1A was—and still is, to some extent—a great disappointment. It was a tricky job to program, and even worse to "watch" and acceptance-test. The box-testers were not ready, and, when they did arrive, the add-on units were missing; then followed a seemingly endless procession of modifications and changes to specifications. The amount of rack-mounted apparatus associated with these diminutive switchboards is enormous, and took a gargantuan chunk of the precious auto. floor. The keyset buttons kept sticking, and the wretched senders would not work properly.

When, at last, we had subdued the beast to a state where the long-delayed opening could take place, the Service Division discovered another host of operational snags: the main-to-subsidiary queue ratios were all wrong, night concentration was difficult, and special arrangements had to be hurriedly made to cope with changed-number interception and subscribers' transfer facilities. The senders were still sulking, and kept locking themselves out—or in. Efficiency was down, since traffic peaks do not produce the same stimulus to work faster as do the mass of glowing lights of a cord-type board, so that the average time-to-answer tended to be longer. Coping with pile-ups following a sudden rush of traffic, such as a glut of emergency calls at night, has its problems, since there is no way of dealing selectively with the queued-up traffic.

I hope we are on our last modifications now—a 750 h sender modification, besides the changing of a mere 20,000 reed-relays—but, needless to say, nobody is taking bets!

Maybe these comments sound too destructive for a construction man, and the last thing we want is an agony page in the *Journal*, but I cannot help reflecting that the British Post Office has had cordless boards in service since the early-1950s, and that, if this is the best we can do, then perhaps we should go back to sleeve control; or is it my nostalgia, recalling those long-lost, carefree days of cord-boyhood?

J. C. Endersby

Holborn Exchange Manhole Fire

On the evening of Monday 21 January 1974, at approximately 23.00, fire broke out in the exchange manhole at the rear of Holborn Buildings. The fire was detected as a result of smoke and fumes, which permeated the building and which, on investigation, were discovered to be coming from an unsealed cable-entry between the cable chamber and the exchange manhole in Whetstone Park.

The Fire Brigade were called, who extinguished the fire by using a water spray on the cables in the exchange manhole, thereby adding to the difficulties of ultimate restoration.

During the ensuing period, the Area Emergency Fault Control advised the Inspector and Assistant Executive Engineer responsible for heavy maintenance, and, as soon as permission to enter the manhole was given by the Fire Brigade, an assessment was made of the damage. As a result of this assessment, it was found that five local cables, comprising a total of 6,000 pairs, and seven junction cables, comprising a total of 4,664 pairs, had been seriously damaged. Consequently, some 5,000 customers in an area bounded by Kingsway, The Strand, Chancery Lane and Whetstone Park were without service, and junctions and pulse-code-modulation system routes serving Holborn 242, 405, Holborn Tandem, Maxwell Trunk Unit and Kingsway Trunk Unit were severely affected.

Work to restore service was started immediately. On the external front, jointers were set to work to shorten-up and piece-out damaged local cables, where this was possible, and arrangements were made to turn out the cable gang and obtain suitable interruption cable. Meanwhile, in Holborn building, staff had been called out, and the work of testing, identifying and, where necessary, isolating defective circuits started. By Tuesday 22 January, a clearer picture of the situation had emerged and, as a consequence, work in Holborn building progressed steadily in re-routing and re-translating traffic, and a control point was set up for the purpose of testing circuits as they were restored.

Work had continued throughout the day on the restoration of local cables, and by early evening, two had been completed and an interruption cable drawn-in for the restoration of a third. Arrangements were also made for a mobile emergency caravan to be brought to the site, and, from Wednesday onwards, this was used as the external control point. During the day, work had also started on the restoration of the junction cables, and this, like the work on local cables, continued on a round-the-clock basis.

By Wednesday, sufficient cable had been obtained to permit interruption of all the remaining damaged cables, but careful planning was necessary to avoid disturbance to jointing operations, and to permit employment of the maximum number of jointers. Consequently, it was necessary to stagger the jointing sites, with the result that two 1,000-pair cables had to be run over the surface. The cable gang commenced operations at midday, working round the clock until 10.00 on Thursday 24 January, when all but one of the interruption lengths had been drawn-in or laid over the surface. The one remaining length was drawn in on Saturday 26 January in order to minimize interference with jointing operations. Meanwhile, jointing and testing of pairs continued without a break, and the jointing work on local cables was completed by Sunday night, closely followed by that on the junction cables, which was completed by 19.00 on Monday 28 January.

There now remained the work of testing and proving all the circuits, a job which was hampered by the fact that, being a high-density business area, it was almost impossible to verify circuits after 17.00 and over the weekend, as premises were closed. Thus, although all jointing was completed, it was a considerable time before it could be confirmed that all circuits were through and tested.

Undoubtedly, the work of restoration was hampered by faulty records—both distribution point and subscribers' records—but customer goodwill was retained, thanks to the Telephone Service Representatives, who maintained a close liaison, and by the public relations exercise mounted by the Area Public Relations Office and the Traffic Division in the early days of the incident. Our thanks are due to the Regional Headquarters staff, from both the Service and Works Divisions, who so willingly provided help and expertise at a time when it was most needed; also to members of the Area staff, who worked so hard to restore service to our customers.

R. E. Howard
R. E. Smith

London Director-Area Reference Centre

Reference-centre working has been accepted as an essential activity in trunk-network maintenance, but its effectiveness in local networks has been in doubt. In London, a supply of valuable information on call-failures is available from the operation of the turn-back procedure, whereby customer-dialling failures are reported, and local exchanges have frequently made good use of this information. Some faults, particularly those at the originating exchange, can be readily identified by exchange maintenance staff, but, for network faults, the pattern of failure, as seen from a single exchange, frequently builds up too slowly to be effective. Call-tracing from a number of exchanges to locate a common fault, such as a disconnected junction outgoing from a tandem exchange, can be wasteful of effort, and some co-ordination is desirable. It was decided, therefore, to introduce reference-centre working to serve the four inner-London Areas from September 1972, to process customer-dialling-failure reports. The reference centre, which is housed in temporary accommodation at Euston exchange, has demonstrated its worth, despite the limitations imposed by manual handling of the considerable volume of call-failure information. It is now proposed to place reference-centre working on a permanent footing in Colombo House, South-Central Area, to cater for the processing of information from the whole of the director area. The opportunity will be taken to combine the present trunk reference centre, serving the central trunk units, with the director-area centre.

At the existing Euston centre, operator reports are, at present, received from auto-manual centres in the four inner Areas, plus North Area. The reports are entered on forms A9130 (national A222 procedure) by operators, and, then, clerical staff plot information on the routing of the failed calls on peg-board wall charts, showing

(*a*) the code-selector levels in the originating exchange,
(*b*) the levels used in tandem exchanges, and
(*c*) the objective exchange selector levels.

Engineering staff are responsible for detecting points of routing correlation and informing exchange staff of any need to initiate fault-location action. Currently, 12,000 customer reports are dealt with weekly, and some 30,000 pegs put into wallboards.

The reference centre has been found to be a valuable means of detecting serious customer difficulties, as well as giving a rapid and sensitive means of detecting unit-performance variations. Cable faults and incoming-service failures can often be noticed at the reference centre before the exchange maintenance staff become aware of the problem. In the absence of telephone-service-observation information on the performance of TXK3 exchanges, reports from the reference centre have been of value to management. In one recent instance of serious incoming difficulty, an hourly record of failure reports proved valuable both as a measure of service variations and as the principal source of failure information available to the exchange staff for the direction of fault-finding activities.

The extension of reference-centre working to the whole of the director area would prove too unwieldy at a centre operating on a manual basis. A computer has, therefore, been ordered for use at the new location in Colombo House, and will be programmed with routing information for all London exchanges. This computer will have a capacity for 8,000 fault messages a day, from 10 individual inputs, and it is expected that call-failure information from other sources, such as call-failure-detection equipment and test-call senders, will be processed. It will be possible to feed out call-failure information to individual exchanges more rapidly than at present, due to the additional amount of information that will become available and the computer's speed in diagnostic processing. It is hoped that this development will be of significant value in assisting exchange maintenance staff to continue the improvement in London's local-exchange service.

W. J. Reilly

North Eastern Region

Warning System for the Elderly

As a result of close co-operation between the Engineering and Marketing Divisions of the Leeds Telephone Area, an order has been placed with the British Post Office (B.P.O.) by the Ossett Council for an alarm-and-enquiry installation to serve the town's old-people's bungalows. The bungalow complex comprises a total of 418 bungalows, grouped together in clusters of varying sizes around the town. Plans are in hand to expand this figure, in the future, to about 800.

At a meeting with the Borough Treasurer, the question was put to the B.P.O. and several competitors, "What sort of warning system can you provide for old people to summon help?".

First thoughts were of a central key-and-lamp installation, with separate tariff-S1 private-wires terminating on separate telephones in the bungalows. This was quickly dismissed, because the large number of circuits made the cost too high. The next step was to consider the provision of multi-point circuits. Normally, a circuit of this nature would be engineered with a total of 10 spurs, but, as the bungalow groupings were in the order of 18 units, permission was obtained from Telecommunications Headquarters to go up to 25 spurs.

The central key-and-lamp unit attendant, when receiving a call, would be able to identify in which group the call originated, but would not be able to determine the particular bungalow. It was agreed that a lamp outside each bungalow's front door would provide the supervisory signal. A power unit and a mercury relay were to be provided on rental terms by the B.P.O., and the mains-powered lamp and flashing equipment by the Council. The supervisory lamp would flash as soon as the telephone handset was dislodged.

This scheme was surveyed, costed and then submitted to the Ossett Council for approval.

In the Council Chambers the B.P.O. scheme was deemed the best of those tendered, but the costs were considered to be too high, and had to be pared.

The basic speech path could not be engineered any more cheaply. Any savings would have to be made with the supervisory equipment. It was decided, therefore, that a strip of low-voltage lamps would be installed in a nominated bungalow, or bungalows, in a group. This meant that two wires had to be provided from each bungalow to its own lamp on the strip. This idea was enthusiastically received by the Council, and the system was re-surveyed and the costs estimated.

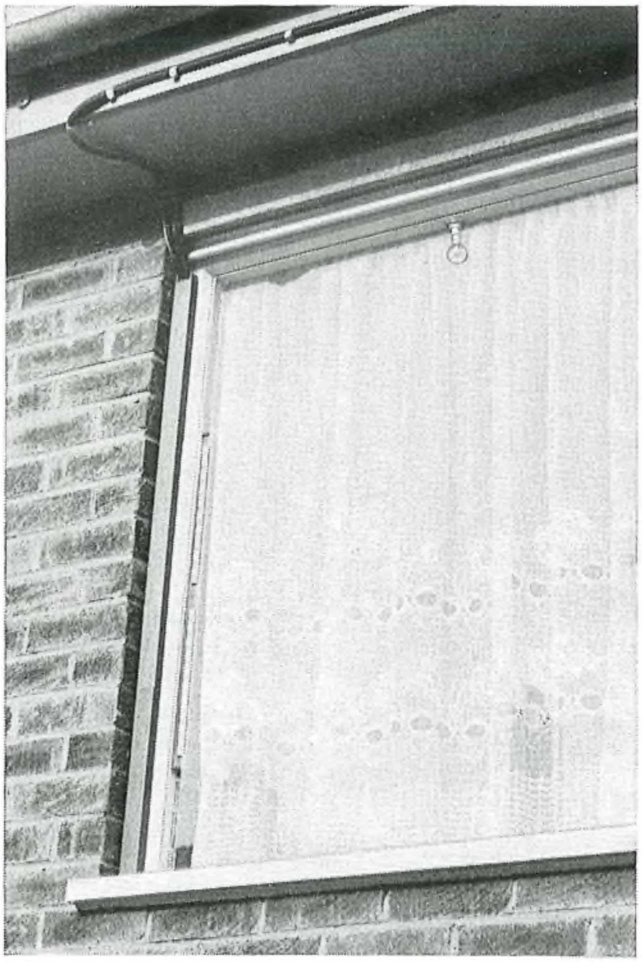
The decision was that, of the 418 bungalows, about 75 would be nominated to display the lamps. The lamps employed were in strips of 10, and were to be housed in a plastic box for mounting in the window of the display bungalow. The lamps had to be in a position where a curtain could not be drawn across them, and had to be water-tight, to prevent condensation or window-washing from causing faults. A larger, pilot light was thought to be a useful addition. After costing, a rental of £2·40 per lamp installation was arrived at. This was readily accepted by the Council, and the only additional expense to them was the provision of a power-point in each of the 75 bungalows.

The central key-and-lamp unit was designed to accept an incoming loop-calling signal from the multi-point circuits, with no outgoing signals required. Other circuits to appear on the key-and-lamp unit were

(*a*) a private circuit to the Citizen's Advice Bureau,
(*b*) an exchange line to call police or relatives,
(*c*) a circuit to a doctor or hospital, and
(*d*) a circuit to a stand-in operator.

Whilst a caller from a bungalow can be connected to one of these services, the operator remains in circuit, and, in the event of a further bungalow call, the established conversation would have to be interrupted to answer that call. An extension alarm can also be supplied when required, to alert a stand-in operator over any of the private circuits.

Multi-point distribution is effected using local line plant, each circuit being two-wire to the location, and then, depending on the geographical location, spurred to the bungalows by various means; for example, via poles or from gable-end to gable-end.



Supervisory lamps in the window of a display bungalow

The telephone is wall-mounted (type 714 CB) and is located near the front door at a height of about 0·9 m to enable a collapsed person to dislodge the handset. A call is deemed an alarm when the caller cannot identify himself. Such a caller can be localized by

(*a*) the lamp indication on the key-and-lamp unit, giving the group, and
(*b*) a visit to the nominated display bungalow, which will indicate which address is calling.

A lamp-test facility is provided by a locking button on the display bungalow's own telephone, and, by pressing the button, the lamps are made to glow, and can be checked by the person in that bungalow. Any faults can be reported using the telephone itself.

The service is adaptable, and can be expanded to serve single private residences of aged or handicapped people. The alarm application could be extended throughout the premises with a simple B.P.O. approved switching arrangement.

The scheme has been working since December 1973, and, during the first four months, over 300 calls have been received. Of these, 30 per cent have been requests for a doctor, 25 per cent to request maintenance to the bungalows, and 30 per cent to services, such as the police or wardens, the remainder being general enquiries.

Elderly people in Ossett have received a new link with life, thanks to the B.P.O.

D. E. F. Turner
K. Dixon

South Eastern Region

Brighton's Local Teletourist Information Service

This new telephone information service, designed to give details of selected entertainment within one hour's travelling time of Brighton, was opened by the Mayor of Brighton, Alderman Stanley Theobald, on 1 May 1972, to coincide with, and feature events connected with, the Brighton Festival.

Bob Gunnell, Manager of Radio Brighton, agreed to produce a daily tape-recording, which would include information provided by Leslie Bedford, director of Brighton Corporation's entertainment and publicity department, and other information which Radio Brighton broadcasts every day in their programme, *Coastwise*.

Mr. Kenneth Burling, General Manager, Brighton Area, undertook to provide the necessary engineering arrangements whereby the daily message could be recorded, stored, and replayed on demand by calling Brighton 8042.

The engineering brief called for a recording machine capable of doing justice to the high standard of audio fidelity practised by the B.B.C. It had to be continuously rated, produce instant play-back and possess a variety of technical features normally found only in professional-type tape recorders. Evaluation of standard British Post Office recorded-announcement equipment of the day, failed to produce anything approaching the desired standard of reproduction. The problem was eventually met by custom-modifying a Ferrograph Series Seven half-track recorder, and fitting it with a continuous-loop cassette to give a three-minute message with repetition, *ad infinitum*, without re-spooling.

Further requirements were that the service should be closed down promptly at midnight and remain out of service until a fresh recording had been made, and that over-riding manual control should be provided whereby the service could be ceased or restored as necessary. In normal operation, a pulse, taken from the routiner fault-recorder control circuit, operates and holds a relay on the recorded-information-service rack. The holding circuit for this relay is broken when a new recording is made, which automatically restores the service.

To enable the tape-recorder to record remotely, a type-16 relay was fitted on a small sub-chassis, within the machine, to effect the necessary switching. Wiring modifications to the auxiliary socket reduced the external connexions to the recorder to just one multi-way cord. The machine was fitted with a continuous-loop cassette, with sufficient magnetic tape to provide three minute's recording time at $3\frac{3}{4}$ in/s. To reduce wear and tear to a minimum, the recorder is set to PAUSE; that is, with the capstan motor in motion, but with the solenoid-controlled, tape-drive mechanism unoperated. A demand from the information-services rack, or Radio Brighton, operates this solenoid, to bring the machine into operation.

Radio Brighton's studios are in the heart of Brighton, some $2\frac{1}{2}$ miles distant from Brighton (Withdean) group switching centre, where the information-services equipment and recorder are situated. A four-wire link between Radio Brighton and Brighton (Withdean) exchange has been provided, with facilities for

(*a*) transmitting the recording to the tape-recorder,
(*b*) instant monitoring by Radio Brighton,
(*c*) switching the recorder to RECORD or PLAY, and
(*d*) a point-to-point telephone link for use when setting-up transmission levels, and fault-finding.

Basically, the arrangement is a high-grade, two-wire link, for the recording circuit, with a 10-volt, d.c. signalling system on the phantom, for calling between the telephones. Another two-wire link, which normally serves as a monitor circuit whereby Radio Brighton can check the recording instantaneously, has a split phantom which is used to control the running and switching of the recorder. When the handset of the telephone at the recorder point is raised, a relay automatically disconnects the monitoring facility, and the second circuit becomes a point-to-point telephone link. Lamps at the recorder point indicate any facility selected by Radio Brighton.

The service has been in operation for almost two years, during which time, the only failures have been due to tape fatigue. In an attempt to overcome this, the cassette has now been loaded with Scotch 156 specially-lubricated, professional tape. A total of 14,200 calls were made to the service during the first year of operation, and figures obtained so far this year confirm its popularity, indicating a 66 per cent increase over last year.

A. E. LUKE
G. G. ELLIS

Associate Section Notes

Aberdeen Centre

Because of the power crisis and industrial troubles, our program has suffered somewhat; a talk on exchange maintenance, and an evening visit to the Helicopter Division of British Airways at nearby Dyce Airport, having to be cancelled. We hope to be able to include both in the 1974–75 session.

Fortunately, it was possible to arrange another evening visit, at short notice, to an international firm in Aberdeen which specializes in electronic equipment used in gaining information from oil wells in various parts of the world. The information obtained is invaluable to drilling contractors, and our members were shown some of the equipment in service.

One of our own members, Mr. M. McCabe, presented a talk on the intricacies of pulse-code modulation for the March meeting. The talk had obviously been well prepared, and the evening proved most interesting and enjoyable.

J. H. MCDONALD

Colwyn Bay Centre

This centre has had two lectures of note so far this session. On 8 November, Morris Byham, of Vickers Oceanic at Barrow in Furness, gave a talk on the development and uses of the Pisces submersible craft. Films illustrated some of the many uses, including cable-laying techniques. We were pleased to have as our guest Mr. C. T. Lamping, our Regional Liaison Officer.

On 26 February, we welcomed a return visit from Eric Salmon, of the British Antarctic Survey. His theme for this lecture was the various expeditions which led to the reaching of the South Pole. There were many questions, including several on the Scott tragedy. We were also treated to the première of a new film about life on Antarctic surveys, sponsored by the National Coal Board. It is a very human film with memorable photography of sculpture-like icebergs.

E. DOYLERUSH

Dundee Centre

The continued support from members and friends is most welcome to the committee, and our thanks go to all concerned.

The meeting on small-bore coaxial-cable jointing techniques unfortunately had to be cancelled, but we hope to be able to present it during the next session.

"Drugs" is a word heard frequently these days, and Detective Sergeant Doogan, of the City of Dundee Police, did an excellent job in explaining how people in all walks of life were affected by the problem, when he addressed the centre. He described the situation in the country as a whole, and in Dundee in particular. Samples were, of course, only on view.

Common-Control Switching Systems was the title of a talk given by Mr. W. G. Carr, of the Scottish Telecommunications Board Headquarters, to a large gathering in Perth on 20 March—a difficult subject to cover in such a short time, but one which was well received by an appreciative audience. Plans for the 1974–75 session are well ahead, and arrangements have been made for a visit to Messrs. Robb Caledon, Dundee, to see cable ships being built.

R. T. LUMSDEN

Eastern Region Centres

Eastern Region Conference

Delegates met on the evening of 13 March at the Regional Training College, Bletchley Park, for an excellent dinner prepared by the college catering staff.

An early start to the conference was made next morning when Mr. S. M. Sheppard, Regional Liaison Officer, introduced the guests: Mr. K. E. Stotesbury, President, Associate Section; Mr. D. Millington, Managing Editor, *Post Office Electrical Engineers' Journal*; Mr. A. H. Watkins, Regional Liaison Officer, South-Eastern Telecommunications Region; and Mr. M. G. Turnbull, Deputy Controller of Planning, Eastern Telecommunications Region. Mr. Turnbull is to be the new liaison officer for the Eastern Telecommunications Region.

A full agenda included a report of the national committee's activities, by E. W. H. Philcox. Editorial policy and future plans for the *Journal* were described by Mr. Millington, and the conference heard reports from centre secretaries of meetings and ideas for programs.

Mr. P. G. Freeman and Mr. E. W. H. Philcox were elected as delegates to the national committee, and Mr. Freeman was appointed Eastern Region secretary.

At the close of the conference, a vote of thanks was given to Mr. Sheppard for his work as regional liaison officer over the previous five years.

P. G. FREEMAN

Kingston Upon Hull Joint Centre

21st-Anniversary Session, 1973–74

The 21st-anniversary session commenced on Wednesday 26 September, when some 30 of us went to the North-Eastern Region Associate Section lecture, held at York College of Further Education. A really excellent paper was presented by Dr. K. Barker, of the University of Sheffield, on multichannel sound. This lecture was well illustrated with both sound and first-class colour transparencies, using two projectors simultaneously in some cases. It was greatly enjoyed by all present.

In October, some 24 members visited Derwent Plastics at Stamford Bridge, near York, seeing an interesting display of various types of precision plastic-moulding techniques and equipment.

The November meeting, at Telephone House, Carr Lane, Hull, was a joint meeting, and was well attended by our own members and our colleagues of the Scarborough Associate Section, and by senior members. The paper, *Latest Developments in Customer Apparatus*, was given by Mr. G. B. Palmer of the Telecommunications Development Department, Telecommunications Headquarters.

The January meeting was a film show and demonstration of machine jointing-systems, presented by Mr. W. Knights of Hull Telephones.

February saw the annual general meeting and film show, again at Telephone House, Hull. The films, loaned by the British Post Office, included *Voices in Orbit*, showing the development to date of satellite communications, and, also, *The United Kingdom–Spain Submarine Coaxial Cable.* Both films can be recommended.

The following officers and committee were elected for the 1974–75 session:

Joint Honorary Chairmen: Mr. L. Anderson and Mr. P. Eglin.

Honorary Secretary: Mr. L. Johnson.

Honorary Treasurer: Mr. G. Mudd.

Committee: Messrs. K. Gibson, J. Glasgow, R. H. Miles, J. A. Moor, G. E. Reed, D. Sharp, E. Shingles, W. Thomas, W. Timson.

The 21st-anniversary dinner was held in Hull on Tuesday 2 April. This was attended by some 70 members and guests, including retired colleagues. The guests included Mr. H. V. J. Harris, who was Telephone Manager, Hull, for many years, and was one of the people instrumental in setting up this joint centre.

After dinner, Mr. P. Eglin introduced Mr. A. R. Matthews, Telephone Manager, Hull, who spoke briefly on the work done by the Institution of Post Office Electrical Engineers and its associate sections.

The chairman then introduced Mr. W. Chatwin, General Manager, York Telephone Area, who gave an entertaining account of his career in the Post Office.

Mr. Eric Hackley, who was the chairman of the centre for 15 years, presented the Honorary Secretary, Mr. L. Johnson, with a brass period mantlepiece clock, on behalf of members and friends, as a gesture of their esteem for the 21 years' service he has given, to date, from the founding of the joint centre in 1952.

Mr. Eglin brought the meeting officially to a close at 22.00, following which, those present circulated freely, the party finishing just after 22.30.

L. JOHNSON

The Associate Section National Committee Report

The last meeting of the Associate Section National Committee was held on Saturday, 2 March, at the Technical Training College (T.T.C.), Stone. The meeting proved to be of great use and much business was covered.

Dr. Bray was presented with a set of six Tyrone Crystal wine goblets and a Life Honorary Membership from the National Committee for his services to the Committee and the Associate Section. Dr. Bray, in return, officially presented Mr. Stotesbury with a fine trophy, commissioned by the National Committee and made by the Tyrone Crystal Company. This trophy will be known as the Bray Trophy, and is to be presented annually to the finalists in the National Technical Quiz Competition.

An encouraging report regarding the growth of the National Committee was made by the treasurer, Mr. P. White. The Committee now represents 95 per cent of the Associate Section membership.

The *National News* is also growing, and many more centres are purchasing copies and enjoying the articles and information provided.

The projects organizer was pleased to report much enthusiasm regarding the National Museum, and thanked those concerned with sending items of interest.

On the whole, the National Committee is functioning very well and is growing from strength to strength. The annual conference is to be held at the T.T.C., Stone, on 18 May.

Long Service

It is with much regret that the National Committee has had to accept the resignation of our vice-chairman, Jack McCallum. Jack has had to resign from his Associate Section activities for health reasons. Jack has served the Associate Section for many years; he was the Scottish regional chairman and has been on the National Committee since its inauguration.

We wish him a speedy recovery, and thank him sincerely for his services to the Associate Section.

Bray Trophy

The final of the National Technical Quiz Competition was held at the Institution of Electrical Engineers, Savoy Place, London, on 1 May. Mr. E. Fennessy, Managing Director, Telecommunications, presented the Bray Trophy to the South Eastern Telecommunications Region, represented by Worthing, who beat Northern Ireland, represented by Londonderry, by 54 points to $37\frac{1}{2}$. The question-master was Mr. J. F. P. Thomas, Chairman of the Council of the Institution of Post Office Electrical Engineers.

On behalf of the National Committee, I would like to thank all those who helped with the organization, and give particular thanks to Mr. E. W. Weaver, Director, London Telecommunications Region (L.T.R.), for his generous assistance in allowing us the use of the L.T.R. outside-broadcast units, which enabled our members in Northern Ireland to watch the proceedings.

P. L. Hewlett

Institution of Post Office Electrical Engineers

Certificate for Mr. Revell

The retirement of Mr. H. J. Revell, Chairman of the Scottish Telecommunications Board, in May, marked the end of an era for the Institution of Post Office Electrical Engineers in Scotland. Chairman of the Scottish centres for ten years, Mr. Revell actively promoted the aims of the Institution in Scotland, taking a particular interest in the encouragement of the Associate Section. In recognition of his outstanding service, the co-ordinating committee for Scotland has appointed Mr. Revell as Honorary Vice-Chairman of the Scottish centres. At the April meeting of the Scotland East Centre, he was presented with a framed certificate, recording this appointment, by the centre's vice-chairman, Mr. H. C. Stevenson.

Mr. E. H. Truslove, Controller and Board Member for Service and Marketing, Scottish Telecommunications Board, succeeds Mr. Revell as Chairman of the Scottish centres.

From left to right: Mr. H. J. Revell; Mr. J. H. W. Sharp, Chairman, Aberdeen sub-centre; Mr. J. W. Longyear, Chairman, Scotland West Centre; and Mr. H. C. Stevenson.

Institution Field Medal Awards, 1972–73

In addition to the Institution's Senior and Junior, silver and bronze medals, the Field Medals are awarded annually for the best papers read at meetings of the Institution on field subjects, primarily of Regional interest.

A Field Medal has been awarded to Mr. W. Piercy, North Eastern Region centre, for his paper, *The New Leeds Postal Sorting Office*, read during the 1972–73 session.

Essay Competition, 1973–74

Prizes and Institution Certificates have been awarded to the following competitors in respect of the essays named:

Prize of £20:

D. M. McGaw, Technical Officer, Glasgow. *The Optimum Use of Local Line Plant.*

Prize of £15:

D. E. F. Turner, Technical Officer, Leeds. *A Post Office Service for the Elderly.*

Prizes of £5:

T. Mackie, Technical Officer, Glasgow. *All Glasgow is our Parish.*

D. E. G. Coles, Technical Officer, Birmingham. *The Effect of Resource Optimization upon the Output of an Expanding Circuit-Provision Group.*

S. E. Warren, Technical Officer, Skipton. *Direct Labour Installation of Post Office Telephone Exchange Equipment.*

Institution Certificates of Merit have been awarded to the following competitors:

C. Kelly, Technician 2A, Rotherham. *The Reliability of Post Office Equipment.*

D. W. Scott, Technical Officer, Spennymoor. *The Construction Hoist.*

S. Lay, Norwich. *The Light Fantastic.*

D. J. Middleditch, Technical Officer, Martlesham. *The Growth of the Post Office Research Centre, Martlesham.*

F. Eastham, Technical Officer, Blackburn. *The Late DP97.*

A total of 24 essays were entered this year, the same as last year, and two thirds of them were from Scotland and the North of England.

The general standard was about the same as last year, but more essays showed some originality in the choice of subject. There were, however, still a number of essays which were simply summaries of reading on a subject.

The Council of the Institution records its appreciation to Messrs. A. C. Eley, J. R. Walters and R. W. Gibson, who kindly undertook to adjudicate on the essays entered for the competition.

A. B. WHERRY
General Secretary

Post Office Press Notices

Strategy for New Telecommunications Systems

With the aim of developing and planning Britain's telecommunications services of the future with greater effectiveness, the British Post Office (B.P.O.) is regrouping part of its research and development into a new department.

The department, the Telecommunications Systems Strategy Department, is charged with creating an overall strategy for the co-ordinated development of new telecommunications systems, with the aim of securing the best and most economic service.

The department will also become a focal point through which the telecommunications industry can work with the B.P.O., and can take into account the wider interests of equipment manufacturers when determining the path along which systems for the U.K. are to be developed.

Professor James Merriman, Board Member for Technology and Senior Director of Telecommunications Development, said, "The potential importance of new high-technology systems, such as *System X*, to the future of U.K. telecommunications services is very great. Within the overall framework or strategy created by this new department, the very many detailed and specific research and development projects that are needed can be controlled and managed with the confidence that total system-effectiveness will be maintained."

He added, "As well as providing the principal focus for industry to participate in the creation of these overall system plans, the new department will also enable industry to be involved in the follow-on tasks of drawing up specifications for major individual development projects."

The new department brings together elements of other departments, formerly concerned with the planning, research and development of future high-technology telecommunications systems.

It will be headed by a new director, Mr. L. R. F. Harris, M.A., C.Eng., F.I.E.E., formerly a deputy director and head of the B.P.O.-Industry Advisory Group on Systems Definitions, which is absorbed into the new department.

Mr. Harris was educated at Nottingham High School and Pembroke College, Cambridge, where he gained a first-class honours degree in the mechanical science tripos of 1947.

He joined the Research Department at Dollis Hill, London, in 1947, and was involved in early research into electronic switching for telephony, notably into time-division multiplex systems. Basic and original work in this phase contributed to the electronic switching research programme undertaken jointly with industry in the late-1950s and early-1960s.

In 1964, as project leader, Mr. Harris undertook day-to-day control of the development of the TXE2 reed-electronic exchange system—now standard provision for small-to-medium capacity telephone exchanges—and the TXE3 system, the forerunner of the TXE4 system, which is a vital element of B.P.O. modernization plans.

He was a founder member of a long-range studies unit concerned with the study of long-term service and system possibilities.

In 1967, he returned to Dollis Hill as Head of the Electronics Switching Research Division, concerned with the continuing digital switching experiment at the Empress exchange in West London, and with the study of software-controlled switching systems.

A year later, he was appointed head of the joint B.P.O.-Industry Advisory Group on System Definitions, set up to advise the B.P.O. on the systems required for the late-1970s and beyond, and on how best to reconcile the advantages of standardization with those of competition, flexibility and technical change. The group has undertaken studies concerned with network and systems architecture, and with specification and development methods and procedures. The group has also laid the foundation for a new family of software-controlled systems—*System X*—and for the creation of a total system strategy for the network as a whole.

During 1972, he took a leading part in discussions with industry, preparatory to B.P.O. decisions on exchange-equipment modernization and the adoption of the TXE4 system.

Mr. Harris, son of the late Brigadier Sir Lionel Harris, a former Engineer-in-Chief, lives at Kenton, Middlesex. He is married, with two daughters, one married and one at York University, and one son at school in Kingsbury.

Overseas Interest in Hoverdrum

Considerable international interest is being shown in a new application of the hovercraft principle by the British Post Office (B.P.O.) for moving 71 × 10^3 kg loads of submarine telephone cable. Successful acceptance trials have just ended at the B.P.O.'s new cableship depot, now being built at Southampton.

When the depot opens later thi. year, the hovercraft technique will be used for moving giant, pre-loaded pans of cable about the dockside at only a tenth of the cost of a mobile crane, yet with much greater mobility.

Four small hover-platforms lift the 5·5 m diameter cable pans. The power comes from a £17,000 compressor tug, which provides the air-flow to the hover-platforms, and manoeuvres the heavy pans by pushing or towing, once they are floating on a cushion of air.

Use of the hovercraft principle is part of a major scheme designed to give the B.P.O. the finest, fastest submarine-cable repair-service in the world.

During the next five years, the number of international telephone calls handled by the B.P.O. will soar, from last year's 60-million to 150-million in 1978, and more cables beneath the sea, capable of carrying huge numbers of telephone calls simultaneously, are among methods being used to meet this growth.

The B.P.O. is responsible for the maintenance and repair of more than 24 × 10^3 km of submarine cable linking the U.K. with the rest of the world, and, with so many telephone calls and other communication services being carried on cables, it is imperative to get them working again quickly, in the event of a cable failure at sea.

Two new cable-repair ships, now taking shape at the Dundee yards of Robb Caledon Ltd., form the hub of the modernization plans. They are designed for pan loading, in which cable is pre-loaded in giant pans, and simply swung on board when needed. This compares with the traditional method of hauling cable in and out of the holds. The most outstanding feature of the new process, which can be compared to loading a camera with a cassette instead of reeling the film by hand, is that it reduces ship turn-round time from days to hours, enabling cable failures to be dealt with much more quickly.

At the same time, all submarine-cable repair work is being centred on Southampton to put cable-repair ships within easy striking distance of the sea areas where Britain's international cables are concentrated; that is, the southern North Sea for communication with Central and Eastern Europe, and the South-Western Approaches, where cables go out to Western Europe and other parts of the world.

The B.P.O. is using its hovercraft technique for moving the cable pans at the Southampton depot because of the economies and flexibility of movement it offers. Although part of the depot complex will need to be surfaced with a special compound to prevent air from the hover-platforms leaking away through gaps in the concrete-slab paving, capital investment is expected to be no greater than £28,000, compared with £250,000 for a crane on rails. While the hover system permits the cable pans to be moved to virtually any location on site, a mobile crane would limit movement to within the range of its railway track.

Already, authorities in four countries, the U.S.A., France, Belgium, and Spain, have called for full details, while others have expressed interest.

The compressor tug, developed to move the cable pans at the dockside, has an air output of 0·284 m^3/s, developing a pressure of 70 × 10^3 kg/m^2. This is regulated down to 35 × 10^3 kg/m^2. Each hover castor can lift a 36 × 10^3 kg load at 35 × 10^3 kg/m^2. Four castors will be used to lift each cable pan, a maximum load of 81 × 10^3 kg. This gives a safety margin of 2:1. The driver can control the air-flow to each castor individually, from controls inside the cab. By increasing the air-flow to any one of them, he can negotiate any unevenness in the ground.

The vehicle was built for the B.P.O. by F. L.Douglas of Cheltenham. It has a wheelbase of 2·44 m, a width of 3·36 m, a length of 4·95 m, a height (including compressor) of 2·75 m, and a turning circle of 11·6 m.

The hover castors are being supplied to the B.P.O. by Applied Technology Co. Ltd., European distributors for the manufacturers, Aero-Go Castors.

Strengthening Cross-Channel Communications

The first sod has been cut on the Tolsford Hill site, near Folkestone, for a new British Post Office (B.P.O.) radio tower which will greatly enlarge Britain's busiest single international telephone link—a 30-mile microwave radio link across the English Channel to France.

The radio mast already standing on Tolsford Hill has been strengthened to take more aerials. This was the first step in a two-stage program; the second will be the setting-up of the new tower, which will enlarge the route's call-carrying capacity in accordance with major B.P.O. plans to keep pace with a rapidly-increasing demand for communications with Europe. The new tower will be ready for service in 1975, when the old mast will be taken down.

This route, from the Tolsford Hill microwave station to its French counterpart at Fiennes, near Loos, handles calls to and from France—people in Britain make nearly four-million calls there a year—and carries many international calls routed across France to other countries, principally Italy, Switzerland, Spain, Greece and Yugoslavia.

Britain's international telecommunication services are doubling every five years and communications with the Continent account for the largest portion of the B.P.O.'s international telephone traffic. Of the 25-million overseas calls from Britain last year, 20 million were to the European mainland. By 1975, 77-million telephone calls a year will be flowing between Britain and the Continent.

Stepping-up the cross-Channel microwave link is part of a big program to meet this expansion, and improve service with Europe generally. By 1978, expanded microwave and cable links will boost the number of telephone circuits to the Continent to 20,000—more than double the existing number.

The new tower has been designed by the Property Services Agency of the Department of the Environment (project manager, R. F. Hughes, Directorate of Post Office Services). Its appearance has been commended by the Royal Fine Arts Commission.

It will be 64 m high, with six galleries, triangular in plan, spaced at 6 m intervals. The top gallery, 42 m above ground level, is surmounted by a 22 m tubular-steel tower. The galleries are supported on five, 1·2 m diameter, circular, reinforced-concrete columns, arranged as a regular pentagon; the vertical members of the steel tower also form a pentagon. Dish antennae will be clamped to tubular-steel risers fixed to the outside faces of the galleries and some antennae will also be mounted on the upper tower. This arrangement gives flexibility in positioning and spacing of aerials for the cross-Channel route, for which space-diversity reception is necessary to combat fading due to sea reflexions. Two receiving antennae are used for each channel, and the better output selected for onward transmission.

£5 M Communications Project for North-Sea Production Platforms

A £5 million project to provide reliable high-quality communications for gas and oil production platforms operating in the North Sea was announced by Mr. Edward Fennessy, Managing Director of Post Office Telecommunications. Heart of the new communication system will be two new radio stations, each costing £500,000. Due to come into service in about 18 months' time, the stations will be sited at Scousburgh in the Shetlands and probably Mormond Hill, 48 km north of Aberdeen, to provide the greatest area of coverage in the North Sea.

Equipped with 12·2 m dish aerials, the stations will provide communications for production platforms working gas and oil finds more than 320 km from the shore.

"The rapid and efficient exploitation of gas and oil finds in the North Sea is of great economic significance to Britain", Mr. Fennessy pointed out. "Since exploration began, the Post Office has recognized the need for good communication between the off-shore operators and the U.K. mainland and has been meeting the needs of mobile drill-rigs, support and supply vessels, and pipe-layers since 1965. This new venture is to meet much more demanding needs during the production phase due to begin in 1975. On it, the Post Office is to spend up to £5 million".

Because many of the gas and oil fields are well out of sight of land, the Post Office is to use a communication technique it has never before used. This is known as trans-horizon radio (tropospheric scatter) with powerful microwave-radio signals beamed into the troposphere to become scattered by atmospheric turbulence, so that a very small, but still usable, signal reaches the receiving aerials.

The two new radio stations will provide direct communications to master production platforms which, in turn, will relay signals to other production platforms in their area by ordinary line-of-sight microwave, using much smaller dish aerials.

The Total Group, consisting of Total Oil Marine Ltd, Elf-ARAP, and Aquitaine, will provide the first two master platforms in the system. These will be the gas production platform now under construction for the Frigg gasfield 193 km east of the Shetlands, and the manifold platform about 172 km east of the northern tip of the Scottish mainland.

The Frigg field platform will be directly linked to the Scousburgh station in the Shetlands, and is well placed to provide spur links to other nearby production platforms such as the Beryl oilfield.

The manifold platform will be linked to Mormond Hill and is in a position to act as master platform for production platforms in the Piper oilfield, 161 km north-east of Aberdeen. Total is the first operator to make a firm commitment with the Post Office to use the new communications system to help operate the Frigg–Scotland gas pipeline.

"In choosing this system, the Post Office was very much alive to the need for highly reliable communications", said Mr. Fennessy. "Although we shall be handling communications with production platforms well out to sea—which is notoriously difficult—we shall be able to guarantee a quality of service which comes very close to the reliability of our systems on land".

The project is the result of a detailed study by the Post Office's North Sea Task Force, a team of communications experts formed earlier this year to examine the needs of the production platforms. During the study, the Post Office worked in close co-operation with Burmah Engineering Co. Ltd., design consultants to Total Oil Marine Ltd., for the communications part of their project.

Production platforms acting as master communication centres will be equipped with 7·62 m diameter dish aerials to communicate with the Post Office's land stations. Ordinary dish aerials will link nearby platforms into the system. The Post Office stations will be able to provide exclusive service for each off-shore production installation. This will probably be over mainly private circuits to the land bases of the companies operating the production plaftorms, carrying telephone and teleprinter calls, data and telemetry communications.

In addition, the Post Office will provide production platforms with a service giving access to the U.K. inland and international telephone and telex networks. It will be possible for an oil production platform 320 km out in the North Sea to send a telex message almost anywhere in the world without calling in the operator, and to make world-wide telephone calls.

The Post Office's proposed over-the-horizon radio relay links with the North ea platforms will operate in the 2 GHz band. Transmissions will be concentrated in 1° beams, between dish antennae, 12·2 km diameter, with a gain of 47 dB, on the mainland, and 7·62 km diameter, 41 dB gain, on the platforms.

At this frequency, the radio beam travels in a straight path, like a searchlight beam. On Britain's inland microwave network, receiving and transmitting antennae are at each end of a line-of-sight path and the length of path is limited to a maximum of about 40 km—the distance to the horizon. At greater distances, because of the earth's curvature, there can be no line of sight between aerials.

Just as a light beam is bent by passing it through a prism, so a radio beam bends as it passes through the lower atmosphere—the troposphere. The density of the air and, therefore, its refractive index (r.i.), decreases with increasing altitude. When the troposphere becomes turbulence, through wind, and convection currents set up by the sun's warmth, air of different r.i. is mixed and pockets of air of one r.i. become distributed through air of a lower r.i. High-frequency radio waves, transmitted through this turbulence, are reflected at the boundaries of these air pockets and refracted in passing through them. The total effect is diffraction and a large proportion of the radio energy in the beam is scattered in many directions. When diffraction occurs in a volume of troposphere visible to the receiving as well as to the transmitting antennae (the common volume), the radio energy scattered in the direction of the receiving antennae provides the second, over-the-horizon, section of the radio path.

Over the distances to be spanned by the North Sea tropo-scatter links, 200–250 km, the common volume lies about 1 km above sea level. The scatter angle, the inclination of the receiver antennae beam to the transmitter antennae beam, is 1°. The attenuation of the signal over the link will be about 210 dB. Because turbulence varies continuously, the level of the signal received, on average 130 dB below 1 watt, fluctuates, and could fall on occasions to become indistinguishable from the general background noise. To safeguard against such signal loss, the Post Office is providing a quadruple diversity system in which there will be two transmitter antennae, one transmitting a vertically-polarized beam, the other a horizontally-polarized beam. There will also be two receiving antennae, each receiving the two signals and separating them to feed them to separate receivers. The terminal examines the outputs of the four receivers continuously to select the most powerful output for further amplification and onward transmission. With this arrangement, the signal-to-noise ratio on telephone calls will not be less than 40 dB for 99·9 per cent of the time, and the data error rate on telegraph transmissions will not be worse than 1 in 10^5 at 2,400 bit/s for 99·98 per cent of the time.

System bandwidth is 1·5 MHz, giving up to 72 one-way telephone channels in each direction, transmitted by f.m./f.d.m. Mainland and off-shore transmitter output stages will each have a power of 1 kW, which, allowing for a 1 dB feed loss, gives an effective isotropic radiated power of 80 MW.

Calling China by Satellite

Britain's telephone service with the People's Republic of China, which has been available for only three hours a day, became full-time on 4 April with a switch to satellite communications.

The move follows the opening, in China, of a satellite earth-station, using the INTELSAT IV communications satellite positioned 22,300 miles above the Indian Ocean. The British Post Office (B.P.O.) already uses this satellite for eastern-hemisphere communications.

Telephone calls from Britain to China are now beamed from the B.P.O. earth-station at Goonhilly Downs, Cornwall, and received by China's new earth-station, near Peking.

Power from the Line—Requirements for Attachments

In June 1973, the British Post Office (B.P.O.) announced that it had decided to permit attachments to the telephone to be operated by the power-flow from the telephone line, the technical specification to be published later. The requirements for line-powered attachments are now available and are reproduced below.

As from July 1, 1974, certain attachments are permitted to draw their activating power from B.P.O. exchange lines or private branch exchange extensions. The requirements and conditions applied to such devices in addition to existing requirements for self-powered attachments to the public switched telephone network are as follows:

1. The B.P.O. will not undertake to provide lines to a particular standard. Line-powered attachments must function with conditions normal to the telephone installation and be independent of line polarity.
2. Suppliers and users must accept that attachments may be rendered unusable by B.P.O. system changes. A minimum of two years' notice of such changes is normally given by the B.P.O. To safeguard the interests of users in the event of system changes, line-powered attachments must be supplied on rental terms.
3. Telephone exchange battery voltage limits are 46–52 volts and may contain ripple components not exceeding 2 millivolts. P.B.X. line voltage limits are normally 45–55 volts, but some p.b.x.s have lower nominal voltages and limits. Line current may be any value between 25 and 110 milliamps depending upon the combination of feeding, line and terminal resistances. It should be noted that additional power components exist on lines which might affect line-powered attachments. These are
   (*a*) longitudinal induced voltages up to 20 volts r.m.s. at 50 Hz,
   (*b*) uniform spectrum and random noise having a power not exceeding —45 dBm over the band 300–3,400 Hz, and
   (*c*) random impulsive noise in excess of —22 dBm.
4. Power may be drawn from line only when the line is diverted to the attachment by means of a telephone pushbutton switch which is restored by replacing the receiver. Power may be drawn from line only during the chargeable duration of a call. The line-terminating condition consists of the following conditions presented to line by the attachment:
   (*a*) a direct-current (d.c.) circuit with resistance not exceeding 300 ohms, and
   (*b*) an alternating-current circuit with impedance in the range of 400–900 ohms with angle not greater than 45 degrees in the frequency range 300–3,400 Hz.

   The circuit must be capable of carrying d.c. up to 120 milliamps without going outside the limits in 4(*a*) and (*b*) above.
5. Motors, or other components liable to introduce electrical interference into the telephone line, may not use line power.
6. Attachments connected to line through B.P.O. modems may not use line power.
7. The decision to permit line powering is most likely to affect multi-frequency data devices, but is not restricted to such attachments.
8. The terms of Technical Guide No. 26 (Protection) apply if the attachment is powered partly by a private power supply or is connected to another device which is powered by a private power supply,
9. Designers and suppliers are advised to consider the need to protect the attachment from voltages which may be impressed on B.P.O. lines by lightning and other extraneous sources. These voltages may be unidirectional or alternating and of a transient nature. Transient and prolonged voltages are also on many B.P.O. circuits as normal functional characteristics. They may reach a peak value of several-hundred volts. Prolonged voltages of at least 100 volts peak may be encountered (e.g. from ringing current). Circuits containing semi-conductors are particularly vulnerable to damage by comparatively small excess voltages, even of short duration. The B.P.O. will not accept any responsibility for damage caused to attachments by any of the above conditions.
10. The B.P.O. reserves the right to withdraw the line powering concession at reasonable notice. All applications for consideration by the B.P.O. should be submitted to Post Office THQ, Sv1.1.3, 45 Moorfields, London EC2Y 9TH.

Copyright

The entire contents of this *Journal* are covered by general copyright, and special permission is necessary for reprinting long extracts, but editors are welcome to use not more than one-third of any article, provided that credit is given at the beginning or end, thus: "From *The Post Office Electrical Engineers' Journal.*"

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles or the correspondence in this *Journal*, unless such statement is made specifically by the Board.

Subscriptions and Back Numbers

The *Journal* is published quarterly, in April, July, October and January, at 26p per copy, 36p per copy including post and packaging (£1·44 per year; $3.75 Canada and U.S.A.).

The price to Post-Office staff is 21p per copy.

Back numbers will be supplied if available, price 26p (36p post paid). At present, copies are available of all issues from October 1969 to date, with the exception of April 1971 which is now sold out. Copies of the October 1966, July 1967 and January 1968 issues are also still available at present.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £2·25 including return postage, by sending the complete set of parts, with a remittance to Press Binders Ltd., 4 Iliffe Yard, London, S.E.17.

Remittances

Remittances for all items (except binding) should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Advertisements

All correspondence relating to advertisement space reservations, copy, proofs, etc., should be addressed to the Advertisement Manager, *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, EC2V 7AG.

Distribution and Sales

Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London, EC2V 7AG.

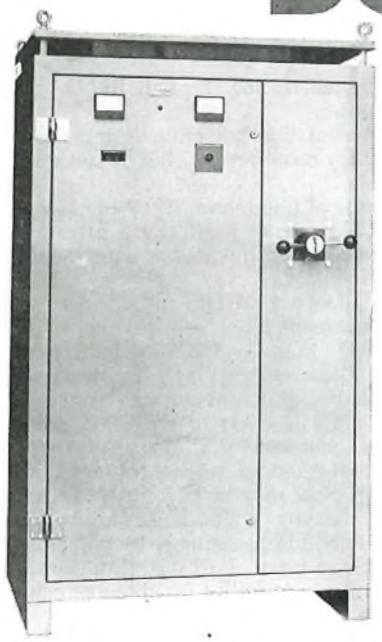
Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08A, River Plate House, Finsbury Circus, London, EC2M 7LY.

Model Answers Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the *Journal*.

ERSKINE TECHNOLOGY:2



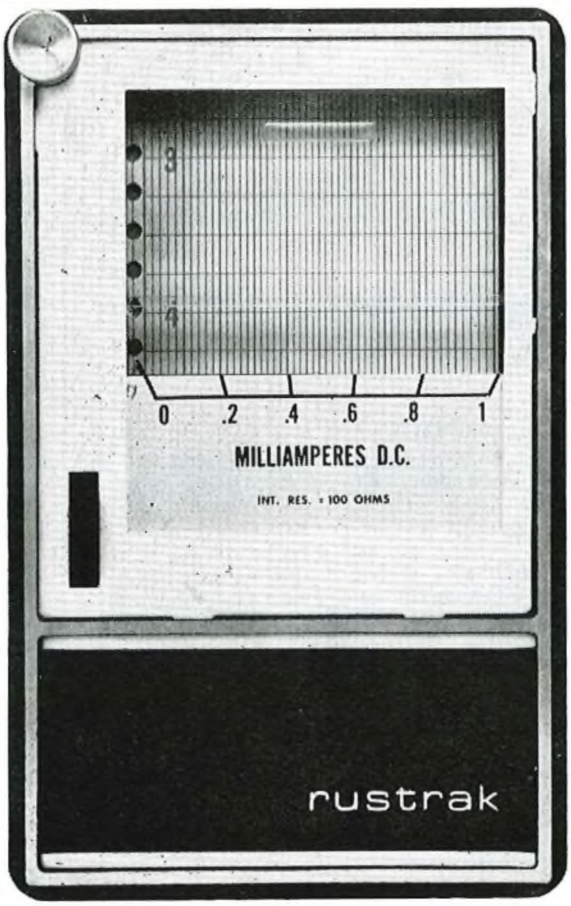
DC Power Supplies

Lead Acid or Alkaline battery back-up facilities.

- Solid state thyristor control.
- 24, 50, 110 and 220 volt systems.
- Single or three phase to 1000 amps.
- ±2% regulation for 0 to 100% load as standard, +0.5% to order.
- Current limit with full overload protection.
- Smoothing to Telecommunications requirements.
- Standard units or custom built.
- Chassis chargers available ex-stock.

ERSKINE

Erskine Systems Ltd., Scarborough, Yorkshire YO12 6UE. Tel: 07232433
Telex: 52562 A Member of The Dale Group of Companies



Rustrak Miniature Strip Chart Recorder

Rustrak miniature strip chart recorders are available as potentiometric or galvanometer type instruments which produce a permanent record of virtually any parameter that can be converted into an electrical signal; temperature, pressure, flow, level, watts, frequency, humidity, events and many more.

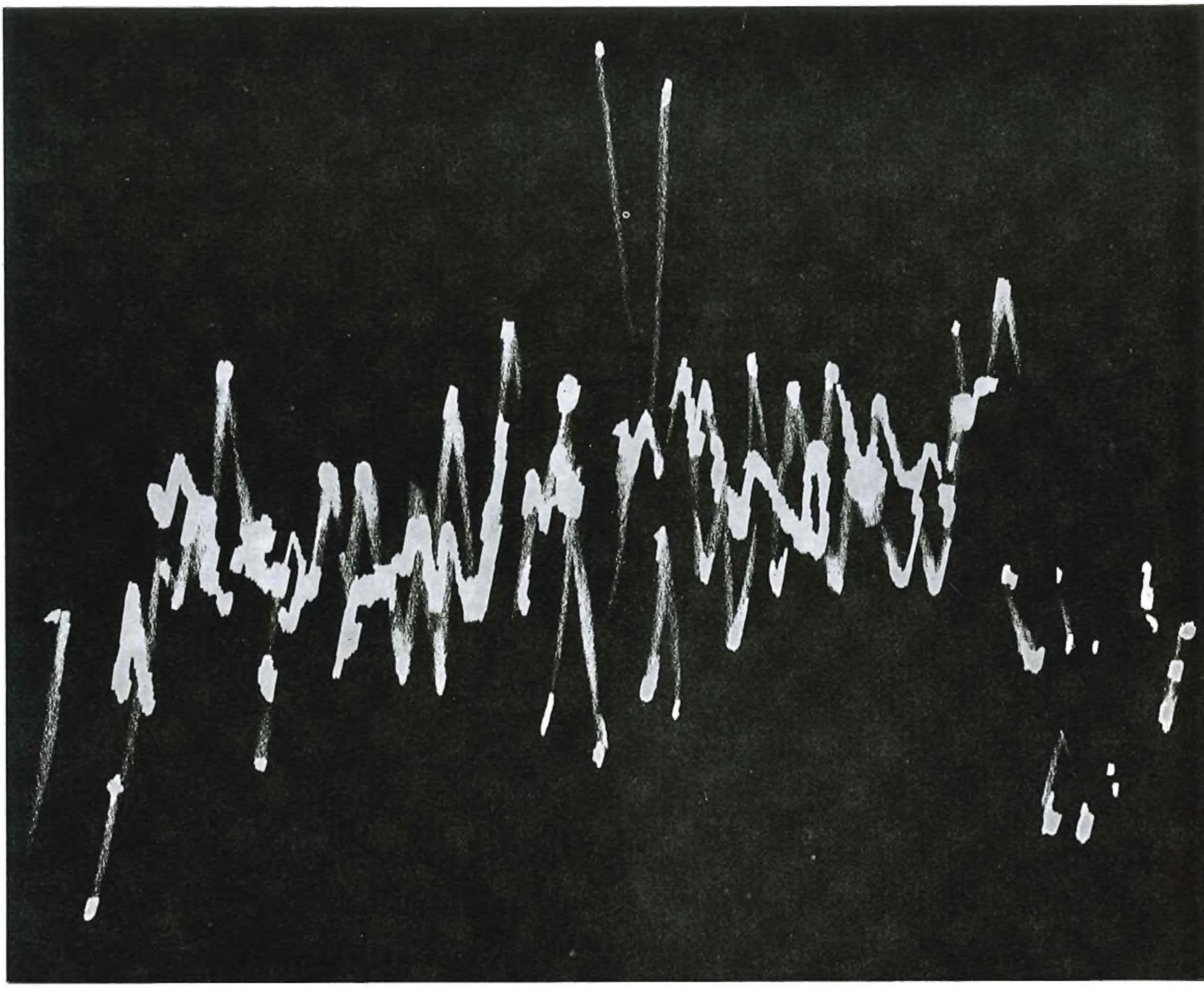
Data is recorded on pressure sensitive paper, obviating the many problems that can result from the use of ink. A wide range of motor speeds and interchangeable gearboxes is available to give over 50 chart speeds.

Of attractive design, the low-cost Rustrak recorder measures only $5\frac{5}{8}''$ high by $3\frac{5}{8}''$ wide.

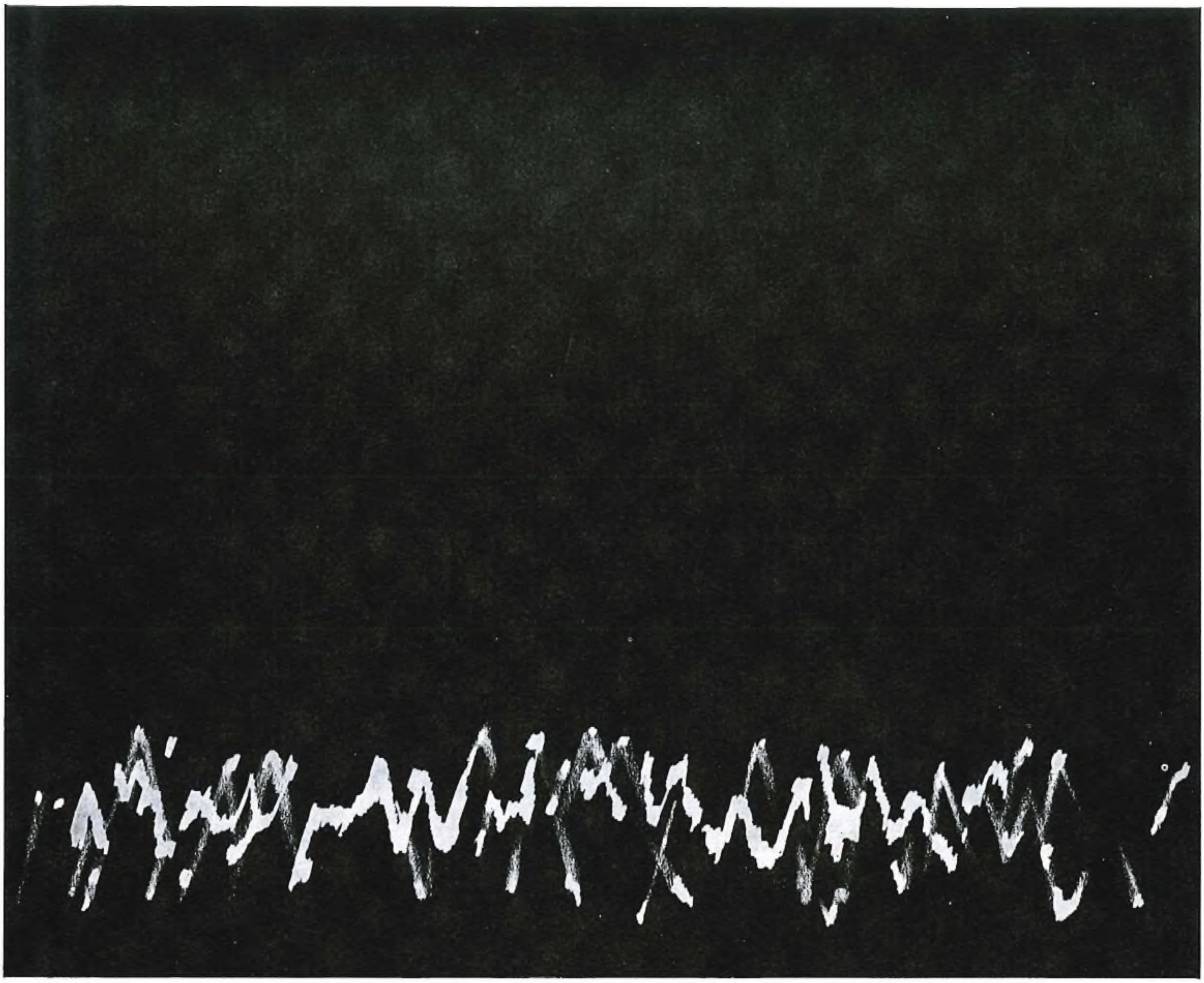
Considerable savings in time and cost are made by hand from indicator readings.

Delivery of the standard instrument is 2–3 weeks and a complete advisory service on your particular recorder problems is available from our experts.

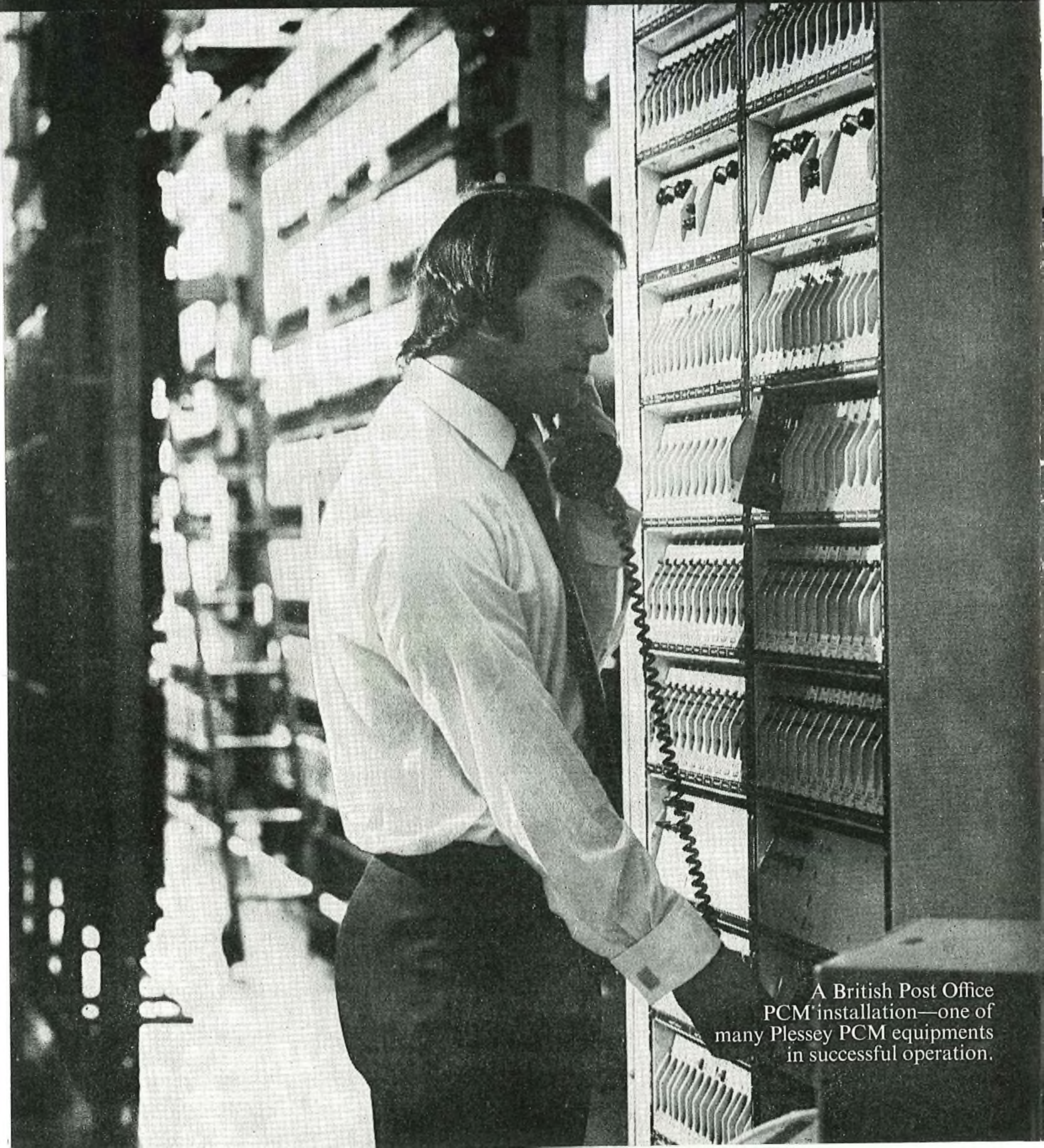
Gulton
EUROPE
Rustrak Instrument Division
BRIGHTON BN2 4JU



We've added something important to our new transceivers.



Speech quantity plus speech quality-



A British Post Office PCM installation—one of many Plessey PCM equipments in successful operation.

Marconi

Radio/Telephone Terminal Systems

Marconi radio/telephone terminal equipment provides the essential interface between h.f radio circuits and associated telephone networks, and ensures the maintenance of high quality speech during adverse propagation conditions.

The Marconi advanced range is the most comprehensive available, and Marconi systems are in use by more than 40 administrations throughout the world.

The wide choice of assemblies meets the technical and operational needs of large or small operators and includes split-band privacy, echo suppression, speech band inversion, two-channel multiplex and speech processing by conventional techniques or Lincompex.

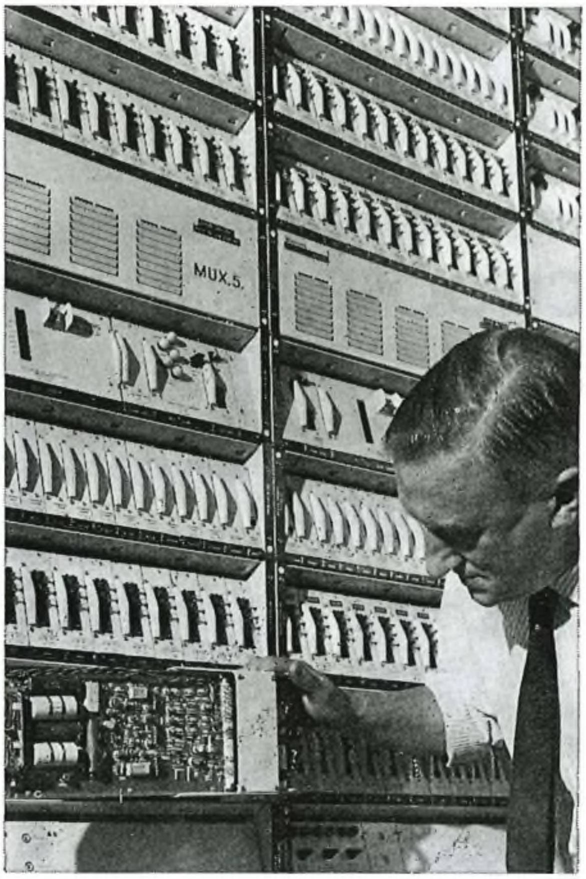
H97

Marconi

PCM Systems

Marconi is the foremost manufacturer and exporter of PCM systems in the United Kingdom. More than 100,000 channel ends have been sold to the British Post Office, overseas telephone authorities and public utilities, because of technical quality, cost effectiveness and prompt delivery, coupled with highly experienced planning, installation and commissioning services.

Marconi PCM interfaces with most modern automatic exchange systems, and is also suitable for future integrated switching systems. It tolerates low-quality audio cable and operates in adverse environments. It can be expanded economically and flexibly and can also provide teleprinter channels and data transmission facilities.



U 65

Marconi Communication Systems

Complete civil and military static and mobile communication systems

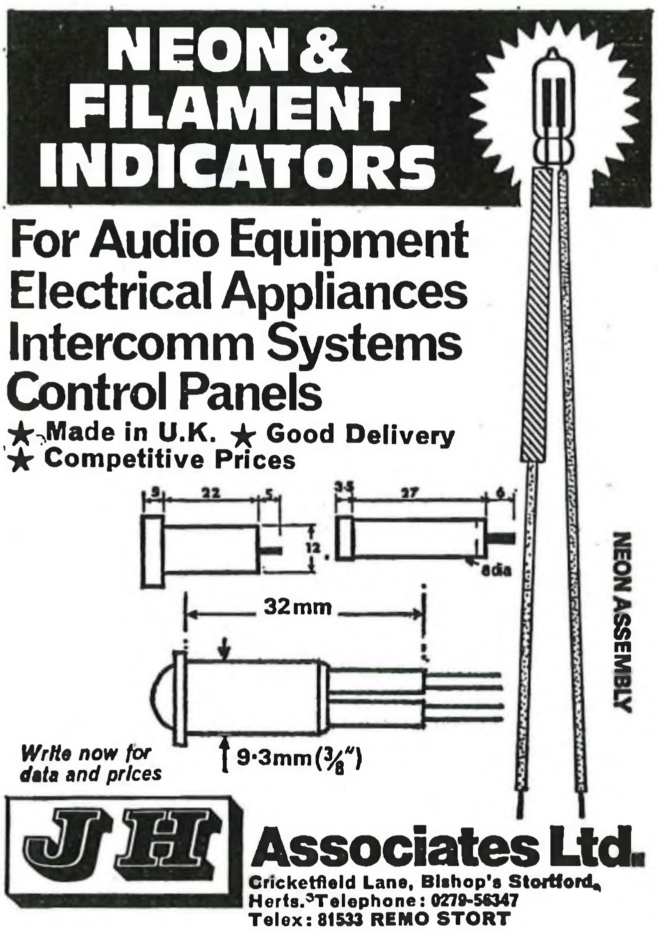
Marconi Communication Systems Limited, Chelmsford, Essex, England

A GEC-Marconi Electronics Company

LTD

INDEX TO ADVERTISERS

	Page
AB Electronic Components Ltd.	18
Berco Controls Ltd.	18
Cotron Electronics Ltd.	17
Erskine Systems Ltd.	9
GEC Telecommunications Ltd.	2–4
Gulton Europe Ltd.	9
GTE Information Systems Ltd.	11, 12
Hallam Sleigh & Cheston Ltd.	8
Herman Smith Ltd.	19
ITT Business Systems Ltd.	7
ITT Flygt Pumps Ltd.	17
J. H. Associates Ltd.	17
Marconi Communications Systems Ltd.	16
Mullard Ltd.	5
Plessey Telecommunications Ltd	13, 14
Standard Telephones & Cables Ltd.	6
Telephone Cables Ltd.	10
Telettra Spa Milan	1
Whiteley Electrical Radio Company Ltd.	15



Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, E.C.2, and printed in Great Britain by Unwin Brothers Limited, Old Woking, Surrey

BERCO

over 40 years experience in VOLTAGE, CURRENT & SPEED CONTROL

BERCOSTATS

REGAVOLTS

REGASPEED/HSR

BERCOTROL

POWER RESISTORS

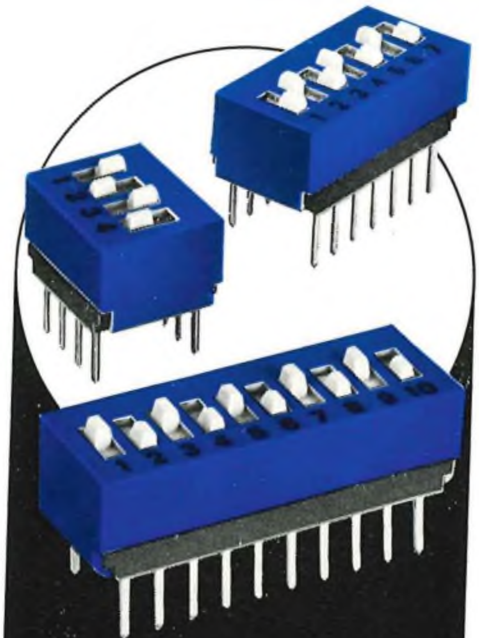
VOLTAGE STABILISERS

- BERCOSTATS – Power Rheostats Potentiometers
- REGAVOLTS – Variable Auto Transformers
- REGASPEED and HSR – Open Loop Speed Controllers (for use with D.C. Shunt Motors)
- BERCOTROL – Closed Loop Thyristor Speed Controllers (for use with D.C. Shunt Motors)
- Fixed and Preset Power Resistors
- PVS Voltage Stabilisers

Write or telephone for new literature

BERCO CONTROLS LIMITED
Baird Road, Enfield, Middlesex EN1 1UA Tel: 01-804 2411

No upsets with A.B.'s new set-up switch



The slide action of our new 206 DIL component makes it less liable than other kinds to accidental de-programming.

It's flexible (from four to ten sections at a 2·54 mm pitch), it has contact wiping on make-or-break and gold-plated contact arms for long-term corrosion resistance.

High quality, sensible price, AB back-up. You should find out more.

A.B.Controls
(A Division of AB Electronic Components Ltd.)
Abercynon, Glamorgan, Great Britain, CF45 4SF.
Telephone: Abercynon (044 374) 331 Telex: 49606