The Post Office Electrical Engineers' Journal

VOL 65 PART 2/JULY 1972

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL 65 PART 2 JULY 1972

Contents

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

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

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

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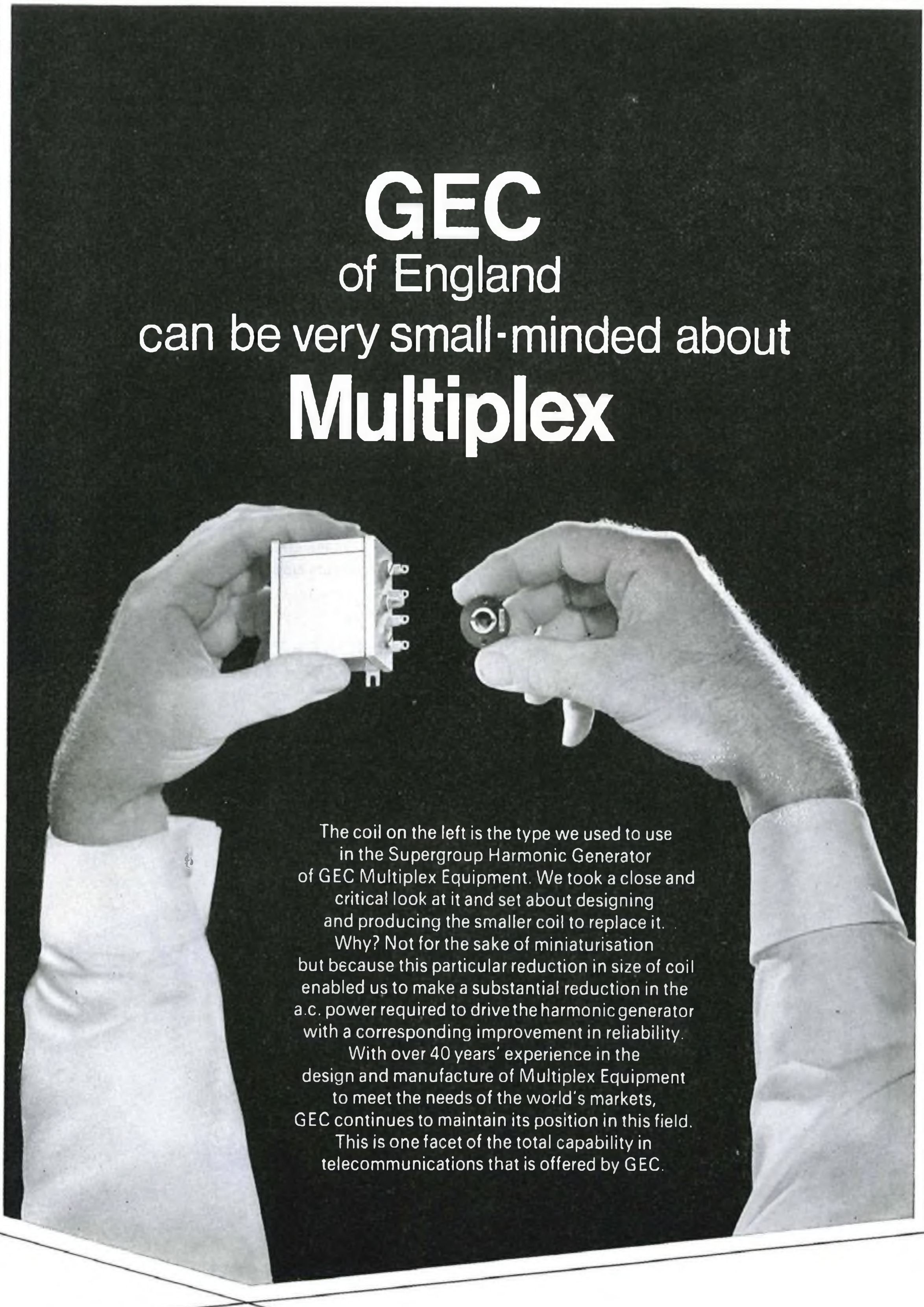

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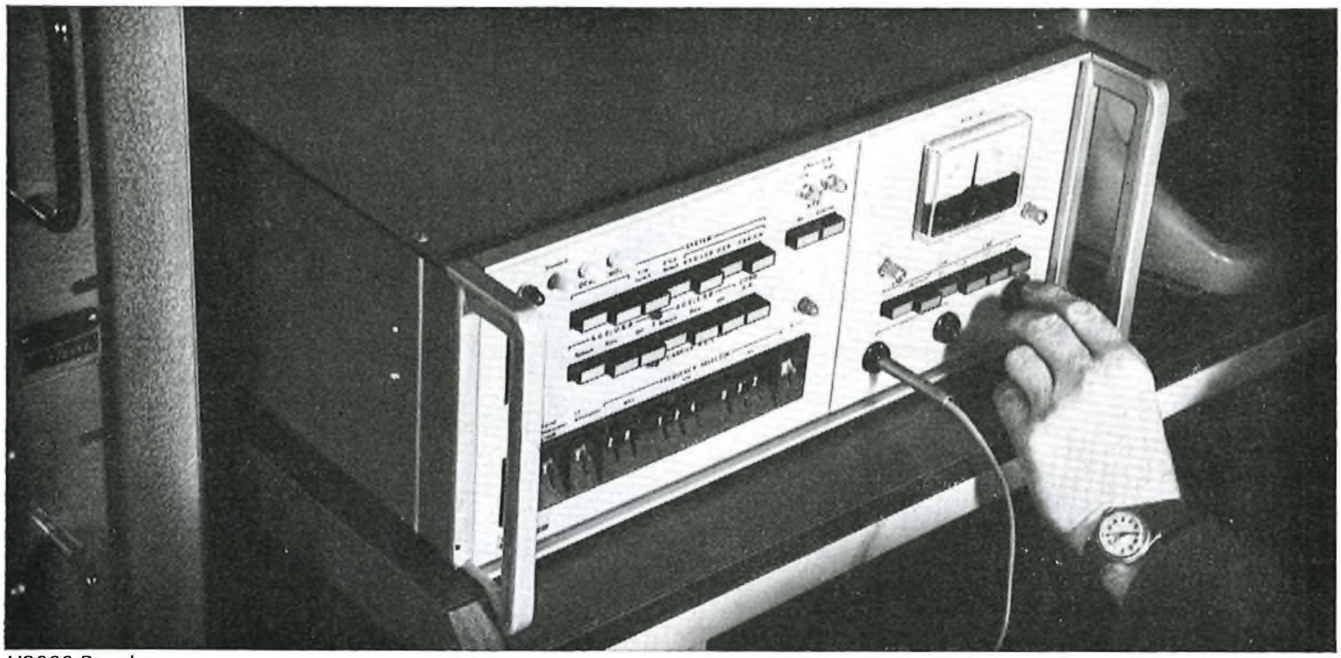

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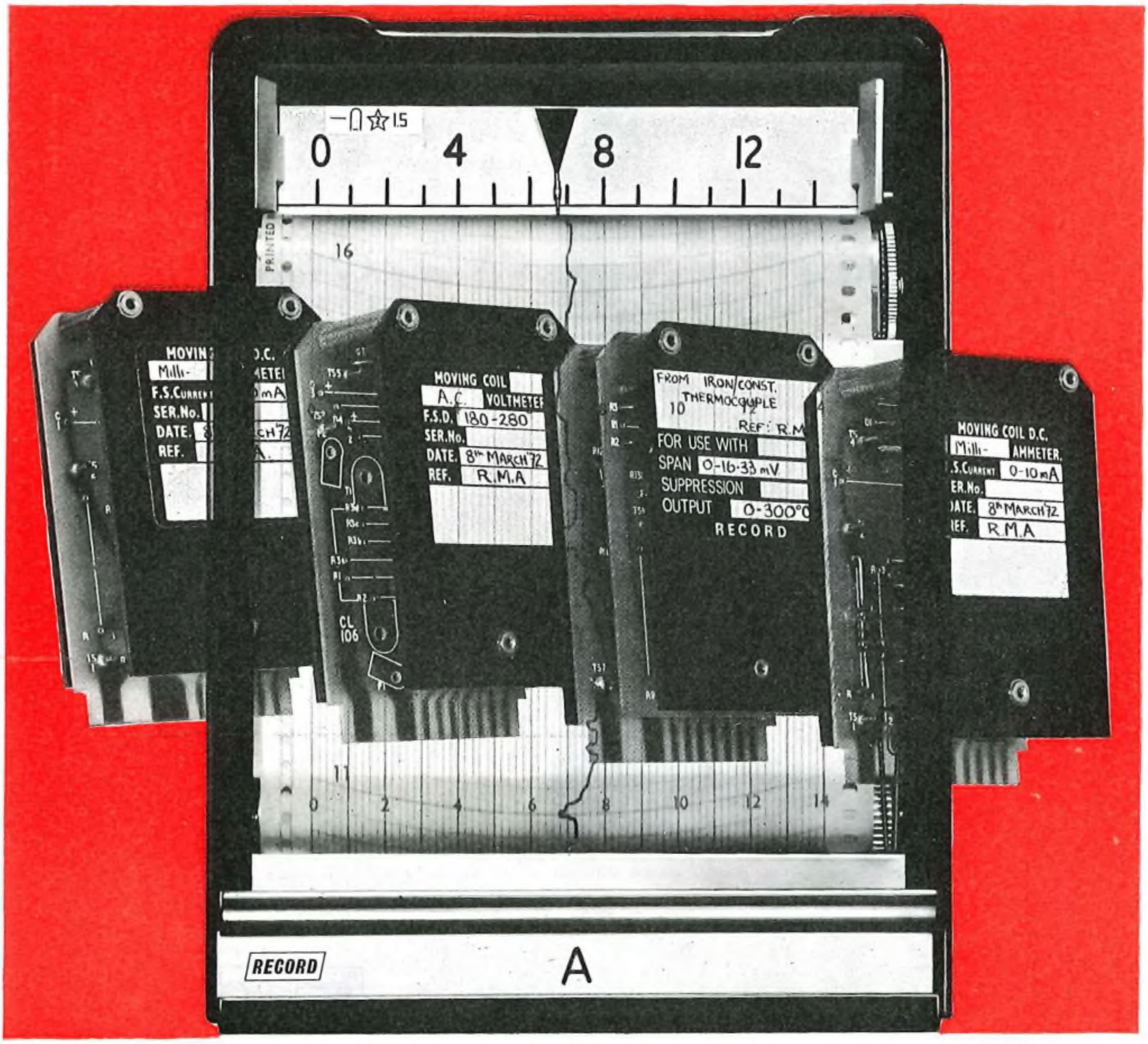

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The Post Office Electrical Engineers' Journal

EDITORIAL

The British Post Office Research Department has won a Queen's Award for technological innovation in the development and production of high-quality transistors for use in under-sea cable systems. The advances achieved in this field have been a major factor in enabling administrations throughout the world to keep pace with the increasing demand for submarine cable services and at the same time stabilizing and even reducing costs. That this has been possible within an operational organization makes the achievement even more praiseworthy and the Board of Editors takes this opportunity of congratulating all concerned.

This issue includes further articles on aspects of data transmission and there are two articles related to computers, namely methods of acceptance and a review of visual display techniques. The theory and application of negative impedance devices, clearly an important feature of future telecommunications systems, is described and another article deals with the new London Radiophone System.

Dataplex Service 110—A New Service for Time-Sharing Computer Bureaux

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U.D.C. 681.327.8:621.394.4

Dataplex Service is a generic title used by the British Post Office to describe data services which involve multiplexing. This article describes the Dataplex Service 110 which enables customers in a remote area to have access to a time-sharing computer bureau. The service is a modified version of the Datel 200 Service and avoids the customer incurring the cost of s.t.d. calls as well as reducing congestion on the trunk network.

INTRODUCTION

Computer bureaux have been established in major cities in the United Kingdom during the past five or six years to enable the facilities of powerful computers to be made available economically to a wide range of customers. These include business, industrial and teaching organizations whose day to day usage would be insufficient to justify the exclusive use of a computer and the large capital expenditure involved in its purchase.

Where it is not essential to process the data immediately, the data can be stored on magnetic or punched paper-tape and sent to the bureau for processing, to be returned, usually, the following day. A more convenient and increasingly-used method of operation is the ON-LINE REAL-TIME mode where the British Post Office (B.P.O.) Datel 200 Service can be used. The Datel 200 Service provides for the exchange of duplex-serial-binary data over a connexion on the public switched telephone network (p.s.t.n.) by using Datel Modems No. 2.[1]

A computer bureau generally comprises a central computer installation with the capability to handle simultaneously a large number of data-processing transactions. Access to the bureau is generally obtained over direct exchange-lines, each terminated at the bureau by a Datel Modem No. 2. The relatively low cost and ease of becoming a customer to a computer bureau offers considerable attraction as by renting a B.P.O. approved type of teleprinter connected to a modem terminating a direct exchange-line, a customer can dial up a computer bureau and access the computer on an ON-LINE basis.

Whilst operation at rates up to 300 bit/s is now possible using the Datel 200 service, computer bureau data is generally exchanged at rates up to 110 bit/s, the actual rate being determined by the customer's terminal equipment. At local call charges, the p.s.t.n. provides a convenient, flexible and economic medium by which a computer bureau is able to attract a large number of customers to rent time on its computer.

The holding times for data calls are generally of much longer duration than those for normal speech calls and in many instances can be of the order of 45 minutes. Where local-call charges apply, the cost to the customer of these calls is generally insignificant compared with the charges made by the computer bureau for computer usage time. Where the subscriber trunk dialled (s.t.d.) network is involved, however, the call charges approach those made by the bureau. The high capital cost of computers generally precludes a computer bureau organization from operating a large number of computer installations in different parts of the country, and a bureau is somewhat handicapped in attracting customers from areas out of the local-call charge range.

The current range of Datel Services is being extended to offer customer services involving multiplexing, a technique for transmitting a number of information channels simultaneously over a common circuit. The first of these services to be made available is the Dataplex Service 110. The facilities are provided by a Dataplex 1/240F system which establishes a concentration point in a distant town for the extension of a modified form of the Datel 200 service over a 12-channel multi-channel voice-frequency telegraph (m.c.v.f.t.) system connecting the distant concentration point to the computer bureau. A single dedicated circuit is thus able to carry twelve simultaneous computer-bureau data calls. The Dataplex 1/240F system is rented by the B.P.O. to the computer bureau whose remote customers in the area of the concentration point are then able to access the bureau at local-call charges via the concentration point. The system, therefore, enables the area over which a computer bureau can economically attract customers to be greatly increased without the bureau incurring the costs of equipment and accommodation at the remote concentration point.

SYSTEM DESIGN CONSIDERATIONS

A major consideration influencing the design was the requirement to maintain the standard operating procedures established by both the customer and the computer bureau for the normal Datel 200 method of access. Instead of answering the data call on a modem at the computer bureau the solution adopted was to answer the call on a modem situated at the concentration point and to extend the modem data and control interchange circuits over a channel of the m.c.v.f.t. link to the computer bureau. Another consideration was the requirement to offer service quickly, necessitating the use of standard B.P.O. equipment as far as possible to minimize new design work.

Twelve-channel voice-frequency telegraph (v.f.t.) equipment was adopted for the link between the computer bureau and the concentration point. This m.c.v.f.t. equipment imposes a limit of 100 bit/s on the maximum data transmission rate but, since the majority of bureau customers use 110 bit/s teleprinters, this limitation is acceptable. To make full use of each

† Network Planning Department, Telecommunications Headquarters.

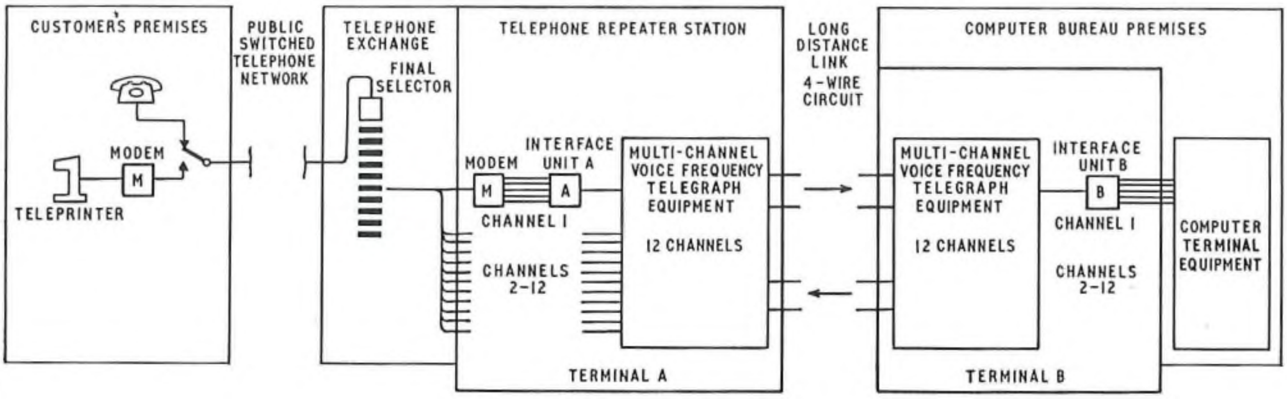


FIG. 1—Dataplex 1/240F system

of the 12 v.f.t. channels for data, both the modem control and the modem data interchange circuit signals are extended over the same v.f.t. channel.

The use of an m.c.v.f.t. link in the Dataplex 1/240F system precludes the offering of an alternative voice facility. However, since most bureau calls are answered automatically by the bureau without operator intervention, the loss of this facility is considered acceptable.

The high concentration of traffic through the Dataplex 1/240F system and the 24-hour operation of bureaux, calls for a high degree of reliability in the Dataplex equipment and rapid indication of any fault conditions. The extension of a p.s.t.n. call over a v.f.t. channel requires careful consideration of the overall system-control arrangements to avoid the possibility of signalling lock-up conditions occurring.

SYSTEM FACILITIES

The facilities incorporated into the Dataplex 1/240F system to meet the design requirements are:

(*a*) full duplex transmission of serial digital data signals at rates up to 110 bit/s between a customer and a bureau over a p.s.t.n.-Dataplex 1/240F link, all calls being originated by customers,

(*b*) the bureau is able to answer an incoming call by the use of connect-data-set-to-line operating mode,

(*c*) both the customer and the bureau are able to clear down an established call at any time during the course of, or at the end of, data transmission,

(*d*) the provision of backward-busying facilities under the control of bureau staff to prevent incoming calls on any particular data channel,

(*e*) the p.s.t.n.-Dataplex 1/240F link provides a code-independent transmission-medium in both directions, with the restriction that the sending of a repetitive start-stop signal where each element is of a nominal half-second duration is prohibited as this signal is used for control purposes,

(*f*) the provision of lamp indications at the bureau terminal showing the operational state of each data channel at any instant, and

(*g*) the provision of visual and audible alarms to indicate system failure.

OUTLINE OF THE SYSTEM

The main features of a p.s.t.n.-Dataplex 1/240F link are shown in Fig. 1. A 12-channel v.f.t. system provides the long-distance link. The v.f.t. equipment uses frequency-division multiplex (f.d.m.) techniques to enable 12 channels, spaced at 240 Hz intervals, to be provided over an audio bandwidth of 360 Hz to 3,240 Hz.

Full duplex data-communication between the customer and the concentration point, termed terminal A, is provided using Modems No. 2 at both these locations. These modems use frequency modulation and, by conversion of data-interchange-circuit d.c. signals into v.f. signals, enable data to be exchanged over the p.s.t.n. connexion. The modem data and control-signal interchange-circuits comply with C.C.I.T.T.* recommendations V21 and V24.[3]

The exchange lines are equipped for incoming calls only from a private branch exchange group on the 11-and-over final-selectors and each of the 12 exchange lines is terminated by a Modem No. 2 in terminal A, which also incorporates the m.c.v.f.t. equipment and 12 interface units A. A call originated by a customer to terminal A causes the telephone-exchange final-selector to hunt for a free line. The lines appropriate to modems 1 to 12 are taken into use progressively until the twelfth modem is in use. Recorded announcement facilities can be provided on outlets above the twelfth so that when all 12 exchange-lines are in use customers can be advised to call later. Terminal A is generally located in a telephone repeater-station convenient for the concentration point.

The computer bureau terminal, or terminal B, is located within the bureau premises and incorporates the m.c.v.f.t. equipment together with 12 interface units B. Interface units A and B, at the respective ends of a v.f.t. channel, enable the modem data and control interchange-circuit signals to be transmitted over the single v.f.t. channel and to be reconstituted at terminal B. The interchange circuits and signal-voltage levels and sequences presented to the computer terminal-equipment (c.t.e.), therefore, correspond in general to those that would be encountered if the normal Datel 200 method of access was used with the modems located at the bureau.

Description of Terminal A

Terminal A, shown in Fig. 2, comprises a 9 ft, type-62 rack accommodating the 12 modems, 12 interface units A, m.c.v.f.t. equipment and the power-supply units. Fig. 3 outlines the circuit arrangements and shows the interconnexion of the various units.

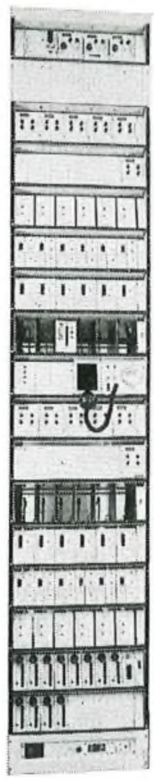
* C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

The present design of Modem No. 2 consists of a modulator, demodulator, control unit and a.c. mains power-supply unit contained in a case for desk or table mounting. For Dataplex 1/240F use, to minimize space requirements, these modules are mounted directly on the rack shelves. The m.c.v.f.t. equipment is powered from the station d.c. supplies.

Since the exchange of signals between each v.f.t. channel and the appropriate interface unit A is at levels of +6 volts and −6 volts d.c., each of the 12 v.f.t. channel modules is strapped to accept these signal levels instead of the +80 volts and −80 volts d.c. normally encountered in telegraph practice. For signalling purposes, in the receive direction, supplies of +6 volts and −6 volts d.c. are obtained from a zener diode arrangement connected to the output of the power supply unit of the modem associated with that particular channel.

A test-access unit is also associated with each modem and provides lamp indication of the operational state of the modem by monitoring the CALLING INDICATOR, DATA-SET READY and RECEIVE-LINE CARRIER-DETECTOR control interchange-circuits. The unit also provides test facilities by means of a test-access socket and change-over links, LK in Fig. 3, to enable the modem to be disconnected from both the interface unit A and the incoming exchange-line. When the LK links are moved to the test position, the incoming exchange-line from the telephone exchange is looped by a 33-kohm resistor. This permits a small exchange-battery current to flow which is detected by a specially-provided transistorized unit at the telephone exchange to result in the telephone-exchange final-selector multiple P-wire being connected to earth to prevent incoming calls. Operation of the LK links also provides an EXCHANGE LINE OUT-OF-SERVICE indication on the test-access unit.

A test-telephone unit, incorporating a dial and handset



Note: Terminal shown equipped with one only of the 12 test-access units

Fig. 2—Dataplex 1/240F system—Terminal A

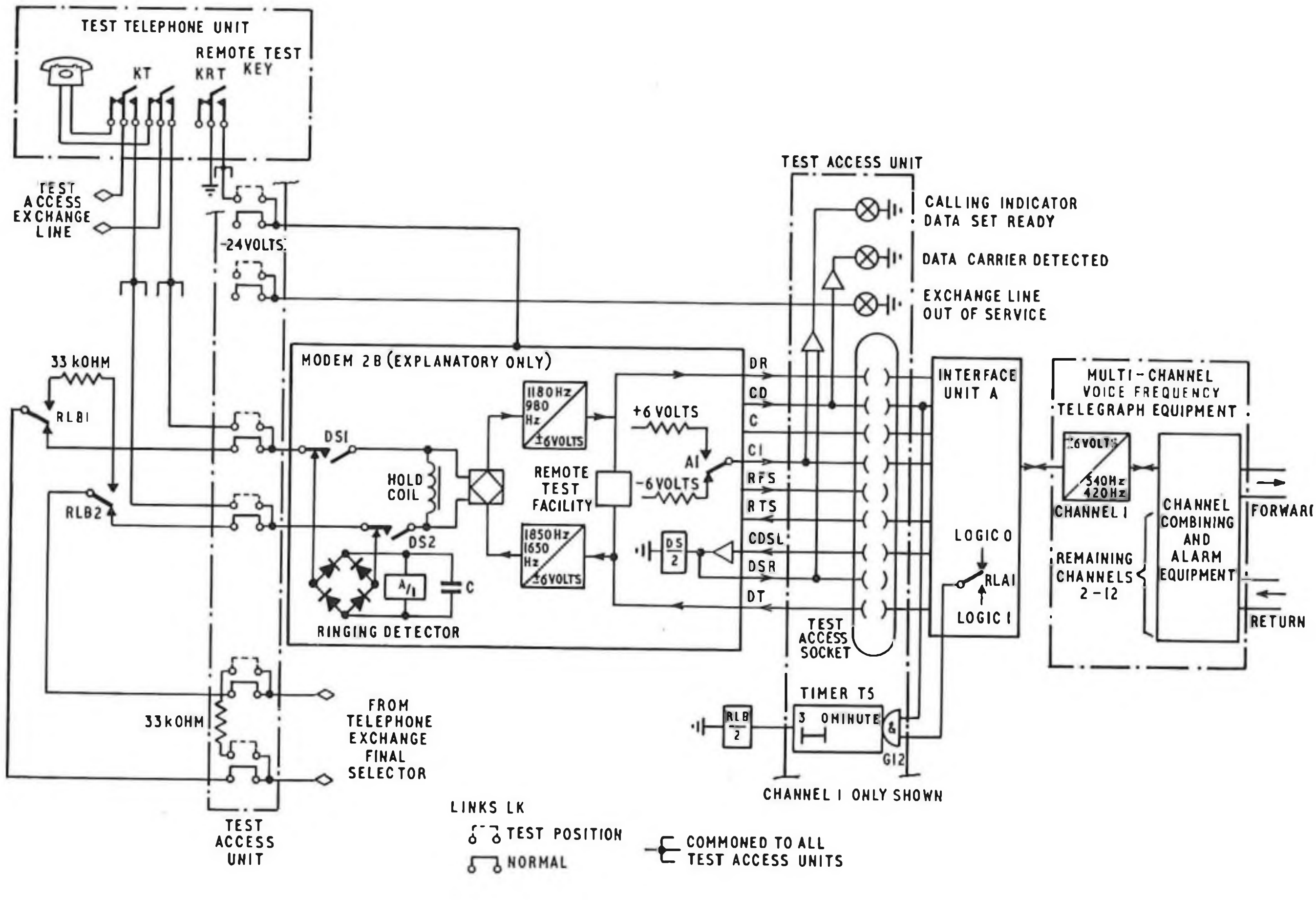


Fig. 3—Terminal A circuit arrangements

associated with a separate test-access direct exchange-line, facilitates the testing of individual modems with the assistance of a datel test centre (d.t.c.). When the test-telephone unit is associated with a particular modem, and a connexion is established with a d.t.c., the REMOTE TEST key on the test-access unit can be operated to enable data, transmitted from the d.t.c. to the modem, to be returned to check that the modem at the installation is functioning correctly.

Terminal A is supplied fully wired and equipped and at installation requires only the connexion of the telephone lines, the telegraph 4-wire circuit and the station d.c. and a.c. mains supplies.

Description of Terminal B

Terminal B, shown in Fig. 4, is designed for installation in computer bureau premises. The terminal comprises a two-tone grey enclosed cabinet accommodating the equipment on type-62 shelves. A hinged door provides access for maintenance. Fig. 5 outlines the terminal B circuit arrangements and shows the interconnexions between the various units. Four interface units B, together with a power-supply unit, are accommodated on each of three shelves. The m.c.v.f.t. equipment, similar to that provided at terminal A, occupies two shelves below the interface units. At terminal B, this m.c.v.f.t. equipment derives d.c. supplies from an a.c. mains operated power-supply unit.

Supplies of +6 volts and −6 volts d.c. for the telegraph received signal outputs for application to the appropriate interface unit B are obtained from a power-supply unit 117A fitted on the lower shelf, which also provides accommodation for spare equipment modules.

A key and lamp unit at the top of terminal B provides visual indication of the operational state of each data channel by monitoring certain interface unit B control interchange circuits. Three lamps and a busy key are provided per channel. The lamp indication functions are as follows:

Lamp	State	Indication
Yellow	Flash	Incoming call
	Steady glow	Data set ready
Green	Steady glow	Data carrier detected
Red	Steady glow	Data channel backward-busied by computer bureau staff

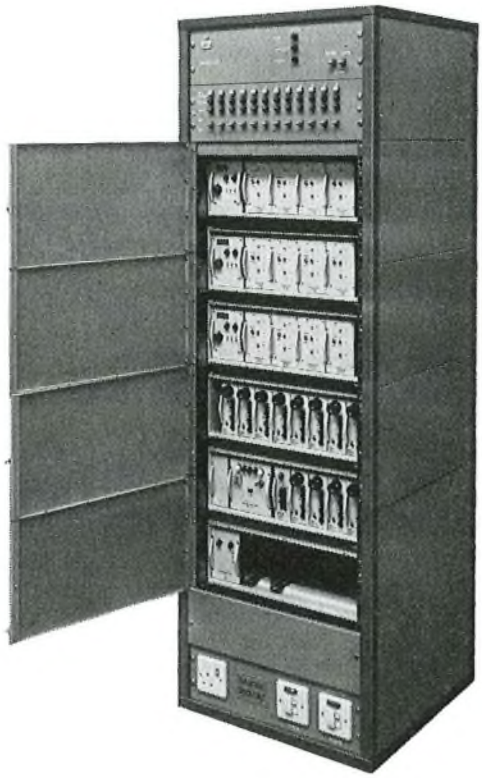


FIG. 4—Dataplex 1/240 system—Terminal B

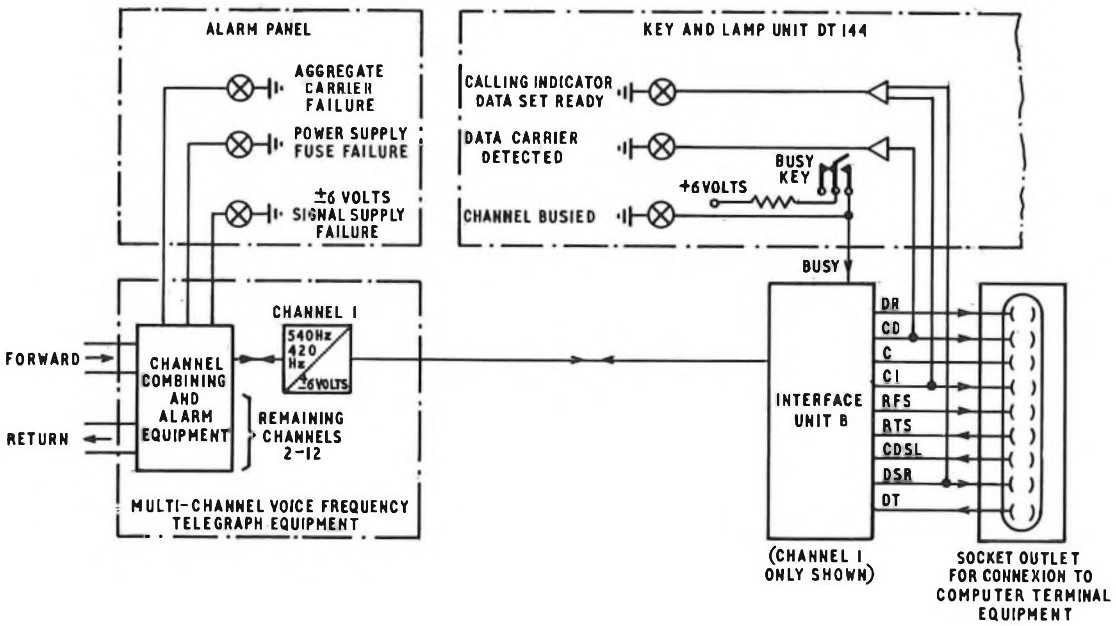


FIG. 5—Terminal B circuit arrangements

The above facilities enable computer-room staff to assess at a glance the traffic loading on the terminal and the state of each data call. The BUSY key permits individual data channels to be busied to prevent incoming calls.

Each interface unit B interchange circuit is terminated on a 25-way D-socket similar to that on a Modem 2B. These sockets are located at the rear of the terminal for connexion of the multiway cables from the computer terminal equipment.

Three alarm-lamps at the top of the terminal provide visual indication of the failure of the aggregate voice-frequency carrier level on the 4-wire m.c.v.f.t. circuit, the m.c.v.f.t. equipment power supply fuses, and the +6 volts and −6 volts d.c. signalling supply. These visual alarms can be augmented by a buzzer if required.

Test U-links at the bottom of terminal B provide a test-access point on the telegraph circuit for B.P.O. staff and also enable a reserve standby local bearer circuit to be patched in if provided.

Terminal B is provided fully-equipped and, at installation, requires only the connexion of the 4-wire m.c.v.f.t. circuit and a.c. mains supply. The terminal is bolted to the computer-room floor and cable access is obtained through the false floor usually found in computer-room installations.

CIRCUITRY AND OPERATIONAL DESCRIPTIONS OF THE INTERFACE UNITS A AND B

The interface units A and B, which were specially developed for the Dataplex 1/240F system, use solid-state logic circuitry and type-62 construction. These units provide for the exchange of forward and return clear signals between the two terminals A and B. In the forward direction, from terminal A to terminal B, it is necessary to inform the bureau when a customer has cleared down his data call on the p.s.t.n. In response, in the return direction, it is necessary for the bureau to be able to switch the terminal A modem from the exchange line. The transmission of such signals in the form of an extended period of start or stop polarity on the v.f.t. channel is not possible since such conditions could easily exist during pauses in data transmission during an established call and would result in inadvertent cleardown occurring. The problem is resolved by transmitting the forward and return clear-information in the form of a signal pattern consisting of successive start and stop elements each of nominal duration 0·5 seconds. In each interface unit, the clear-signal source is provided by a 4 Hz multivibrator followed by two divide-by-two stages to provide a 1 Hz square-wave output. Detection of the signal at the opposite interface unit is achieved by a detector circuit which continuously monitors the data paths through the interface unit.

The basic circuit features of the interface units A and B are detailed in the simplified diagram shown in Fig. 6 and the principles of operation will be illustrated by describing the activities involved in the origination, answering and clearing down of a Dataplex call.

The signals between the modem and the interface unit A and between the latter and the v.f.t. channel comply with the C.C.I.T.T. V24 recommendations using +6 volts and −6 volts signal levels. Voltage conversion is necessary within each interface unit to convert to the logic levels used in the circuitry but for simplicity these voltage conversion stages have been omitted from Fig. 6. In general, the modem interchange-circuits idle in the −6 volts or OFF condition corresponding to

TABLE 1

Modem Interchange-Circuit Abbreviations

C.C.I.T.T. circuit number	Modem interchange-circuit designation	Text abbreviation
103	Transmit data	DT
104	Receive data	DR
125	Calling indicator	CI
108/1	Connect data set to line	CDSL
107	Data set ready	DSR
105	Request to send	RTS
106	Ready for sending	RFS
109	Receive line carrier detector	CD
102	Signal common return	C

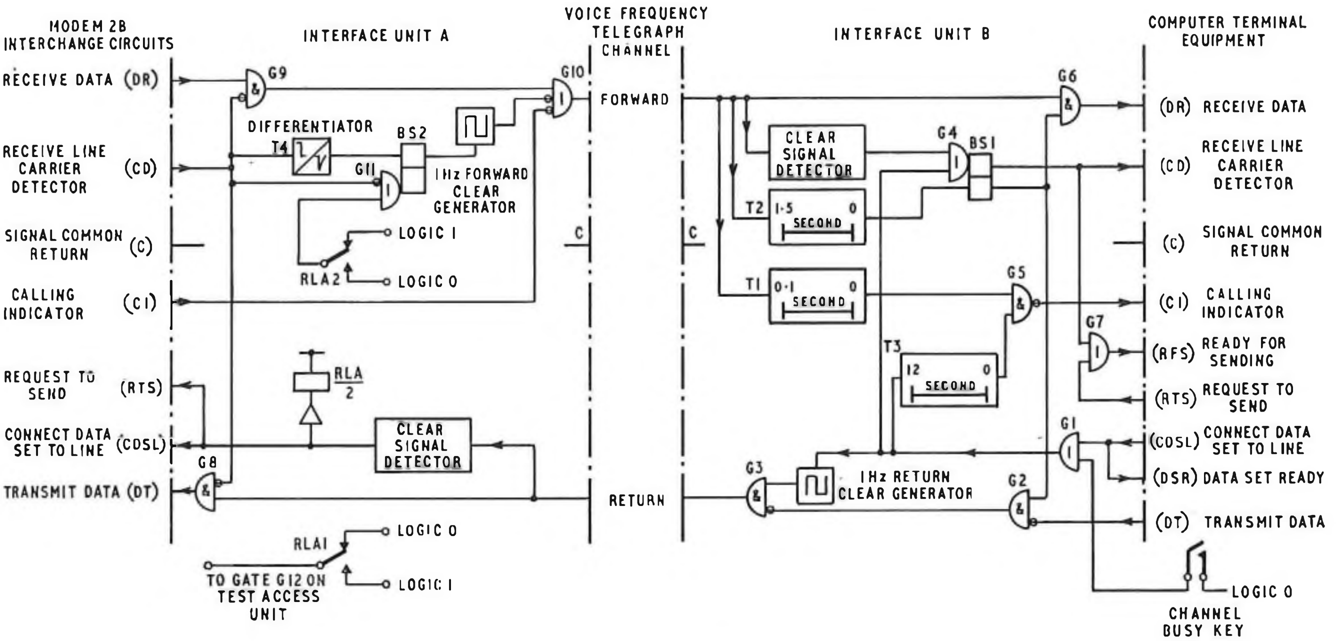


FIG. 6—Interface Units A and B—simplified logic diagram

logic 1. The +6 volts level represents the operational or ON condition corresponding to logic 0.

The signal conditions appearing on the modem interchange-circuits, the m.c.v.f.t. channel interchange-circuits and the interface unit to c.t.e. interchange-circuits are illustrated in Fig. 7, the abbreviations for the modem interchange-circuits shown in Table 1 being assumed for descriptive purposes in this article.

In the no-call state, the OFF condition applied by the c.t.e. to the CDSL interchange-circuit is passed as a logic 1 condition to gate G1 and also as an OFF condition to the DSR interchange-circuit. The logic 1 output from the gate G1, removes the inhibit condition on the output stage of the 1 Hz return-clear generator permitting alternate 0·5 second conditions of logic 1 and logic 0 to be passed to gate G3, the other input of which is being held at logic 0. The resulting alternating logic conditions at the output of gate G3 are converted to −6 volts and +6 volts signal levels before being passed to the m.c.v.f.t. return channel as the RETURN-CLEAR signal. At interface unit A, the alternating +6 volts and −6 volts signals on the m.c.v.f.t. return channel cause an alternating logic condition to be detected by the interface unit A clear-signal detector continuously monitors the incoming data path. Recognition of this return-clear signal results in a logic 1 or OFF condition being applied to the modem CDSL and RTS control interchange-circuits with the result that the modem relay, DS, is not operated and the modem is thus disconnected from the exchange line. Similarly, interface unit relay RLA is unoperated.

At terminal A, the modem is strapped so that under data-carrier-failed conditions an ON condition is present on the DR interchange-circuit. This condition is passed as a logic 0 condition to gate G9 which, together with a logic 1 condition at this time present on the other input to this gate, results in a logic 0 condition being applied to gate G10. With logic 1 conditions on the other two inputs to gate G10 the resulting logic 0 output results in a +6 volts condition being applied to the m.c.v.f.t. FORWARD channel.

PROGRESS OF AN INCOMING CALL

The modem at terminal A is strapped in the AUTO ANSWER operating mode and responds to the incoming 17 Hz ringing signal from the exchange line by the operation of relay A during each application of ringing current. Contact A1 applies an ON condition to the CI interchange-circuit at the ringing cycle repetition rate of, nominally, 0·4 second on, 0·2 second off, 0·4 second on, 2 seconds off. This calling signal is passed to gate G10 and the inverted logic levels are applied as +6 volts and −6 volts conditions to the m.c.v.f.t. FORWARD channel.

At terminal B, corresponding changes of +6 volts and −6 volts on the m.c.v.f.t. channel are passed to the interface unit B. The logic 1 states of, nominally, 0·4 second duration activate the timer, T1, after a nominal recognition time of 0·1 second. This delayed-start timer prevents any short duration spurious conditions on the v.f.t. channel being interpreted as false calling signals. The timer, T1, gives an output of a logic 1 condition for approximately 0·3 second and this output is gated with the enabling logic 1 condition from timer T3, to provide a logic 0 output for approximately 0·3 second from gate G5.

The calling signal on the modem CI interchange-circuit thus appears at the CI interchange-circuit of the interface unit B after having been passed in an inverted form over the m.c.v.f.t. FORWARD channel. This inversion is necessary to avoid operation of the 1·5 second timer, T2, in interface unit B to the 2 second off periods in the calling signal sequence. To answer the call, the c.t.e. applies an ON condition to the CDSL interface-unit of the B interchange-circuit. The corresponding

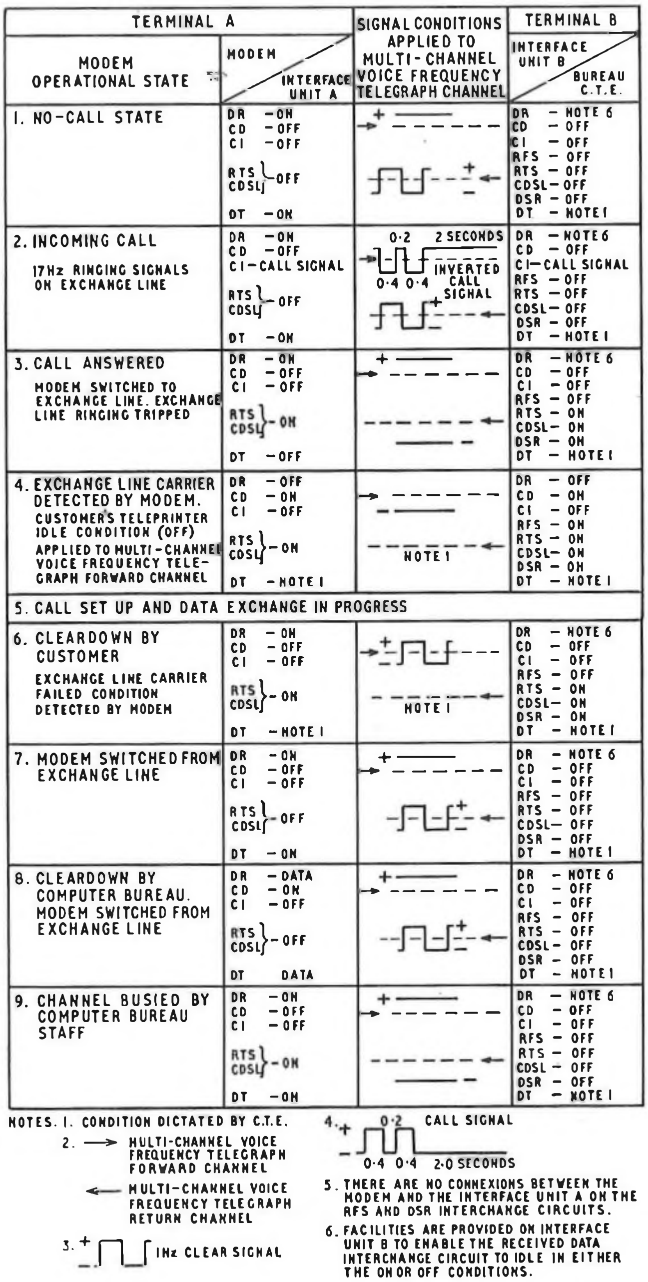


FIG. 7—Signal sequences during call setting up and cleardown operations

logic 0 condition applied to gate G1 and to the return-clear generator results in the inhibition of the return-clear signal generator output which now maintains a logic 1 condition on the input to gate G3 and which, combined with the logic 0 input from gate G2, provides a logic 1 output from gate G3. On inhibition of the return-clear signal, therefore, the m.c.v.f.t. RETURN channel is idle in the −6 volts condition.

The logic 0 condition applied to the CDSL interchange-circuit also causes a logic 0 condition to be applied immediately, via timer T3, to an input of gate G5 which gives an output of continuous logic 1 or OFF condition on the CI interchange-circuit. Timer T3 provides a 12 second delay for input transitions from a logic 0 condition to a logic 1 condition only and does not at this stage introduce any delay. At interface unit A, the disappearance of the return-clear signal is detected, which results in a logic 0 or ON condition being applied to the modem CDSL and RTS interchange-circuits to operate the modem relay DS. Contacts of this relay connect the modem to the exchange line and cause a carrier-frequency signal to be transmitted to the customer originating the call.

Relay RLA also operates and contact RLA2 applies a logic 0 condition to one input of gate G11, whilst contact RLA1 applies a logic 1 condition to an input of gate G12 on the appropriate test-access unit. As an OFF condition is existing on the modem CD interchange-circuit, the logic 1 condition applied to the other input of gate G12 causes the three-minute timer T5 to commence timing.

Within this three-minute period, however, the customer, on hearing the modem carrier frequency signal, switches his modem to line and applies an ON condition to his modem interchange circuit. This causes a carrier frequency signal to be transmitted to the terminal A modem and the CD interchange-circuit switches from OFF to ON. Timer T5 is thus reset. The ON condition is applied as a logic 0 condition to gates G8 and G9, removing the inhibition on the receive and transmit data paths. At the instant of switching the modem to line, the customer's terminal equipment, e.g. teleprinter, is idling in the stop, or OFF, condition. The carrier-frequency signal received by the terminal A modem, therefore, corresponds to an OFF condition which now appears at the modem DR interchange-circuit. When gate G9 is enabled, this logic 1 condition is applied to the m.c.v.f.t. FORWARD channel as a −6 volts condition.

At interface unit B, this extended −6 volts condition is applied as a logic 1 condition to timer T2. After the nominal 1·5 second recognition period, timer T2 applies a logic 1 condition to bi-stable circuit BS1 to trip it. The resulting logic 1 output from bi-stable circuit BS1 is applied to inputs of gates G2 and G6 to remove the inhibition from the data paths, permitting data signals to be transmitted through the interface unit B in both directions. The logic 0 output from the other side of bi-stable circuit BS1 is applied to the CD interchange-circuit as an ON condition.

The logic 0 output from bi-stable circuit BS1 is also applied to an input of gate G7, so that when an ON condition is applied by the c.t.e. to the RTS interchange-circuit, an ON condition is returned on the RFS interchange-circuit. Full duplex data transmission can now take place between the customer and the computer bureau.

Call Cleared Down by a Customer

On the completion of data exchange with the bureau, the customer switches his modem from the exchange line and replaces the telephone handset. At terminal A, the loss of the received carrier-frequency signal is detected by the modem and the CD interchange-circuit reverts to an OFF condition, and the logic 0 condition being applied to gates G8 and G9 is replaced by a logic 1 condition to inhibit the data paths. The transition from logic level 0 to logic level 1 is differentiated by T4 and applied as a logic 1 pulse to bi-stable circuit BS2. Since at this point in time relay RLA is operated, the modem being connected to line, the output of bi-stable circuit BS2 changes to a logic 1 condition which is applied to the forward-clear signal generator to permit alternate logic 1 and logic 0 conditions to be passed to the m.c.v.f.t. FORWARD channel via gate G10.

At interface unit B, detection of this forward-clear signal causes a logic 1 output to be applied via gate G4 to trip bi-stable circuit BS1. The logic 0 or ON condition appearing at the CD interchange-circuit is, thus, replaced by a logic 1 or OFF condition. Simultaneously, a logic 0 condition is applied to gates G2 and G6 inhibiting the data paths. The bi-stable circuit BS1 logic 1 output also removes the enabling condition applied to gate G7, resulting in an OFF condition appearing at the RFS interchange-circuit.

The reversion of the CD interchange-circuit to an OFF condition, informs the c.t.e. that the customer has cleared down and to switch the terminal A modem from the exchange line. The c.t.e. removes the ON condition on the CDSL interchange-circuit and the return-clear signal is sent once more to interface unit A via gate G3.

The re-appearance of the return-clear signal is detected at interface unit A and the ON condition, being applied to the modem CDSL and RTS interchange-circuits, is replaced by an OFF condition which disconnects the modem from the exchange line by release of modem relay DS. Relay RLA also releases. When contact RLA2 is normal, a logic 1 is applied to an input of gate G11 which causes bi-stable circuit BS2 to operate. A logic 0 state on the output of this bi-stable circuit inhibits transmission of the forward-clear signal.

The reversion to an OFF condition at the interface unit B CDSL interchange-circuit also causes a change from a logic 0 condition to a logic 1 condition at the input to the timer T3. After a nominal delay of 12 seconds, gate G5 is enabled when the input changes from a logic 0 condition to a logic 1 condition. The 12 second delay is necessary to allow the forward-clear signal to cease before the CI interchange-circuit of the interface unit B is opened to further modem calling signals.

Cleardown Initiated by the Computer Terminal Equipment

If the bureau wants to initiate cleardown of an established call, the ON condition applied to the interface unit B CDSL interchange-circuit is removed causing a return-clear signal to be transmitted to the m.c.v.f.t. RETURN channel. The logic 1 output from gate G1 is also applied to an input of gate G4 to trip bi-stable circuit BS1 which applies a logic 0 condition to gates G2 and G6 thus inhibiting them. Bi-stable circuit BS1 also applies a logic 1 condition to the CD interchange-circuit. At interface unit A the appearance of the return-clear signal is detected by the cleardown-signal detector and an OFF condition is applied to the modem RTS and CDSL interchange-circuits to disconnect the modem from the line as previously described.

The release of relay RLA causes a logic 1 condition to be applied to an input of gate G11. This time, however, when the OFF condition appears at the modem CD interchange-circuit the resulting logic 1 pulse output from differentiator T4 is unable to trip the bi-stable circuit BS2 and the forward-clear signal is not transmitted. The interface unit B also incorporates a facility similar to that in the Modem 2B whereby, in the absence of an ON condition on the CD interchange-circuit, the DR output interchange-circuit can be strapped to idle in either the ON, or OFF condition. For simplicity, this facility has not been shown in Fig. 6.

BACKWARD BUSYING FACILITIES

To prevent incoming calls on any data channel, the appropriate BUSY key at terminal B is operated to inhibit the transmission of the return-clear signal. The modem at terminal A is connected to the line and relay RLA applies a logic 1 condition to an input of gate G12. Since the CD interchange-circuit ON indication is not received, after a nominal three minute delay-period, provided by timer T5, relay RLB operates to remove the modem loop condition from the exchange line, replacing it by a 33 kohm resistance.

The resulting small current flow in the exchange line from the telephone exchange battery is detected by a specially provided transistorized unit, at the telephone exchange, which operates to apply an earth condition to the telephone-exchange final-selector multiple p-wire to busy that outlet to further calls.

DESIGN FEATURES

Fig. 8 outlines the principles used in the detection of the cleardown signals. A high input-impedance buffer stage passes data path signals to a notch filter. The notch filter has a centre

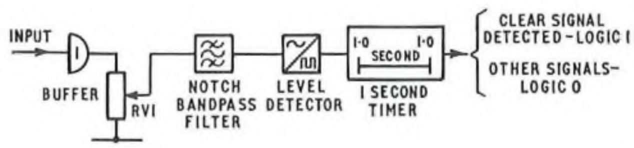


FIG. 8—1 Hz cleardown-signal-detector

frequency of 1 Hz and produces a sinusoidal voltage waveform when a square wave is applied to its input. The amplitude of this sinusoidal waveform rises to a maximum when the frequency of an input square wave approaches 1 Hz. Potentiometer RVI is used to set the buffer-stage output at a level suitable for the notch-filter output-level detector. When the 1 Hz cleardown pattern is recognized, a logic 1 pulse is applied, at 0·5 second intervals, to a timer circuit. After a nominal recognition delay of one second, the output of this timer becomes a logic 1 state denoting that the cleardown pattern has been detected.

The transmission of the return-clear signal in the no-call state implies that, in the event of bearer circuit failure, the transmission of this signal is interrupted to result in all the exchange lines being busied out of service.

Arrangements have also been made that, in the event of the a.c. mains supply to terminal B being switched off by computer-room staff, the m.c.v.f.t. carrier-frequency signal being received from terminal A is returned by the switching of relay contacts in the 4-wire circuit to avoid inadvertent operation of the m.c.v.f.t. aggregate carrier-frequency signal failure alarm.

CONCLUSIONS

The Dataplex Service 110 has been made available for general applications with time-sharing computer bureaux following field trials with three prototype systems to confirm the feasibility and prove the design principles used for the standard Dataplex 1/240 F system. Access to a remote bureau without incurring the cost of s.t.d. call charges provides worthwhile savings for customers, and also permits the time sharing bureau operators to extend their sales area without the need to set up a number of computer installations.

The present design, providing for up to 12 simultaneous calls, offers a reasonably economic method of providing service for a group of customers in a remote area. However, where a larger number of channels are required, systems having a greater channel capacity become more economic. At present, systems involving time-division-multiplexing techniques are being investigated to provide an increased number of channels operating at higher speeds to augment the present systems.

Dataplex Service 110 also enables the B.P.O. to meet the urgent requirements of bureau operators where spare local-line plant to the serving exchange is inadequate to provide the number of exchange lines required for the normal Datel 200 Service, or in circumstances where additional exchange switching equipment cannot be readily provided.

Another advantage of this service is that the diversion of computer bureau traffic, with its characteristically long holding time off the s.t.d. network, provides a measure of relief from congestion on trunk circuit routes and exchange switching stages.

ACKNOWLEDGEMENTS

The interface units are manufactured by the Marconi Company Ltd. to B.P.O. Specifications, and the terminals are constructed by the B.P.O. Factories Division.

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Book Review

"Extraction of Signals From Noise." L. A. Wainstein, and V. D. Zubakov. (Translated from the Russian by Richard A. Silverman). Constable Publishers, xii + 382 pp. 62 ill. £1.75.

Let the reader beware. The title of this book suggests that the subject matter should be of interest to all engaged in communications. In fact, it is for a much more limited class of readers. It contains, on average, five equations per page and assumes a better knowledge of probability theory than many engineers (especially the older ones) possess. Practical engineers will look in vain for handy design formulae, but those whose job it is to study the theory of communications systems will find much of value.

It is only in about the last twenty years that an attempt has been made to solve the problem of synthesis of optimum systems which extract signals with least-mean-square error from the combination of signal plus noise by utilizing, to the full, the differences between the statistical properties of the signal and those of the noise. This book, translated from the original Russian ten years ago, can act as an excellent introduction to the subject. The treatment brings out the physical significance of the relationships deduced.

The first third of the book is devoted to the theory of filtering and prediction of stationary random processes, the filtering of signals of known form and the filtering of random sequences. The main part of the book is concerned with the statistical theory of optimum receivers. Much of the material in this section is applied to problems in radar where the form of the signal is known. There are chapters on normal random variables and modulation by normal random processes.

Non-linear and time-varying filters, such as band-pass limiters and phase-locked loops, are not discussed.

The authors are admirably honest. They note that the optimum circuits obtained by solving the synthesis problem (when it can be solved) have all turned out, in practice, to coincide with, or be very close to, the circuits already in use, which were designed by analysis and intuition. The value of synthesis, in this context, is that it assures us that it is impossible to construct a better device. Thus, we are saved the labour of attempting the impossible.

R. R. W.

Engineering-Cost-Study Methods in the British Post Office and their Financial Background

D. C. HOLMES, A.M.I.E.E., GRAD.I.E.R.E., and K. E. PARISH.†

U.D.C. 658.15:332.67

For some considerable time, the British Post Office (B.P.O.) has recognised the importance of properly-based engineering cost studies in achieving a sound appraisal of investment proposals. This has resulted in many more engineers becoming involved with comparison-cost studies. This article gives some background to B.P.O. finance and describes costing techniques currently in use.

INTRODUCTION

Overall control of capital in the public sector—public corporations, nationalized industries and central and local government—is maintained by the government, and allocations are made to serve national and local needs, priorities being determined by the government of the day.

Certain industries in the public sector are set overall financial targets so that a suitable return is achieved, in terms related to the specific nature of an industry. In assessing demands for new capital, the exchequer takes a favourable view of submissions from industries that earn a good return and can, therefore, meet an increasing proportion of future capital requirements from their own resources.

The public sector spends about half the total capital available to the nation and without governmental control, the public sector allocation could increase disproportionately to that for the private sector. The amount of capital available in any one year is limited and depends on the investment and savings set aside by a country's population and forms part of the gross national product (g.n.p.). About two-thirds of the g.n.p. is spent on consumer goods and about one-sixth is absorbed in capital formation. The capital formation available depends on the balance between the willingness of people to forego a rise in the standard of living in the short term and the better long-term prospects brought about by the investment of savings.

CAPITAL EXPENDITURE IN THE B.P.O.

The total B.P.O. capital requirement comprises that necessary to meet development programs and that required for the day-to-day financing of the business. The capital required for network expansion, in which engineering planners are primarily interested, is that needed to pay for the total costs of construction and renewal, after deducting the net value of recovered plant.

The B.P.O. capital requirement is financed partly by the exchequer and partly from its own resources, namely, profits and plant-depreciation provision. The money allocated to depreciation is treated as a source of capital and is ploughed back into the business. The level of borrowing from the exchequer is, therefore, reduced and the B.P.O. benefits by restricting interest charges on the residual amount. The exchequer loans are authorized by Parliament in Post Office Acts, and the amount authorized is limited in any one year. At the present time, the borrowing to self-financing ratio is about 1 : 1.

In B.P.O. accounting, there is no actual repayment of loans, but interest is charged at a rate appropriate at the time the loan is incurred. Currently, the advances are made for a definite period, 25 years, and at maturity, are eligible for renewal at the rate of interest then appropriate. The total borrowings are, therefore, cumulative and, together with the general reserve ploughed back into the business, balance against the net assets, allowing for depreciation, held by the B.P.O. The amount of capital that can be borrowed is allotted a ceiling at any one time, (*Post Office Borrowing Powers Act*, 1967). At the present time, the B.P.O. has authority to borrow up to a ceiling of £2,800M, the level being reached from annual requirements occurring over a number of years. Statements on B.P.O. finances may be found in the annual *Post Office Report and Accounts*.[1]

RETURN ON CAPITAL

The government has stipulated that the B.P.O. should meet the following financial targets at the present time.

(*a*) The Telecommunication business, which involves heavy capital expenditure, should achieve a 10 per cent return on net assets; that is, profit, before charging interest and supplementary depreciation, expressed as a percentage of average net assets. A short fall in one year can be offset against a higher return in another, the average being 10 per cent over a period of time.

(*b*) The postal business should achieve a 2 per cent return on expenditure: that is, profit as a percentage of expenditure. This is a more appropriate target, since high annual labour costs are incurred rather than capital investment.

The concept of earning a satisfactory rate of return is also conditional on an industry meeting its social obligations. It may be necessary, for social reasons, to run a particular service, although it may be unprofitable. The possibility exists that such services may have to be subsidized as was suggested in the Prices and Incomes Board Report.[2]

For a number of reasons, the rate of return on new capital is not the same as the overall return on net assets already described.

The return on net assets depends on:

(*a*) actual profits after allowing for running costs, interest and depreciation charges, including supplementary depreciation and taking into account schemes which, for social reasons, may involve a loss,

(*b*) the rate of interest paid on capital loans, which is at a level reflecting rates in force at the time of borrowing and not wholly related to the long-term situation,

(*c*) supplementary depreciation provision, which allows for price level changes, this being additional to historic deprecia-

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tion, which is based on straight-line depreciation of historic plant cost over the life of plant,

(*d*) overall net assets (allowing for historic depreciation) which again takes into account investment in schemes which may operate at a loss.

Investment appraisals for new capital, however, do not consider the results of past investment and are expected to earn a return equivalent to that obtained on a "low risk project, undertaken for commercial reasons". In simpler terms, this means an investment which is almost certain to yield the specified financial return and which is, therefore, a safe fund for investing capital to gain financial reward by interest receipts. For example, gilt-edged stocks are regarded as safe investments and, because of this, usually have lower yields than commercial stocks which are at risk. However, the social benefits gained by a particular investment could influence a decision where the return would otherwise be unacceptable, and the final acceptance would depend on both these factors. Referring to social benefits, some attempt at assessing these in relation to specific projects has been made recently[3].

TEST DISCOUNT RATE

To achieve the required return on new capital, the government has asked that all investment studies should be tested at an agreed value of discount rate. These studies should take into account the timing of cash outlays and receipts, and express the project cost in terms of present value. The discount rate allows for the fact that money, when invested, can earn interest. If the capital is used to finance a project, then that project should be costed at a discount rate sufficient to earn, at least, a return estimated to be achievable by safe investment elsewhere.

Present valuing is merely the converse of the normal compound interest earning concept. At 10 per cent interest rate, £100 invested now would be worth £110 in a year's time or, alternatively, the present value of £110 in a year hence is £100, at an interest or discount rate of 10 per cent.

The test discount rate recommended by the government, is currently at a level of 10 per cent and this is the rate to be used in cost studies involving such techniques as *discounted cash flow* (d.c.f.) or *present value of annual charges* (p.v. of a.c.).

ENGINEERING COST STUDIES

Most engineering cost studies are concerned with long-term economic comparisions which include elements of capital, maintenance and running costs. Some of these studies may be concerned with the economic provision of service or circuits by alternative plant or systems, possibly of a tentative or proposed nature. Other studies may be concerned with the determination of the optimum time to replace obsolescent equipment with newer designs.

Two main techniques are available to carry out cost comparisons of engineering projects and these are detailed below.

Discounted Cash Flow

A statement is prepared showing actual cash outlays (capital expenditure) and income (revenue) against the year in which they occur, for a period long enough to allow a fair assessment to be made of all alternatives.

The cost study period depends, in practice, on such factors as plant lives and accuracy of long-term forecasting .The most common period used in the B.P.O. is 20 years. Running costs, including maintenance and power consumption are shown as annual outlays and capital credits for plant net recovery values (n.r.v.) are shown for plant recovered at the end of its life with debits introduced for replacement plant costs. Net recovery value is defined as the scrap value of plant less recovery costs. Credit for plant life outstanding at the end of the cost study period must also be allowed for and is usually calculated as follows:

$$\text{credit} = \frac{X}{Y}\{\text{total cost} - \text{n.r.v.}\} + \text{n.r.v.},$$

where X = present value of £1 per annum over remaining years of life, and

Y = present value of £1 per annum over full life.

Each cash outlay and income in the completed statement is discounted at the appropriate test rate to obtain a project present value. The difference between the present value of cash outlays and cash incomes gives an indication of the financial viability of the project. If the present value of cash income is equal to, or greater than, the present value of cash outlays, the project has shown itself to earn a return at least as great as the discount rate used in the study. The actual rate of return can be calculated graphically by plotting net present value, that is, the difference between cash income and outlay, for various discount rates and evaluating the point of zero net present value. Fig. 1 indicates a possible relation-

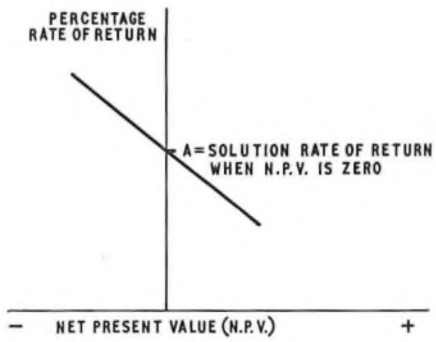


FIG. 1—Variation of net present value with test discount rates.

ship between actual rate of return and net present value to give the solution rate. Normally, in engineering cost studies, the cash income (revenue) is unknown and the comparison is carried out between methods of providing the service on a present-value basis. The project having the lowest present value is then usually accepted as it should achieve the highest return. It is important that the test discount rate used is adequate since it can have a decisive influence on investment appraisals.

Present Value of Annual Charges

This method entails the conversion of all costs incurred into a uniform annual charge which is paid over the life of the plant in question. The factors which comprise this annual charge are detailed below.

Interest on borrowed capital

This is usually assumed to be at the same rate as that for the discount rate used for present valuing.

Depreciation of plant

This is expressed as a uniform annual charge, but it is assumed that the contributions will earn interest so that the total depreciation at the end of life of plant will be made up partly from payments and the rest from interest on the payments. This is known as the sinking-fund principle. Figs. 2 and 3 demonstrate the principle of investing equal annual repayments which attract interest to build up to the required replacement cost.

The item can also be considered to have a theoretical depreciated value over its life span, as illustrated at a particular year x in Fig. 3. This, however, may not correspond to its practical value at any one time, which depends on its usefulness as newer systems are introduced. The depreciation rate will be affected, on a percentage ratio basis, if the plant has either a positive or negative net recovery value at the end of life.

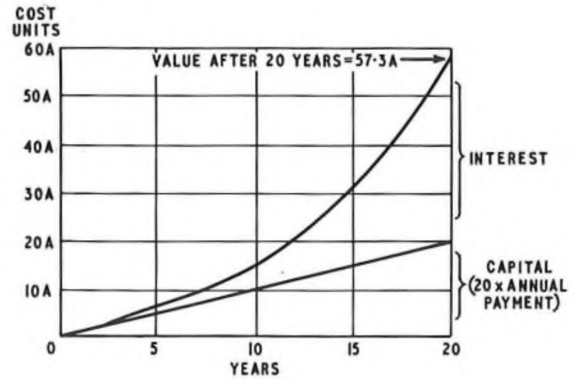
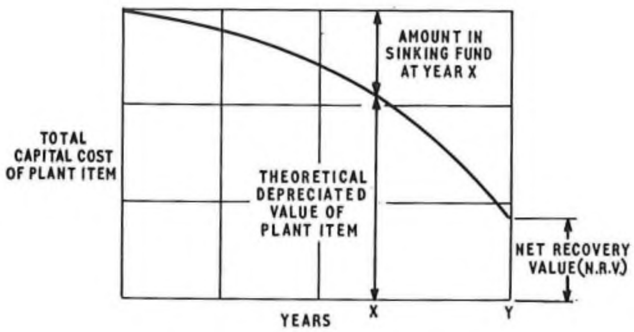


FIG. 2—Effect of investing A cost units per annum for 20 years at 10 per cent interest rate

Interest and depreciation payments are known as the capital recovery payments, that is, they enable the capital to be recovered over the life of the plant whilst also allowing for the appropriate interest charges to be paid on that loan. It is of interest to note that for a life of Y years, (see Fig. 3) the present value over those years of interest and depreciation



Note: In this illustration, n.r.v. is positive

FIG. 3—Relationship of sinking fund to capital and n.r.v.

plus the present value of n.r.v. equals the original capital outlay, where present-value factors, interest, and sinking fund are calculated using the same interest rate.

Running costs

For some items of plant (for example, external) these are expressed as direct percentages of the capital costs. For other items, these costs are composed of:

(*a*) maintenance stores (assumed as a small percentage of the capital costs),
(*b*) maintenance labour (derived from the annual manhours appropriate to a particular item multiplied by the current manhour rate), and
(*c*) power consumption.

Accommodation

The cost of accommodation used by the plant may be included and, if so, is expressed as an annual charge for interest, depreciation and running costs (including heating and cleaning) as outlined above.

All annual charges incurred over the cost-study period are present valued, using the discount rate, to give a total project present value. If the revenue is known, the cash receipts can be treated in a similar manner and a net present value obtained, this being the difference between the expenditure and revenue present-value streams. In most engineering cost studies, the revenue is normally unknown, but if it is accepted that there is a need to provide a particular service, it is sufficient to compare the present values of expenditure for each of the available methods of meeting that service.

Comparison of Methods

If the same rates are used for interest, sinking fund and discount factors, d.c.f. and p.v. of a.c. techniques give the same comparison results.

In d.c.f. calculations, capital sums are shown in the cash flow statement for replacement plant, with allowances for net recovery value of retired plant. P.v. of a.c. assumes the sinking-fund concept, giving a uniform annual charge for depreciation. No account need be taken during the cost study period for replacement plant, since the continuation of full annual charges is sufficient until such time as the service is no longer required.

In p.v. of a.c. studies, credit at the end of the cost study period is automatically allowed for by including only the annual charges falling within this period. Capital credits need to be assessed at the end of the costing period in d.c.f. studies for outstanding life, these being discounted to the beginning of the period as lump sums.

It is interesting to note the effect of an increase in discount or interest rate. The present value of expenditure decreases with an increasing discount rate because of the higher earning power of invested money. The result could be that a scheme which is marginally beneficial using the lower discount rate may be rejected at the increased rate if it involves higher initial capital expenditure (or maintenance costs) compared with other alternative schemes. Variation of the discount rate, therefore, acts as a financial control on the capital-expenditure level.

P.v. of a.c. methods give a similar reaction to increased interest/discount rates as d.c.f. calculations, but the effect is more complex. The interest charged on capital increases, but this is offset by decreases in both discount (or present value) factors and depreciation allotments.

The total effect of a change of discount rate on a complete study, however, may be quite small.

FACTORS USED IN ENGINEERING COST STUDIES

Capital costs used in studies include overheads and indirects, that is, they are the direct costs of equipment plus freightage and installation, with additions for B.P.O. overheads such as clerk of works, clerical work and mechanical aid costs. For study purposes, a Comparative Capital Cost (C.C.C.), which includes differential overheads, is used for comparing engineering projects. Further additions can be made to the overheads and indirects (applied to the direct costs) to give Rental Capital Cost (R.C.C.), formerly known as Inclusive Capital Cost (I.C.C.), which can be used for special studies, such as derivation of tariffs, when full overheads should be included. These extra overheads are generally independent of a particular engineering project.

It is assumed that the whole of the capital required for a project is borrowed. The profit and depreciation provision can be regarded as a source of finance on which it is necessary to earn the appropriate financial return, that is, it can be treated as borrowed capital from an investment point of view.

No allowance is made for changes in general price level over the cost-study period and the test discount rate does not reflect this factor. Future forecasting of equipment prices and wages can be difficult in view of such factors as technique changes and money rates. However, these trends can generally be assumed to apply to all alternatives, unless there is special cause to think that one scheme may be affected more than another. Where differing cost trends can be foreseen, these can be built into the costing exercise on a relative basis.

MARGINAL COSTING

Marginal costing assesses the costs involved in increasing or decreasing production by one item, that is, the costs incurred in increasing or decreasing the useful output of a business by one unit. The revenue obtained from this unit can also be determined and the net marginal gain or loss assessed. Discounting techniques, as described earlier, can be applied to the flow of marginal costs and revenues.

The technique is useful, for example, in assessing the cost of providing an extra circuit on a route. On the one hand, the cost could be small if spare line plant and switching equipment exists and all that may be required is provision of jumpers and relay-sets. Alternatively, a route may be fully utilized and the extra circuit requires augmentation of line and terminal plant. The revenue estimated to be achieved on the circuit can be assessed and an appraisal, therefore, made on the financial implications of provision of that circuit.

The principle of marginal costing recognizes three cost areas:

Direct costs (*CC*)

These are the costs covering the purchase and installation of equipment or maintenance thereof. The costs would include that of contract work or purchase and installation under direct labour work, and field maintenance costs. For stable conditions, the cost per unit (*CC*) remains constant, even if the quantity involved varies over consecutive periods.

Overhead costs (*OH*)

These cover the administration expenses, such as, research and development, marketing, sales, planning and clerical functions. They do not alter much in proportion to fluctuations in service demand and, therefore, no fixed relationship exists between these costs and the direct costs.

Revenue (*R*)

This is harder to define since the earning power of a circuit, for instance, varies as its position in the grading alters. However, an assessment should be possible on a per-unit basis.

The direct costs (*CC*) and revenue (*R*) per item are similar ratios and the difference between the two (*R–CC*) gives an indication of profitability. However, account must be taken of overhead cost (*OH*) which can generally be considered as a constant. Profit is therefore, given by:

$$\text{Profit} = (R\text{–}CC) - OH.$$

Further, the term $\Sigma\,(R\text{–}CC)$ can be considered to be the sum of all marginal costs and revenues over a period and the expression becomes:

$$\text{profit} = \Sigma\,(R\text{–}CC) - OH.$$

As an example, if 1,000 circuits are provided in a period, the total direct cost of provision is $1{,}000CC$. The total expense over this period is, therefore, $1{,}000CC + OH$. If, in the following period, 1,001 circuits are provided, the total expense becomes $1{,}001CC + OH$. The additional cost of the extra circuit is, therefore,

$$1{,}001CC + OH - (1{,}000CC + OH) = CC.$$

(*OH* covers the overhead costs associated with the provision of circuits in this example.)

CC is defined as the marginal cost of the provision of one unit. The subject of marginal costing is treated in greater detail in reference 4.

It may be desirable to include an assessment of maintenance cost as well as capital involved. Suitable definitions can be used for unit costs in terms of *CC*, *OH* and *R*, and the principles applied as before.

Marginal costing allows an assessment to be made of the costs involved in, say, adding an additional circuit to the network. The revenue likely to be achieved by its provision can be assessed and the return evaluated in the light of these costs. This method clearly shows an advantage against use of average circuit costs which are based on total system costs, that is, including an allowance for overhead costs. The marginal costs can vary appreciably up or down compared with average costs, depending on the amount of plant needed for the marginal requirement.

Finally, it may be useful to indicate the meaning of the term *long-run marginal cost*, referred to in the Prices and Incomes Board Report. It is based on the concept of long-run avoidable costs, either total or marginal. Total long-run avoidable costs are those incurred or saved by starting or ceasing a service. Similarly, marginal long-run avoidable costs are those incurred or saved by an addition or subtraction from a service.

The term *long-run* implies an adjustment of service to a permanent change, i.e. including plant and accommodation as well as labour and materials. This is not the same as the short-term change of a temporary nature involving, possibly, just labour costs.

The term *avoidable* relates to the cost differences incurred due to a change in a service or facilities; that is, costs which would otherwise be avoided or incurred by not providing for the change.

CONCLUSIONS

The value of the B.P.O. engineering investment program, currently running at a level of £500M annually, highlights the importance of using sound costing techniques in decisions relating to the provision of services.

The application of discounting principles to cost studies, which is universally regarded as good commercial practice, enables the comparisons of alternative schemes to be evaluated on a common basis. The considerations of timing of expenditure and revenue receipts are important in the prevailing limited capital market.

Methods of assessing plant provision on a sound economic basis have been described in this article, together with a broad appreciation of their financial background.

The B.P.O. is actively encouraging the use of these methods, in training and in instructions, so that they form an integral part of engineering planning.

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A New Automatic Call-Sender

C. WROE†

U.D.C. 621.395.636:621.395.121

The application of call-sending techniques to the acceptance of new telecommunications equipment is now firmly established. In a previous article[1] the basic philosophy was explained, together with a description of the first production model. This article describes a new and more powerful call-sender and the expanding field of application which it is intended to serve.

INTRODUCTION

The introduction of the TXE2[2] electronic exchange system stimulated the introduction of new acceptance testing methods and led to the development of an automatic call sender. The technique has proved to be so successful that it is now being applied to other new systems, notably crossbar and pulse-code modulation, and further applications are anticipated. Call-senders have also been used to generate calls into Strowger type exchange equipment, but general use for acceptance testing of Strowger exchanges is not envisaged at present owing to the shortage of these testers. The basic philosophy of the call-sender rests on its ability to behave like a number of subscribers making calls in a random manner and it follows, therefore, that a change of subscriber behaviour must occur before the tester becomes unsuitable for testing new exchange systems. Further development was required to increase the sending capability of the tester in order to test large new systems such as the TXE4[3] electronic exchange and the introduction of integrated circuits into the logic has led to a one-cabinet design with additional facilities aimed at reducing manpower requirements.

In designing a new and more powerful call-sender, care has been taken to ensure that the improved range of facilities has not also led to further complications in the operating procedure. Nevertheless, many improvements have been made to allow the call-sender to work into exchange types which themselves impose new conditions on its operation. Notable among these is the inability of new common-control exchanges to deal with large numbers of near-simultaneous calls. When this feature was first encountered on the TXE2 exchange, the previous version of the call-sender was arranged to apply calling signals at 100 ms intervals so as not to overload the common equipment. The new call-sender (Fig. 1) can not only vary this interval from 64 ms up to four seconds but it also provides individual dial-pulse feeds to each digit-sender so that no two exchange input-circuits operate exactly in synchronism.

OPERATION OF THE CALL-SENDER

The purpose of the call-sender is to generate a large number of test calls into a sample of normal subscribers' line circuits and to evaluate the performance of the exchange being tested by analysing and recording call failures. Fig. 2 shows a block diagram of the call-sender and its interface with exchange line circuits. Digits to be dialled are inserted into the test-number store before testing starts. Individual sending elements S1 to S20 control the line circuits and collect information for analysis and fault display. All sucesssful test-calls are terminated by standard test number circuits specially provided for use with the call-sender and 3,000 calls per hour are easily attainable.

THE BASIC TEST CALL

A test-call starts with simple line tests to ensure that the voltage on each wire of the circuit is normal and that the circuit is ready to accept a new call. Seizure of the circuit is followed by a test for dial tone before dialling is allowed to commence. These tests are carried out by individual test elements within the sender circuit and only when the full sequence is completed is a request made to the common equipment for test-call digits. When this demand is received by the processing logic, an exclusive address containing the test number is allocated to the sender and the first digit of the test number is presented to the sender on the digit highway, which is time shared with all other senders.

The sender accepts the digit data into a temporary store and sends out loop-disconnect pulses accordingly, using a mercury-wetted reed-relay. As the sending of each digit is completed, the digit highway data is updated to offer each new digit in turn until the whole test number is completed. During the interdigital pause, the sender line-circuits check that no irregular line conditions or tones have been encountered. The last digit of a test number is augmented with a last-digit signal to advise the sender that dialling-out is to stop.

At this point in the call, the sender begins to monitor the line and presents to the common analysis system a digital signal representing the 400 Hz content of the line signals. The reason for this is that the variety of supervisory tones which might be encountered is too complex to be decoded economically on an individual sender basis. The analysis system takes a sample of this digital signal every 8 ms and from the accumulated data over a period of 12 seconds is able to return a discrete signal indicating the type of supervisory tone encountered.

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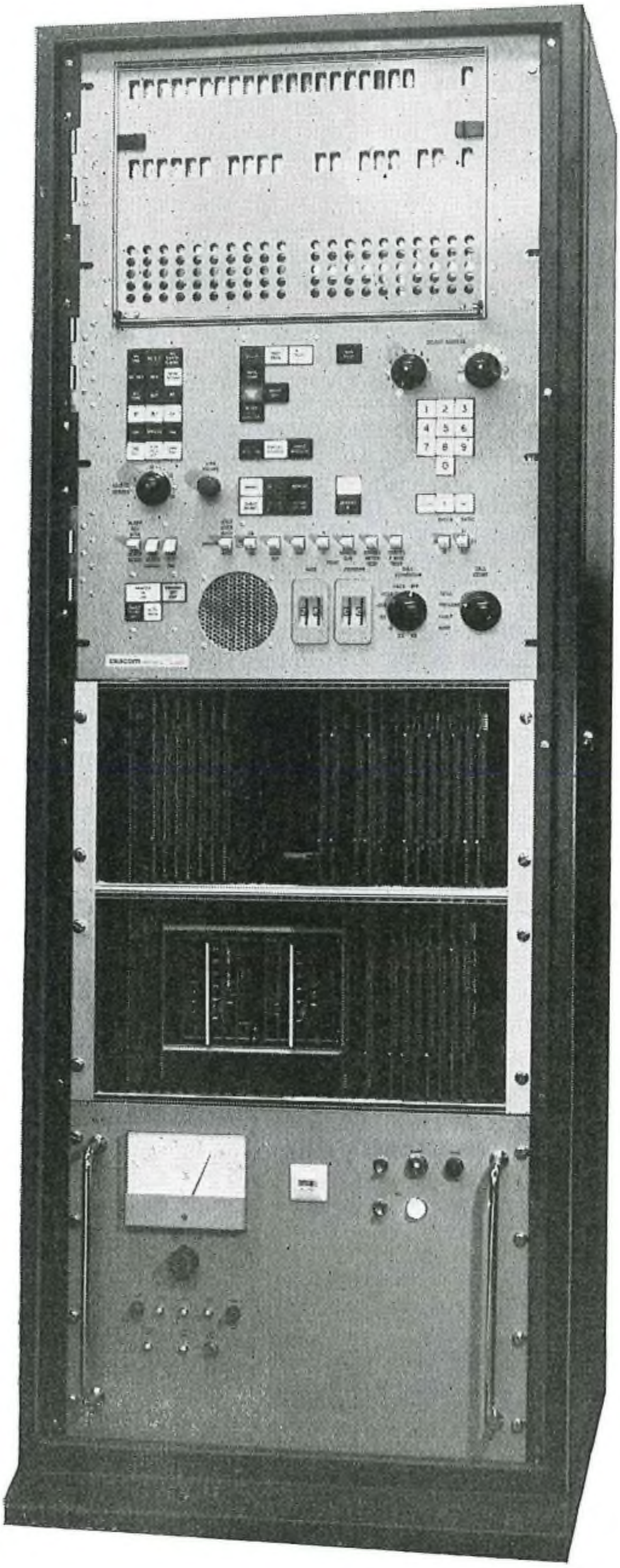

FIG. 1—The new automatic call-sender

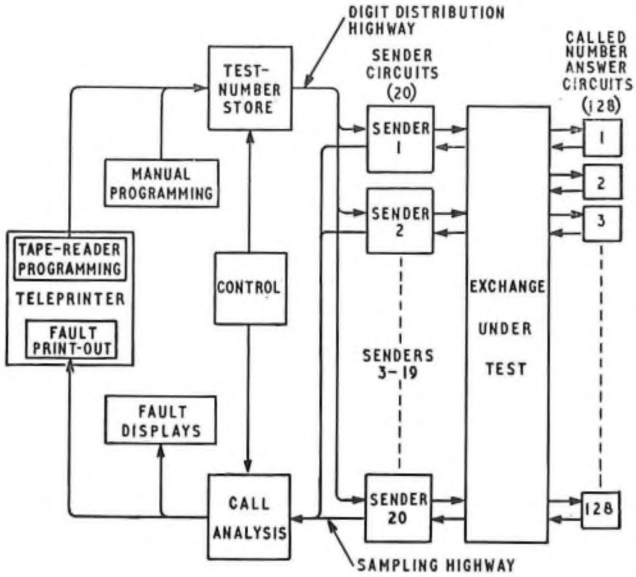

FIG. 2—Block diagram of the call-sender operation

PROGRESS WITH PROGRAM DESIGN

The design of test-call programs is a new skill which has developed along with the call-sender. Its objective is to originate calls from exchange inlets in such a way that after a large number of calls, all switching equipment has had a statistically-equal chance of carrying traffic. A typical TXE2 exchange test-call series would require about 20 test programs, each individually compiled by the clerk-of-works of the exchange in readiness for the formal acceptance tests.

The process of entering program data manually into a call-sender's store, and subsequently the recording of fault data have proved to be exacting and time consuming tasks and, therefore, in the design of the new call-sender a teleprinter has been included for fault printout and automatic tape programming purposes. The punched paper-tapes are prepared by a central organization from details supplied by the exchange clerk-of-works, and the call-sender is then programmed on site by using the teleprinter to read the tape, enter data into the test number store, and, simultaneously, to print out the data for the benefit of the testing officer. When the test program is started, the teleprinter continues the print-out with one line of data for each fault encountered. At the same time, the use of the tape punch will produce a punched tape record of the fault data.

DESCRIPTION OF THE CALL-SENDER

The call-sender uses two Mullard 8,192-bit ferrite core stores (Fig. 3) to perform all memory functions. Up to 128 test numbers may be stored in address locations each capable of holding up to 20 digits and this data is transferred as required to senders, one digit at a time. The store is driven by a crystal-controlled waveform-generator having a basic frequency of 2 MHz, stored information is scanned cyclically, and the maximum access time to any bit of data is 32 ms.

The print-out of fault data has required the inclusion of several support facilities. For each line of print, a fault serial number is inserted, followed by time, date and program identification. The fault data proper, is extracted from the normal analysis system as it is required and, therefore, there is no need for a separate fault data store. When the print-out facility is in use, the normal sender-release sequence is delayed until the associated fault print-out has been completed.

FIG. 3—The 8,192-bit ferrite core-store

Waveform Generator

Fig. 4 shows a block diagram of the waveform generator system. A crystal-controlled oscillator (2 MHz) is connected to a series of binary dividers which are arranged for synchronous switching. The first two stages produce strobing pulses with a repetition rate of 4 μs. The next five stages form the X-scan waveforms of the core-store (32 combinations) and are followed by the READ/WRITE bi-stable circuit. The Y-scan waveforms of the core-store follow with five stages similar to the X-scan, and there are two X-scans for each Y-scan clock position occupying a total time of 256 μs.

A complete Y-scan occupies about 8 ms and cycles 32 address locations. Two further bi-stable circuits complete the identification information for the four addresses in each Y-clock position namely STORE 1/STORE 2 and FRONT (X1-16)/ REAR (X17-32). Each complete cycle, therefore, occupies 32 ms. Finally, a further five-bit binary counter produces a slow waveform family identifying individual senders for control purposes.

The Digit-Shift Register

Each of the 128 addresses in the stores is read out once every 32 ms into the digit-shift register which consists of eight separate 15-stage shift registers operating in parallel. Fig. 5 shows the allocation of these 120 bits. The actual digits are stored in lines 6–15, and lines 1–5 contain a variety of control bits. The sender-used bits 1–20 (lines 3, 4 and 5) perform the function of marking those sender circuits which have successfully completed test calls to the associated test number. The BUSY bit (line 5) is filled by the sender which is actually using the address for the duration of the call to prevent selection by another sender. This function, together with the sender-used bits, allows selection of new addresses to take place on the basis that the choice must be free from association with other senders and not used before by the requesting sender.

The sender-using-address bits (line 1) are used to store the binary identity of the sender which is currently associated with this address. As the data appears in the digit-shift register during the normal cycling of information, these five bits are decoded to produce a discrete signal to advise the sender concerned that its associated address information is available and that its next digit is, therefore, present on the digit-distribution highway. The digit-order counter (line 2) determines which of the 20 stored digits is to be presented on each occasion. Two repeat memory stores also appear in the digit-shift register. The repeats in line 5 are programmed to determine the number of attempts each address is to have. The repeats in line 1 count the number of calls actually made to the address at any point in time. When the two counts coincide, the present call ends with the selection of a new address, and the clearing of the line 1 repeat data in readiness for the next allocation of this address to a new sender.

Call-count bits (lines 1 and 2) are part of a separate subsystem which performs all call-count functions formerly performed on electro-mechanical counters. Interface circuitry is thereby eliminated as well as a troublesome source of electrical interference.

Store Operation

Fig. 6 shows a block diagram of the Mullard FI2 Core Store. At the beginning of the first X-scan the eight parallel outputs from store 1 carry address 1 data to the digit-shift register. Lines 1 to 15 (referred to in Fig. 5) are shifted in at 4 μs intervals until the shift register is completely filled with the 120 bits comprising address 1, a process occupying 60 μs. The data is then held stationary in the shift register for the rest of the time making up the first X-scan i.e. 68 μs. During

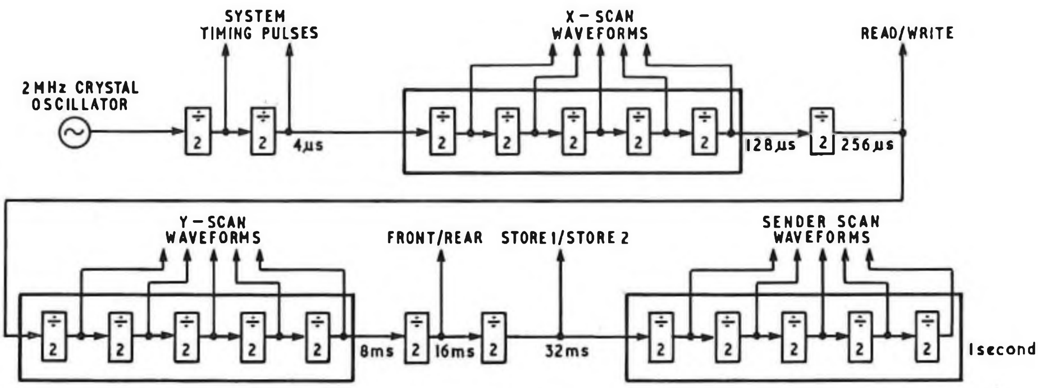

FIG. 4—Block diagram of the waveform generator

LINE	SHIFT REGISTER No. 1	2	3	4	5	6	7	8
1	SENDER USING ADDRESS			REPEAT	SENDER USING ADDRESS			REPEAT
2		DIGIT ORDER COUNTER				CALL	COUNT	BITS
3	SENDER-USED BITS 13	14	15	16	17	18	19	20
4	5	6	7	8	9	10	11	12
5	1	2		REPEAT	3	4	BUSY	REPEAT
6		DIGIT 19				DIGIT 20		
7		DIGIT 17				DIGIT 18		
8		DIGIT 15				DIGIT 16		
9		DIGIT 13				DIGIT 14		
10		DIGIT 11				DIGIT 12		
11		DIGIT 9				DIGIT 10		
12		DIGIT 7				DIGIT 8		
13		DIGIT 5				DIGIT 6		
14		DIGIT 3				DIGIT 4		
15	1-2-4-8 CODING	DIGIT 1				DIGIT 2		

FIG. 5—Allocation of bits in the digit-shift register

this period, the data is available for use by sender circuits, and the stored data can be modified by them as required. The start of the second X-scan terminates the availability period for stored data and the digit-shift register operates again to return the data to store 1, a process again requiring 60 μs.

Addresses 2 to 32 appear in succeeding pairs of X-scans in a manner similar to address 1. Addresses 33 to 64 are also held in store 1, but occupy lines 18–32 on each plane. To obtain this data in the shift register the start of the shifting process is delayed until line 18 occurs, and the data-shifting is completed by line 32. Since the writing-back process is also delayed in the second X-scan the data is stationary in the shift register for the same length of time but it now occurs at the beginning of the second X-scan instead of the end of the first X-scan. All 64 addresses in store 1 are scanned in 16 ms.

Store 2 addresses 65–128 are scanned in exactly the same way as store 1, taking a further 16 ms before the whole sequence recommences at address 1.

Tone analysis information relating to each sender circuit is stored in lines 16 and 17 of succeeding pairs of X-scans. Thus each sender circuit is allocated one of the 32 time slots derived from the Y-scan waveforms and uses it to forward a sample of the tone present on its test line to the analysis processing logic and the associated store locations in lines 16 and 17.

The significant feature of these two data cycles is that the sender 1 analysis-data is available every Y-scan i.e. every 8 ms, whereas, address 1 is available every four Y-scans i.e. every 32 ms.

Memory Retention

Security circuits have been provided to ensure that stored data is not mutilated by power failures. When a power-supply disturbance is detected, the store is shut down as soon as data

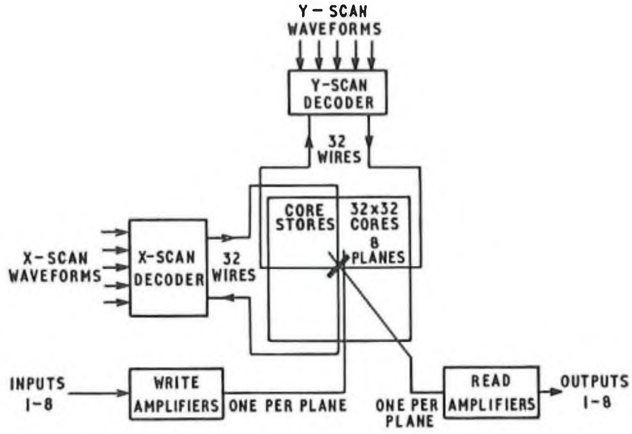

FIG. 6—Block diagram of the core store

in the digit-shift register has been secured. The power reserve on the main power-supply smoothing-capacitors comfortably exceeds the maximum time of 256 μs needed to complete the operation.

Programming Circuitry

There are two methods of inserting test program data into the call sender. Information may be entered manually using push buttons on the control panel grouped in a manner similar to the push-button telephone. For much more rapid and error free data injection, use is made of the tape reading facility of the teleprinter. Address data consists of three items of information:

(*a*) *Selected address.* This determines the location of a test number in the store.

(*b*) *Test number digits.* These are inserted one-at-a-time via a temporary store until the processes of storage is completed.

(*c*) *Repeats information.* This determines the number of attempts made by a sender to each address and can be set to one, two or three. Operation of this function terminates an address storage sequence.

Manual programming, therefore, consists of setting a *select address* switch and keying in the *test number* followed by *repeats information.* The prepared tape for automatic programming follows this sequence by identifying each data group by an identifying letter. Fig. 7 shows a section of tape.

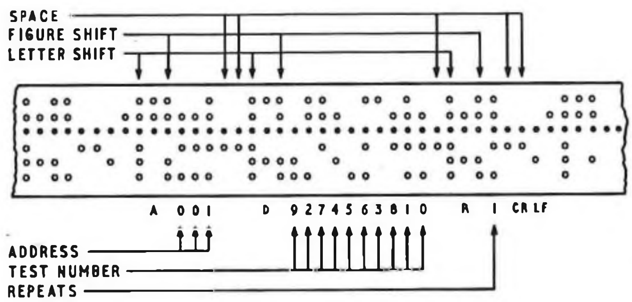

FIG. 7—Section of the programming tape

Fault Print-out

Fault data ready for print-out occasionally accumulates faster than it can be processed owing to the relatively slow speed of the teleprinter mechanism. Some form of storage of data, or alternatively, queuing of data sources is, therefore, required. Since the fault data is already stored in the analysis system, although in a code which is unusable, the release of senders holding fault data is prevented and they are placed in a queue to await the services of the teleprinter.

It is of vital importance that faults are dealt with in the order in which they actually occur in order to analyse correctly the behaviour of the exchange being tested. Fault data in the tone analysis system is assembled one-sender-at-a-time in the analysis shift register, and each is identified by the Y-axis clock waveforms. It is, therefore, logical to store in a queue the five Y-axis clock feeds of each fault as a means of identifying the sender concerned.

Lines 25 to 30 of the analysis shift register Y-scans are used to hold the queueing of sender identities. Thirty bits of each line are used, providing six queue-positions in each line, and making 30 places in all. New sender identities are inserted into position 1 of line 25 and are automatically moved forward into free positions and from line to line until position six of line 30 is occupied. The outputs from this position are used to select that senders' fault data from the analysis shift-register and forward it as required to the print-out system.

Fig. 8 shows a typical fault print-out. I, D and T data groups are inserted automatically before the actual fault data contained in R, S, A and F data groups is extracted from the fault analysis system.

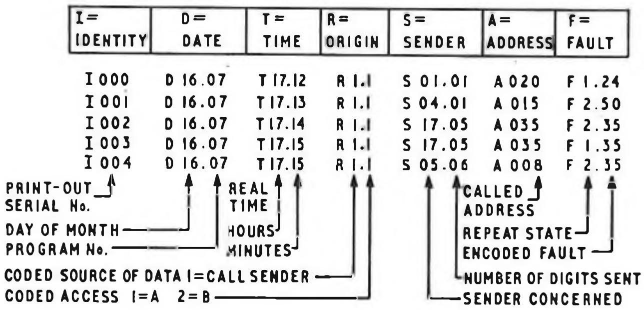

FIG. 8—Typical fault print-out

The numerical coding allotted to the data produces a neat and intelligible print-out format from which similarity patterns can readily be detected by the controlling engineer.

TESTING AND DEMONSTRATING

The nature of acceptance testing is such that call-senders require support systems which can be brought into use when operating difficulties or faults occur.

A unit has been designed which will absorb and check the digits transmitted by senders and subsequently return suitable tones and line conditions for interpretation by the call reader's analysis system. Each input of the check circuit behaves like an exchange line connexion and can absorb and display incoming dialled digits.

THE FUTURE

Twelve call-senders of this type have been ordered and they are planned to begin exchange acceptance testing in August 1972. Further developments are in hand to extend the use of this call-sender design to the testing of four-wire switching exchange systems.

Acknowledgement

Fig. 3 is reproduced by permission of Mullard Ltd.

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Book Reviews

"Modern Wiring Practice." W. E. Steward. Newnes Butterworth, 279 pp. 209 ill. £3.00.

This well-prepared book—now into its seventh edition—is a complete survey of all methods of wiring in domestic, commercial and industrial premises for electric lighting, heating and power and has been revised to metric standards including the latest amendments to the 14th edition of I.E.E. Regulations.

It is entirely practical in its content and covers a wide range of subjects associated with installation practice in buildings. The author's explanation of the various systems used in all types of buildings is comprehensive, well illustrated and easy understand. The index has been given considerable thought and the range of tables and diagrams adds to its usefulness as a reference book.

As an up-to-date guide to all approved methods of installation practice, it should prove a useful adjunct to the designers reference library, an aid to the installation engineer and a book of interest to all concerned with electrical engineering.

S. J. H.

"Applied Electromagnetism." P. Hammond. Pergamon Press Ltd., xiii + 378 pp. 213 ill. Hard cover £3.00. Flexi-cover £2.25.

The book, which is intended for undergraduates with some previous knowledge, has a physical rather than an applied approach to the subject. Although this approach makes it more easily read, the subject is not divorced from the necessary mathematics and a sound knowledge of vector algebra is required.

In its introductory chapters, the book outlines the concepts on which it is based and gives a useful review of elementary electromagnetism. Detailed consideration is given to electrostatics, magnetostatics and radiation (mainly of linear antenna) with supporting chapters on the effects of time variance and relativity, and on the experimental and numerical solution of problems. An exercise is given at the end of each chapter, although a few worked examples would have been of benefit.

S.I. units are used throughout the book. Coverage of some aspects could have been usefully extended, notably in the treatment of transmission lines and waveguides.

Although suggested both in its title and in its opening pages, the book does not contain a significant amount of application, most being contained within the exercises. It is, therefore, more useful for students wishing to supplement their practical knowledge with a more sound, theoretical background.

J. M. P.

Interference and Frequency Co-ordination at Earth Stations

R. A. BEDFORD,* C.ENG., M.I.E.E., and J. E. PURDY†

U.D.C.621.391.82: 621.396.946

A detailed study of all likely sources of interference is of paramount importance when considering the suitability of a site for a satellite-communication earth station. Co-ordination is required at both national and international level to minimize the possibility of interference from terrestrial radio-relay systems which share the same frequency bands. These and other aspects are discussed with particular emphasis on the agreed co-ordination procedures which have been laid down by the International Telecommunications Union.

INTRODUCTION

The planning and provision of an earth station for operation in an international telecommunication-satellite network starts with the search for a suitable site. Among the many factors which have to be considered is the susceptibility of the satellite system to interference. In order to evaluate, quantitatively, the interference likely to occur, a rigorous examination is necessary of the parameters of the satellite and other relevant radio systems and the intervening propagation media.

Earth-station receiver sensitivity and transmitted power are such that the problems of interference can extend well beyond national boundaries, and for the United Kingdom (U.K.) can encompass parts of France, Ireland, Holland and Belgium. Co-ordination with these countries on the use of frequencies might therefore be necessary before a system can become operational.

The interference mechanisms are discussed together with the methods adopted to resolve the problems which arise from placing a new earth station in an area already well populated by terrestrial microwave-radio systems. Brief consideration is also given to the problems likely to arise with the introduction later in this decade of systems using higher-frequency bands.

INTERFERENCE MECHANISMS

Interference to Earth Stations

Interference to earth stations can arise from many sources, the main ones being:

(*a*) terrestrial radio systems sharing the same frequency bands,

(*b*) harmonic or spurious emissions from fixed or mobile transmitters operating in a different frequency band, e.g. radar,

(*c*) aeronautical navigation systems transmitting in adjacent frequency bands,

(*d*) man-made noise sources near the earth station, e.g. power lines, ignition systems, industrial installations and microwave ovens, and

(*e*) aircraft in the vicinity of the earth station causing reflexions or blocking due to their physical presence.

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With present-day systems the major problems arise from sharing frequency bands with terrestrial radio systems. The current frequency band allocated for reception at earth stations in the INTELSAT system is 3·7–4·2 GHz, this band being shared with a number of services as shown in Table 1 (extracted from the 1968 edition of the International Telecommunications Union (I.T.U.) *Radio Regulations*). The main types of interference are as follows:

Interference from spurious or harmonic radiation. This commonly takes the form of high-level spikes of power with an energy content covering a wide frequency spectrum. In the case of radar (and this can be military or civil, airborne or shipborne) the source is usually a magnetron in the transmitter. Interference of this type can be severe and is eliminated either by filtering at source or by suitable shielding at the earth station.

Interference from aircraft. One form of interference experienced at Goonhilly earth station has arisen because the station is located in an area used for aeronautical training by the Royal Navy; the radio altimeters on the aircraft transmit in the frequency band adjacent to the earth-station receive band (see Table 1). The amplitude/frequency characteristic of the low-noise parametric amplifiers used at Goonhilly as first-stage receive amplifiers has a slow roll-off at the band edge in order to achieve good in-band linearity. Consequently, the altimeter signals are admitted, and, in certain conditions, saturate the amplifiers. The problem has been solved by fitting band-stop filters.

There are three mechanisms whereby the physical presence of an aircraft can cause interference to a satellite system. They are reflexion, blocking, and absorption and re-radiation. Interference effects are greatest when the aircraft is flying within the main beam of the earth-station aerial—approximately 10 minutes of arc wide. Aircraft flying outside the main beam have minimal effect. Of the three mechanisms, reflexion is the most significant and theoretical investigation has shown that, provided the earth station is kept at least 8 km from the nearest airport, the probability of interference is negligible.

Noise-source interference. Man-made noise can take the form of spikes or wide-band noise-like interference. As this is usually of relatively low power, and is only of significance at short distances from the source, it can normally be avoided by careful siting of the earth-station.

TABLE 1

Main Frequency Allocations

<table>
<tr><th>Direction</th><th>Europe</th><th>U.S.A.</th><th>Far East</th></tr>
<tr><td rowspan="4">Satellite to Earth</td><td rowspan="2">3·4–3·6 GHz
for fixed, mobile, radio-location and communication-satellite services</td><td colspan="2">3·4–3·5 GHz
for radio-location, communication satellite and amateur services</td></tr>
<tr><td colspan="2">3·5–3·7 GHz
for fixed, mobile, radio-location and communication-satellite services</td></tr>
<tr><td>3·6–4·2 GHz
for fixed, mobile and communication-satellite services</td><td colspan="2">3·7–4·2 GHz
for fixed, mobile and communication-satellite services</td></tr>
<tr><td colspan="3">4·2–4·4 GHz
for aeronautical radio-navigation services</td></tr>
<tr><td rowspan="3">Earth to Satellite</td><td>5·85–5·925 GHz
for fixed, mobile and communication-satellite services</td><td>5·85–5·925 GHz
for radio-location and amateur services</td><td>5·85–5·925 GHz
for fixed, mobile, radio-location and communication-satellite services</td></tr>
<tr><td colspan="3">5·925–6·425 GHz
for fixed, mobile and communication-satellite services</td></tr>
<tr><td colspan="3">6·425–7·25 GHz
for fixed and mobile services</td></tr>
</table>

Interference from Earth Stations

Interference from earth stations to terrestrial systems is possible if terrestrial systems sharing the same frequency bands are within a certain distance, known as the co-ordination distance, of the earth station. This distance is determined by the characteristics of both systems and the intervening propagation medium.

If interference is likely, then steps must be taken to minimize the effect, either by avoiding co-channel frequencies or by providing suitable shielding.

TRANSMITTED SIGNAL LIMITS

The C.C.I.R.* has studied the characteristics of satellite and terrestrial radio systems sharing the same frequency band and has recommended radiated power and other limitations to allow an orderly and reasonable sharing of the frequency spectrum. For satellite systems a limit is recommended on the power transmitted from earth stations and satellites in terms of maximum effective isotropic radiated power (e.i.r.p.) per unit bandwidth and power flux density, i.e. power per unit area. Terrestrial systems are limited in terms of maximum e.i.r.p. in the horizontal direction and maximum transmitter power.

These recommendations have been enacted by the I.T.U. and are now embodied in the articles of its *Radio Regulations*.[1]

Earth-Station Limits

The limits placed on earth stations have been derived after careful consideration of the requirements of the modulation techniques likely to be employed by satellite systems and the characteristics of the large aerials used. Briefly, the current limits are

(*a*) an e.i.r.p. of not greater than +55 dBW in any 4 kHz band in a horizontal direction (exceptionally, +65 dBW by agreement with the administrations concerned), and

(*b*) earth-station transmit aerial elevation angles shall be not less than 3 degrees, measured from the horizontal plane to the central axis of the main lobe, except by agreement between the administrations concerned.

These limits[2] were derived from the following restrictions: the maximum noise power (due to interference) in the worst channel of a 2,500 km hypothetical reference circuit in a terrestrial system should not exceed, at a zero relative level point,

(*i*) a mean power of 1,000 pW, psophometrically weighted, in any hour,

(*ii*) a one-minute mean power of 1,000 pW, psophometrically weighted, for more than 20 per cent of any month, and

(*iii*) a one-minute mean power of 50,000 pW, psophometrically weighted, for more than 0·01 per cent of any month.

Terrestrial System Limits

The terrestrial systems of interest, i.e. inland microwave-radio links operating on a line-of-sight basis with terminals 30 km–70 km apart and mobile units operating in the 4 and 6 GHz bands, are limited as follows:

(*a*) the maximum effective radiated power of the transmitter and associated aerial shall not exceed +55 dBW, and

(*b*) the transmitter power at the input to the aerial shall not exceed 12 watts.

These limits[3] were derived from the following restrictions: the maximum noise power (due to interference) in a telephone channel of a satellite system should not exceed, at a zero relative level point,

(*i*) a mean power of 1,000 pW, psophometrically weighted, in any hour,

(*ii*) a one-minute mean power of 1,000 pW, psophometrically weighted, for more than 20 per cent of any month, and

(*iii*) a one-minute mean power of 50,000 pW, psophometrically weighted, for more than 0·03 per cent of any month.

* C.C.I.R.—International Radio Consultative Committee.

FREQUENCY CO-ORDINATION PROCEDURES

International Procedure

The administrative procedure for dealing with co-ordination of earth stations and terrestrial systems in shared bands is clearly defined in the *Radio Regulations* of the I.T.U.

Any administration wishing to register a new station with specified operating frequencies must first consult administrations of other countries whose services might be interfered with, or whose services might cause interference to the new service. The administration that has been approached then examines the proposals and informs the proposing administration, within sixty days, whether an interference problem is likely to result. Clearly, both administrations must be in a position to deal quickly and efficiently with these situations when they arise.

The administration introducing the new service is required to construct a geographical map of the earth-station location, on which the co-ordination contours are shown. The contours indicate the distance from the station within which interference is possible. This map, together with all pertinent technical characteristics of the station, is then sent to those administrations whose countries fall within the contour.

U.K. Procedure

In the U.K., the Ministry of Posts and Telecommunications (M.P.T.) is responsible for co-ordination and registration of new services with other administrations and with the International Frequency Registration Board (I.F.R.B.). The British Post Office (B.P.O.) has therefore evolved, in conjunction with the M.P.T., a procedure to deal with the co-ordination of B.P.O. earth stations. This involves a process of detailed examination and consultation between the various B.P.O. Departments. This procedure leads to the identification of specific frequency bands where co-ordination may be difficult, and eventually to the notification of agreed frequency assignments.

DERIVATION OF CO-ORDINATION DISTANCE

General

Co-ordination is necessary because satellite systems and terrestrial systems share the same frequency bands. An essential step is the determination of the co-ordination distance in all azimuthal directions from the earth station.

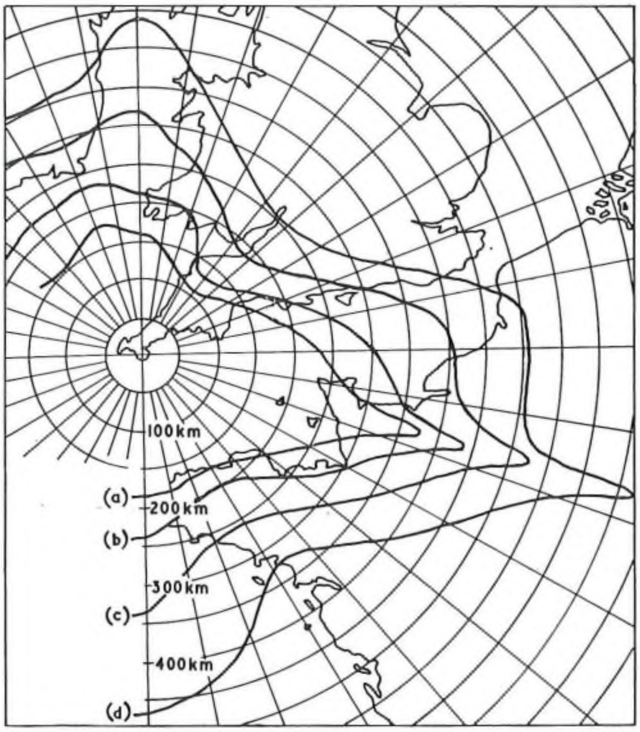
The co-ordination distance is defined as the maximum distance from the earth station at which a terrestrial station could produce (or suffer) interference when the terrestrial-station aerial is pointing directly at the earth station, and all other parameters give worst-case conditions.

Since worst-case parameters are used to determine the co-ordination distance it can be assumed that the probability of interference from terrestrial links outside the co-ordination area is negligible, and conversely, any links within the area will need individual co-ordination using actual system parameters.

In the calculation of co-ordination distance, separate consideration is necessary for interference from earth-station transmitter to terrestrial receiver, and interference from terrestrial-station transmitter to earth-station receiver.

In general, the latter gives the greatest co-ordination distance for current systems operating in the 4 and 6 GHz band, since the earth-station receiver is usually of the cooled low-noise type and is therefore much more sensitive to interference than the standard radio-relay link which operates at ambient temperature.

In addition, it is useful to show co-ordination contours for other than worst case assumptions, since this can save time in the initial assessment by ruling out borderline cases. Fig. 1 shows typical co-ordination contours for Goonhilly earth station.



(*a*) Telephony transmit
(*b*) Television transmit
(*c*) Telephony receive ($G_t + P_t$ = 45 dBW)
(*d*) Telephony receive ($G_t + P_t$ = 55 dBW)

FIG. 1—Example of a co-ordination map for mixed land and sea paths

Permissible Interference Levels

The starting point in the calculation of co-ordination distances is the determination of the level of interference that can be tolerated at the input to the receiver. To a large extent this depends on the nature of both the wanted and the unwanted signals and, of course, the level of noise that can be tolerated in the audio channel, as already discussed. This noise level is a statistical function of time and the criteria are quoted at three values, the median value, the 20 per cent value and the 0·01 per cent value. The most stringent values are 0·01 per cent for distances greater than about 100 km and 20 per cent for distances below about 100 km. For co-ordination purposes, the minimum distance is taken to be 100 km so that in the preparation of co-ordination curves the value associated with the smallest percentage of time is taken to be the critical one.

In its simplest form, the relationship between allowable signal-to-interference power ratio in the audio channel ($P_s/P_{i(a)}$), and carrier-to-interference power ratio at radio frequency ($P_c/P_{i(r)}$), can be reduced to a single factor, B, as follows

$$P_s/P_{i(a)} = P_c/P_{i(r)} + B$$

Factor B, for present day frequency modulated (f.m.) systems, is positive and is therefore sometimes referred to as the interference reduction factor. It can be derived rigorously by convolution* of the power-density/frequency (spectral) distributions of the interfering and wanted transmissions,[4] or by using graphical methods.[5] The value of factor B, assuming co-channel interference and current f.m. systems, is usually of the order of 25–35 dB, indicating the considerable tolerance to interference that exists between these systems.

* Convolution—a mathematical process which in this application derives the probability distribution of the sum of two independent variables where the probability distribution of each is known.

The calculation of the allowable carrier-to-interference power ratio for co-channel transmissions can be simplified by assuming that:

(*a*) the spectral distribution of a communication-satellite carrier is Gaussian. This is essentially true for current satellite systems using wide deviation, provided the carrier concerned is fully loaded. (When the carrier is lightly loaded an energy dispersal signal is applied which limits the maximum spectral density to approximately the same value as for the fully loaded case), and

(*b*) virtually all the energy of a terrestrial radio-relay carrier is contained in the carrier-spike, so that the relatively-low-level sidebands can be ignored.

Co-Channel Interference from an Earth Station into a Terrestrial Station

From assumption (*a*) above, the power distribution of the earth-station signal can be considered essentially constant over the relatively-narrow band of the wanted terrestrial carrier, and is given by

$$\frac{1}{\sqrt{(2\pi)}f_{\text{rms}}} \text{ watts per hertz,}$$

where f_{rms} is the r.m.s. deviation of the wanted carrier. The power can then be specified in a 4 kHz band and the following simple relationship applies:

$$\frac{\text{tolerable interference in a telephone channel}}{\text{thermal noise in a telephone channel}} = \frac{\text{tolerable interference power in a 4 kHz band at the receiver input}}{\text{thermal noise power in a 4 kHz band at the receiver input}}$$

Since all other factors are easily ascertained, the equation can be solved to give the maximum permissible interference power in a 4 kHz band that can be tolerated at the receiver input.

Co-channel Interference from a Terrestrial Link into an Earth Station

Here the interference is not uniformly distributed over the spectrum and factor B has to be calculated by evaluation of the convolution integral. However, if assumptions (*a*) and (*b*) given above are accepted, and zero frequency separation is assumed, the interfering spike would be dispersed and appear in the baseband with a spectral distribution similar to that of the wanted carrier which has a known Gaussian distribution. Factor B can then be derived from the Gaussian curve and is given by the following equation:

$$B = 10\log[\sqrt{(2\pi)}(\mathrm{d}f)^2 P f_{rms} \exp(f_m^2/2f_{rms}^2)/0{\cdot}0031 f_m^2] \text{ dB},$$

where $\mathrm{d}f$ = test tone deviation of wanted carrier in MHz,
P = pre-emphasis factor,
f_{rms} = r.m.s. deviation of wanted carrier in MHz, and
f_m = top baseband frequency in MHz.

The relationship

$$P_s/P_{i(a)} = P_c/P_{i(r)} + B$$

can now be applied and, again, since all other factors are easily ascertained, the equation can be solved for $P_{i(r)}$ which gives the total allowable interfering carrier power level at the receiver input.

Basic Loss Concept

Once the permissible interference level has been determined then the required basic path loss, L_b, to reduce a known (or assumed maximum) e.i.r.p. to the tolerable level, can easily be derived from the formula.

$$L_b = (P_t + G_t) - F_s - (P_{i(r)} - G_r) \text{ dB},$$

where P_t = maximum power available in the reference bandwidth, in dBW, at the aerial terminals of the interfering station,
G_t = isotropic gain, in dB, of the transmit aerial in the pertinent direction,
F_s = site shielding factor in dB,
$P_{i(r)}$ = tolerable interference level in the reference bandwidth, in dBW, for the required percentage of time, and
G_r = isotropic gain, in dB, of the receive aerial in the pertinent direction.

The values of aerial gain to be used for the radio-relay station are maximum values (worst-case conditions), but for the earth station, actual values should be used in the pertinent direction (which is towards the horizon at the azimuth angle being considered).

The site-shielding factor, F_s, is an additional propagation loss which is added to the basic loss where the earth station is shielded by the surrounding terrain. It is a function of the elevation angle towards the horizon as seen from the earth station and also a function of the final co-ordination distance. In order to take full account of the latter, successive approximations are required, and to avoid this complication a simplified table, Table 2, is used which gives conservative values of site shielding.

TABLE 2

Site-Shielding Factor

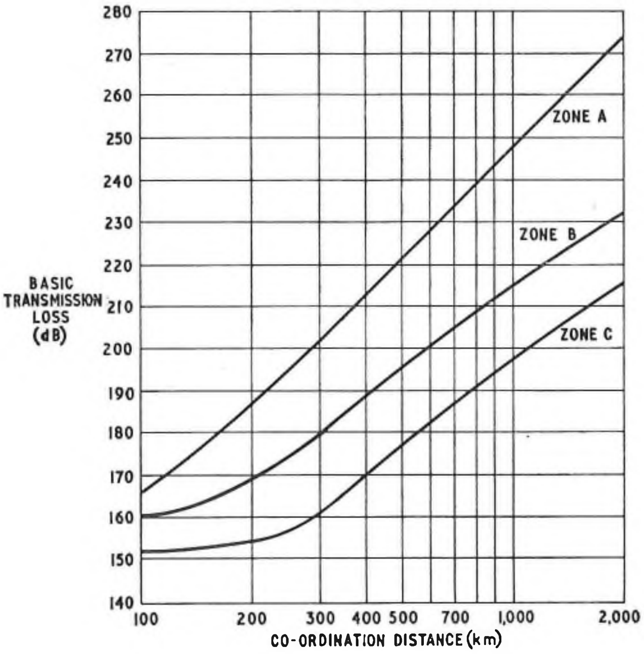
Elevation to horizon, θ (Degrees)	Site-shielding factor (dB)
$\theta < 1$	0
$1 \leq \theta < 2$	10
$2 \leq \theta < 3$	17
$3 \leq \theta < 4$	23
$4 \leq \theta$	25

The site-shielding factors given in Table 2 are minimum values for the reason given above but it is recognized that in some circumstances they could be considerably higher, and provided prior agreement is reached between the administrations concerned, then the more appropriate values should be used. There is room for further research on the question of site shielding, particularly in the near-field of a large aerial, and the B.P.O., in recognizing this fact, has recently awarded a study contract to evaluate the problem. The study will be carried out using a scaled model and by applying computer techniques. A more detailed account of site shielding is given in the list of references.[6]

Co-ordination Distance

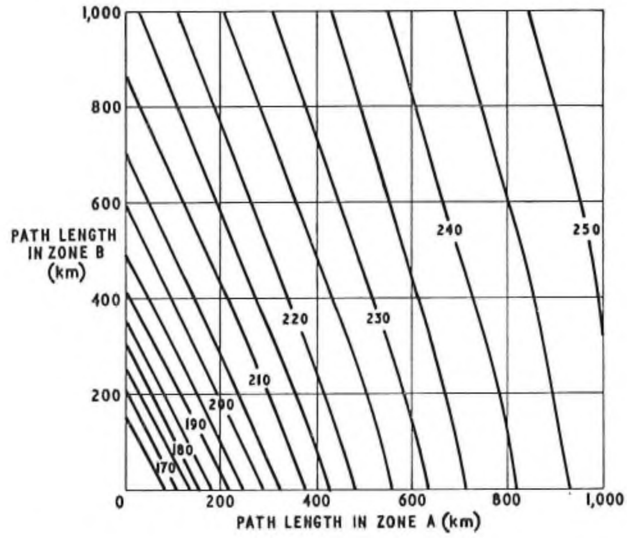
The values of minimum basic loss for each azimuth angle can be converted to distance by reference to appropriate propagation curves, examples of which are shown in Fig. 2. To obtain predicted path losses which are not exceeded for 0·01 per cent of any month at 4 GHz, and 0·05 per cent of any month at 6 GHz, 10 dB is subtracted from the basic loss curves.

For mixed propagation paths which cross from one zone to another, a simple procedure has been evolved which allocates the path loss according to the proportion of path in each zone. Charts have been prepared which assist in the determination of the resultant co-ordination distance. Fig. 3 shows the chart for mixed-path calculations in Zones A and B (see Fig. 2), and Fig. 4 shows an example of how this chart can be used for deriving a co-ordination distance from a basic path loss of 190 dB.



Basic transmission loss, at 4 GHz, not exceeded for 0·1 per cent of the time.
Zone A—Land
Zone B—Sea at latitudes greater than 23·5° N. and 23·5° S.
Zone C—Sea at latitudes between 23·5° N. and 23·5 S.°

FIG. 2—Simplified tropospheric propagation curves for calculation of co-ordination distance



Basic transmission loss L_b dB, at 4 GHz, not exceeded for 0·1 per cent of the time.

FIG. 3—Chart for co-ordination distance calculations for mixed paths in Zones A and B (see Fig. 2)

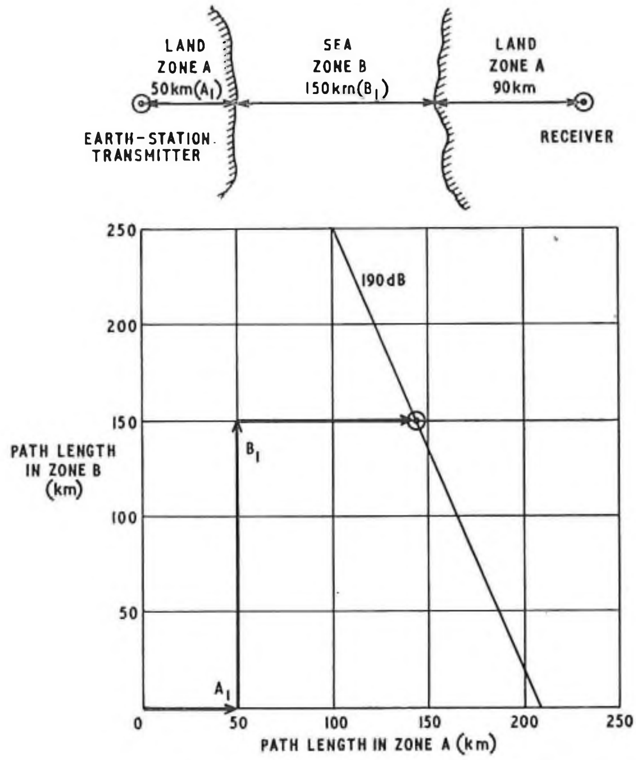


FIG. 4—Example of co-ordination distance calculation for mixed paths

Interference within the Co-ordination Contour

Once co-ordination maps have been prepared and distributed it is necessary to consider separately, and in detail, each radio-relay station which lies within the contours. For the majority of cases the more detailed calculations prove that the interference level is negligible as the radio-relay station aerial is most unlikely to be pointing directly at the earth station. Additional discrimination is also probable from frequency spacing, site shielding of the terrestrial station and other factors for which conservative values are assumed in the initial calculations of co-ordination distance.

Where the interference is likely to be greater than the tolerable level, further action has to be taken to eliminate the interference possibility either by adopting alternative frequencies or by providing additional discrimination at either station by improvement of the aerial response or reduction of radiated power, if this is practicable.

PROPAGATION DATA

The propagation data used for derivation of co-ordination distance and subsequent detailed consideration of individual cases are of prime importance if these procedures are to be meaningful, and effective control of interference is to be obtained. The most critical aspect of this subject is the propagation phenomena that are effective for percentages of the time of the order of 0·01 per cent. Collection of precise data for such small percentages of time requires years of observation. Considerable work has already been done in this direction.[7] Difficulties arise, however, when generalizations are made, as in the *Radio Regulations*, where the number of climatic regions is reduced to three. If the generalizations are on the pessimistic side, as they must be in order to cover the worst conditions that obtain in a particular region, then the majority of earth stations in that region may, on using the data, find that a large area has to be co-ordinated. Conversely, a minority of earth stations may find the data underestimates the strength of signals likely to be received for small percentages of the time. For example, the B.P.O. earth station at Goonhilly has experienced interference from the Continent as a result of anomalous propagation conditions. Short-term data for eight climatic regions is given in the list of references[6], but even this does not adequately cover effects such as mixed-path propagation or shielding from surrounding terrain, since no attempt is made to separate the several mechanisms which contribute to this short-term data.

These problems are recognized by the C.C.I.R., and study programs have been drawn up for improving the existing data and also for evaluating the individual short-term propagation mechanisms so that they can be applied separately. For particular paths, measured data may be valuable and can be used as a basis for calculating path losses and co-ordination distances provided the method is acceptable to all the administrations involved. It is important, however, to realize that measurements must be of long duration (2–3 years) for their results to give a representative sample of short-term phenomena, since 0·01 per cent of the time is approximately one hour per year.

FUTURE DEVELOPMENTS

With the increasing use of the frequency spectrum, the bands currently allocated and occupied have become more congested. One solution to this problem is to look to the higher frequencies where more spectrum is available.

In the case of satellite-telecommunication systems, additional frequency bands were allocated at the World Administrative Radio Conference in June 1971 to allow for this expansion.[8]

Therefore, when assessing sites for earth stations, the possible use of these frequencies must be taken into account.

Two factors likely to be encountered in future systems, and which will affect the co-ordination contours, are the use of advanced modulation techniques, e.g. pulse code modulation (p.c.m.)/phase-shift keying (p.s.k.) using time division multiple access (t.d.m.a.), and the serious effects on propagation of local weather conditions, e.g. rain, snow and hail, which will require the use of higher e.i.r.p.s to overcome them.

Satellite-system designers are looking increasingly towards p.c.m. techniques to provide greater capacity and more flexibility. Consequently, the interference susceptibility and the interference potential will have to be given careful study so that the implications in terms of co-ordination distance are fully realized. A limited amount of work is being and has been carried out by the C.C.I.R.[9] and other bodies.[10] For example, it has been established that if energy dispersal in the form of a pseudo-random pulse train is applied to a p.c.m./p.s.k. transmission then that transmission is not likely to be any more detrimental as a source of interference than an equivalent capacity f.m. system. It is likely, therefore, that techniques of this nature will find a use in future systems.

A more detailed C.C.I.R. review of recent developments, together with a study of present and proposed co-ordination methods, led to the conclusion that it should be possible to evolve a unified procedure for determination of co-ordination distance covering all frequencies between 1 and 40 GHz, and any of the modulation systems likely to be used in the near future. The key to this approach is the generation of a set of propagation curves in which the distance-dependent elements of frequency and site shielding have been extracted. A fairly complex basic equation is then applied which requires the summation of all the variable factors affecting the required basic loss, such as the type of modulation system involved and the small percentage of time that interference should not exceed a permissible level. The object is to pre-determine and tabulate these factors, so that they can be easily extracted and used in the basic-loss equation. The procedure after the required basic loss has been established takes into account more fully site shielding and scatter from hydrometeors.*

The propagation data suggested is founded on C.C.I.R. Report No. 244, but with modifications giving somewhat smaller co-ordination distances. A more realistic path model with a radio-relay station height of 580 m has also been assumed. These proposals have now been ratified and will be incorporated in the revised *Radio Regulations* which will be effective from January 1973.

CONCLUSIONS

The numerous interference problems affecting operation of an earth station working to the INTELSAT system have been enumerated and discussed.

It is concluded that interference at earth stations is most likely to arise from terrestrial radio-relay systems which share the 4 and 6 GHz bands, and that strict adherence to the internationally agreed co-ordination procedures is necessary to preserve an orderly situation.

The application of the principles used in international co-ordination is also necessary in selecting new sites for earth stations.

References

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4 MEDHURST, R. G., and ROBERTS, J. H. Expected Interference Levels due to Interaction Between Line-of-Sight Radio-Relay Systems and Broadband Satellite Systems. *Proceedings I.E.E.* Vol. III, March 1964.

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* Any weather phenomenon which depends on the moisture content of the atmosphere.

Acceptance Trials of Digital Computer Systems

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U.D.C. 681.33.001.41

Acceptance trials of computer systems of duration of not more than 100 hours can establish, to a reasonably high degree of confidence, that the system is correctly assembled and commissioned and is capable of fulfilling the task for which it is purchased. Also, the trials can ensure that the advertised features function as specified and the equipment is in accordance with the contract.

INTRODUCTION

Digital computers for use by British government departments are purchased by H. M. Stationery Office and tested in accordance with procedures laid down in H.M.S.O. contratual documents. Similar procedures are applied to computers purchased with the aid of government grants for use at universities. The testing is normally arranged and supervised by the Technical Support Unit (T.S.U.) of the Department of Trade and Industry.

Since T.S.U. was formed in 1958, from a group of British Post Office engineers, it has been responsible for more than 800 acceptance trials of new computer systems and enhancements to existing systems. Approximately 500 computer systems have been tested, varying in complexity from simple systems, costing £3,000, to large scientific systems, costing more than £1M and have included equipment supplied by most computer manufacturers.

This article describes the form of trial adopted as standard from 1968 on, and shows the results obtained in a series of trials. The testing methods and results may be of interest to engineers responsible for specifying acceptance trials of other complex electronic equipment.

STANDARD TRIALS CONDITIONS

When a computer system has been installed in a customer's premises the contractor carries out a series of tests with the object of ensuring that the installation has been correctly completed; this process is known as commissioning. If it is carried out thoroughly it should result in the system being capable of performing the task for which it was purchased.

The need for acceptance trials became apparent in early 1959 when it was found that the reliability performance of newly-delivered (and paid for) computers fell far short of that expected. Experiments showed that a pre-determined test, adequately supervised, was capable of revealing most of the prevalent defects and, when those were identified and removed, the subsequent performance was improved. An attempt was, therefore, made to draw up a standard test procedure.

Any form of acceptance test must be based on prior knowledge of the design and inherent reliability. Production engineering and quality assurance procedures are vitally important factors to be assessed before placing the contract. Quality control procedures are vetted by T.S.U. as part of the system appraisal and certain omissions in the contractor's testing can be catered for in acceptance trials.

It was decided that all systems should have site trials, firstly, to ensure that the equipment was in accordance with the contract, with all advertised features working as specified; secondly, to establish confidence in the capabilities of the system fulfilling the task for which it is being supplied; and thirdly, to hand over the system to the operations manager, in good working condition, so that he, in turn, can establish confidence in the system. Also, new and early production models should have trials at the contractor's factory as part of the design evaluation and as validation of quality control procedures.

The trial is divided into two parts, *demonstrations* and *cyclic running*, which are detailed in a set of schedules, agreed before the trial commences. A total of three attempts to pass a trial is allowed, whether at the factory or on site, and if a third one fails the contract is terminated.

Demonstrations

Demonstrations are run to establish that the speeds of peripheral equipment, processor instruction times and system speeds are not less than 95 per cent of the specification; that data can by physically interchanged between compatible items, e.g. magnetic tape units or exchangeable disks; and that the advertised hardware and software features function satisfactorily.

Cyclic running

Cyclic running is intended to exercise the system thoroughly and to simulate working conditions as nearly as possible. It enables the performance of the system to be judged in a user environment and consists of repetitively running a *test cycle.* The test cycle consists of a series of 15-minute tests comprising processor engineering diagnostic programs, peripheral functional engineering programs and user programs, representative of the type of work which the customer intends to run. Short programs are combined, if necessary, to build up the 15-minute tests. The user programs and, where possible, the functional engineering programs, are run under control of the supplied software system, where appropriate. The programs are chosen, and running order organized, to maximize equipment utilization and system interaction; each program is self-checking or produces printed output which can be checked visually.

Trials procedure

The trial is run under the direction of the T.S.U. supervisor who issues a docket for every unexpected occurrence, except obvious operator errors, and the contractor's personnel are required to investigate, correct any faults and give full explanations on the docket. The T.S.U. supervisor's role,

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during the trial, is to ensure that the output is accurately checked and to provide rulings on individual test failures and determine any associated revised program-running sequences. It may be considered that rulings on all occurrences could be agreed prior to the trial but, unfortunately, computer systems are far too complex for all eventualities to be forecast. Also, any one apparently unsuccessful test could be caused by factors outside the contractor's control, for which no penality is given; so the supervisor's role is characterized by constant discussions on all the possible causes of (or excuses for) occurrences, be they operator or program errors, stationery faults, dust, variations in environmental conditions or mains surges.

The main criteria for the trial are that all demonstrations should be successful and, for cyclic testing, that each 15-minute test should run successfully in each of six successive attempts. Hence, for a trial, during which no faults occur, the duration of cyclic testing is six times the duration of one cycle and, when faults occur, somewhat longer; thus, systems which have been properly prepared by the contractor have shorter trials than those which have not received so much attention.

As the main purpose of the trial is to show that the equipment is adequately commissioned and is working sufficiently well for the customer to apply live work, ideally, testing would be continued until all faults have been eliminated and success achieved. However, practical considerations dictate that there should be a time limit (or a number of trials would go on for months). The time limit is arrived at by calculating the nominal (fault-free) duration of the trial then adding to it an allowance equal to 100 per cent of the demonstration time plus 50 per cent of the cyclic running time. A minimum allowance of four hours is given. The nominal duration of a trial is typically 25 hours for a small system and up to 100 hours per processor for a large system.

The results achieved in the first 100 trials carried out under the standard conditions are described below. First, a short account is given of alternative methods of test which were examined but not adopted.

OTHER TEST METHODS

Reliability Trials

An ideal form of trial would be one which showed that the equipment reliability specification was being met. Certain computer systems with a large amount of peripheral equipment have an overall mean time between failures (m.t.b.f.) as poor as 5 hours or less. For these systems, it could be considered that a reliability trial of 25–50 times the m.t.b.f. would achieve the desired result of proving that the quoted reliability figures were being met. However, there are certain snags; firstly, many of the failures are repeated incidents of intermittent faults and the m.t.b.f. derived from the manufacturers' specification would reflect a random failure rate, and could be as high as 25 hours for the system mentioned previously. Secondly, an overall m.t.b.f. figure is rather meaningless, as a computer workload consists of a series of processes, each made up of one or more programs. Although the overall m.t.b.f. figure is being met, the m.t.b.f. of one or more of the programs may be well below the expected value. These problems could be overcome with a reliability trial based on the failure rate of individual (or groups of) programs or devices. For the system mentioned above it is likely that certain critical programs or devices would have m.t.b.f.s of 200 hours or more and, hence, a trial of 5,000–10,000 hours might be required to prove the reliability. For more reliable systems the time to prove reliability is likely to be longer than the equipment's required lifetime of 7–10 years. Because of the time and effort involved a reliability trial of this form is not practical.

Reliability of computer systems purchased by H.M.S.O. is covered, to a certain extent, by special clauses in the maintenance contracts and records are kept which enable reliability to be calculated. Also, with the number of contracts being handled by H.M.S.O., the threat of unreliability of existing systems on potential orders can hasten improvements.

During standard acceptance trials there is no intention to prove reliability but, occasionally, when equipment which has a history of unreliability is tried, acceptance is given, subject to satisfactory operation over an appropriate period.

Monitoring Performance During Initial Service

A further trials procedure, which has often been suggested, is to let the contractor install a system to his satisfaction then hand it over to the customer for a trial consisting of normal live operational work for a month or so. An efficiency ratio is usually suggested as a means of judging performance, a figure of the order of 90 per cent being proposed by contractors and greater than 95 per cent by customers, but this would normally exclude program-testing time and would represent total system efficiency.

Although in certain isolated cases this type of procedure is considered adequate, it was rejected as a basis of standard trials as, very often, customers do not have sufficient live work to thoroughly exercise the equipment at delivery time and the conditions of testing are neither strictly controlled nor, in most cases, sufficiently stringent.

RESULTS OF RECENT TRIALS

What follows is an account of the first 100 trials carried out using the standard acceptance procedure described earlier. The systems tested were supplied by 11 different contractors and the results of the trials have been examined to establish the usefulness of the method of trial adopted. All systems completed demonstrations but 23 trials failed during cyclic running.

DEMONSTRATIONS

The times for many demonstrations are dependent on operator actions and, usually, a generous time allowance is given. Hence, in 42 of the trials none of the extension periods were taken and in most others, less than the minimum allowance of four hours were used. Appendix, Table A gives details of 102 faults encountered in 538 hours of demonstrations indicating a marginally higher fault rate for unsuccessful trials. Also shown are the major demonstration failures encountered (Appendix, Table B), most of which were in different trials, indicating that in approximately 20 per cent of trials some significant departure from specification was found. For most failures the specification was met after the equipment had been adjusted but, sometimes, the contract had to be renegotiated before acceptance was given.

CYCLIC RUNNING

Fig. 1 shows the percentage of the nominal time taken for successful trials. The extra time taken was mainly due to

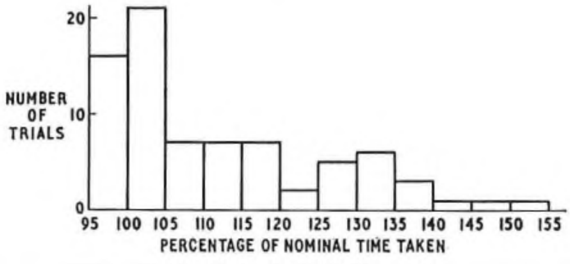

FIG. 1—Percentage of nominal time taken to complete cyclic testing during successful trials.

repeating tests after failures, repair time being minimal as most of the faults were on peripheral equipment and were investigated and rectified as the trial progressed. Most of the unsuccessful trials were abandoned by the contractors before the time was exceeded.

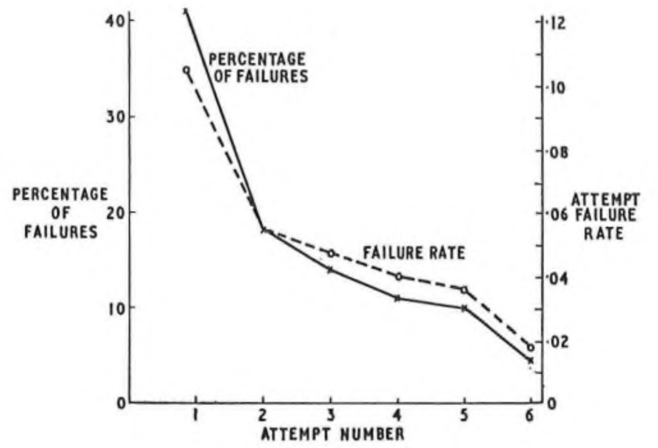

FIG. 2—Percentage of failures and failure rate at each of the six test attempts

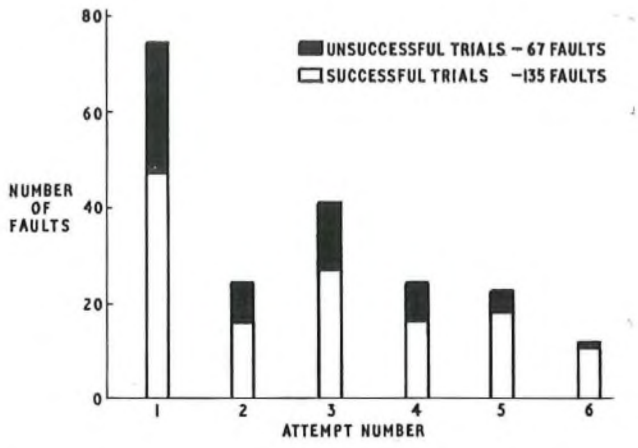

FIG. 3—Faults with one occurrence only—number of faults recorded at each of the six test attempts

During 1,770 hours of cyclic testing 573 test failures were recorded in 10,754 test attempts, giving an overall test attempt failure rate of 0·053. Fig. 2 shows the percentage of failures recorded in each of the required six attempts, showing that 41 per cent occurred at the first attempt reducing to 4·4 per cent at the sixth. However, the figures are slightly misleading as all failures cause tests to be re-started at a new attempt 1 and failed trials often did not reach attempt 6, so the number of tests run at successive attempts is different (reducing from 2,211 tests run at attempt 1 to 1,493 at attempt 6).

The failure rate at the individual attempts is also shown on Fig. 2, indicating a failure rate of 0·1 reducing to 0·017. If only random failures occurred in the trial the failure rate would be expected to be constant at 0·053. To explain the meaning of the failures they have been divided into faults with one occurrence, intermittent faults and multi-programming failures. These categories are described in the following paragraphs.

Faults with one Occurrence

Fig. 3 shows the number of faults which did not recur during cyclic testing. Most of the faults were on the peripheral equipment, each device showing a similar pattern (see Appendix, Table D). They tended to be of an electro-mechanical nature reproduced by the relatively high activity during the cycle. It should be noted that the overall fault rate during attempt 1 of the tests, representing some 370 hours of operation, was much higher than during demonstrations where the activity is not so high. However, some of the faults may have developed during demonstrations but did not reveal themselves until the failing functions were thoroughly exercised for the first time. A few of the faults found during the first cycle were due to the subjective impressions of the supervisor on such things as the quality of printing or the straightness of lines on a graph plotter. Others were due to errors found in checking output which is not usually carried out as thoroughly by the contractor prior to the trial. The faults giving rise to peaks in the later cycles were not particularly associated with those in cycle 1 and are thought to be caused by the long-term activity over a day or more causing maladjusted equipment to fail finally.

In the contractor's preparations for the trials all the tests are usually run but often this is not carried out in the same sequence, nor with the same controlled continuous activity as during the trial, leading to the above failure pattern.

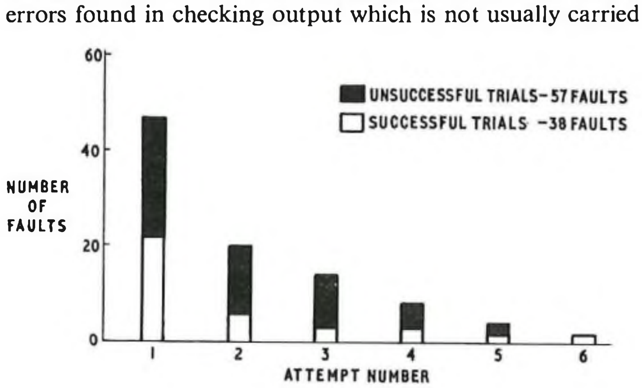

FIG. 4—First occurrence of intermittent faults—number of faults recorded at each of the six test attempts

Intermittent Faults

Some of the faults which occurred once were intermittent faults which were investigated and repaired before the failing test was repeated. This section deals with intermittent faults which gave further occurrences later. Figs 4 and 5 show the number of failures caused by the first and subsequent occurrence of intermittent faults. Fig. 4 indicates that the intermittent faults either developed during demonstrations or, more likely, were present during the contractor's preparations, and were thought to be due to external causes, such as mains supply variations or operator errors, rather than machine faults. Fig. 5 shows that the majority of repeat occurrences of intermittent faults recurred within the six attempts and, for those affecting one program, it has been calculated that the mean time between repeat incidents is 20–30 minutes of running the failing program.

The lack of preparation for trials which failed is further emphasized by the higher proportion of intermittent faults where 27 of the 57 intermittent faults represented in Fig. 4 gave failures in different programs, whereas in successful trials 33 of the 38 faults affected one program only. A measure of intermittency of faults is an incidents-per-fault ratio, where

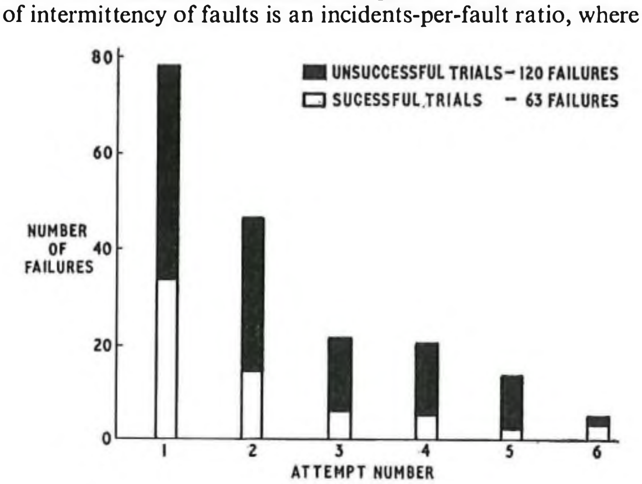

FIG. 5—Second and subsequent occurrences of intermittent faults—number of failures recorded at each of the six test attempts

an incident is counted for each occurrence of a particular fault. The incident-per-fault ratio obtained during the trials (see Appendix, Table D) is much less than that obtained in normal service as, during acceptance trials, highly competent commissioning engineers are usually available and are given every opportunity to investigate faults. If acceptance tests were not held, it is likely that such commissioning engineers would not be available and intermittent faults would give rise to far more failures than those observed in the trials.

Processor and Software Faults

The processor and software faults included in Figs 3, 4 and 5 followed the same distribution as intermittent faults without any peaks of failures after cycle 1 (see processor and software faults in Appendix, Table D). Certain of the software faults occurred once in cycle 1 and did not recur in the later cycles; some of them were rectified before the trial continued and others are thought to have been induced by hardware faults. The figures do not reflect all failures encountered during the trials as, sometimes, especially on new systems, predetermined software failures were allowed without penalty.

Twelve processor faults were recorded during successful trials only four of which gave repeat occurrences but, in trials which failed, 12 of the 17 faults were intermittent. Processor faults are best considered over the appropriate running times rather than by the number of tests and give the results shown in Table 1.

TABLE 1
Occurrence of Processor Faults

	Test Period	Running Time (hrs)	Number of Faults	Mean Time between Faults (hrs)
Successful Trials	Demonstrations	368	3	123
	Cyclic Testing	1,236	12	103
	Attempt 1	230	5	46
Unsuccessful Trials	Demonstrations	170	4	42
	Cyclic Testing	534	17	31
	Attempt 1	140	9	16

The above indicates that, overall, due to the higher activity, proportionally more failures occurred during cyclic testing than in demonstrations, especially at attempt 1, again reflecting the advantage of controlled, continuous activity.

Undetected Faults

One of the objects of the trials is to reveal faults which would normally be undetected and, to achieve this, all output produced is checked visually or by reading it on an input device. Consistency of correct results is checked by repeating the tests.

About one-third of the faults observed in the trials could be classified as undetected, or producing wrong results without indication. The number of undetected faults varied considerably according to the type of equipment. The highest percentage of undetected faults was on paper-tape punches, where 90 per cent of the faults were due to mis-punched tape; on card punches, with in-built checking facilities, only 40 per cent of the faults were due to undetected mispunches. Undetected misreads gave rise to 50–60 per cent of faults on card-readers and paper-tape readers, and about 20 per cent of faults on magnetic-tape units and disks. Misprinting gave rise to about two-thirds of the line-printer faults but most of these were observed as one column not printing and were fairly obvious.

Processor faults were generally indicated as parity failures or caused the system to stop processing, but six of the 29 faults produced wrong answers. However, four of the latter were on systems without the benefit of parity-checking circuits. Besides software faults which produced consistently wrong answers, three of an intermittent nature were recorded.

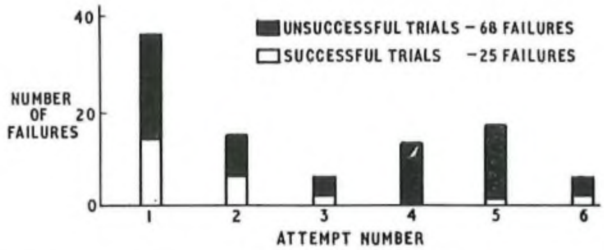

FIG. 6—Multiprogramming failures—number of failures recorded at each of the six test attempts

Multi-Programming Failures

The remaining failures were caused by faults affecting more than one program running concurrently on multi-programming systems. The distribution shown in Fig. 6 is not particularly significant as the failures tended to be caused by intermittent processor and software faults, causing failures in different groups of programs, each at different attempts. As many as nine programs were failed by one incident.

THEORY OF RANDOM FAILURES

Most of the failures described previously were due to incorrect assembly or commissioning of the equipment but a certain number of random faults also occurred. For random faults the distributions are usually calculated using the exponential law of reliability, where the probability of survival q of a test of duration t is given by:

$$q = e^{-t/m},$$

where m is the mean time between faults. The probability of failure p, where $p = 1 - q$, is given by:

$$p = 1[- e^{-t/m}].$$

If the specified figure for the mean time between faults on individual tests were 200 hours, the probability of failure during one 15-minute attempt would be 0·00125. Therefore, less than two random faults could be expected in the 1,242 tests run at attempt 6 in the successful trials. The fact that 13 faults were recorded might be taken as indicating that the specified reliability figure was not being met. However, on the electro-mechanical parts of a computer, even when properly commissioned and maintained, a different class of random failure can occur under a combination of adverse conditions and can cause design margins to be exceeded.

The random-error rate of a paper-tape punch, included in many of the trials, is often assumed to be 1 mispunch in 10^6 characters and that for the paper tape reader, 1 misread in 10^7 characters. Since in a 15-minute test attempt an average of nearly 60,000 characters are punched and read, the probability of failure from this source could be calculated to be 0·064.

In considering the number of random failures at the various attempts, if p is the probability of failure and q is the probability of success of one attempt, the probability of failure at various attempts is as shown in Table 2.

If N tests are run at attempt 1, then Nq^6 tests could be expected to run the required six times without failure or if M tests are required to be run until successful ($M = Nq^6$), then the total attempts could be expected to be:

$$\frac{M}{q^6} + \frac{M}{q^5} + \frac{M}{q^4} + \frac{M}{q^3} + \frac{M}{q^2} + \frac{M}{q}.$$

During successful trials, 70 engineering and customer paper-tape tests of the type described above were run to completion, the expected and actual results being as shown in Table 3.

TABLE 2

Theoretical Probability of Success or Failure

	Attempt					
	1	2	3	4	5	6
Probability of success at attempts 1–6 in succession	q	q^2	q^3	q^4	q^5	q^6
Expected proportion of tests reaching attempts 1–6	1	q	q^2	q^3	q^4	q^5
Expected proportion of failures	p	pq	pq^2	pq^3	pq^4	pq^5

During the trials many of the failures were claimed to be due to minor maladjustments of the tape-reader, whereas it is more likely that the paper tape had been punched out of tolerance. Nevertheless, most of the recorded faults in the paper-tape test could be considered as being due to random errors. Some of the failures specified as intermittent faults, at the time of the trial, could also have been due to random errors.

Devices such as card-readers and card-punches have similar error rates to paper-tape readers, as they have in-built error-detection facilities. Character-error rates of magnetic tape and disk units are much less but, due to the higher transfer rate, can produce one random error per 200 15-minute test attempts.

Hence, although less than two of the 13 faults recorded in cycle 6 of successful trials could be expected to be due to equipment failures, which required repair, most of the remainder could be considered to be due to random errors. This may also apply to some of the failures thought to be repeat occurrences of intermittent faults.

ENGINEERING TESTS VERSUS CUSTOMERS' TESTS

The contractor's engineering test programs are included in the trials as they check all functions of all equipment and some worse-case parameters but, usually, the functions are checked in fixed sequences which bear no resemblance to normal user operations. Although the main function of the customer-type programs is to exercise software and to establish confidence in the capabilities of the system, they often reveal many hardware faults by providing a variety of activity which is not adequately covered in the engineering tests.

Appendix, Table C shows the fault rates of individual engineering tests, giving an overall rate for 6,273 test attempts of 2·6 faults per 100 attempts. During 4,481 customer tests the fault rate was about 3 per cent but, excluding software failures, it was about the same as during engineering tests. An indication of the efficiency of engineering tests is given by considering intermittent faults where, out of 42 such faults occurring in customer programs, only 9 were indicated in engineering tests although, in most cases, the appropriate engineering tests were run alternately with the failing programs.

Therefore, the inclusion of customer programs is necessary if any level of confidence on the capabilities of the system is to be obtained. As an extension of customer programs, special self-checking equipment and system-exerciser tests have been written by T.S.U. in high-level languages.

UNSUCCESSFUL TRIALS

When trials failed, it was usually due to excessive faults on peripheral equipment. However, six trials failed due to processor faults, two due to software and two due to equipment design deficiencies. The unsuccessful trials were typified

TABLE 3

Comparison of Expected and Actual Results

	Attempt						Total Failures
	1	2	3	4	5	6	
Expected failures	6·6	6·2	5·8	5·5	5·1	4·8	34
Actual faults	8	6	8	4	6	5	37
Repeat occurrences of intermittent faults	7	1	3	1	1	0	13

by excessive numbers of intermittent faults, which, in spite of the high level of engineering expertise available and faults occurring repetitively in engineering tests, were not found within the period of the trial. Several trials were abandoned by the contractor rather than run to completion and were deemed to be failed trials by the supervisor. The abandonment was usually made when the contractor realized that no progress was being made in finding the faults. In other trials, extensions above the specified 50 per cent were given when the contractors considered that the faults had been rectified, but all these trials were finally terminated in order to force thorough investigations without the pressure of completing a trial.

The division between trials which failed or passed was not always very great, as sometimes, the failures were due to one device being faulty and the repeat trial consisted of testing that device only. For successful trials, sometimes systems were accepted except for one device, or a conditional acceptance was given. The pass or fail decision for the above was made by taking into account the circumstances of the faults and the likely effects on the particular application. None of the systems tested in this period failed three trials but three systems failed twice. When they were tested a third time, after a long delay, they were virtually fault-free.

The faults which caused trials to fail were fairly obvious and readily reproducible when programs were run in a controlled, continuous fashion. This emphasized, once more, the lack of adequately-supervised preparation by the contractors. Sometimes the deficiencies were known but the equipment was offered for trial with the contractor's declared intention of rectifying the problems as the trial proceeded.

FACTORY TRIALS

Twenty-four of the trials were conducted at the contractors' factories and eight of them failed, representing a higher failure rate than site trials. Although systems which had factory trials had a slightly lower site-trial failure rate than those which had site trials only, the difference was not significant. It should be borne in mind that the factory trials were held on first-off or early production systems so to have site-trial failure rates equal to those on established systems is an achievement in itself.

POST-TRIAL EXPERIENCE

Most systems operated relatively fault-free for the period immediately following a successful trial but many developed problems after a few months due to poor maintenance practices as, unlike the commissioning engineers available for trials, the maintenance technicians available were not always sufficiently experienced. One further source of trouble, starting at this point in time and continuing through the systems' lifetimes, are newly-developed intermittent faults where the combined lack of expertise, poor diagnostic tests and lack of automatic fault logging and recovery facilities, produced incident-per-fault ratios much greater than those encountered during trials (see Appendix, Table D). Although the number of repeat occurrences of intermittent faults is excessive, where it is not unknown for one fault to give more than 50 incidents over a period, the reliability specifications in terms of mean time between faults is often met. In the circumstances described above, as the systems are handed over in good working condition, the computer managers are in a position to know that all is not well and to make strong representations to the maintenance authority.

On a few systems, problems were encountered immediately following completion of acceptance trials due to intermittent faults which were thought to have been rectified, workload or software system differences to those used in the trial, or, again, poor maintenance practices. However, for the majority of systems, the objectives of the trial were met.

CONCLUSIONS

With the form of trials adopted, the contractors know in advance what programs are to be run so, theoretically, the trial should be a mere formality and equipment performance should be relatively fault-free. In practice, however, the trials often act as a final commissioning period and the main reason for trials failing is inadequate preparation by the contractors.

Other forms of trials could be devised to establish hardware reliability and to check all software functions but these would be excessively time-consuming and costly. Experience indicates that it would be difficult to better the cost effectiveness of the system adopted. The criterion of running tests six times in succession without failure establishes to a reasonably high degree of confidence that assembly and commissioning faults have been rectified and that the system is capable of fulfilling the task for which it was purchased.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance given by their colleagues in T.S.U. in preparing this article, especially for the accurate records and recollections of trials events. Acknowledgement is also made the to Head of C.S.E. Division of the Department of Trade and Industry for permission to publish this article.

TABLE B

Demonstration Results

Cause of Failures	Number of Failures	Number of Successes*
Processor instruction times slow	1	88 Systems
Magnetic tape units incompatible	3	69 Systems
Magnetic tape units transfer rate slow	4	327 Units
Exchangeable discs incompatible	1	40 Systems
Exchangeable discs head movement slow	2	107 Units
Exchangeable discs transfer rate slow	1	107 Units
Graph plotter slow	3	22 Units
Line printer printing slow	2	91 Units
Paper-tape reader transfer rate slow	1	84 Units
Paper-tape punch transfer rate slow	0	76 Units
Card-reader transfer rate slow	0	77 Units
Card-punch transfer rate slow	0	42 Units
Fortran programs wrong results	2	
Software timing test slow	1	
Software error recoveries not working	2	

* Demonstrations often not re-run on repeating failed trials.

References

[1] Bennett, R. O. and Stringer, J. B. Acceptance Trials of Computer Systems for Government use, *Computer J.*, Vol. 4, p. 185, 1961.

[2] Barnett, V. D. and Ross, H. F. Statistical Properties of Computer Acceptance Tests, *J. R. Statist. Soc.*, Series A, Vol. 128, p. 361. 1965.

APPENDIX

TABLE A

Faults on Demonstrations

Equipment	Number of Faults		
	Successful Trials	Un-successful Trials	All Trials
Central Processing Unit	3	4	7
Magnetic Tape Unit	14	16	30
Exchangeable Disc Unit	5	6	11
Card Reader	1	4	5
Card Punch	0	2	2
Paper-Tape Reader	2	1	3
Paper-Tape Punch	1	1	2
Graph Plotter	2	4	6
Line Printer	3	8	11
Other	14	4	18
Software	3	4	7
Total Faults	48	54	102
Repeat occurrences of intermittent faults	2	6	8
Total times taken (hours)	368	170	538

TABLE C

Faults on Successful and Unsuccessful Trials and in Engineering Tests During Cyclic Running

	Total Faults		Faults in Engineering Tests		
	Successful Trials	Un-successful Trials	No. of Faults	No. of Attempts	Per-centage Fault Rate
Processors	12	17	7	846	0·8
Magnetic tape units	30	26	34	2,098	1·6
Disc units	15	12	13	696	1·9
Card readers	12	10	16	507	3·2
Card punches	5	5	9	261	3·5
Paper-tape readers	20	14	3	278	1·1
Paper-tape punches	26	7	40	486	8·2
Line printers	18	14	22	573	3·9
Graph plotters	7	6	9	95	9·5
Software	6	11	—	—	—
Other	22	2	9	433	2·1
Total faults	173	124	162	—	2·6
No. of test attempts	7,977	2,777	—	6,273	—
Time taken (hrs.)	1,236	534	—	—	—

No. of customer test attempts 4,481
No. of faults in customer tests 135
Fault rate 3 per cent

TABLE D

Faults on Devices in Various Attempts During Cyclic Testing

UNIT	Attempt						Total Faults	Total Incidents*	Incidents Per Fault
	1	2	3	4	5	6			
Processors	14	8	4	1	1	1	29	60	2·1
Magnetic Tape Units	18	6	14	10	6	2	56	70	1·25
Disc Units	13	5	6	1	1	1	27	56	2·1
Card Readers	11	6	1	3	1	0	22	53	2·4
Card Punches	3	0	3	2	1	1	10	22	2·2
Paper Tape Readers	11	5	9	2	5	2	34	49	1·45
Paper Tape Punches	8	5	8	6	3	3	33	47	1·4
Line Printers	16	2	5	3	6	0	32	44	1·4
Graph Plotters	8	0	2	2	1	0	13	15	1·15
Software	11	3	2	0	0	1	17	36	2·1
Other	9	5	2	3	2	3	24	28	1·15
Total	122	45	56	33	27	14	297	480	1·6
No. of Tests Run	2,211	1,954	1,829	1, 677	1,590	1,493	10, 754		

* Incident = Faults (prime occurrence) + further occurrences when intermittent.

An Improved Radiophone Service for London

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U.D.C. 621.396: 621.395.4

The original London radiophone service is now less efficient than modern techniques allow. An improved replacement service is described which has a greater traffic-carrying capacity and gives better coverage of the service area. Salient features of the fixed and mobile radio equipment are given, together with a summary of the system operation.

INTRODUCTION

A radiophone service allows subscribers to make and receive telephone calls to and from their vehicles by means of radio calls set up between the mobile unit and a fixed radio station. The fixed station is connected by land-lines to a controlling exchange where a telephone operator can make the necessary connexions to the public telephone network. Generally, a radiophone area is large enough to require a number of fixed radio stations, all under the control of one central exchange. Two radiophone systems are already in service, one in South Lancashire[1] and one in London.[2] The new system described in this article will eventually replace the existing London system which has been in use for 7 years.

The existing systems employ a control channel for the establishment of contact between telephone operator and mobile subscriber, and a number of traffic channels over which the final connexion between mobile and fixed subscriber is made. Using one control channel with speech calling, and five traffic channels, the South Lancashire system has 270 subscribers. The old London system uses one control channel with selective calling, and nine traffic channels to accommodate 320 subscribers. These two services are now less efficient than modern techniques allow.

The South Lancashire system uses voice calling on a control channel. This is time-wasting and can lead to congestion. It also demands that mobile subscribers listen continuously to a calling channel in order to intercept calls.

The old London system uses selective calling on a calling or control channel. A 10-second period is required to call the mobile subscriber and this is slow by modern standards. At busy periods the control channel is unable to cope with the number of calls presented to it.

On both of these systems the telephone operators tend to make repeat calls because of uncertainty regarding the signalling effectiveness, and in addition, a close listening watch has to be kept on the traffic channels in order to ascertain when a subscriber has cleared down. These practices reduce the effective use of the radio channels. Both systems tend to suffer from ignition interference in the busiest parts of the cities they serve. Neither of them offer privacy and mobile subscribers can overhear each other's conversations.

The new radiophone system has been designed to overcome these disadvantages. It has a selective calling system which operates at a much higher speed than that of the early London service and this allows many more calls to be passed by the controlling exchange. Telephone operators are given a positive signal when a mobile set accepts a call and the need for repeat calls is greatly reduced. They are also given an indication when a subscriber clears down. This simplifies call timing and eliminates the need to monitor the calls continuously.

The channels of the new system are spaced at 25 kHz intervals, compared with 50 kHz spacing on the existing systems, thus exploiting more efficiently the available frequency bands. Special attention has been given to ensuring a good signal strength in the city centre. The new system affords a high degree of privacy so that it is not possible for one subscriber to overhear the calls of another.

Fig. 1 illustrates the basis of the new system.

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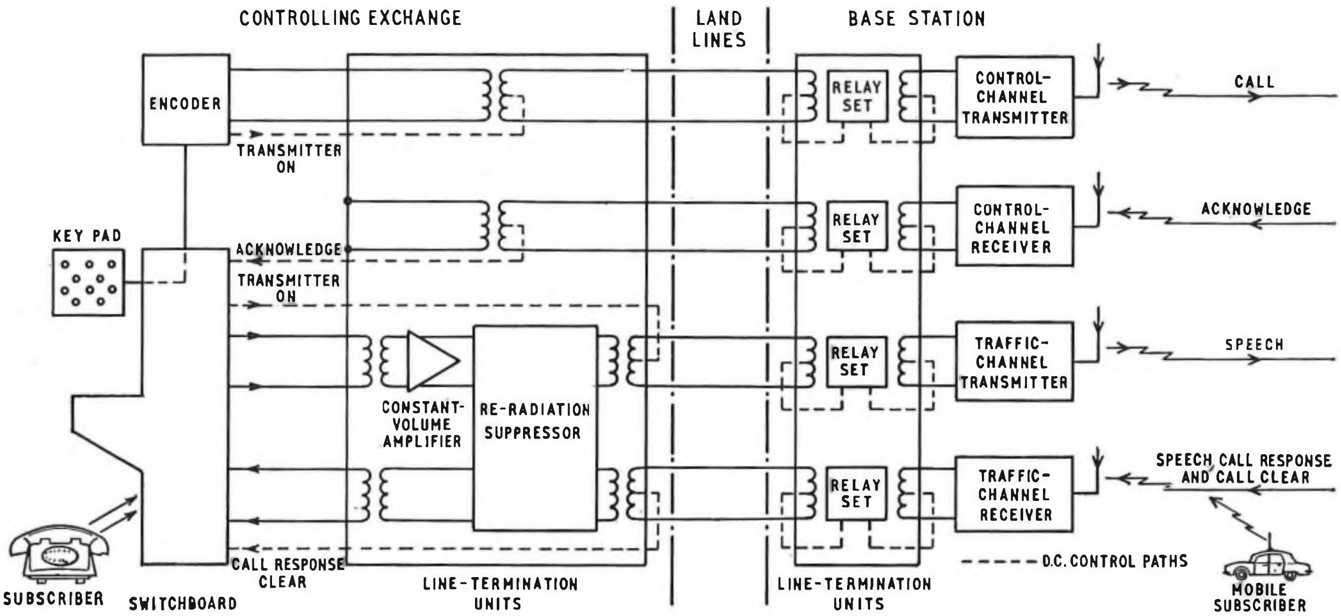


Fig. 1—Basic radiophone system

AREA COVERAGE AND CHANNEL PLAN

Originally, it was intended that all the available radiophone channels would be distributed between the three base stations at Pimlico (North West), Kelvedon Hatch (North East) and Beulah Hill (South), which already serve the older London system. However, field tests showed that much of the city centre, which should have been covered from Beulah Hill, received inadequate signals. A fourth base station (Central) was therefore sited 1·6 km south of the Thames, near Waterloo. The building used is an eleven-storey telephone exchange and office block. This site gives excellent coverage of central London. The outer boundaries of the service area are substantially the same as for the old London system, as shown in Fig. 2. Various aspects of mobile-radio system planning were described in an earlier article.[3]

At present, 37 very high frequency (v.h.f.) channels are available for the radiophone service. These are spaced at 25 kHz intervals (half the spacing of the first London service). They extend from 163·5–164·4 MHz for base-station transmitters, and from 159·0–159·9 MHz for mobile transmitters. The mobile sets have a capacity of nine traffic channels and the total radiophone frequency spectrum has been divided into five frequency-groups known as L1, L2, L3, L4, and L5. Certain frequencies are shared between groups, and others are exclusive to them, as shown in Table 1.

TABLE 1

Channel Plan for the New London Radiophone Service

Channel Number	Distribution of London Frequency-Groups (L1–L5)				Base-Transmitter Frequency (MHz)	Base-Receiver Frequency (MHz)
	Central	South	North-West	North-East		
01	2				164·400	159·900
02			4		164·375	159·875
03	4				164·350	159·850
04				4	164·325	159·825
05	3, 4				164·300	159·800
06			3, 4, 5		164·275	159·775
07	3, 4				164·250	159·750
08				3, 4, 5	164·225	159·725
09		3, 4			164·200	159·700
10			2		164·175	159·675
11		3, 4			164·150	159·650
12			3		164·125	159·625
13		2			164·100	159·600
14				3	164·075	159·575
15	3				164·050	159·550
16					164·025	159·525
17		Control	Control	Control	164·000	159·500
18					163·975	159·475
19		2			163·950	159·450
20				2	163·925	159·425
21	1, 2				163·900	159·400
22				1, 2, 5	163·875	159·375
23	1, 2				163·850	159·350
24				1	163·825	159·325
25		1			163·800	159·300
26			2, 5		163·775	159·275
27	1				163·750	159·250
28			1		163·725	159·225
29		1			163·700	159·200
30			1		163·675	159·175
31	5				163·650	159·150
32	5				163·625	159·125
33					163·600	159·100
34	5				163·575	159·075
35		5			163·550	159·050
36					163·525	159·025
37		5			163·500	159·000

The distribution of channels between the four base stations is such that a mobile subscriber, regardless of his assigned frequency group, will find that his set is equipped to operate on three Central-station channels and two channels each for the South, North-East and North-West stations. Although the channel-selector switch on the mobile equipment is numbered 1–9, these figures do not relate directly to the specific channel numbers of any particular frequency. However, on the mobile sets, the frequencies are arranged so that numbers 1, 2 and 3 on the mobile channel-selector switch always provide Central-station channels; numbers 4 and 5, South-station channels; 6 and 7, North-West and 8 and 9 North-East-station channels.

Calling channel

The calling channel frequency is not radiated from the Central station. The efficiency of the signalling system used is such that it can operate satisfactorily in conditions of high electrical noise which would be unacceptable for speech circuits, and full coverage of the service area can be obtained by using the other three stations. Calling signals are not transmitted simultaneously from the three outstations since interference and possible mutilation of the calling code could occur in the areas of overlapping coverage. The central switching apparatus ensures that the calls are transmitted cyclically from each of the outer base stations in turn.

MOBILE EQUIPMENT

The mobile equipment for the new London radiophone system is built in two units. One unit, consisting of the radio transmitter and receiver, is generally mounted in the boot or rear of the vehicle. It is connected by cable to a second, smaller unit which is usually fixed on or near the dash-board. This second unit contains the indicator lamps, switching circuitry and the selective call-decoder and is provided with a volume control, channel selector and call button. It also has lamps which indicate when the equipment is switched on, when an engaged channel has been selected and that a call has been received. This latter function is supplemented by a buzzer which gives a 1–5 second audible alarm.

Because mobile-radio equipment with a ten-channel capability is manufactured in quantity for private mobile systems, ten channels has been adopted as the standard capacity for the new radiophone system sets. One of the ten channels is used as the control channel and nine as traffic channels. Each mobile set is therefore provided with a common control-channel, which will be the same on all sets, and nine traffic channels, the frequencies of which vary from set to set. The mobile set is designed to switch to the control channel when the handset is in its holder. Selection of the traffic channels is by means of a switch which is under the control of the user whenever the handset is lifted from its holder.

The mobile-radio equipment employs frequency modulation (f.m.), is fully transistorized and has transmitter powers of 10–15 watts. The maximum carrier deviation is ± 5 kHz. The equipment operates in the simplex mode (press-to-talk operation). Generally, a common quarter-wave whip aerial mounted on the roof of the car serves both transmitter and receiver.

Customers obtain their mobile equipment from approved manufacturers who supply, fit and maintain the sets by arrangement with the individual users. Examples of such equipment are shown in Fig. 3.

CALLS TO AND FROM SUBSCRIBERS

Calls to mobile subscribers

When an operator is asked for a call to a mobile subscriber the appropriate number is transmitted over the control channel to the fixed radio stations. If the subscriber's set is switched on, and the handset is in its holder, it will be tuned to the control channel. If the subscriber is within radio range, the

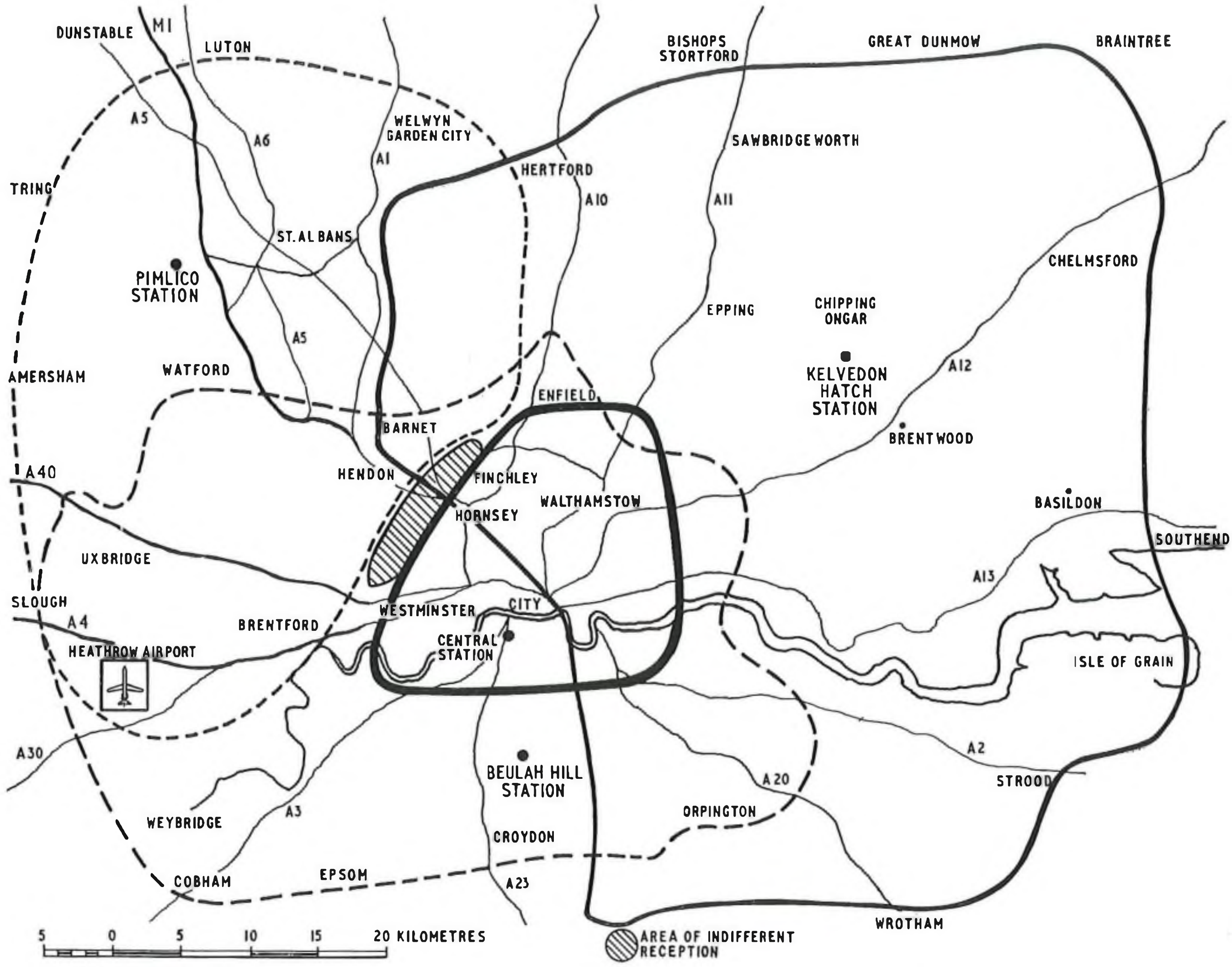


FIG. 2—Service area boundaries

call is detected and decoded in the mobile receiver and the subscriber is alerted by means of a buzzer and an indicator lamp. At the same time, the mobile transmitter is energized and modulated at 2,400 Hz for 150–400 milliseconds. This signal is transmitted to the base station where it is detected and a signal returned to the operator via the land-line in a form suitable for the illumination of the switchboard acknowledge lamp. If the subscriber then responds to the call, he lifts the handset and selects a free channel by ensuring that his channel-engaged lamp is not illuminated. He then presses the call button which modulates the transmitter at 2,600 Hz for a short period. This signal, radiated over the traffic channel, is detected at the base station and returned to the operator over the traffic channel land-line as a d.c. condition. At the exchange a calling lamp is illuminated which shows that the mobile subscriber is responding to the call. After answering, the operator connects the mobile subscriber to the calling subscriber. At the end of the call the mobile subscriber replaces the handset. This causes the mobile transmitter to be modulated at 2,400 Hz for a short period. This signal is radiated on the traffic channel, after which the mobile equipment reverts to the control channel. As before, this audio tone is detected at the appropriate base station and is returned to the controlling exchange as a d.c. condition which gives the operator a positive clear-down indication.

Calls from mobile subscribers

The mobile subscriber initiates a call by lifting the handset and selecting a free channel suitable for the location. (If a busy channel is selected, the channel engaged lamp lights, the receiver is muted and the transmitter disabled). He then presses the call button which energizes the transmitter and modulates it at 2,400 Hz. This tone is detected at the base station and relayed as a d.c. condition to the controlling exchange where it is recognized as signalling a new incoming call as distinct from a response. A second lamp associated with the traffic channel is provided for this purpose. The operator answers the mobile subscriber and makes the necessary connection. The clear-down indication from the mobile set is transmitted in the normal way at the end of the call.

The various audio frequencies used to provide the controlling exchange with the necessary signalling information are listed in Table 2.

TABLE 2

Audio Frequencies Used for Exchange Signalling

Function	Frequency (Hz)	Carrier Deviation (Hz)	Duration (ms)
Call	2,400	3,000	150–400
Acknowledge	2,400	3,000	150–400
Respond	2,600	3,000	150–400
Clear-down	2,400	3,000	150–400

FIG. 3—Examples of proprietary mobile-radio equipment

FIXED RADIO-STATION EQUIPMENT

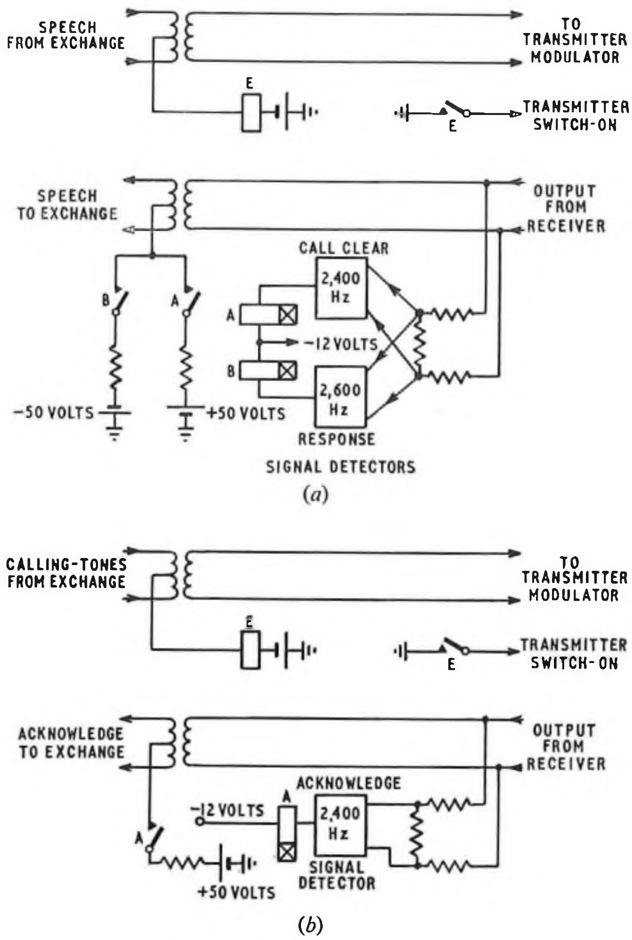
At a base station each channel requires its own transmitter and receiver. These are virtually standard single channel frequency modulated (f.m.) items of equipment designed to operate with carrier deviations of ±5 kHz. The transmitters are rated at 50 watts output power and the receivers are required to deliver a 1 milliwatt output signal with a 20 dB signal-to-noise ratio for a radio-frequency (r.f.) input signal of 2 microvolts. At present, each transmitter uses its own single-dipole antenna, but the receivers are fed from a distribution amplifier which allows eight receivers to be coupled to one receive aerial. Base-station receive aerials have a gain of 3 dB to compensate for the somewhat lower power of the mobile transmitters.

In order to minimize the level of intermodulation products radiated from the base stations, ferrite isolators are inserted into the coaxial cables which are connected to the transmitter aerials. These restrict the amount of r.f. energy which can be fed from one transmitter to another and reduce the amount of non-linear mixing which can take place in the transmitter output stages, thereby significantly lowering the levels of radiated intermodulation products.

Part of the channel equipment at the base stations is a line-termination unit, the function of which is to associate the voice-frequency signals from the four-wire exchange lines with the radio equipment. Fig. 4 illustrates the principles of the control-channel and traffic-channel line-termination units.

Audio signals from the exchange are passed via one pair of the four-wire line via the line transformers to the modulator of the transmitter. When an operator connects to a traffic channel, an earth condition is applied to the phantom of this pair via the sleeve circuit. This causes relay E to operate in the line-termination unit.

Relay E contacts close and fully energize the transmitter. The transmitter radiates carrier continuously during the call. Speech signals from a mobile set are received at the base-station receiver and passed via the transformer to the receive pair of the four-wire line, leaving the phantom circuit available for d.c. signalling purposes. When a mobile subscriber initiates a call his transmitter is modulated at 2,400 Hz for a short period. This signal is passed from the base-station receiver to the line-termination panel where it is detected and



(*a*) Traffic channel
(*b*) Control channel

FIG. 4—Line-termination units

operates relay A. Relay A applies +50 volts to the phantom of the receive pair. At the exchange, this condition is used to alert the operator to the incoming call. On completion of the call the mobile set again transmits a 2,400 Hz clear-down signal. The +50 volts condition is applied to the receive-pair phantom and the switching equipment at the exchange now interprets it as a clear-down signal and gives the appropriate supervisory indication to the operator.

When a mobile subscriber responds to a call from the exchange he does so on a traffic channel. Because his selective call decoder will have operated, the logic circuitry in the mobile equipment causes the frequency of the tone transmitted back to the exchange to change from 2,400 to 2,600 Hz. This is detected in the line-termination panel and operates relay B, applying −50 volts to the receive-pair phantom. At the exchange, this condition is used to give the operator an indication that a subscriber is responding to signalling. Thus, the operators are given a clear distinction between calls which are initiated by a mobile subscriber and those which are in response to signalling.

The control-channel line-termination unit functions in a similar way to that of the traffic channel, but is simpler because it need not pass speech. In the transmit direction from the exchange, relay E is operated to energize the control-channel transmitter prior to the arrival of the calling tones which signal to the individual mobile subscribers. This is done automatically by the exchange encoding-apparatus. In the receive direction, only one 2,400 Hz detector is required to respond to the automatic acknowledgement signal from mobile sets. Detection of this signal applies +50 volts to the control-channel receive-pair phantom. At the controlling exchange, this condition is used to indicate to the operator that the call has been received and correctly decoded.

TRANSMISSION EQUIPMENT AT THE CONTROLLING EXCHANGE

The audio signals from the exchange to the base-station transmitters are routed via constant-volume amplifiers to ensure an adequate degree of modulation in the face of large variations in signal level from the public telephone network. These amplifiers are mounted in the exchange and are powered from the exchange 50-volt supply. Due to the characteristics of f.m. radio signals, the speech from the base-station receivers into the exchange is reasonably constant in level and is not given any additional amplitude control.

However, it is necessary to guard against the possibility of the exchange hybrids having low values of trans-hybrid loss. Any leakage signals would be amplified by the constant-volume amplifiers and re-radiated. To prevent this, voice-operated re-radiation suppressors are fitted which detect the presence of speech on a receive pair and insert a high degree of attenuation into the transmit path. Thus, mobile and fixed subscribers cannot speak simultaneously, but no operating difficulties have arisen from this.

SIGNALLING SYSTEM

A key feature of any radiophone service is the signalling system to call the mobile subscribers. It must be capable of transmitting the calling information at high speed in order to make efficient use of the control channel and to avoid the need for operators to queue for access to the signalling apparatus. The selective calling system employed for the new London radiophone service uses a sequential train of audio-frequency pulses. Each digit from 0–9 is represented by a separate frequency. Thus, a call to a subscriber having a five-digit number (as is the case for the new system) comprises a brief train of five audio-frequency pulses corresponding to the numbers concerned. Each pulse is of 70 milliseconds duration, and as there is no pause between successive pulses, a complete five-digit number can be transmitted in 350 milliseconds.

TABLE 3

Audio Frequencies Used for Selective Calling

Digit	Frequency (Hz)	Carrier Deviation (Hz)
1	1,060	3,030
2	1,160	3,150
3	1,270	3,240
4	1,400	3,360
5	1,530	3,450
6	1,670	3,540
7	1,830	3,660
8	2,000	3,780
9	2,200	3,900
0	2,400	4,020
Repeat	2,600	4,140

Because the five pulses are transmitted without a pause between them, it would be difficult to decode a number which had adjacent digits of the same value. To overcome this an eleventh frequency is employed for a repeat pulse. If, say, the number 23345 is to be transmitted, the audio-frequency pulse corresponding to the figure 2 is sent first. This is followed immediately by the pulse corresponding to the figure 3. The repeat signal is then sent which instructs the mobile set that figure 3 occurs again. The pulses for figures 4 and 5 are transmitted in the normal way. The frequencies used are shown in Table 3.

This calling system has been tested in all parts of the service area and promises to be extremely reliable.

To give adequate stand-by facilities, three encoders are provided in the exchange. One is held in reserve and calls can be transmitted from either of the other two.

MOBILE TEST-STATION

In the past, with radiophone systems having a maximum of ten working channels, testing was facilitated by providing a standard mobile equipment in the vicinity of the controlling exchange and making or receiving calls from it. To monitor effectively all 37 channels of the new London service would require four separate mobile sets, even if stand-by facilities were not taken into account. Such an arrangement would be cumbersome, expensive and difficult to operate. Accordingly, a 60-channel marine equipment was modified to work at radiophone frequencies. Two of these sets were installed at the controlling exchange and fitted with special control panels. These provide all the calling and signalling functions to be found on a normal mobile equipment. The selective call decoder is set to the number 01234; to check the control channels the operator transmits this number from any one of the base stations. If the system is functioning correctly, the mobile test-equipment receives and decodes this number and returns an acknowledgement signal. Traffic channels are tested in conjunction with a maintenance engineer who uses the equipment to originate and receive calls.

The advantages of this equipment are that all channels are available on one mobile set, and unlike the public sets, the control circuitry has been arranged to permit the engineer to hear the audio calling tones as well as to receive a visual indication of the various functions. This can be of considerable help in fault tracing.

CONCLUSIONS

A radiophone service for London has been developed which is capable of giving to its subscribers better service than systems previously employed. Subscriber calling is more efficient both in terms of calling rate and reliability. Operating staff are now given positive information regarding the progress of a call, and it is no longer possible for one subscriber to use his set to overhear the calls of another.

Although this system has been developed to enable the London service to grow to 2,000 or more subscribers, it is designed to form the basis of a possible national system. The frequency plan adopted is such that similar systems could be used in other parts of the country, and that subscribers could have access to the telephone network in any radiophone area that they visit.

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Negative-Impedance Boosters

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U.D.C. 621.316.722.3:621.375.132

Amplification on standard two-wire British Post Office audio circuits is provided by use of hybrid amplifiers or negative-impedance amplifiers. These circuits are usually provided on 10 lb/mile or 20 lb/mile cable using standard loading, for use in the junction network. Negative-impedance boosters offer an alternative method of providing amplification for such circuits using small-gauge, unloaded cable pairs. The circuits so far developed have improved transmission characteristics, particularly in respect to group-delay, compared with the standard methods of provision.

INTRODUCTION

The action of an electrical system may be represented by a circuit comprised of resistance, inductance and capacitance. Such elements can be present by design, when the values are controlled, or present inherently as parasitic elements. To combat the effect of resistance (R), inductance (L) and capactiance (C), use can be made, both in theory and in practice, of components having electrical characteristics the reverse of those mentioned, i.e. $-R$, $-L$ and $-C$. Such elements can be provided by means of active devices, requiring the provision of a power supply, and permit positive values of resistance, inductance and capacitance to be cancelled by their negative counterparts. This cancellation effect results in the circuit having reduced loss.

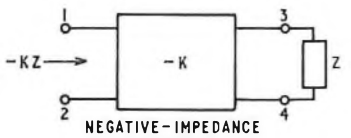

FIG. 1—Negative-impedance convertor

Negative-impedance elements may be produced by the use of a negative-impedance-convertor (n.i.c.), in conjunction with a passive component, or combination of components. In Fig. 1 the passive impedance Z, appears at terminals 1 and 2 reversed in phase, and modified in magnitude by K, the constant associated with the n.i.c. Thus, it is possible to provide negative resistance, inductance and capacitance, or combinations of these, to complement the positive elements already available.

THE NEGATIVE IMPEDANCE ELEMENT

The advantages to be gained by use of negative-impedance, particularly that of negative resistance, have been understood since the early part of this century. Practical difficulties in producing stable n.i.c.s, however, especially during the era of valves, prevented the widespread use of such devices. Much of the work carried out in this field has been directed towards the use of negative-impedance elements. Combinations of these elements may be placed in transmission lines to provide amplification on two-wire audio circuits.[1, 2] Economic pressures, linked with technical advances, particularly in the field of transistor technology, have led in post-war years, to the introduction of negative-impedance amplifiers[3] for use on loaded line-plant. The negative-impedance amplifier used by the British Post Office (B.P.O.) is intended for use on 10 lb/mile or 20 lb/mile loaded conductor and uses a combination of negative-impedance elements, to give a four-terminal device introducing gain in both directions. This amplifier is the only negative-impedance device used by the B.P.O. to give amplification on two-wire circuits.

The two-terminal elements incorporated in the above amplifier can be used in their own right to provide amplification, though using a different design philosophy. Negative-impedance devices have a negative real component at some, if not all, frequencies. This negative resistance may be used to cancel parasitic positive resistance, thereby giving amplification. A two-terminal element used for such a purpose, has been termed a negative-impedance booster (n.i.b.).

This article outlines the theoretical basis for use of n.i.b.s on transmission lines, and describes recent work carried out to investigate their properties, and feasibility of use. Two forms of booster are available, one for use in the series mode, the other for use in a shunt configuration. Interest has mainly centred on the series form of booster, and it is this device that has been used for the experimental work described in this article.

N.I.B. THEORY

Series connected n.i.b.

The insertion of a resistor, R_N, between source and load resistors R_0, as shown in Fig. 2 gives an insertion loss (IL dB)

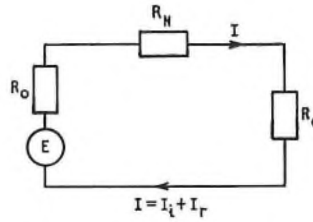

FIG. 2—Series-connected n.i.b.

given by equation 1.

$$IL = 20 \log_{10}\left(1 + \frac{R_N}{2R_0}\right). \qquad \ldots\ldots (1)$$

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If R_N is a negative resistance, equation 1 becomes a gain instead of a loss, with the current, I, changing from,

$$\frac{E}{2R_0 + R_N} \text{ to } \frac{E}{2R_0 - R_N}. \quad \ldots\ldots(2)$$

The current flowing is composed of an incident current I_i plus a reflected current I_r, i.e.

$$I = I_i + I_r. \quad \ldots\ldots(3)$$

When R_N is negative, equation 3 becomes:

$$I = \frac{E}{2R_0} + \frac{E}{2R_0}\left[\frac{R_N}{2R_0 - R_N}\right]. \quad \ldots\ldots(4)$$

Thus an ideal n.i.b. results in an increase in current flow [provided $|R_N| < |2R_0|$], the enhanced current being derived from the impedance mismatch it introduces.

Shunt connected n.i.b.

The insertion of a resistor in shunt with the source and load resistors, as shown in Fig. 3, gives an insertion loss given by equation 5.

$$IL = 20 \log_{10}\left(1 + \frac{R_0}{2R_N}\right). \quad \ldots\ldots(5)$$

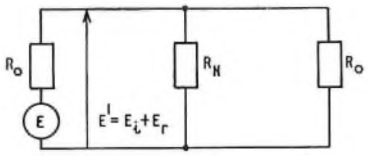

FIG. 3—Shunt-connected n.i.b.

If R_N is a negative resistance, equation 5 becomes a gain, with the e.m.f. transmitted from the source, E', being given by equation 6.

$$E' = \frac{E}{2} - \frac{E}{2}\left[\frac{R_0}{R_0 - 2R_N}\right]. \quad \ldots\ldots(6)$$

Thus, the use of a n.i.b. again leads to an increase in gain derived from the impedance mismatch it introduces.

APPLICATION OF N.I.B.s TO TRANSMISSION LINES

A transmission system may be viewed as a linear four-terminal network, having passive terminating impedances. For any passive load, stability can be achieved by ensuring that the image impedances[4] have positive resistive components at all frequencies.[5] In electrically long lines, where the repeater is placed a distance greater than a quarter of a wavelength from either line terminal, the amplifier is designed to have an impedance equal to the characteristic impedance of the line. This design philosophy is used in the case of the negative-impedance repeater.

Short sections of line, with relatively small attenuation and phase shift, can, in general, be best improved, from a transmission point of view, by mismatch between the image impedance of the repeater and the characteristic impedance of the line. The use of n.i.b.s at the centre of electrically short transmission lines is an example of this technique, and offers an alternative method of obtaining two-wire amplified circuits. Since the n.i.b.s are placed at the centre of short sections of line, power has to be fed along the line to activate them. This problem is most easily resolved by use of the series type of n.i.b.

The placing of negative-impedance elements at the centre of transmission lines permits the line, plus the n.i.b., to be viewed as a whole, rather than as separate identities. This is of use in considering the transmission line equations for propagation constant, p, and characteristic impedance, Z_0.

$$p = a + jb = \sqrt{\{(r + j\omega l)(g + j\omega c)\}}. \quad \ldots\ldots(7)$$

$$Z_0 = R_0 + jX_0 = \sqrt{\left\{\frac{(r + j\omega l)}{(g + j\omega c)}\right\}}. \quad \ldots\ldots(8)$$

where

ω = $2\pi \times$frequency,
r = resistance/unit length,
l = inductance/unit length,
c = capacitance/unit length,
g = leakance/unit length.

The use of a n.i.b. to reduce r to zero, on a cable having negligible conductance, leads to equations 7 and 8 being modified to give:

$$a + jb = 0 + j\omega \sqrt{(lc)}. \quad \ldots\ldots(9)$$

$$R_0 + jX_0 = \sqrt{(l/c)} + j0. \quad \ldots\ldots(10)$$

Equations 9 and 10 describe a lossless transmission line, having a resistive characteristic impedance, and zero phase distortion when placed between resistive terminations. In practice, these conditions are only approximated to, owing to the effect of g, and the need to build stability into the system. Thus, by distributing negative-impedance elements at fixed spacing along a transmission line, in the same manner as inductance loading, low loss, two-wire circuits can be achieved, each section having to be unconditionally stable.

The design of n.i.b. line sections, is best achieved by relating stability to the properties of the negative-impedance and the line. This type of relationship has been developed[6] for a structurally symmetrical system as shown in Fig. 4. The two

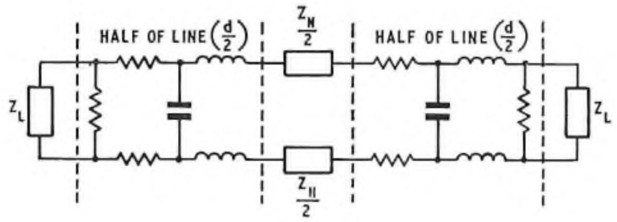

FIG. 4—Symmetrical negative-impedance booster line of length d

main conditions to be satisfied are:

(*a*) The n.i.b. must be of the open-circuit stable type,[3] the voltage/current characteristic being of the form shown in Fig. 5.

(*b*) The short-circuit impedance for a half-section n.i.b.

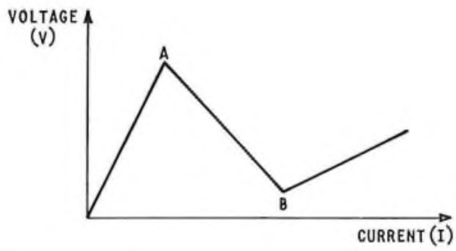

FIG. 5—Voltage/Current characteristic of a series-connected negative-impedance booster

line, given by equation 11, must have a positive resistive component at all frequencies.

$$Z_{scB} = Z_{oc}\left[\frac{\left(\frac{Z_N}{2}+Z_{sc}\right)}{\left(\frac{Z_N}{2}+Z_{oc}\right)}\right] \qquad \ldots\ldots (11)$$

where, Z_{scB} = short circuit impedance of a n.i.b. line $\frac{d}{2}$ in length,

Z_{sc} = short circuit impedance of a line $\frac{d}{2}$ in length,

Z_{oc} = open circuit impedance of a line $\frac{d}{2}$ in length.

Thus for a selected cable, the design problem becomes that of designing Z_N to achieve suitable transmission properties, while satisfying the given stability criteria.

THE N.I.B. CIRCUIT

The d.c. characteristic required for an open-circuit stable device is shown in Fig. 5. A negative-impedance can be achieved with this device, by use of the negative $\delta V/\delta I$ slope between points A and B. Many circuits have been produced to obtain such a characteristic,[7] and the use of a particular circuit is dependent upon such factors as the dynamic range required, quiescent power-feed conditions and ease of control of characteristic. One such circuit is shown in Fig. 6, along with its a.c. equivalent circuit in Fig. 7.

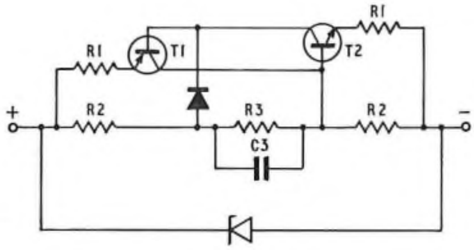

FIG. 6—Negative-impedance booster circuit

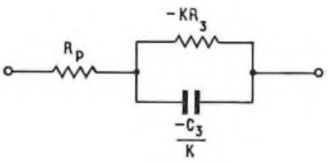

FIG. 7—Equivalent circuit of the negative-impedance booster

The d.c. characteristic may be explained by reference to Fig. 6. Application of low valued currents, in the sense shown, leads to a voltage drop across the n.i.b. terminals of $V = I(2R_2 + R_3)$. This relationship applies in the region below A (Fig. 5), at which point transistors T_1 and T_2 start to conduct, as a result of the biasing voltage across resistor R_2. In the active region of transistors T_1 and T_2, between points A and B, an increase in the current input leads to a reduced terminal voltage as a result of the shunt path they provide. This is the region used to provide an a.c. negative-impedance. The transistors continue to provide a negative slope until they saturate at point B, the slope, thereafter, having a positive value.

Appendix A gives a simple analysis of the n.i.b. circuit, less diodes, and shows that the overall impedance of the n.i.b. consists of a positive resistance, R_p, in series with a negative-impedance $-KZ_3$. The design value of K is obtained by selection of suitable values for resistors $R1$ and $R2$.

The application of the stability criteria in equation 11 to the n.i.b. transmission-line problem, results in the n.i.b. impedance having to be complex, rather than purely resistive. In order to minimize the transmission loss in the audio band, while maintaining circuit stability, the n.i.b. impedance must reduce with increasing frequency. This is because the mutual capacitance of the line reduces the resistive component of the line, as seen by the n.i.b. The rate at which this resistive component is reduced, for increasing frequency, must be matched by a reduction in the negative resistance presented by the n.i.b. The simplest circuit to achieve such a condition is an impedance $Z3$, comprised of a capacitor and resistor in parallel, i.e. capacitor $C3$ and resistor $R3$ in Fig. 6. The impedance plot for such a circuit is shown in Fig. 8, the

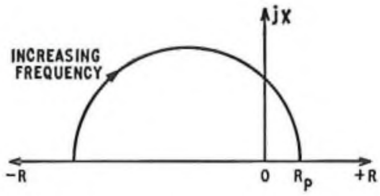

FIG. 8—Impedance plot for the negative-impedance booster

reactive component being in the +j sense. Thus, in designing the n.i.b., resistor $R3$ must be large enough to introduce sufficient negative resistance for a low-loss circuit, and capacitor $C3$ must allow for the bandwidth required, while providing ample stability.

POWER FEEDING

The n.i.b. elements, being active devices, require a d.c. power supply. Owing to the fixed spacing requirement of such circuits, and the inaccessibility of the points at which they are located, it is necessary to power feed the n.i.b.s, in series, along the cable pairs. Open-circuit stable n.i.b. devices, having the d.c. characteristic shown in Fig. 5, are current controlled and, hence, are fed from constant-current sources.

Field Trials

During field trials, power was fed to line using an earth-return system. Equal valued, but opposite in direction, currents were fed over the A and B wires, as shown in Fig. 9.

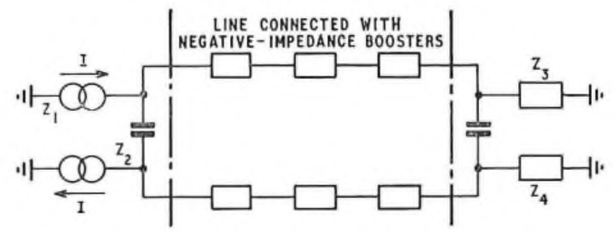

FIG. 9—Power-feed arrangement for the negative-impedance booster line

This arrangement gives a zero standing current overall, between the power-feed units at either end of the system.

The dynamic range of the n.i.b.s lies between 10 and 30 mA. During call conditions, they are biased to 20 mA, to optimize use of this range for speech signals. When the circuits are in the idle state, a lower valued current of 10 mA is sent on each wire. The line-feed voltage required for such an arrangement is in the order 100 to 150 volts. To achieve the power-feed configuration, and to obtain isolation between terminal and line equipment, transformers are incorporated at each end of the line. The use of n.i.b.s modifies the image impedance of the line, and, therefore, use is made of these transformers for impedance matching purposes. The centre-tap capacitor associated with the power-feed equipment, provides d.c. isolation between the A and B wires, and a low impedance path for speech signals.

SIGNALLING

Both a.c. and d.c. signalling arrangements are possible over n.i.b. lines. The relative cost of such systems, however, usually favours a d.c. arrangement for short length circuits. D.C. signalling over n.i.b. lines, has been achieved by conversion of the usual loop-disconnect pulses to loop-high-resistance pulses. The latter pulses are used to produce current changes on the line, in sympathy with the signalling information. The provision of such a system requires the interconnexion of power feed and signalling circuitry, and certain overall system requirements must be satisfied. In particular the terminations, at both ends of such circuits, must be well balanced, in order to ensure good crosstalk figures for speech signals.

The basic signalling system is shown, in simplified form in Figs. 9 and 10. Impedances $Z1$ and $Z2$ are, in practice, constant-current generators, and are designed to alternate the supply current to line, in sympathy with the incoming loop-disconnect pulses. Incoming pulses are detected on the primary side of the outgoing-end transformer, and interfacing equipment used to pass loop-high-resistance conditions to the constant-current sources. The current changes result in voltage changes across the passive terminations, $Z3$ and $Z4$, at the incoming end. High-impedance detector circuits may be used to detect these pulses with minimal effect on circuit conditions. At the incoming end, received pulses are sent out on the exchange side of the transformer, via interface equipment, as restored loop-disconnect pulses.

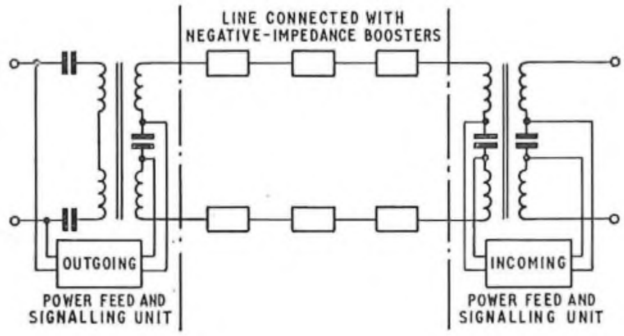

FIG. 10—Signalling arrangement for the negative-impedance booster line

The signalling system developed for initial field-trial work provides balanced signalling arrangements. Changes of current in each wire are arranged to be equal valued, but opposite in sense, i.e. $-dI_1 = dI_2$. The system also utilizes an important feature of lines connected with n.i.b.s, namely the amplification of signals down to extremely low frequencies. This means that gain is provided at signalling frequencies. At these frequencies the n.i.b. elements contribute mainly negative resistance, reducing the overall line resistance to a few ohms. Some further work would be required before a fully engineered system could be produced.

APPLICATION OF N.I.B.s TO SMALL-GAUGE CABLE

Economic advantages can be obtained by the use of n.i.b.s in conjunction with small-gauge cable. The 0·4 mm cable (4 lb/mile), was selected on the basis that the greatest probability of economic success, lay in producing junction circuits of up to 10 miles in length, with acceptable transmission properties. Use was made of a computer to investigate the feasibility of using such a cable, predictions of transmission loss and group-delay, being obtained at an early stage in the development. These early results indicated that adequate circuit properties could be achieved, and led to a small-scale field-trial being undertaken.

Since 0·4 mm cable is not available in the telephone network in suitable lengths to provide 10 mile circuits, circuits of this length were formed by looping pairs in a specially laid length. A 1,000 yd length of 100 pair 0·4 mm cable, was laid in circular fashion. Thus, both ends of the cable were available at a single terminating point, pairs being looped or n.i.b.s inserted at this location as required. Four circuits were provided, of 10 miles length, with n.i.b.s inserted at 2,000 yd intervals. The n.i.b. elements had temperature compensating resistors incorporated in the design, to take account of seasonal temperature variations of the cable. These elements were housed in a temperature-controlled environment, in order that temperature effects could be evaluated. In a working system, temperature control would have to be provided by some other means.

As described earlier, the use of n.i.b.s in conjunction with a transmission line, leads to modifications of the secondary coefficients of that line. In the case of 0·4 mm cable, the use of n.i.b.s at 2,000 yd intervals modifies the attenuation, phase and impedance characteristics as shown in Figs. 11 and 12. It is seen that, not only is the attenuation reduced and the phase characteristic linear, but that the line image-impedance is reduced and near constant over the usable frequency-range.

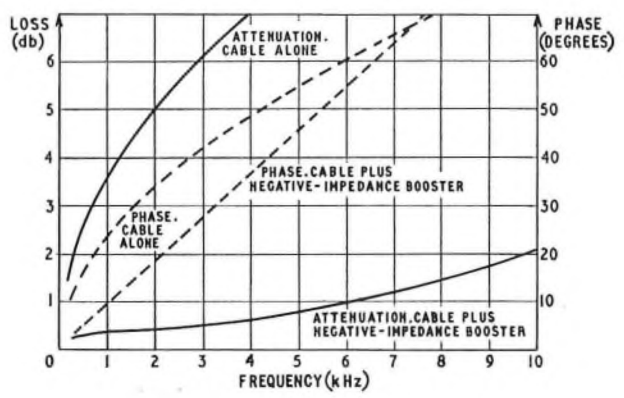

FIG. 11—Attenuation and phase coefficients for a 2,000 yd section of 0·4 mm cable

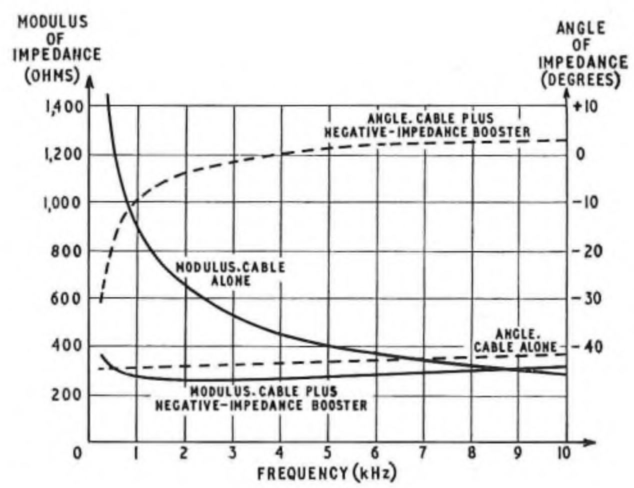

FIG. 12—Line image impedances for a 0·4 mm cable with negative-impedance boosters spaced at 2,000 yd intervals

These modified characteristics enable circuits to be produced, having both low loss and near-constant group-delay. The four experimental circuits demonstrated these properties. Overall loss for these circuits was 3 dB throughout the year, each having a 4 kHz bandwidth. Insertion-loss/frequency and group-delay/frequency characteristics are shown in Fig. 13.

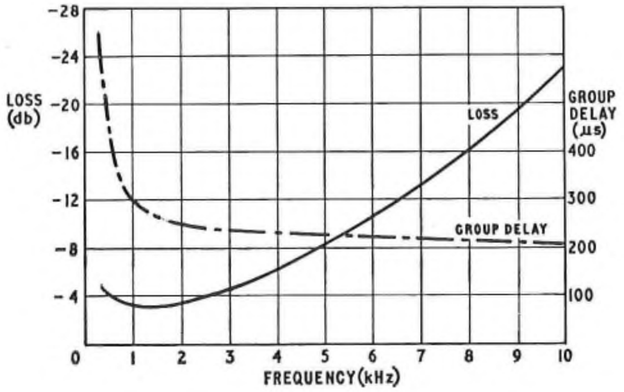

FIG. 13—Group-delay and loss characteristics for a 0·4 mm cable with negative-impedance boosters spaced at 2,000 yd intervals

The near-constant group-delay characteristic is maintained up to 13 kHz.

PROVISION OF N.I.B.s

To provide amplified circuit by means of n.i.b.s involves changes in provisioning methods, as applied at the present time. It is envisaged that such circuits would utilize n.i.b.s at 2,000 yd spacing, and that these would be housed in underground repeater cases. Space savings may be expected with an integrated circuit form of construction, and possibly the n.i.b.s may be jointed directly into the cable. The limiting factor in housing such devices, however, may be that of heat dissipation for several hundred n.i.b.s at a single amplifying point. Such circuits would require terminal signalling and power-feed units, and, for small-gauge cable, additional temperature-compensation circuitry. Inherent limitations on distance exist for n.i.b. lines, owing to power-feeding and overall transmission-loss criteria. The major effort in developing n.i.b.s has, thus, been applied to investigating their use on junction routes. Since the average length of junction circuits is approximately seven miles, the majority of such circuits lie within the range of n.i.b. plant, using small-gauge cable. A preliminary economic comparison of lines connected with n.i.b.s with current audio and pulse-code-modulation methods of circuit provision, indicate that significant savings are possible by use of 0·4 mm and 0·5 mm cable, on low growth-rate routes.

CONCLUSIONS

Field trials of circuits connected with n.i.b.s have demonstrated the feasibility of using n.i.b. elements to provide two-wire amplified circuits. The circuits provided gave the required 3 dB loss and also had an improved bandwidth in comparison with the amplified circuits available on comparable plant. An important feature of these circuits is the excellent group-delay characteristic. This parameter is of particular importance in the transmission of data, and this is a possible area of application. Thus, so far, lines connected with the n.i.b.s developed show an improved transmission performance over present plant, while being provided on smaller gauge cable.

In addition to the improved transmission properties, d.c. signalling has been achieved on these lines. The interlinking of power feeding and signalling equipment provides a solution to this problem, as an alternative to the use of an a.c. signalling system. The major problem outstanding, is that of establishing a suitable method of temperature compensation. Possible methods are local compensation at amplifier points and the use of a dedicated monitoring pair within the same cable.

Amplification of cable pairs by means of n.i.b.s, leads to an improvement in crosstalk in comparison with conventional amplified two-wire circuit arrangements. The advantage stems from the amplification being introduced on a distributed basis, rather than at a single point. In practice the more constant signal levels, to be found on such lines, results in an improvement in crosstalk, or alternatively offers the possibility of using an inferior type of cable.

At present, lines connected with n.i.b.s have been developed which are unconditionally stable and have amplifier points at 2,000 yd intervals. These features, together with the technical and economic results quoted earlier, indicate that n.i.b.s may eventually be suitable for use in the junction network. Additional development may lead to the achievement of wider bandwidth circuits and extended range of possible use.

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APPENDIX

NIB Circuit Analysis

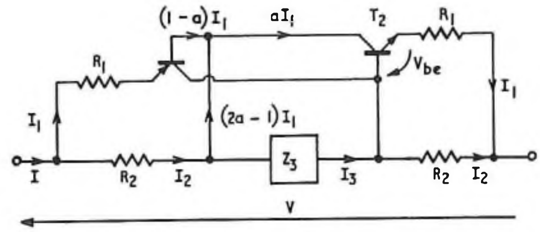

FIG. 14—Symmetrical negative-impedance booster circuit

Consider the n.i.b. circuit to have complete symmetry as shown in Fig. 14, the transistors having a current gain of a. Then:

$$I = I_1 + I_2. \quad \ldots\ldots (1)$$

$$I_3 = I_2 - (2a - 1)I_1. \quad \ldots\ldots (2)$$

$$V = 2I_2R_2 + Z_3I_3. \quad \ldots\ldots (3)$$

$$I_2R_2 = I_1R_1 + V_{be}. \quad \ldots\ldots (4)$$

In an a.c. analysis, equation 4 becomes,

$$\mathrm{d}I_2R_2 = \mathrm{d}I_1R_1.$$

Hence, $\mathrm{d}I_1 = \frac{R_2}{R_1}\mathrm{d}I_2. \quad \ldots\ldots (5)$

From equations 3 and 4,

$$\mathrm{d}V = 2R_2\mathrm{d}I_2 + Z_3[\mathrm{d}I_2 - (2a-1)\mathrm{d}I_1]. \quad \ldots\ldots (6)$$

$$\mathrm{d}V = 2R_2\mathrm{d}I_2 + Z_3\left[1 - (2a-1)\frac{R_2}{R_1}\right]\mathrm{d}I_2. \quad \ldots\ldots (7)$$

From equation 1,

$$\mathrm{d}I = \mathrm{d}I_1 + \mathrm{d}I_2 = \left(1 + \frac{R_2}{R_1}\right)\mathrm{d}I_2. \quad \ldots\ldots (8)$$

Substituting equation 8 in equation 7 gives,

$$\frac{\mathrm{d}V}{\mathrm{d}I} = 2 \times \frac{R_1 \times R_2}{R_1 + R_2} - Z_3\left[\frac{(2a-1)R_2 - R_1}{R_1 + R_2}\right] = Z_N. \quad \ldots\ldots (9)$$

Let $\frac{2R_1 \times R_2}{(R_1 + R_2)} = R_p.$

and, $\left[\frac{(2a-1)R_2 - R_1}{R_1 + R_2}\right] = K.$

Thus, the impedance of the negative-impedance booster is given by,

$$Z_N = R_p - KZ_3. \quad \ldots\ldots (10)$$

Visual Display Terminals for Computer-Controlled Systems

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U.D.C. 681.327.12

The visual display terminal is making an important contribution to the success of on-line computer systems. This type of terminal is being used by the British Post Office (B.P.O.) in its London Airport Cargo Electronic Data Processing Scheme (L.A.C.E.S) installation and it could find increased use in future B.P.O. systems. This article, mainly concerned with the alpha-numeric visual display terminal, explains its utility as an on-line terminal and describes, in broad outline, its technical make-up.

INTRODUCTION

During the past four years, there has been intensive development of the visual display terminal (v.d.t.) and its application as an input-output device for on-line computer systems. The computer in an on-line system allows data to be input directly for immediate processing or for enabling file enquiries to be made. It then transmits the data resulting from processing or enquiry to the required destination and has a sufficiently fast response to control a complex system.

For input and display of data communicated between the computer and the on-line system user, v.d.t.s have proved to be effective in a number of fields of application including commerce, the B.P.O., air-traffic control, power-station and electricity-grid distribution control, and computer-aided design.

In the U.K. commercial field, airline seat reservation is the largest application, more than 700 v.d.t.s, distributed throughout the world, being used on B.O.A.C.'s *Boadicea* system at Heathrow Airport. A London stockbroker firm's share price enquiry, West Midlands' Gas Board account enquiry and a mail-order firm's input processing are some of the smaller scale examples of commercial applications of up to 100 v.d.t.s.[1] The B.P.O. has provided more than 200 v.d.t.s. for its L.A.C.E.S. system at Heathrow Airport (see Figs. 1 and 2). L.A.C.E.S. enables airlines, importers' agents and H.M. Customs to have an automated system for inventory control of air-cargo imports which makes possible fast clearance of import procedures and goods on arrival. These examples illustrate present application of the v.d.t. in relatively large numbers. There are numerous cases, however, of the use of the v.d.t. in small numbers in commerce and the B.P.O., and in engineering applications of computer-aided design.

Requirements of system users have led to the development of two classes of v.d.t.—alpha-numeric and graphics. The graphics v.d.t. is used mainly for computer-aided design. By means of programs held in the store of a dedicated on-line computer, the graphics v.d.t. enables designers to develop visual representations of their designs rapidly and to modify them readily to meet criteria which they have specified by program. The computer can carry out complex calculations on the proposed design at high speed, checking its performance whilst the designer is developing his ideas. The graphics v.d.t. is more complex and costly in hardware than the alpha-numeric v.d.t., and, if standard program packages (software) are not available or applicable, program development costs can be high.

FIG. 1—A L.A.C.E.S. v.d.t.

The alpha-numeric v.d.t. is designed to input and display messages composed of alphabetic characters and numerals and it can contribute to efficient communication of messages between users and the computer of an on-line system. There could, therefore, be considerably increased use of this type of v.d.t. in future B.P.O. computer-based systems especially as its cost is falling with advances in technology.

CONTRIBUTION OF THE ALPHA-NUMERIC V.D.T. TO SYSTEM EFFICIENCY

The v.d.t. appears physically as an alpha-numeric keyboard and a display screen which is, generally, a cathode-ray tube. To present a steady visual image, almost all v.d.t.s are provided with a digital store to enable the displayed characters to be regularly rewritten (refreshed) and this can also be used

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FIG. 2—A L.A.C.E.S. v.d.t. being operated in an air line office

for message assembly. The v.d.t. enables message handling between an on-line user and a computer to be achieved with rapid display, flexibility, reliability and quiet terminal operation which could all be important system requirements.

The v.d.t. does not provide local permanently-printed copy (hard copy) of displayed messages. However, message printing can normally be achieved elsewhere, such as, at the computer site, thus avoiding a lot of paper which could be troublesome for, say, a clerk in an airline seat-reservation system who deals directly with customers. However, where occasional local hard copy is required, additional hardware in the v.d.t. provides the data at a rate suitable for a message printer.

The v.d.t. uses electronic techniques for message display and encoding of characters input from the keyboard and, therefore, has more reliable and more easily maintained hardware than an electro-mechanical terminal.

COMPARISON BETWEEN V.D.T. AND TELETYPEWRITER

The utility of the v.d.t. is illustrated by comparing its operation as an on-line terminal with that of the electro-mechanical 8-unit code (7-bit character plus parity bit) teleprinter, the teletypewriter, which is commonly used as an input-output device for computer time-sharing bureaux.

Speed of Display

Because of its electro-mechanical limitations, the teletypewriter prints messages at about 10 characters/second. The v.d.t., however, generates and displays characters in the order of 5,000–10,000 times faster. This permits the line speed of data transmission to the v.d.t. to be chosen so that the rate of message display more closely matches the requirements of users of an on-line system. Considering a line speed of 2,400 bit/s and 8-bit character serial transmission, a message of 1,000 characters can be displayed in just over 3 seconds on a v.d.t. Printing of the same text would require about $1\frac{1}{2}$ minutes on the teletypewriter. Where demands from users for information held on the computer files are frequent and rapid presentation of long lists is needed, the teletypewriter is unable to satisfy speed requirements. The v.d.t. provides the necessary fast response enabling the user to make his selection and transmit the details to the computer for immediate updating of the records.

Flexibility

The teletypewriter normally transmits single characters of a message to the computer as they are keyed in. If the message needs editing, it is normally performed by the computer's software in response to user commands. A detailed command language must be used where it is necessary to make more than simple insertions or deletions of a character or line. The computer must transmit the message to the teletypewriter if it is necessary for the user to check the edited message. Editing on the teletypewriter, therefore, increases the computer workload and is time consuming for the computer and the on-line users.

To compose a message on the v.d.t., the user keys in characters which are stored and not transmitted to the system computer until the message is complete. Each character keyed

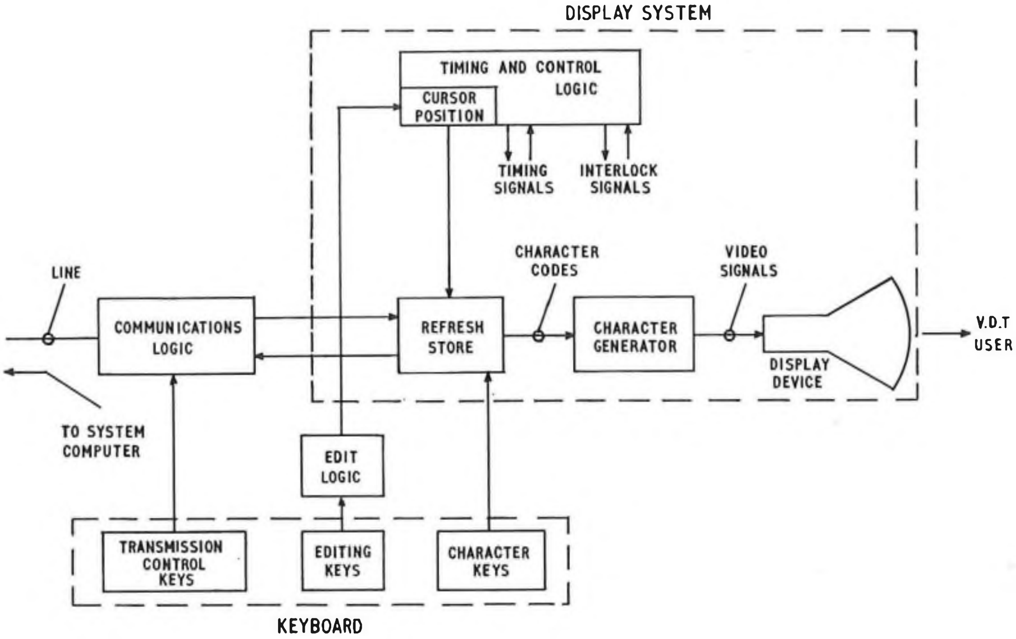


FIG. 3—Block diagram of the alpha-numeric v.d.t.

in is displayed to the user on the v.d.t. viewing screen and an illuminated marker (cursor) indicates the position to be occupied by the character. After keying of each character, the cursor steps automatically to the next available character position. Control keys are provided to shift the cursor to any character position on the screen except those protected to prevent the v.d.t. user over-writing characters input from the computer, such as, fixed headings for lists of items. Cursor control keys and editing keys enable format and message changes to be carried out quickly and effectively without using the system computer. The user sees immediately the effect of his editing and, therefore, wastes less computer time due to erroneous messages transmitted. The user signals that the message is available and this is transmitted when the computer is able to accept it. The computer checks the message for certain types of error (e.g. format, validity of information). If none is found, the v.d.t. user can proceed to the next transaction. If, however, the message is found to contain errors, the computer transmits to the v.d.t. an indication of the errors together with the original message for correction. The computer can also transmit cursor-control codes which protect those character positions on the v.d.t. screen occupied by error-free fields of the message and direct the user to the fields containing the errors thus facilitating speedy correction of the message.

Therefore, compared with the teletypewriter, the v.d.t. enables the user to compile and edit long messages more quickly and accurately without loading the system computer. Furthermore, there is a significant saving in computer time as the message is transmitted in a block instead of in single characters.

Quiet Operation

An on-line system having several terminals sited in one office will be more efficient if the terminals operate quietly, particularly if other system tasks have to be performed in the same office. The printing mechanism of the teletypewriter generates a level of impulsive-type audible noise sufficiently high to render its use undesirable in this situation. The noise can be reduced by acoustic shielding of the teletypewriter cover but the reduction is limited by the introduction of overheating problems. The v.d.t. is almost silent in operation.

FUNCTIONAL ELEMENTS OF THE ALPHA-NUMERIC V.D.T.

Referring to the block diagram of the v.d.t. shown in Fig. 3. the keyboard, the refresh store, and the display device are items of hardware. The control logic, the edit and communications logic, and the character generation can be based on hardware control, on software (i.e. program) control, or on combinations of these.

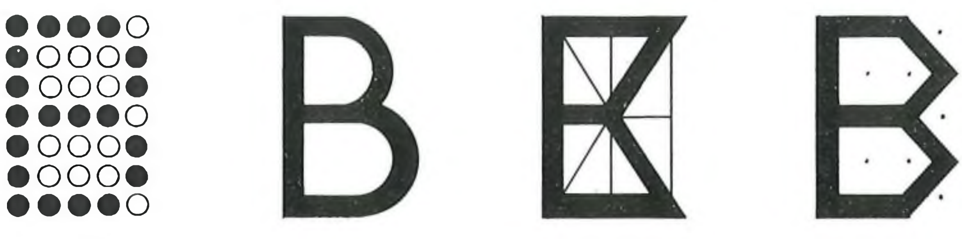
The v.d.t. can be used in single units (stand-alone-type) or in groups (cluster-type) usually served by a single communication link with the system computer and geographically concentrated. Of 29 models now current in the U.K., 21 are hardware-controlled comprising cluster- and stand-alone types. The remaining eight models are programable and are offered with a specified control computer.

Hardware-based V.D.T.

In the hardware-based v.d.t., all the functional elements are controlled and provided by items of hardware, such as, electronic gates, registers and counters, which, in the case of the stand-alone-type v.d.t., are generally contained within the terminal. For the cluster-type v.d.t.s, a separate dedicated hardware controller normally provides communication with the system computer. The cluster-type v.d.t. contains less hardware and is cheaper than the stand-alone-type since timing, logic, storage, and character generator are generally concentrated in the controller for use by all the v.d.t.s in the group. Changes of the functional elements of the hardware-based v.d.t. cannot be made without modifying the hardware which must be allowed for in the design of the v.d.t.

Software-based V.D.T.

In the software-based v.d.t., a dedicated computer responds to v.d.t. user commands and controls the hardware in the v.d.t. The control computer enables changes in v.d.t. edit and communications logic to be made readily by changes in its programs. Changes in the v.d.t. character set can also be made easily if characters are generated by program. The computer can control a group of v.d.t.s, carry out validation checks on v.d.t. messages and thereby reduce the loading on the system computer to which it transmits the messages. Some early



(*a*) Dot matrix | (*b*) Monoscope | (*c*) Stroke (starburst) | (*d*) Stroke (dot-matrix based)

Note: These characters are shown five times displayed size.

FIG. 4—Form of displayed character

examples of the software-based v.d.t. used a controlling computer which provided character generation by program and character refresh for a group of v.d.t.s in addition to edit and communication control. This additional loading on the control computer limits the maximum displayable message length and number of v.d.t.s in the group. It also limits the rate of character refresh, and the choice of available display devices.

Combined Software/Hardware-based V.D.T.

Recently, the programable terminal has been designed to meet requirements for a small group of v.d.t.s. (typically up to eight). The terminal uses a small computer which may be contained in one v.d.t. and provides extensive facilities, including, control of edit and communication procedures by program. The computer may control character refresh for each v.d.t. but hardware control is used for character generation resulting in reduced loading on the computer. In one commercial version of the terminal, character refresh is also controlled by hardware in each v.d.t., thus, reducing computer loading even more. Use of combined hardware and software control contributes to overcoming the above mentioned restrictions on displayable message length and problems posed by the display devices in addition to providing the user with programable facilities.

TECHNICAL DESCRIPTION

The techniques used to provide functional elements of display systems currently available in U.K. using hardware for character generation are described below in general terms.

Character Generator

The character generator is a read-only store for the data required to display any of the v.d.t. characters. At present, the dot matrix, monoscope, and stroke character generators are in use and Fig. 4 shows the displayed form of letter B which is representative of these generators.

Dot Matrix

Dot matrix is used in most v.d.t.s employing hardware-controlled character generators. Each displayed character is an assembly of illuminated dots based on a rectangular matrix of horizontal rows and vertical columns (Fig. 4*a*). For each character in the v.d.t. character set, an array of storage elements holds data composed of binary 1's and 0's forming the character-defining pattern. The storage elements are scanned to produce timed digital signals for controlling visual output of the display device. A basic 5×7 array is normally used providing a maximum of 35 dots per character which generates an alpha-numeric character set generally restricted to upper-case alphabet. In some v.d.t.s, however, basic arrays of 7×9 and 7×10 are used to permit the display of upper- and lower-case alphabet. Medium-scale-integrated MOS circuits[2] are now used for the character-set arrays, array-addressing logic and data-output register. For example, a single encapsulated silicon chip can be utilized for the (5×7) dot matrix character generator and can have a very high reliability.

Dot matrix, using MOS integrated circuits, is suitable for v.d.t.s employing television-type raster scanning for the display device in which digital signals from the arrays generate illuminated dots on the horizontal scans of the raster. Therefore, several horizontal scans are required to display each line of characters. Television-type raster scanning allows cathode-ray tube (c.r.t.) monitors to be used. These are extensively used for closed-circuit television reception and are readily available and cheap. The combination of the two techniques, therefore, results in a relatively low cost v.d.t.

In general, a v.d.t. using dot matrix character generation is capable of displaying characters that are recognizable and unambiguous despite font restrictions imposed by the number of dots in the matrix. These restrictions demand careful choice of display device design parameters, such as, permitted spacings between individual dots of a character, adjacent characters, and adjacent lines of characters to ensure ease of character legibility and viewing comfort.

Monoscope

The monoscope technique is utilized in only two types of available v.d.t.s. However, it is used in a large number of v.d.t.s supplied by one manufacturer which have been operational for at least 18 months. The technique allows flexibility in the choice of character font and the character set can contain up to 96 characters permitting upper- and lower-case alphabet, numerical and other symbols to be displayed (Fig. 4*b*).

The technique is based upon image scanning and requires a special purpose, electrostatic-deflexion c.r.t. (the monoscope) which is auxiliary to the main c.r.t. used as the display device. The monoscope has no phosphor-coated screen but has a polished aluminium target electrode on which the v.d.t. character set is printed in a carbon-based ink. Character images are located in rows and columns in order to facilitate addressing. Carbon has a higher ionization potential than aluminium and so bombardment of the target surface by the monoscope electron beam causes a carbon character image to emit secondary electrons less easily than its aluminium surround. This provides the physical basis for generation of character forming signals.

In order to display a character, the position of its image on the target is selected by means of address logic and is scanned by the monoscope electron beam. Scanning is performed by applying a sinusoidal voltage having a frequency of about 1 MHz to the vertical deflexion plates of the monoscope simultaneously with a ramp voltage waveform to its horizontal deflexion plates. The target current varies with the shape of character image and this results in timed signals which control the visual output of the main c.r.t. The electron beams of the main c.r.t. and monoscope are synchronized, and so the character image is reproduced on the v.d.t. viewing screen.

The monoscope technique can produce characters equivalent to good quality print, but the display device is relatively costly because a television-type c.r.t. monitor cannot be used. The main c.r.t. is scanned by a coarse raster dependent upon the number of lines of displayed characters with the 1 MHz sub-raster superimposed for synchronization with the monoscope.

The monoscope is not a long life device since its performance can deteriorate quite rapidly if there is an excessive display of any particular character. A much longer life, however, can be expected from the printicon, a variation of the monoscope utilizing similar scanning technique in which character images are formed by etching shaped holes in a copper target electrode thus avoiding the problem of character wear.

Stroke

The stroke technique is utilized in six available v.d.t.s in which each character is displayed as an assembly of directional straight lines (strokes) which are connected to form the shape of the character. There are two main types of stroke character generator.

(*a*) The generator permits display of a basic pattern of strokes which serves as the framework for the whole character set and only those strokes of the pattern which are relevant to the character being displayed are illuminated (Fig. 4(*c*)).

(*b*) The generator produces a unique pattern of strokes for each character. Fig. 4(*d*) shows such a pattern and indicates the closer approximation to curves that can be achieved. This generator permits a larger character set and more flexibility in character font but requires additional hardware.

The generator in (*b*) above is based on the use of an X, Y coordinate matrix to position the strokes and a maximum of 24 strokes is available for drawing a character. An array of storage elements holds the fixed data required for producing each stroke of each character. The data is held in digital form, each stroke being represented by a code of binary 1's and 0's which defines the X, Y coordinates of the next position to be occupied in the matrix relative to a reference position, and whether or not the stroke is to be illuminated. On timed read-out from the array, binary 1's are translated into voltages by digital-to-analogue converters. Two of these voltages produce ramp waveforms which control minor X and Y deflexions of the electron beam of the c.r.t. display device. A third voltage controls the visual output of the display. In this way, one stroke of the character is drawn. Successive read-out of the codes held in the array results in display of the character.

To display a line of characters and the required number of lines, the electron beam of the c.r.t. display device is subjected to main X and Y deflexions on which are superimposed the minor X and Y deflexions for forming the strokes of individual characters. The technique, therefore, precludes the use of a television-type c.r.t. monitor as the v.d.t. display device.

Display Device

Currently available alpha-numeric v.d.t.s utilize electromagnetic deflexion types of c.r.t. as the display device and have display capacities in the range 200–2,000 characters. For this range, the c.r.t. is the only electronic display device at present which satisfies the display-format and known human-factor requirements at a low cost per displayed character. The human-factor requirements define the needs of the v.d.t. operator for ease of character legibility and viewing comfort in a working environment. The display format, that is, number of displayable lines of characters and characters per line, is modifiable to enable the v.d.t. manufacturer to meet market demand. The c.r.t. satisfies these requirements because it can display character detail as fine as the eye can resolve and provide the necessary contrast between characters and the background. It has the necessary flexibility to permit easy alteration of character dimensions, spacings between characters and between lines of characters. Of particular importance are the relative cheapness and proven reliability of the c.r.t. which derive from a highly-developed technology.

Some v.d.t.s use a specially-developed c.r.t. Many of the v.d.t.s, however, use c.r.t.s which are identical in design and construction with those employed in monochrome television monitors enabling v.d.t. manufacturers to save on development costs. About half of these v.d.t.s display green instead of white characters because the c.r.t. viewing screen is coated with aluminized P31 phosphor (green-light emission) in place of the normal aluminized P4 phosphor (white-light emission). P31 and P4 phosphors have the following properties which account for their common, but not exclusive, usage in v.d.t. c.r.t.s:

(*a*) The spectrum of the emitted light matches the generally-accepted colour-sensitivity characteristic of the average human eye.

(*b*) They have a high brightness capability such that the v.d.t. operator can readily resolve details of characters having a brightness comparable with that of the working environment which may be high (40 foot lamberts or more). Contrast is a function of character brightness and influences the permissible minimum character dimensions.

(*c*) They have a high efficiency in converting electron-beam energy into light energy. This enables a low electron beam current to be used for a given brightness of displayed characters.

(*d*) Operation at low beam current produces a high resistance to phosphor burns which permits display of a fixed message format for long periods.

Of the two phosphors, P31 is superior in brightness capability and efficiency and its light output is at wavelengths at which the average human eye is most sensitive instead of in a wide spectrum as in the case of P4.

Most v.d.t.s use c.r.t.s which are not self storing. Phosphors used for the c.r.t.s have persistences* in the range tens of microseconds to a millisecond. For ease of character legibility and viewing comfort, each character must be regularly regenerated (refreshed) often enough to achieve the required average brightness and to prevent annoying flicker. The shorter the phosphor persistence, the higher must be its peak light output to provide the required average brightness. The high ratio of peak-to-average light output causes the sensation of flicker which is less noticeable as refresh rate is raised. The minimum refresh rate required for flicker to be just perceptible is known as the critical fusion frequency since a higher rate results in apparently continuous light output and is 40–50 Hz at 50 foot-lambert character brightness for short persistence phosphors P31 and P4.[3] Refresh rates of about 50 Hz are used and so flicker is usually negligible, in practice.

The normal viewing distance for v.d.t.s is 0·3–0·6 m and to suit this viewing distance, many v.d.t. manufacturers utilize a c.r.t., with a screen diagonal dimension of 300–310 mm. Almost all v.d.t.s using this c.r.t. screen size have a maximum available display capacity in the range 1,000–2,000 characters. Some v.d.ts, however, have a c.r.t. with a larger screen (380 mm diagonal) for the same range of maximum available display capacities and this provides more flexibility in the choice of character dimensions, spacings between characters and between lines of characters. To cater for differing system requirements, many v.d.t. manufacturers offer a series of v.d.t.s using the same basic design and c.r.t. as for maximum display capacity to provide v.d.t.s with capacities which are sub-multiples of this (e.g. 2,000, 1,000 and 500 characters) by proportionate reduction in the number of displayable lines of characters.

* Persistence—the time taken for the brightness to decay to 10 per cent of its initial value.

For v.d.t.s of a given display capacity, character dimensions, spacings between adjacent characters in a line and between lines of characters vary with v.d.t. manufacturer and may also vary for v.d.t.s in a series offered by a particular manufacturer. In choosing v.d.t design parameters, the manufacturer aims to provide ease of character legibility and viewing comfort for the v.d.t. operator to the extent which his marketing price for the v.d.t. will allow. Account must also be taken of the different visual tasks which the operator may be required to perform, such as message text scanning, word and individual character reading in the text. Choice of character generator can contribute significantly to the quality of displayed text but affects the cost of the v.d.t. Manufacturers of v.d.t.s are now tending to use the dot matrix type character generator in combination with a c.r.t. television monitor to produce a relatively low cost and reliable v.d.t. Restrictions imposed by this technique can, however, have adverse effects on character legibility and viewing comfort if insufficient attention is paid by the v.d.t. manufacturer in his design to the quality of displayed text. There is a pressing need for comprehensive and reliable human-factor information directly relevant to v.d.t.s which would enable v.d.t. customers to assess manufacturers' products more accurately and which could also be of value to v.d.t. manufacturers who are unable to bear the cost of the necessary research.

The v.d.t. c.r.t. provides information in different ways to assist the operator in carrying out his tasks. It is common practice, for example, for the v.d.t. cursor to flash at a low rate (2–3 Hz) to enable rapid identification of its position on the c.r.t. screen. A similar technique may be used to direct the operator's attention to message errors detected by the system computer. For form-filling applications of the v.d.t., messages are likely to be composed more quickly and to contain less errors if:

(*a*) the fields for holding keyed characters are clearly indicated to the operator, and

(*b*) the visual representation used for message headings (fixed fields) transmitted by the system computer to the v.d.t. is clearly distinguishable from that used for message text (variable fields).

The length of each variable field can be defined by codes also transmitted by the system computer which enable display of illuminated markers at each character position in the field. As characters are keyed by the operator, these markers are replaced by the characters.

Message headings and message text can be distinguished for example, by use of upper- and lower-case character fonts. This increases the cost of the v.d.t. because a more complex character generator is needed but may be required if the operator has a lot of text reading to do. Some v.d.t.s can display characters at two levels of brightness (dual-intensity electron-beam modulation) but do not appear to be generally satisfactory since the v.d.t.s may have to work in high ambient-lighting levels. A technique which appears suitable, economic and illustrates the flexibility of the c.r.t. is used in one available v.d.t. In this v.d.t., the television raster based c.r.t. displays either illuminated characters on dark background or dark characters on illuminated background. This technique enables clear indication of variable field lengths and distinctly different visual representations for message headings and message text at negligible additional cost.

Refresh Store

A v.d.t. which does not utilize a self-storing c.r.t., that is, a direct storage tube, must be provided with a store to enable regular refreshing of displayed characters. It is economic for this to be a digital read-write type store so that it can also be used to hold characters input to the v.d.t. from either the keyboard or the system computer. Although the store may enable message assembly in addition to display refresh, it is commonly known as the refresh store.

Each character input to the v.d.t. is in the form of a fixed-length binary code, sufficient bits being used to enable all the displayable characters in the v.d.t. character set to be defined and also the control function codes required for the v.d.t. and for communicating with the system computer. A 7-bit code permits a maximum of 2^7 (128) different characters. The code held in the refresh store for each displayable character is used as the address, required by the v.d.t. character generator (read-only type store), to select the fixed data for displaying the character corresponding to the code. Codes for characters displayed on the c.r.t. screen generally occupy consecutive locations in the refresh store. Hence, repetitive sequential read-out of these codes, synchronized with the c.r.t. electron-beam movement, results in refresh of the displayed characters. Synchronization is achieved by means of counters driven by timing pulses from the v.d.t. clock.

The refresh store capacity, that is, the number of storage elements provided is mainly influenced by the display capacity of the c.r.t. screen and the required length of the character code (commonly 7-bit). The store speed, that is, the rate at which stored character codes can be read, must meet the requirements of the c.r.t. refresh rate, the screen display capacity, and the method adopted for display, a higher store speed being required for a v.d.t. using a television raster than for one using a coarse raster owing to the increased number of store accesses necessary to generate the dot-matrix based characters. The following techniques are currently used for the refresh store:

(*a*) the delay-line store,
(*b*) the MOS integrated-circuit shift register,
(*c*) the ferrite-core random-access memory.

Delay-line and MOS shift-register stores are used in the majority of the v.d.t.s in about equal ratio. Only a few v.d.t.s use ferrite-core store which can have a higher speed, has the property of being non-volatile (that is, store contents are not lost if v.d.t. power supply fails), but is relatively expensive. Its use in v.d.t.s of recent origin, however, is likely to be influenced by other factors such as programability.

In the delay-line store, character codes are continuously circulated in series under the control of the v.d.t. clock. This type of store has been used almost exclusively for hardware-controlled v.d.t.s for a considerable time as its cost for a given capacity was much lower than any other suitable store. In terms of present cost for a given capacity, however, it is now surpassed by stores based on MOS integrated-circuit shift-registers which are readily available as standard items resulting from developments in MOS technology. Almost all v.d.t.s of recent origin use this type of store which has the additional advantages of much smaller bulk, much higher potential reliability and higher speed resulting from the paralleling of shift registers. With one exception, the stores of these v.d.t.s use dynamic-type MOS devices which enable a higher degree of circuit integration than static-type MOS devices. The advantages are lower cost for a given capacity and potentially higher reliability resulting from the reduction in the number of external connexions.

TELETYPEWRITER-COMPATIBLE V.D.T.S

Computer time-sharing bureau service in U.K. is commonly based on customer use of the ASR33 teletypewriter terminal for communicating on-line with the bureau computer which is used for development and execution of customer programs. The computer-system software (that is, supervisory programs for automatic control of job scheduling and control of input–output) and channel hardware, such as, multiplexers and customer buffer stores, are, therefore, designed for handling short messages (up to 80 characters or one line on the teletypewriter) at low speed to and from the terminals.

Development of the alpha-numeric v.d.t. has led to v.d.t.s being offered by manufacturers to meet bureau customer market demand for a quiet terminal which is more reliable and requires less regular maintenance than the ASR33 teletypewriter. There are 12 hardware-controlled stand-alone type v.d.t.s now available in the U.K. which are called teletypewriter-compatible v.d.t.s. The ASR33 teletypewriter transmits single American Standard Code for Information Interchange (A.S.C.I.I.) characters as they are keyed in and receives A.S.C.I.I. characters transmitted from the bureau computer at a rate of 110 bit/s. The v.d.t.s are capable of being operated in similar manner. In any particular computer system, when a teletypewriter is to be replaced by this type of v.d.t., all character codes used by the v.d.t. must be given the same meaning as those used by the teletypewriter.

Some of these v.d.t.s have been designed to meet general purpose v.d.t. market demand in addition to that of the bureau customer. For example, in addition to being capable of operating in teletypewriter-compatible mode, seven of the twelve v.d.t.s can also be operated in page mode (a page corresponds to the c.r.t. screen display capacity). In this mode, characters keyed in are held in the refresh store and displayed but are not transmitted to the computer until the message contained within the page is complete. Message editing can be performed using the v.d.t. cursor control keys. Provision of additional editing facilities (for example, insert/delete, character/line) is generally limited, however, presumably to enable the v.d.t.s to be marketed at a price more comparable with the ASR33 teletypewriter. With one exception, these v.d.t.s do not have the variable tabulate facility which can be very useful for form-filling applications. Each of the twelve v.d.t.s is capable of transmitting and receiving data for display at rates higher than 110 bit/s. The v.d.t.s which are capable of operating in page mode can, for example, transmit messages in block form to the computer at 600 bit/s or higher rate.

CONCLUSION

Within the past two years there has been a large increase in the number of alpha-numeric v.d.t. models available. Planners of computer-controlled systems are no longer faced with the limited choice that existed previously and intensive competition between v.d.t. manufacturers and the increasing application of medium- and large-scale integrated-circuit techniques are contributing to falling cost of the v.d.t. Whilst cost to the customer will always be influenced by the facilities and the number of v.d.t.s required for any particular system application, there is a reasonable probability that, with the passing of the present economic recession, market demand and continued development will result in significant reduction in the cost of general-purpose v.d.t.s. In aiming to meet this demand, the v.d.t. manufacturer must ensure that the necessary attention is paid to the human-factor requirements upon which successful system operation depends.

ACKNOWLEDGEMENTS

The author expresses his thanks to Messrs R. Bishop, J. Driscoll and other colleagues for their assistance in preparing this article, and to Mr. B. Copping for assistance on human-factor considerations of visual display terminals. The author also expresses his thanks to N.D.P.S. for permission to publish the photographs of the L.A.C.E.S. v.d.t.

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Book Review

"Electric Network Analysis." R. G. Meadows. The Athlone Press, 492 pp. 322 ill. £6.

The book is intended to be an introduction to electric network theory mainly for first-year students of degree and diploma courses. It is considered desirable that readers know the basic concepts of electricity and magnetism and have a knowledge of mathematics at intermediate standard.

With regards to the contents and presentation of the book, there are eight main sections, namely: Introduction to voltages, currents, and the lumped-circuit elements of resistance, capacitance and inductance; phasor and complex—notation methods of steady-state network analysis; transient analysis of networks by classical methods; resonance in electric networks; network topology and steady-state mesh and nodal methods of analysis; network theorems, equivalence and reduction; Inductive coupling and transformer networks; lumped circuit models for practical component and impedance measurements. In addition, there are two appendices dealing with determinants and matrix algebra.

There are numerous worked examples in the text, followed by several problems at the end of each chapter, the answers to which are supplied at the end of the book.

The number of aspects of network analysis covered is very large and, therefore, it is not possible to discuss all chapters in detail in a short review. Briefly, the early chapters deal with basic principles of Ohm's law, Kirchhoff's laws and a.c. theory, and then there is a gradual progression through various network theorems to more advanced work requiring the use of matrices.

Parts of the book will be of use to most students on electrical courses. For example, sections of the Telecommunication Principles syllabuses of Courses 49 and 300 of City and Guilds of London Institute are covered. This also applies to other lines of study of this standard. The complete range of subject matter, however, would only be required for more advanced courses.

With regards to the presentation, the only criticism of the book is that the various headings are not bold enough.

This is an excellent publication, but, owing to its comparatively high price and extensive coverage, the book can only be recommended as a purchase to students on degree and diploma courses. Other classes of students should obtain the book from a library and decide for themselves whether or not to buy.

J. F.

The Maintenance of Datel 600 Multipoint Networks

J. J. HART†

U.D.C. 621.394.4:681.31

Multipoint working, using a network configuration interconnecting a number of terminals, has a particular application in modern communications for data transfer and computer utilization. The use of multipoint working for data-communication networks to meet such needs, to reduce line costs and to satisfy a high serviceability requirement has led to the introduction of special arrangements to aid their maintenance. This article describes a typical multipoint system for data transmission purposes, and also the fault diagnostics and methods employed for maintaining the British Post Office plant used.

INTRODUCTION

For many data-communication systems, the call setting-up time, the speed limitations, the tariff structure and other characteristics of the public switched telephone network may be acceptable. However, if these features are incompatible with the overall plan, some form of closed (private) circuit network is usually necessary. One critical factor in determining the type of network required for a particular system is the cost of the interconnecting transmission media. Various techniques are available to minimize this cost, and one method successfully adopted in the United Kingdom is the use of multipoint data circuits, whereby a number of outstations are connected to one circuit serving a central point, generally a computer.[1] The computer and appropriate outstation equipment is provided and maintained by the user, whilst the transmission network is provided and maintained by the British Post Office (B.P.O.). In addition, the B.P.O. usually provides the requisite modems to permit data transmission over the present analogue transmission plant.

At present, about 8,000 Datel Modems No. 1 have been installed for the Datel 600 Service,[2] and 70 per cent are used for multipoint working. Large networks have been set up by the B.P.O. for banks, building societies and similar concerns which have a large number of branches distributed throughout the United Kingdom and, in some instances, overseas. The total dependence of the outstation on communication witn the central computer, often working in real time, for the normal day-to-day business operations also requires that the serviceability of the transmission system should be of a high order. Special facilities have been provided to help in the localizing of faults and to minimize out-of-service time caused by faults on the circuits and modems.

SYSTEM DESCRIPTION

A simple multipoint circuit is made up of a main section, usually long, and a number of spur sections of various lengths radiating from a branching point, as shown in Fig. 1. The circuits are 4-wire throughout and splitting and combining networks are fitted at the branching point. These allow signals from the computer centre to be transmitted to all the outstations and signals from any outstation to be transmitted to the centre, but there is no intercommunication between the outstations. More than one branching point may be needed, resulting in double or triple star configurations. However, the maximum number of spur sections is kept to 12 due

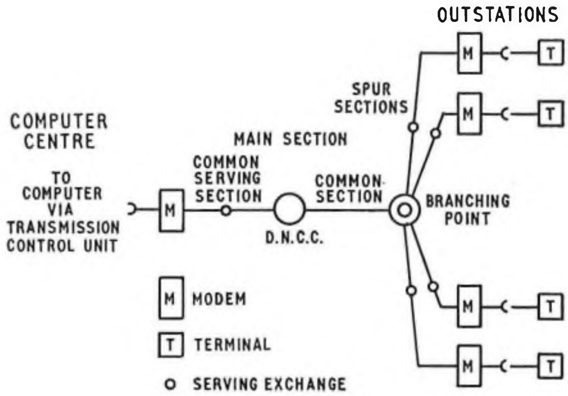

FIG. 1—Single star multipoint circuit

mainly to cumulative noise limitations. The type of circuit provided depends on the data-transmission speeds required and, for 600 or 1,200 bit/s transmission, the lines are to the private circuit S3 speech tariff standard, and a nominated reserve circuit is provided for the common section. To safeguard service, diversity routing is used between the serving exchange and the computer centre whenever possible, and all terminals are normally provided with a standby facility permitting use of the telephone switched network at an appropriate speed.

In order to aid the breakdown of barrier resistances in the unsoldered joints used in the local-cable network and to provide identifying potentials to cable maintenance personnel. d.c. wetting is supplied from the local cable terminating exchanges on a loop basis.

The Datel Modem No. 1 can be adjusted for different modes of operation by means of internal straps and, in this application, the modem is strapped for 4-wire full-duplex working. The alternative access over the public switched telephone network, provided for standby working in the event of the private circuit failing, is also utilized for testing purposes. Connexion of the modems to the customer's terminal equipment at outstations and to the computer, via its transmission control unit, is by the modern interface[3] plug and socket. The B.P.O. maintenance responsibility extends from modem interface to interface and the data performance is to the C.C.I.T.T.* recommendations.[4] Spare modems and line flexibility facilities are fitted at the computer centre

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

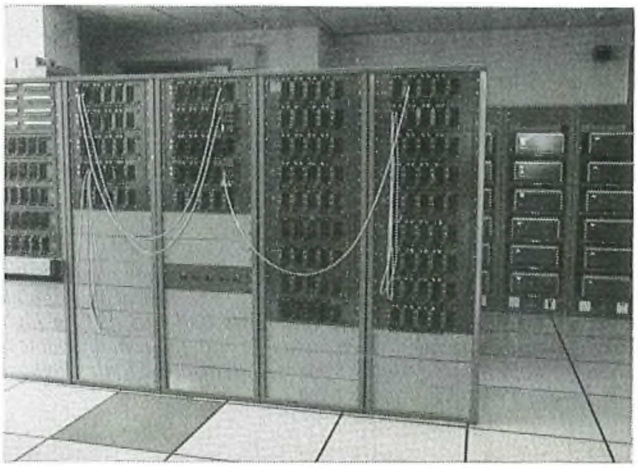

FIG. 2—Modems and line flexibility rack at the computer centre

(Fig. 2) for substitution purposes under circuit-failure conditions and the user has the necessary control facilities appropriate to his system.

SYSTEM OPERATION

Because of the shared common section, a line discipline is necessary and this is controlled by the computer. No terminal is permitted to transmit signals until requested to do so by the central computer. In a typical system, the modem at the centre is permanently on-line and a steady signal is present on all sections of the transmit pair. The carrier detector of each outstation modem is operated and a message sent from the computer is demodulated by all outstation modems and passed in d.c. binary form to each terminal. This message, termed the polling message, includes a unique address code that is recognized by one particular terminal, whereupon, the modem modulator is connected to line and the terminal acknowledgement is transmitted to the computer. Having established contact with the required terminal, data traffic can then be exchanged.

If the terminal addressed has no information ready for transfer, a data signal to this effect is returned in response to the polling message and the computer then broadcasts another polling message which will be recognized by the next terminal in the polling schedule. This procedure is repeated until all terminals on the multipoint line have been interrogated. Simultaneously, other transmission control units associated with the computer operate on other parts of the system and a complete network consisting of about 900 terminals can be polled in approximately 10 seconds. Asynchronous working at 1,200 bit/s, using the International Telegraph Alphabet No. 5,[5] is commonly used and, if errors occur in the messages, requests for re-transmissions are made by the computer. Polling messages and terminal responses are usually only a few characters in length, and, under quiescent idling conditions, the line signals appear as audio pulses with a characteristic rhythm.

FAULT DIAGNOSTICS

The nature of the system operation effectively provides network surveillance and any impairments are rapidly brought to the attention of the line controller at the computer centre. Faults can be broadly divided into catastrophic, such as failure to obtain a response to the polling message, or intermittent, when, for example, an abnormally high number of message re-transmissions is occurring. It is possible to set limits in the control program and, when they are exceeded, an alarm condition is printed out at the user's network-control console. From the print out, the line controller can monitor the overall efficiency of the network and can generally identify and locate failures within the system. This is an important and necessary step, as there is a division of maintenance responsibility with respect to the network, computer and associated hardware. Out-of-service time can be minimized and abortive visits by the various maintenance organizations avoided if a comprehensive diagnostic procedure can be evolved.

For example, failure of all terminals on a line to respond indicates a fault on the main-circuit section, the branching panel, the computer-centre modem or transmission control unit. If, after substitution by the line controller of another transmission control unit and modem, service is not restored, the fault is handed to the B.P.O. as a main-section fault. Similarly, failure of only one terminal to respond suggests a fault on the spur, an element of the branching panel, outstation modem, or the terminal equipment. Provided the terminal is proved to be fault free and the user can continue working by switching to the standby telephone line and establishing connexion direct to the computer centre over the public switched telephone network, the fault would be reported by the user as a spur fault. If, after proving the terminal to be fault-free, the standby facility proved ineffective and the terminal were completely isolated, the failure would be reported to the B.P.O. as a probable modem fault.

Most of the system control and fault diagnosis takes place at the user's computer centre and, for the effective control of maintenance, it is desirable for the line controller to liaise with one fault reception point within the B.P.O. maintenance organization. This point is the Trunk Maintenance Control Centre (T.M.C.C.) which is geographically adjacent to the computer centre. The main sections are routed through the T.M.C.C., which is invariably the circuit control for private circuits. This is termed the Data Network Control Centre (D.N.C.C.) for the network. The D.N.C.C. has the responsibility of progressing faults with the various sub-controls and of calling in the Datel Test Centre (D.T.C.) if necessary. Outline network diagrams are supplied to the D.N.C.C. and the line controller to facilitate diagnosis and fault reference.

B.P.O. circuit testing follows the well-established principles used for speech circuits, and the maintenance limits for attenuation/frequency response, crosstalk, and continuous and impulsive noise closely correspond to those used for commissioning the circuits for data purposes. For faults diagnosed to a spur, tests would be made from the branching point and test access is provided for this purpose. To ensure adequate testing co-operation, particularly during the normal working day, the branching points are selected to be at exchanges of group switching centre (g.s.c.) status whenever possible.

Because the line transformer of the modem is not designed to carry d.c., an additional transformer is required to enable loop d.c. wetting to be applied and test-access and a simple line-looping facility which can be operated by the customer is also provided. This equipment is mounted in a moulded plastic case and provides a standard line termination for the private circuit (Fig. 3). With customer co-operation, transmission testing is, therefore, possible from the branching point, without B.P.O. staff at the outstation. Theoretically, it is possible to test from the D.N.C.C., but, normally, this is inadmissible as the remainder of the multipoint network is in operational use.

Methods of Testing

For proving the modem, the standard remote test facility, built into all the present range of B.P.O. modems, is used. The test is performed by the nominated D.T.C. using the standby 2-wire telephone line access, bypassing the normal 4-wire

FIG. 3—Outstation showing Case No. 200, modem, standby telephone and the customer's terminal

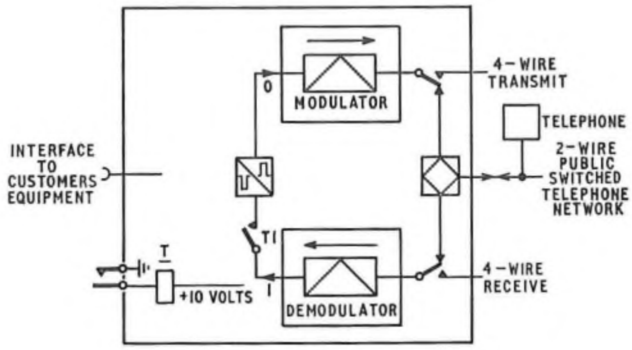

FIG. 4—Remote testing of the modem

private-circuit line. The D.T.C. contacts the outstation and the customer removes the interface plug, thus making the test independent of the terminal. When requested, the test button on the back of the modem is depressed to operate a test relay within the modem. The actual test performed depends on the particular usage of the modem under test, but, for 4-wire working, the demodulator and modulator are connected together via an inverter. When a steady tone representing a binary 1 is received, it is inverted and passed, back to the modulator as a binary 0. The hybrid completes the loop and a self oscillation of 160 bit/s is set up (Fig. 4). This characteristic oscillation can be detected by the D.T.C. using a Datel Tester No. 1[6] and gives an indication of the state of the modem, although the test is limited by the capabilities of the telephone network and the economics of providing additional circuitry in the modem solely for more sophisticated testing over the 2-wire circuit.

A better test of the modem can be performed if the user, on request, replaces the normal interface plug by a specially-strapped dummy plug that loops the demodulator to the modulator and conditions the modem for 1,200 bit/s working. When the test button is depressed, data signals, transmitted to the modem on the transmit pair of the private circuit, are returned on the receive pair and can be checked. For full exploitation of this facility, a modem and Datel Tester No. 1 would be needed at each branching point, but, at present, it is only economical to equip the D.N.C.C.s. However, a simple test of modem continuity can be made from the branching point using conventional transmission testing equipment by transmitting a tone of 1,300 Hz (binary 1) or 2,100 Hz (binary 0) and measuring the returned signal.

The customer is contractually obliged to prove that the terminal is fault-free before reporting that a failure is due to B.P.O. services. However, this often presents difficulties owing to the lack of technical user staff at the outstation, and the desire to keep terminal costs low. Thus, line controllers are sometimes willing to check that B.P.O. plant is fault-free, by conducting data loop round tests using the dummy plug even though the line has to be closed down temporarily to normal traffic. In some systems, the computer can be programmed to make the test, thus avoiding the need for a datel tester at the computer centre.

The most comprehensive test is made by end-to-end testing using a Datel Tester No. 1 connected to the modems at the centre and the outstation, in place of the customer's equipment. This is the method used for commissioning and it meets the C.C.I.T.T. recommendations for testing in a synchronous mode with 511-bit pseudo-random pattern. However, it does not simulate exactly the polling operation. In some user systems, incorrect functioning can be caused by adverse tolerances in the timing of the interface signals between the modem and the customer's equipment. Such difficulties might arise, however, with any design of modem and a timing tester suitable for checking this feature of B.P.O. modems is being developed. A high-speed multi-channel recorder technique is showing promise for use in detailed investigation of relationship between the various signals. For these types of test, when the interface signals have to be monitored, the test points provided on the modem modules allow convenient access whilst the customer's equipment remains connected by the interface socket and in an operational mode.

Intermittent faults are the most troublesome to the customer and the maintenance engineer. Line continuity can be checked by using standard in-service monitoring equipment in which a tone, outside the data frequency band, is injected into the circuit, and, at a distant point, it is filtered, detected and applied to a recording decibelmeter. Checks on the long-term reliability of data performance are also becoming necessary and a data logger, for associating with the Datel Tester No. 1, will soon be available. The majority of intermittent faults have been found to be in the local-line plant and the general approach, where these persist, is to conduct a detailed and exhaustive check and overhaul. Such work is time consuming and requires considerable perseverance on the part of the maintenance staffs concerned.

Restoring Service

For a complex fault, the administrative difficulties in controlling engineering effort simultaneously at a number of places and co-operating with the customer's engineers can be formidable. The reluctance of the customer to release parts of the networks, or the modems, for further testing when they are partly operational can lead to delays and often results in the maintenance work being postponed until after the normal working hours.

If a main section fails, service can be rapidly restored by changeover to the nominated reserve, and, to enable faulty branching panels to be changed quickly, the transmission levels are set to a common standard. Records of all B.P.O. modems fitted in the United Kingdom are held by the D.T.C.s, and the changing of faulty modems is under their control. Field staff are required to carry out further local diagnosis with D.T.C. co-operation, as necessary, and the modem is made good by replacing faulty modules from a locally-held stock of spares. Each Telephone Area holds an appropriate percentage of each type of module for this purpose. Faulty modules are returned to a central repair point and no module repairs are carried out in the customer's premises.

The D.T.C. organization serves a valuable function to the field staff at customer and system operational points by assisting them with the day-to-day problems that arise in maintaining a relatively new service. It also permits the performance of the modems and the growth of the service to be readily measured.

CONCLUSIONS

The use of multipoint working for data communications brings the serviceability of the plant, particularly the lines that were not designed primarily for the transmission of data, under continuous close scrutiny. Out-of-service time is critical to the customer and accurate fault diagnosis from the computer centre is necessary. This has been recognized by the B.P.O., special facilities having been provided for helping the customer to isolate faults and for facilitating prompt restoration of services. Experience has shown that present testing methods are not all-embracing and it is occasionally necessary to make special tests of the important characteristics involved when sending polling messages to the terminals.

The knowledge gained in maintaining Datel 600 multipoint networks will be valuable when considering the requirements necessary for the more sophisticated data-transmission systems now being planned.

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4 C.C.I.T.T., White Book, Vol. VIII. Recommendation V 53.

5 Chesterman, D. A. International Telegraph Alphabet No. 5. *P.O.E.E.J.*, Vol. 62, p. 89, July 1969.

6 Quinney, R. E. Recent Improvements in Datel Testers. *P.O.E.E.J.*, Vol. 64, p. 27, Apr. 1971.

Satellite Communications via Goonhilly Aerial No. 3

U.D.C. 621.396.946

The introduction of a third aerial system at Goonhilly will enable the United Kingdom's earth station to maintain its major role in the expanded network of global communications made possible by a new generation of communication satellite, INTELSAT IV.

When the third aerial system at Goonhilly earth station is brought into service, it will be possible to route intercontinental circuits to and from the United Kingdom via either of the two new INTELSAT IV satellites located over the Atlantic Ocean, to any country having an earth station in the Atlantic Ocean region. Initially, the No. 3 Aerial system will provide a total of 384 circuits to interconnect Goonhilly, via the satellite, with 17 other earth stations. As installed, the system is capable of expansion to 22 routes and the design caters for ultimate growth to 35 routes by the provision of additional equipment.

The £2M contract for provision of Goonhilly No. 3, let to Marconi Communications Systems Ltd in August 1970, was the first British Post Office contract requiring the design and construction of a complete earth station. Approximately 85 per cent of the equipment, including the aerial, is Marconi's proprietary design and is similar to that installed at several other earth stations overseas, but Aerial No. 3 has a significantly greater complement of telecommunications equipment to match the U.K.'s service commitments. The non-standard features are concerned mainly with improved standards of safety and additional facilities to reduce the out-of-service time at Goonhilly, now one of the largest earth stations in the world. All the equipment complies with the agreed INTELSAT standards of technical performance.

In the transmitting system, the normal outgoing telephony channels are concentrated at baseband frequencies into two groups, one of 252 channels, the other of 132 channels. An additional group of 132 channels can be activated when required for contingency services, e.g. to provide alternative circuits during a transatlantic cable failure. Each group of outgoing channels modulates an exclusive multi-destination carrier at the intermediate frequency of 70 MHz and, after appropriate pre-emphasis and bandwidth control, is converted in one stage to the final radiated frequency in the drive system. Each transmitting chain is duplicated to give the reliability required. Modulated carriers can be combined, as required, at the input of the final transmitting stages comprising four wide-band 8kW travelling-wave tubes. Two working transmitters and one stand-by normally serve for the telephony traffic. The fourth transmitter is normally used for television but also serves as an additional reserve for telephony during routine transmitter maintenance.

The common receiving equipment comprises duplicated cryogenically-cooled parametric amplifiers mounted in the high-level aerial cabin and connected, by means of a wideband waveguide and second-stage amplifiers, to a branching network in the central building. Here, the individual carriers from the distant earth stations are filtered out and converted to the intermediate frequency (70 MHz) in two stages, using stripline[1] techniques throughout. Bandwidth restriction and de-emphasis networks appropriate for the channel loading of the carriers are included in the demodulating equipment. Reserve equipment is brought into use automatically when required. Despite the complexity arising from the number of received s.h.f. carriers it has been possible to integrate the Goonhilly No. 3 control arrangements with those existing for Goonhilly Aerials Nos. 1 and 2.

When Goonhilly Aerial No. 3 is operating, Aerial No. 2 will be modified in service to conform with the new performance standards required for INTELSAT IV operation and it will continue to carry a major share of the heavy traffic to North America via the second Atlantic INTELSAT IV satellite. Goonhilly Aerial No. 1 will continue in its role of providing service to countries east of Britain via the Indian Ocean satellite.

The Goonhilly No. 3 aerial and its tracking system have already been described in some detail in this Journal.[2] An article dealing with the earth-station equipment for operation with INTELSAT IV satellites will be published in a later issue.

V. C. M.

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2 Meller, V. C., and Duffy, P. S. J. The Large Steerable Aerials at Goonhilly Earth Station. *P.O.E.E.J.*, Vol. 65, p. 2, Apr. 1972.

Notes and Comments

J. A. C. Kynaston, C.Eng., M.I.E.E., M.E.R.E., M.B.I.M.

Jack Kynaston's promotion to Controller Planning & Works, Wales and the Marches will be warmly welcomed by all his many friends both inside and outside the Post Office.

He joined the Post Office in Shrewsbury in 1933 and after general training progressed through the minor engineering grades, spending two years at the Research Station, Dollis Hill. In 1941 he was promoted to Inspector and then Assistant Executive Engineer working on external and internal planning and works in Area and Regional offices until 1960, when he was made Executive Engineer on accommodation planning. His next appointments were S.E.E. in 1966, on equipment planning and design, and R.E. in 1970 on exchange equipment work, power plant, accommodation services and critical

path analysis. His progress is unusual in that, with the exception of short absences in T.H.Q. and Midland Region, his whole career has been spent in Wales and the Marches. His wide knowledge of both the work and the Region make him an excellent choice for C.P.W.

In spite of the many demands of his official activities he has cultivated a range of other interests and hobbies including rowing, archery, oil painting and churchwork, and in the latter case has been responsible for the Christian Stewardship Campaign at his local church for more than 8 years.

His enthusiasm, coupled with a kind and sympathetic disposition and unfailing courtesy, has always brought out the best in others and ensured complete loyalty in his staff and will continue to ensure success in his new post.

H.M.

J. F. P. Thomas, B.Sc., C.Eng., M.I.E.E.

Frank Thomas joined the Post Office Research Station at Dollis Hill in 1937, becoming a Probationary Inspector in 1942 and a Senior Executive Engineer in 1957.

Much of his early career was spent in the physics laboratory where he worked on a wide variety of tasks including investigations into magnetic materials.

In 1948 and throughout the '50s he worked on the design of repeater components and terminal equipments for the first Transatlantic Telephone Cable (TAT 1) and contributed to many other aspects of that taxing project, in particular the laying of the cable across Newfoundland.

In 1963 he was promoted to Assistant Staff Engineer in the old LMP Branch with responsibilities for planning the inland trunk network and in 1966 he took charge of the Branch as Staff Engineer. His time in LMP Branch coincided with a marked expansion of the inland trunk network which has continued unabated through all the changes in Post Office organisation. These changes brought his Branch into Network Planning Department which he left in 1970 when he became Deputy Regional Director, L.T.R., first on service and then on planning. He took this complete change of

environment in his stride but never made any secret of his continued interest in his old department.

We were therefore not surprised when he returned to Network Planning in 1972 as D.D.E. in charge of the Line, Radio, Datel and Submarine Division. Within a few months he was appointed Director, Network Planning, a task which he is tackling with his usual good humour, drive and robust common sense. We wish him well in his new job.

K.F.

K. J. Chapman, B.Sc., C.Eng., M.I.E.E.

There can be little doubt in the minds of all who know him that in promoting Keith Chapman to Personnel Controller as Deputy Head of the Appointments Centre, those responsible have chosen well.

An engineer at heart, yet with a physics degree, Keith brings to the job a wealth of experience both technical and practical combined with a wide knowledge and understanding of people.

During the war years he served with the Royal Signals attaining the rank of Captain. The keen interest in communications aroused by this experience shaped his career.

In 1950 he joined the Research Department and worked on submarine systems. Then in 1965 he moved to electronic

switching on promotion to A.S.E. Later he left Dollis Hill to join the Appointments Centre as an Assessor and subsequently transferred to Telecommunications Development Department for work on the proposed digital data network.

Keith comes to his new job with a wide background of social activities. For many years he played leading parts in the Dollis Hill pantomimes and is a past Chairman of the Research Social Club. At home, he has for long played important roles in local amateur operatic productions. Having a family of four boys, almost inevitably he is chairman of the local Scout group.

Keith's boundless energy and good humour erupt in that brief, explosive, magnificent belly laugh which still echoes in the corridors of Dollis Hill.

All his friends will want to congratulate him on his appointment. We also congratulate the Appointments Centre.

E.F.S.C.

R. E. G. Back, C.Eng., F.I.E.E.

Mr. Back has spent the last six years in the field of satellite communications and has made himself known to a large circle of colleagues in the tasks for which he has been responsible in the provision of the second and third large-dish aerial terminals at Goonhilly. Initially as an A.S.E., and in the past three years as head of the Earth Station Planning and Provision Branch, he has shown himself more than equal to the wide range of challenges that this demanding work has involved. Under his guidance, the work of the Branch has progressed in several ways, notably in the R & D field and by the establishment of a consultancy group which has secured advisory work on the construction of earth stations overseas.

Prior to this period he was involved in a number of diverse projects ranging from deep-cable construction to the external construction of a large v.l.f. radio station. In all these assignments he has earned the respect of his colleagues for his ability to get action just where it was most needed, at the right times. His appointment as Deputy Director in charge of

the Line, Radio, Datel and Submarine Division of Network Planning Department is one to which he will bring those qualities of leadership and drive for which he is well known. His many friends congratulate him and wish him well in this new sphere of work.

J.K.S.W.

New I.Mech.E. Postal Engineering Section

The Institution of Mechanical Engineers (Manipulative and Mechanical Handling Machinery Group) has recently formed a specialist section to deal with Postal Engineering. This has followed from the running of a very successful British Postal Engineering Conference in May 1970 which 339 delegates attended including 51 from 19 different overseas countries. (The opening paper of this conference was published in 3 parts in previous issues of the Journal.*) The Proceedings† are still in demand from overseas as being the only comprehensive text-book on the subject. Subsequent to this conference, three evening discussion meetings have been held at the institution's headquarters in Westminster with attendances of about 150.

The object of forming this specialist section is to ensure that adequate time and effort is devoted to discussion and debate of topics in, what the Institution of Mechanical Engineers has recognized to be, the important and developing field of Postal Engineering. This includes the handling of letters, parcels and packets but in addition mechanical equipment for GIRO or the agency services of the Post Office could be the subject of review. The section committee with representatives from the Post Office and industry organizes meetings, conferences, evening debates etc. on Postal Engineering matters and liaises with the I.P.O.E.E. and the I.E.E. Control and Automation Division.

The future plans include evening discussion meetings for Thursday 14 December 1972 on "Can packets be mechanically handled?" and Thursday 5 April 1973 on "Human factors on the design and operation of new mechanization systems"; a one day conference on "The design, testing and commissioning of postal mechanization systems" is planned for 27 February 1973. The second Postal Engineering Conference will take place later and an international flavour is proposed.

Anyone interested in the future programme of the Postal Engineering Section, whether or not a member of a professional institution, may obtain further details and enrolment forms from Mr. P. A. Lancaster, The Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1H 9JJ.

* N. C. C. de Jong: Progress in Postal Engineering, *P.O.E.E.J.*, Vol. 63, p. 63 *et seq.*

† Published by the Institution of Mechanical Engineers.

Letters to the Editor

Dear Sir,

I thought I would write and tell you how much I appreciate the *Post Office Electrical Engineers' Journal* that comes to me free every quarter. I am particularly pleased to read the Press Notices because one of the problems of a retired officer still interested in the progress of the service is to obtain information as to what is going on. It is just over ten years since I retired from Home Counties Region and I have enjoyed my retirement very much.

Yours sincerely,

J. McA. OWEN

Eilean Aigas,
20 Roundwood Park
Harpenden,
Herts.

Dear Sir,

As you know we frequently discuss on the Editorial Board the problem of keeping our *Journal* image up-to-date over the years. The style and content have been changed with that in mind. However, we have not gone as far in either content or external appearance as some of the other professional journals. The *New Civil Engineer* which seems to have been modelled on the American *Time* and *News Week* styles, is a case in point.

It would be most interesting to read some views from our readership on this problem before we carry out a further review on editorial policy.

Yours faithfully,

N. C. C. de JONG

Postal H.Q.,
St. Martin's le Grand,
London EC1A 1HQ

Dear Sir,

We would like to comment on the article by Messrs Harris and Kilsby entitled "Terminating External Cables in Telephone Exchanges" (published in the April 1972 issue), as there are some statements made therein which could be misleading.

Firstly in the second paragraph "Main Distribution Frames" it is inferred that either side of the rack type frames can be erected independently of the other. This is not so as only the line side rack will stand unaided, being constructed to provide the supports for the jumper field. The exchange-side rack is dependent on the line-side rack for support.

The authors then go on to state that on pre-rack type frames it is a general rule that the 11th (bottom) block on each vertical of the line side is used for junction cables whilst the local cables utilise the remaining 10 blocks. This may well be the case in u.a.x.'s or small n.d. exchanges with only one or two junction routes but certainly cannot be quoted as a normal happening. In large exchanges all 11 positions are used to terminate junction cable in sequence, as contractors providing new junction plant object to terminating cables on only the bottom spaces left by the Post Office.

In some cases cables have been numbered top to bottom of the vertical, but in general on new m.d.f.s it has been numbered bottom to top.

In the L.T.R. 11th block working has often been used as an expedient where the m.d.f. cannot be extended and is nearing saturation.

On page 46 it is stated in the second paragraph that pre-rack type frames are built up from sections of 4 verticals. We feel that this should have read "rack type frames" as the old type frame is built up on site from mild steel strips and any number of verticals can be specified, apart from the initial provision which is a minimum of 3.

The statement in the "cables" paragraph that with the exception of small (up to 100 pairs) polythene local distribution cables, paper is used to insulate the conductors of most external cables, again may be true of rural areas but cannot be stated as a general rule. Apart from which this is somewhat contradicted in the section "Protecting Cables on the M.D.F." where the authors discuss protection problems of large (over 400 pairs) polythene–insulated cables now being terminated onto m.d.f.s

Further reference can be made to P.O. Educational Pamphlet, Draft Series, General 3/8, P.O. Specifications T1101 and T1103, P.O. Drawings 8858 and TP 351.

We are interested in the amount of time (money) being spent on the problems of randomly-terminated cables, mentioned in the article. Whilst we agree that it takes extra time, initially, for the jointing staff to bring out cables in correct pair order, may we point out that this is a once in 30 year (possibly more) operation. Also one must consider the other end which on large cables can terminate in more than one place, e.g. part in a cabinet, part in a subscriber's premises, the rest in an auxiliary joint, thus surely making the keeping of correct records essential.

Does the cost of development, and provision of electronic identification equipment, not to mention staff training in its use, outweigh the initial cost of laying out the cable in correct order, plus the subsequent ease of use?

Surely a simpler solution can be found to the problems of petroleum jelly.

Yours faithfully
K. S. LONG and *R. H. WOODWARD*

London Telecommunications Region,
Director's Office,
Camelford House,
87 Albert Embankment,
London SE1 7TS

Dear Sir,

I am aware that the Oxford English Dictionary gives "connexion" as a preferred spelling, and that some dictionaries list "reflexion" as an alternative to reflection". However, I can find no precedent for printing "direxion" as on p. 22, second column, line 14 of the April 1972 *P.O.E.E. Journal.* If this substitution of an "x" for "ct" is to become P.O. or *Journal* policy, would you have us write as follows:

Despite his obvious affexion for the tower, he spoke with dejexion, "After careful inspexion of the erexion, and dissexion of various parts, our collexion of data is now complete. The cure for the deflexion of the top sexion, which had previously escaped detexion, is apparently the injexion of a selexion of plastics materials. This will ensure our future protexion and lead to the rejexion of any further claims."

Yours faithfully
W. G. T. JONES

Telecommunications Headquarters,
Research Department,
Scottish Mutual House,
Lower Brook Street,
Ipswich, IP4 1DW

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 1972.

Letters intended for publication should be sent to the Managing Editor, *P.O.E.E. Journal,* Post Office Factories Headquarters, Bovay Place, London, N7 6PX.

Your Journal

Over 38,000 copies of each issue of the *Journal* are printed. Inevitably, some do not reach their intended destination. The distribution system has recently been completely revised to try to improve the service that we give our readers. If something does go wrong and your copy does not reach you, the following notes tell you what to do.

External non-Post-Office readers

Subscriptions for all non-Post-Office readers at home and abroad are dealt with by the Subscription Agent at 2–12 Gresham Street. Subscriptions can run for any period of four issues and, with the last issue, a renewal slip is included which should be returned with a remittance if you wish to continue to receive the *Journal.* If any queries arise it helps, although it is not essential, if you can quote the period for which your subscription has been paid. Subscriptions can be made direct, or, if you prefer it, through a bookseller dealing with periodicals.

Corresponding and retired members of the I.P.O.E.E.

These members receive their *Journals* directly by post. The membership list is maintained by the General Secretary of the Institution. If any corresponding or retired member is not receiving his *Journal* regularly or wishes to notify a change of address, he should write to the General Secretary, I.P.O.E.E., 2–12 Gresham Street, London EC2V 7AG, stating the category of membership.

Post Office staff who are members of the Institution

Members of the Institution receive the *Journal* as part of the services paid for by their subscription. Copies are actually distributed by *Journal* local sales agents, but the agents merely act on the instructions of the local secretary of the Institution who is responsible for maintaining the membership roll. Any member of the Institution who is not receiving his *Journal* reguarly should, therefore, inform the local secretary. The local secretary should also be advised of changes of official address by the member concerned. It is emphasized that the subscriptions paid by members of the Associate Section do not include payment for the *Journal*. Associate Section members only receive the *Journal* if they pay for it separately by deduction from pay, or by cash, and they should arrange for this by contacting their local sales agent.

Post Office staff who are not members of the Institution

Members of the Post Office staff who are not members of the Institution may pay for the *Journal* by deduction from pay, or by cash, and receive the *Journals* from *Journal* sales agents. There is a sales agent in every Telephone Manager's Office and in every Regional H.Q., Postal or Telecommunications. Usually the agent is situated in a domestic or literature duty. In T.H.Q. there is an agent in every Department or Division, in the appropriate domestic duty. Complaints about non-receipt or changes of address should be made to the sales agent. The enquiry point in the Area, Region, Division or Department should be able to tell you the name of the local sales agent. In cases of difficulty write to the *P.O.E.E. Journal*, 2–12 Gresham Street, London EC2V 7AG, and we will forward your letter to the sales agent.

Notes for Authors

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

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

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

Model Answer Books

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

The Telecommunication Principles B Answer Book is out of print at the moment but a reprint is in preparation and an announcement will be made in the *Journal* when it becomes available.

Articles on Current Topics

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

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

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

Post Office Electrical Engineers' Journal

Would one of your colleagues like to take the Journal? A regular supply will be sent to anyone filling in and returning the form. If someone borrows your copy suggest he gets one of his own. Cut on dotted line.

To The Managing Editor,
P.O.E.E. Journal (Sales),
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THE POST OFFICE
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Regional Notes

South Eastern Region

Subaqueous cables for the Central Electricity Generating Board control circuits

New power stations being built by the Central Electricity Generating Board (C.E.G.B.) depend on Post Office cables for their remote control and efficient operation. A main and an alternative outlet-cable are provided and security arrangements demand adequate separating distance between them.

The new power station being built at the Isle of Grain posed separation problems between the site and the local telephone exchange at All Hallows. If both new cables were to be drawn in this direction, approximately 9 km of duct would have to be laid in the carriageway to augment the existing duct route laid in 1915, and which as a result of road improvements frequently crosses the carriageway. Alternatively, if only the main outlet-cable was pulled in, no additional duct would be required for future local requirements as sufficient bore space exists.

On economic grounds, and with the approval of the C.E.G.B., a completely separate route for the alternative cable was proposed by laying a subaqueous cable across the mouth of the river Medway from the Isle of Grain to Sheerness (Fig. 1). During discussion with the C.E.G.B., it was realized that this route could be used earlier than originally planned for an alternative outlet from a new 400 kvolt sub-station at Pheasant Farm near Sittingbourne, due to be commissioned in January 1972.

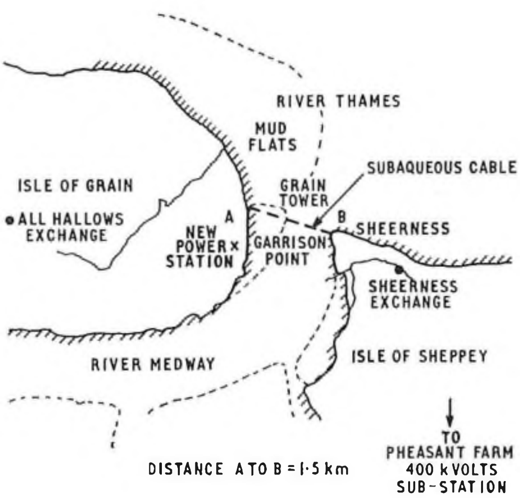

FIG. 1.

The work was staged in two parts. Firstly the main outlet, a 60-pair cable, was pulled in from All Hallows unit automatic exchange to the access road leading to the Isle of Grain power-station. This was jointed to a 28-pair cable which continued to a joint box on the land side of the sea wall, where another joint was made to the 28-pair armoured subaqueous cable. On the other side of the estuary, from Garrison Point, a 28-pair cable was pulled in. These cables were loaded and fully balanced.

Because of the possibility of flooding, the Kent River Authority would not allow pipes to be laid through the sea wall unless precautions were taken in the form of the construction of a coffer dam. This would have been a very expensive operation and the problem was overcome by building a reinforced concrete chute 30 m long and 500 mm deep, fitted with removable concrete lids from below high water mark and extending up and over the sea wall where the subaqueous cable was anchored and jointed to the land cable.

The second stage will be required in 1975 and consists of the continuation of the main outlet-cable into the control-room of the Isle of Grain power-station, and an alternative cable to Sheerness using a second subaqueous cable which will be routed to the power station via the cooling water outfall.

From the execution side, and apart from the normal junction jointing, it was more a matter of providing sufficient staff to land the shore ends rather than an engineering problem, in fact the main problem was a nautical one.

At the Isle of Grain end, there are mud flats that extend out from the shore line for a distance of 800 m. In consequence, they are covered at the deepest point by only 1·5–2 fathoms of water, this depth being available for a period of only one hour at the highest point of the tide.

A local boat was hired for the cable crossing and manned by a crew from the Post Office Cableship *Iris*. The boat stood off at the Isle of Grain end as close to the shore as possible and a steel rope was taken out to it by dinghy. The cable was then winched ashore on buoyancy bags and the end made secure.

The Sheerness end was comparatively straight forward as the deep water runs very close to the shore. Steel articulated ducts were fitted on this side which allows movements by tide but protects the cable at the same time.

Finally the 800 m of cable was dug in across the mud flats on the Isle of Grain side. Owing to the soft estuary mud and the speed at which the tide came in across this section it was not possible to use mechanical aids at all.

R. APPLEYARD
P. B. LOVELOCK

Eastern Region

The show must go on

The Post Office have secured the contract to provide piped television for the new city of Milton Keynes and the development corporation requested us to provide the service to a show house to be opened by Mr. Julian Amery, M.P., on 25 February 1972.

All kinds of difficulties were hurriedly overcome; these included refusal of planning consent for the original aerial mast site, early provision of a new-type coaxial cable and apparatus and temporarily erected poles to carry power to the hastily revised mast site.

The weather was also against us, but a few days before the required date, the show house sticking out like a sore thumb in a vast sea of mud, was wired and ready.

Unfortunately after all this effort, Mr. Amery owing to other commitments, was unable to be present and at this late hour, was unable to find a suitable replacement.

N. R. WILLIAMS

Northern Ireland Directorate

Delivery of poles from Poling Contractors

There are two standard methods of unloading poles from the poling contractors onto a pole stack:

(*a*) The contractor throws the poles onto the ground near the pole stack and the Post Office subsequently lifts them onto the stack.

(*b*) The poles arrive, with the slings already in position, in groups of five medium or 10 light poles per pair of slings. The Post Office use these slings to lift the poles direct from the vehicle to the pole stack with a crane.

Until now it has not been possible to use either of these methods in Northern Ireland. Alternative (*a*) is impracticable because of the design of the pole carrier, which is primarily built for boat loading. Alternative (*b*) was unacceptable to the contractor as there was no means of ensuring the return of his slings since the vehicle does not go back to the pole depot, as is usual in the standard method.

The method currently used in Northern Ireland, where a crane is available, is to sling the poles on arrival. This is both slow and unsafe.

Agreement has now been reached between the Northern Ireland Directorate, Telecommunications Headquarters and one poling contractor to a modified pre-sling method as follows:

The slings are normally held at the creosoting depot but are owned by the Telephone Manager, Belfast. They can be identified as his property in the following way:

(*i*) They are stamped "P.O." on the loop;
(*ii*) They are 14 ft long, all contractors slings being 16 ft long.

The use of 14 ft slings instead of 16 ft slings should enable the mobile crane to position the poles on a standard pole-stack without the use of the manually extendable jib, and this may have application in other Regions.

Subject to experience gained on this trial it may be extended to other Telecommunications Engineering Centres.

F. J. Rowbotham

Midland Region

Leicester Cardinal Exchange

The tallest building in the centre of Leicester has been designed to house a trunk switching complex to be known as Leicester Cardinal and an international control centre (i.c.c.) to be called Wolsey; it was taken over from the Department of the Environment on the last day of 1971 to allow equipment contractors to start installation. These names commemorate the local connexions with Cardinal Wolsey who died at Leicester Abbey in 1530. The ruins of the Abbey are in Abbey Park three-quarters of a mile north-west of the exchange, from which it can be seen over the surrounding building.

The tower block has 17 floors rising above a podium of four floors, parts of which bridge a street. The trunk and junction switching unit of 5005-type crossbar equipment will work with the present Wharf Street Trunk non-director and junction tandem exchange to serve the Leicester Zone. It will open with approximately 6,200 ft^2 of space on four floors. A 60-position cordless switchboard to carry automanual traffic will be laid out like an open plan office in a pleasant switchroom on the third floor.

Leicester Wolsey i.c.c., with 70 positions of four-wire switching sleeve-control switchboards on the second floor, will control English speaking international traffic from the Birmingham and Leicester main switching centre areas, the catchment area extending as far as Lowestoft, Potters Bar, Gloucester, Matlock and Lough.

A new repeater station, Leicester D, will occupy 10,000 ft^2 and initially will be provided with 70 hyper-group and 400 group terminations.

The crossbar power-plant has two 15,050 ampere hour batteries on the eighth and eleventh floors with four 2,000 ampere rectifiers on the tenth floor. This power equipment is at the east end, but the apparatus lift is at the west end and the two large ventilating units will have to be partially dismantled to manoeuvre 15 tons of power equipment through a passage barely 5 ft wide.

The high-voltage switchroom is designed to provide 6 Mwatts. The medium-voltage power distribution uses 68 cables, 48 of which are 960 mm^2 solid-aluminium conductors providing essential and non-essential feeds of 1,000 amperes per phase to floors one to eight and nine to 17 as well as separate feeds to each main power-plant.

Three standby engine sets, of 1·2 Mwatts each, have to be lowered to the upper basement. The alternators are already on site but each engine, weighing 17½ tons, will have to be removed from its bed-plate in the street and lowered in two parts. Because of the angle of lift, a crane of 50 tons capacity will be necessary and the street will have to be closed on a Sunday for the delivery of each engine. The three exhaust pipes are of 20 in bore and have a 330 ft vertical rise to the outlets on the tower-block roof.

The heating and ventilating system is unique. Vertical ducts have been formed behind the windows on the back and front faces of the tower by an inner skin with corresponding windows. High- and low-level grilles on each floor will provide a cross-flow of air. Four floors in the tower house large ventilators, each serving two floors above and two floors below. Hot air taken from the equipment floors will be re-used after washing, filtering and mixing with cool air.

A three-level manhole has been built on the corner of the site. On the upper level, a 7 ft tunnel leads to the entrance of 114 duct-ways in a 4 ft 6 in pipe to Wharf Street exchange. The centre level gives access to the riser for high frequency cables, with two 48-way and two 24-way incoming ducts. At the lowest level, access to the cable chamber, 28 ft below ground level, has a 60-way inlet with provision for a second 60-way. Two main risers carry the external cables to the fourth floor where initially, 20 co-axial cables will terminate on the repeater station in the north wing, and 24 audio cables on the main distribution frame in the tower block.

A project of this scope and magnitude requires a great deal of co-operation and co-ordination at national and local levels and inevitably causes abnormal pressures on the various groups of staff involved as the job proceeds, but all concerned are intrigued to see plans commenced years ago beginning to take shape as Cardinal Wolsey rises again in Leicester.

C. C. Pikett
R. Clark

Associate Section Notes

Edinburgh Centre

On Tuesday, 11 January, Mr. H. C. Stevenson, Personnel Division, Telecommunications Headquarters, Scotland presented his talk, "Preparation for Interview". The speaker explained the reason for holding promotion boards, what is expected of the man interviewed, and the way each man should approach it. Some dummy boards were illustrated by means of tape recordings and after a short tea-break Mr. Stevenson was kept busy answering the many questions put to him. This meeting produced an all time record attendance for the Centre of 92.

At our next meeting, on Wednesday, 9 February, Mr. T. C. Watters of Service Division, Telecommunications Headquarters, Scotland, gave his talk "Service in the Seventies". This was a new look at exchange maintenance, new maintenance aids, etc. Mr. J. McKain, who assisted, described and demonstrated a new electronic test-call sender.

Thursday, 24 February was the date for a talk by two representatives of Audio Aids, Edinburgh, entitled "An Informal Insight into Hi-Fi". This was a very interesting evening, the speakers demonstrating the qualities of various stereo systems.

On Tuesday, 7 March, Messrs. J. I. Murray and C. J. MacPherson of Service Division, Telecommunications Headquarters, Scotland, presented a talk on "Island Communications". This was followed by a showing of the colour film on the Highlands and Islands scheme, "In Touch".

M. K. Finland

Sheffield Centre

The opening meeting of 1972 was held at Sheffield University on 19 January where Mr. M. Bennett, a local member, presented an excellent paper entitled "Basic Microwave Systems". On 16 February Mr. A. G. Bradley, also of Sheffield, recounted some of his experiences in Sweden following his recent exchange visit. He added considerable interest to his talk by telling us not only about telecommunications in Sweden, but also about the Swedish way of life.

An informal film show was arranged by Mr. J. P. Cooney on 24 February when the variety of subjects ensured an entertaining evening.

Sixteen of our members visited the Post Office Factories at Birmingham on 8 February, and during the remainder of the session visits have been arranged to the Ideal Homes Exhibition and British Leyland Motors.

Other events held at the end of the session were papers by Mr. S. Watkins, Area Engineer, Sheffield, entitled "The Future of Telecommunications in Sheffield", and by Mr. Kirby of Telecommunications Headquarters, entitled "Practical Aspects of Traffic Engineering", presented on 21 March and 24 April respectively.

The annual general meeting was held in May.

K. H. Barker

Aberdeen Centre

Our last meeting of 1971 was an evening visit to the Head Post Office in Aberdeen on 15 December. We were given a conducted tour by a local member, Mr. J. McIntosh, and were shown Postal Mechanization in progress. The evening proved to be extremely interesting.

The first visit of 1972 was to a local newspaper, *The Press and Journal*,, on the evening of 18 January. We were given a very interesting tour of the plant, preceded by a brief history of the paper. The visit was well attended by members despite severe weather conditions and power cuts.

Our first talk of 1972 was on "Why Watch Birds" given by Dr. G. M. Dunnet of Aberdeen University. The talk, illustrated by slides, was about pollution and conservancy and was well received by members who attended.

J. H. McDonald

Dundee Centre

The final meetings of the 1971–72 session were a visit to the National Engineering Laboratory, East Kilbride and the annual general meeting in April. The program has proved to be fairly popular, but the inclement weather conditions and illness prevented some members being present more often. Bob Topping, our Chairman, has recovered from his enforced lay-off and is back to work and attending meetings. Dave Millar is resting by order of the doctor and George Duncan is spending a rather lengthy term in hospital.

Apart from a maximum attendance of 56 to hear Mr. Stevenson's talk on "Preparation for Interview", the "History of Old Dundee" in the form of a visit to the museum and a talk by Mr. W. Blair, author of *Witches Blood*, proved most popular. The members' slide night with the best-slide competition had to be postponed till a later date, yet to be decided.

The committee wish to thank members and friends for their support during the session.

R. T. Lumsden

Institution of Post Office Electrical Engineers

Institution Field Medal Awards, 1970–71 Session

In addition to the Institution 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.

Field Medals were awarded to the following authors for papers read during the 1970–71 Session:

R. D. Cull, North Eastern Centre. "An Insight into Transmission."

W. Kirby, North Eastern Centre. "Practical Aspects of Telephone Traffic Engineering."

Essay Competition 1970–71

Prizes and Institution Certificates have been awarded to the following competitors:

Prize of £15 to A. Buttrie, Technical Officer, Wakefield area, "Emergency, Which Service Do You Require?"

Prize of £10 to R. Andrews, Technical Officer, Glasgow area, "Simple Project Control."

Prize of £6 to D. W. Kidd, Technician IIA, Preston area, "A Postal Transfer Data Network."

Prize of £6 to J. Parker, Mechanic Nottingham area, "An Outline of the Motor Transport Organization."

Prize of £3 to D. J. Griffin, Technical Officer, Glasgow area, "Some Relay Techniques in Telecommunications."

Five certificates of merit were awarded to:

Mr. A. D. Ward, Technician IIB, Birmingham area, "Engineering Activities in the Post Office—Underground Cabling Duties, What Does It Involve?"

Mr. A. W. Pettie, Technical Officer, Edinburgh area, "A Need to Communicate."

Mr. A. Barclay, Technical Officer, Glasgow area, "Some Changes I've Seen."

Mr. J. Morrison, Technical Officer, Dundee area, "Computers in Exchanges—An Introduction to Stored Program Control."

Mr. M. I. Stephenson, Technician IIA, Scarborough area, "My Training at Scarborough Repeater Station."

Twenty-three essays were entered this year—an increase on last year. It is interesting to note that 19 of them came from north of the line Bristol Channel to the Wash and of these 19, 10 were from Scotland.

The essays were generally well presented and in most cases the authors took a great deal of trouble to make interesting reading, few failing to achieve this objective. The majority submitted very good essays.

The Council of the Institution records its appreciation to Messrs. A. C. Eley, S. Rata, and A. W. Welsh, who kindly undertook to adjudicate on the essays entered for the Competition. The prize-winning essays will be kept in the Institution Central Library and will be available to borrowers.

A. B. Wherry
General Secretary

Additions to the Library

Library requisition forms are available from Honorary Local Secretaries, from Associate Section Centre Secretaries, and representatives, and from the Librarian, I.P.O.E.E., 2–12 Gresham Street, London, EC2V 7AG.

Members are reminded that Prize Essays, Associate Section Prize Papers, and various unpublished papers are held in the library for loan, and that a list will be sent on request. Field Medal award-winning papers are also held for loan and are listed in the Supplement to the Library Catalogue.

5075 *Signal Processing: Modulation and Noise.* J. A. Betts (Brit. 1970).
Intended primarily for the under-graduate student studying communication principles but will also provide a useful reference for the professional engineer who is concerned with the fundamental theory of information transmission. Is suitable for self-study.

5076 *Improving Industrial Communication—A Basic Guide Line for Managers.* A. S. Irvine (Brit. 1960).
A comprehensive and practical book for any manager with responsibility for people at work.

5077 *Creative Systems Design.* D. Rogers (Brit. 1970).
Recommended for anyone practising in Management Services—and for managers who want to know how Management Services can help them.

5078 *Statistics: A First Course, 2nd Ed. (Metric).* R. Loveday (Brit. 1970).
Designed for those who require an elementary introduction to the subject before embarking upon a more mathematical treatment.

5079 *Computer Appreciation.* T. F. Fry (Brit. 1970).
Will be of help to students with the computer content of the Ordinary National Diploma and Ordinary National Certificate in Business Studies but will also be of value to those reading it for interest.

5080 *A Social History of Engineering.* W. H. G. Armytage.
Begins with the stone age and ends with the space age.

5081 *Electrical Installation Technology.* M. Neidle (Brit. 1970).
Written as a text book for the City and Guilds Electrical Installation Work, Course C. SI units are used throughout.

5082 *Power Engineering using Thyristors, Volume 1: Techniques of Thyristor Power Control.* Mullard Ltd. (Brit. 1970).
This volume is concerned with the thyristor itself and the basic control techniques. The applications of thyristors are considered in a general way.

5083 *Modern Electronic Maintenance Principles.* D. J. Garland and F. W. Stainer (Brit. 1970).
Deals with the principles of electronic maintenance at a level which is suitable for technicians and should interest those pursuing Ordinary and Higher National Certificate and Diploma Courses and City and Guilds Technicians Courses.

5084 *Semiconductor Pulse Circuits with Experiments.* B. B. Mitchell (Amer. 1970).
A comprehensive textbook on pulse and switching circuits which provides the design, analysis, and the synthesis of the basic pulse and switching circuits, and introduces these circuits in their simplest form.

5085 *Vector Analysis for Mathematicians, Scientists and Engineers.* S. Simons (Brit. 1970).
Aims to supply the necessary understanding of vector algebra and calculus to the extent that the reader will be able to employ them himself in his own brand of science.

5086 *The Use of E.T.V.* T. Gibson (Brit. 1970).
Designed for those who want to know what it involves, what use it can be and how it may affect them.

5087 *Notes on Digital Communication.* G. L. Turin (Amer. 1969).
Written for the first year graduate level and assumes an acquaintance with infinite-dimensional linear spaces and knowledge of the theory of random processes.

5088 *Human Relations in Management.* E. W. Hughes (Brit. 1970).

Attempts to show how tentative working laws about people can be arrived at and used to predict behaviour in future situations.

5089 *Applied Engineering Design and Analysis.* T. V. Duggan (Brit. 1970).

Demonstrates how the engineer can produce real and meaningful solutions to design problems by following a methodical and systematic procedure.

5090 *Electrical Engineering Principles for Electrical Telecommunications and Installation Technicians.* G. S. Stott and G. Birchall (Brit. 1970).

Covers the revised syllabuses of the Part 1 Electrical Telecommunications Installation and the Radio and Television Technicians courses. Contains over 240 worked examples and 370 problems, many from past papers.

5091 *Logic Circuits.* N. M. Morris (Brit. 1969).

Should be of value to all students of logic particularly those in Higher National Diploma, Higher National Certificate and City and Guild Courses.

5092 *A Programmed Book on Semiconductor Devices.* Mullard Ltd. (Brit. 1970).

This book is an introduction to semiconductor devices and its contents should be understood by anyone with a basic knowledge of electronics. Emphasis is placed on the nature, construction and performance of semiconductor devices.

5093 *Mathematics for Engineering Technology and Computing Science.* H. G. Martin (Amer. 1970).

The standard of material presented is mainly higher than that needed for the Higher National Certificate Engineering Courses, but the exposition may suit many students on these courses.

5095 *Telecommunications Pocket Book.* T. L. Squires (Editor) (Brit. 1970).

Written by a number of experts in the telecommunications field and is intended to provide the reader with a broad outline of each division—telephony, television, telex, data communications, etc.

5096 *Motor-Uniselectors with Noble-Metal Contacts in Telephone Switching Systems.* R. Krause (German 1968); Translation Editor: J. F. Hesketh, B.Sc.(Eng.), C.Eng., M.I.E.E., P.O. Research Department.

Deals with the EMD motor-uniselectors and systems as used by the G.F.P.O. and also covers other variations of the system which have found wide-spread application abroad.

5097 *Introduction to Signal Transmission.* W. R. Bennett (Amer. 1970).

Provides a basic understanding of the electrical transmission of signals. The important cases of voice transmission, data transmission and television transmission are explained in detail.

5098 *Report Writing.* A. E. Darbyshire (Brit. 1970).

Gives a simple and straightforward account of the main principles of report writing, and the chief ways of dealing with them.

E. Doherty
Librarian

Book Reviews

"Binary Sequences." G. Hoffman de Visme. The English Universities Press Ltd,. vii + 117 pp. 45 ill. Boards £2.10, Unibook £1.25.

Readers of the January 1972 issue of this Journal will know that one application of binary sequences, that of a pseudo-random-sequence binary-digit generator, has a place in telecommunications; another application is to the construction of error-correcting codes. There are applications in radar for example, and in providing a test signal that can be combined with normal input in, say, chemical plants or aircraft control systems.

The study of binary sequences brings in the Theory of Numbers and, hence, most engineers will be at a loss in trying to follow a theoretical paper on the subject. This book, written by an engineer for engineers, aims at describing "the main properties and theory of binary sequences in a simple and . . . fairly complete form", assuming "no mathematical knowledge beyond A-level". Most of the ten chapters are about the commonly-used linear-feedback shift register (linear because it uses only the "exclusive-OR" function), discussing such things as; synthesizing prescribed transfer functions; periodicity of self-generating systems; noise-like properties of sequences; sampling of sequences. There is one chapter on other forms of binary sequences and one on applications.

The author has, on the whole, succeeded in presenting an introduction to the subject that will be useful to engineers; inevitably, certain parts are difficult, since Number Theory is difficult. There are a few misprints, mostly obvious; lines are missing from Figs. 1.8 and 6.2. There is a curious omission in Chapter 1, in which is presented a canonical realization of a transfer function (with examples in Figs. 1.7 and 1.8); there is no mention of the fact that there is an alternative, (dual or reciprocal or inverse) realization, even though this alternative form is frequently used, for example, in Fig 1.9.

W. E. T.

"Vorlesungen uber Technische Akustik (Lectures on technical acoustics)." Lothar Cremer. Springer—Verlag, Berlin/Heidelberg. xiii+334 pp. 177 ill. DM 29.40.

The book is based on a series of lectures presented over two terms at the Berlin Technical University but the material has been adapted to be equally coherent in written form. It lays the technical foundations for an understanding of the principles of acoustics and does this very thoroughly. For each subject, the reader is taken from the fundamental physical and mathematical phenomena to a point where he is ready to tackle practical problems. The latter, however, are not within the scope of the book, nor are constructional and physical details of the devices discussed. Owing to its logical nature, and the accompanying clear illustrations, the text could be understood by anyone within the field but with only a moderate knowledge of German. Topics covered are: electroacoustics (theoretical bases of microphones, reproducers and recorders; and analysis of sound waves by time and frequency); formation of sound waves (physical basis for generation by strings, tubes etc., propagation, reflexion and bending); spreading of sound waves (geometry of patterns, echoes, measurement, energy dissipation, statistical analysis, absorption); damping of sound waves by walls and people; psychology and physiology of hearing.

H. B.

Post Office Press Notices

More Horses for P.O. Fleet

All new large vehicles coming into service with Post Office Telecommunications will have more powerful engines. The minimum power-to-weight ratio for big vehicles in the 45,000-strong fleet is increased to eight horse power a ton—well above the six horse power a ton envisaged in proposed new legislation.

This move is seen by the Post Office as a positive step to overcome the stranglehold of delay on Britain's roads caused by slow-moving traffic queues on inclines. More powerful engines will give better climbing performance and better cruising speeds, and reduce substantially the risk of exhaust pollution caused by overloading the engine. It also brings the Post Office fleet into line with current Common Market thinking on the power of large vehicles. The EEC is considering a European standard of 6 bhp a ton until 1978, increasing to 8 bhp/ton from then on.

Motor transport chief, Mr. Philip Brownlow, said "As far as I know nobody has tried to evaluate the cost to the economy of delays through slow-moving commercial transport, but it must be considerable. You need only see the long queues of lorries slowed to walking pace by a slight incline to realise the size of the problem."

Post Office Telecommunications first laid down minimum power-to-weight ratios seven years ago, stipulating 7 bhp/ton. In 1965 an attempt was made to raise this to 8 bhp/ton—but not enough engines of this output were available.

The first vehicle to conform to the P.O.'s new standard is a 32-ton Guy Big-J articulated lorry fitted with a 265 horse power Rolls-Royce engine—giving a power output about 35 per cent higher than draft legislation proposal.

Supplied to stringent Post Office specifications, the 32-tonner has just begun service with the long-haul arm of the Post Office Supplies Division. A further 14 Guy vehicles with the same power output and nine with slightly smaller engines—but still conforming to the 8 bhp/ton minimum standard—are to be bought.

All the vehicles will be fitted with the Dunlop Maxaret anti-lock device which electronically reduces the risk of the driving wheels locking—the main cause of jack-knifing. It also shortens the stopping distance under emergency braking. The vehicles will have extra soundproofing in the driver's cab, steering column locks, electric screen-washers, hazard warning lights and automatic chassis lubrication.

Speeding Air Cargo

Handling and clearance time for one in five of all consignments of goods imported into Britain has been halved by a computer system.

Known as LACES (London Airport Cargo EDP (electronic-data-processing) Scheme) the computer system, at Heathrow, has accelerated cargo movement by speeding the control and documentation of imports arriving there, putting vital information literally at the fingertips of the airlines, forwarding agents and H.M. Customs.

LACES first went live in August last year, making Britain the first nation in the world to clear incoming air cargo by computer—at least two years ahead of any other country. By the end of September this advanced on-line system using ICL computers was in full operation. It has since handled 650,000 consignments worth £500 M.

Forerunner of a world-wide network of similar systems, LACES has attracted considerable interest from oversea operators anxious to streamline handling of the swelling tide of international air cargo. The system is expected to be developed later to handle exports and is capable of extension to other airports.

Heathrow receives 20 per cent of all imports into the U.K. Before LACES went live, freight entry, clearance and delivery took four to five days. Now the average time is two to three days. Clerical work which previously took hours is now carried out by computer in a few minutes.

LACES is operated by the Post Office's National Data Processing Service (NDPS) on behalf of airlines, forwarding agents, and H.M. Customs, and so far the project directly involves 18 airlines and 170 agents. The £5 M LACES system was developed to meet a critical hardware and software schedule of less than two years. This involved 500 man-years of effort by all concerned—NDPS who with H.M. Customs and airlines designed the system requirements, International Computers Ltd. (ICL), main contractors for hardware and software, Computer Sciences International (CSI), who were responsible for the software system, and Cossor Electronics, who supplied the visual display units.

The system was ready for testing on schedule, on 1 July, 1971. The two powerful ICL 4–72 computers which form its heart are housed in the NDPS West London centre at Harmondsworth, linked by Post Office lines to input and output terminals in the airport Freight Area over three miles away. One 4–72, with 393 K/bytes of storage, two 5-spindle EDS 30s, two drums, a bank of six magnetic tape decks, a line printer, card and paper tape readers, and three multi-channel communication control units—in effect small computers themselves—is used for real-time control of the terminal network. The other configuration, also with 393 K/bytes of storage and with one EDS 30, one drum, seven magnetic tape decks, two high-speed line printers, card and tape readers and one multichannel communication control unit, is used as a standby machine for batch processing and program testing.

A unique re-configuration switching console enables the standby machine to take over the on-line system within two minutes; it also enables peripheral devices to be changed on-line. The console was designed by ICL in conjunction with NDPS.

CSI were responsible for the management, design and production of all real-time software and applications programs. To complete a scheme of this size and complexity in only two years, CSI undertook simultaneous writing of the operating system software with the applications programs.

Management, design and implementation of the software system was on a fixed-time basis, with a team of over 100 people from 16 countries—CSI personnel and seconded staff from NDPS, H.M. Customs and ICL.

The transactions which the system provides are made available by Cossor DIDS 401E VDUs, free-standing DIDS 402Es and DIDS 425 communications controllers. Data transfer rates between terminals and processor are 300 characters per second.

Each VDU has a keyboard for entering the transmitting data, and a 26-line display screen. The top 24 lines can reproduce a standard Customs form, the bottom two lines being reserved for messages from computer to operator. To enable many formats, special display techniques were suggested and embodied by Cossor. Because of need to restrict some transactions to authorized personnel only, a badge reader providing a very high order of security is standard equipment for each display. There are 60 character printers installed in airline and Customs offices.

Communication Main for Milton Keynes

A twin-cable system is to be provided for all new residents of Milton Keynes to bring them telephone, TV and radio services and pave the way for other communication facilities that could revolutionize urban life by the end of this century.

Building on its experience with "communication main" systems in the new towns of Washington, Craigavon and Irvine, the Post Office has begun installing a cable network capable of two-way operation, at Milton Keynes, new city rising in North Buckinghamshire. By spring 1973 over 2,000 houses are expected to be connected to the system.

On all new estates at Milton Keynes the Post Office is providing two underground cables to each house, in co-operation with the Development Corporation, building contractors, and the other public utilities. Wherever possible, cables are being laid in a communal trench with other services—water, gas, electricity, drainage.

One cable—a standard telephone "pair"—is laid to prepare the way for providing telephone service without inconveniencing householders with piecemeal cable laying. The other—a high-performance coaxial cable—is capable of handling a wide range of services: it is the local end of a network that serves as a communication "main" to carry telecommunications just as a watermain carries water. At first, the network is relaying radio and TV programmes in one direction only. But it is designed for two-way handling of other services as well—such as the remote-meter-reading signals, computer data and viewphone facilities that may well become commonplace by the turn of the century.

The Post Office relay network being installed at Milton Keynes is a hybrid system with transmission at VHF over the main "highways" and at UHF over the local lines in each estate. Like the telephone service network of cables, the wideband network will be centred on the telephone exchanges where equipment for the television head ends will be installed and where, in the more distant future, connexion of new services will be made. The television head-ends will receive television and sound radio signals from the aerial. After amplifying, cleaning-up and frequency changing, the signals are reassembled for transmission into the cable network. On each estate signals from the main highways are applied to a translator fitted in a street cabinet which restores the 625-line television signals to channels in the UHF band and lets 405-line television and sound radio signals go through in the VHF band. The outputs from these translators, in the frequency range 80 to 700 MHz approximately, are delivered to each home by means of the local distribution highways.

A return path transmission capability will be a feature of the system using the frequency band from 0 to 80 MHz approximately. Upstream amplifiers and by-pass circuits will be available for each amplifier point on the highways and the telephone exchanges will contain equipment to receive, process and redirect signals from channels in the upstream band.

At each house the telephone and coaxial cables are each run in 50 mm PVC tubing into a small box let into the wall. The box will contain a joint where the telephone pair leaves the through cable to enter the house and a wideband branching device to supply the TV services over a separate coaxial lead-in. The standard street cabinet which contains the TV translator also contains the telephone cable termination both from households and the telephone exchange.

More Mobile Telephone Exchanges—New Attack on Waiting List

A crash programme to hit the telephone waiting list by supplying service to 225,000 customers is being given top priority by the Post Office.

A scheme for the purchase of more mobile telephone exchanges and special portable exchange equipment has been given impetus by the £100M increase in the investment expenditure of the telecommunications service announced on 1 March 1972, and will be the first of the benefits to be felt.

Much of the extra portable equipment—a new fleet of 268 mobile exchanges which can be moved around the country, together with 150 portable racks of equipment—has already been ordered and will be working within 16 months. This will provide service for about 120,000 waiting customers. Plans are in the pipeline for a further supply of mobile exchanges and portable racks which will add capacity for 105,000 more customers. In all, the Post Office is spending more than £4M on the scheme.

The telephone waiting list is now about 200,000 because of an acute shortage of exchange equipment and an explosive demand for telephone service. Even so, by the end of this month the Telecommunications business will have provided the largest-ever number of exchange connexions in a single year—1·3 million.

The exchange equipment shortage has been brought about largely through delays by contractors in manufacturing and installing the equipment ordered over recent years by the Post Office. Thirty per cent of these contracts—about 700—are on average a year behind schedule. Delays by building contractors have also hindered operations.

The Post Office already provides service to about 165,000 customers by using mobile exchanges and portable exchange equipment.

Many of the new 22 ft mobile exchanges are being delivered direct to Post Office engineering centres throughout the country where they are being fitted out by local technicians. This will supplement mobile units being equipped at Post Office factories at Birmingham and Enfield and will speed the flow of exchanges coming into service.

The 268 new mobile exchanges already ordered, together with those proposed, will provide nearly 155,000 of the 225,000 extra customer lines. Several mobile exchanges can be linked together to provide service for large numbers of lines. The remaining capacity is being provided by transportable racks which can be fitted into spare space in permanent exchange buildings.

Automatic Telex to Lebanon

The opening of an automatic telex link with the Lebanon brings improved communication for exporters.

Most of the 4,000 telex calls a month from the U.K. to the Lebanon come from the "invisible export" areas of banking and insurance, and from the aviation and electronics industries. Oil concerns and a growing tourist industry will also benefit.

The new automatic service costs 79p a minute with a one-minute minimum. Previously the minimum charge was £2·37.

To set up calls to the Lebanon telex operators will use the standard procedure for intercontinental calls. The keying code for a Lebanese number is 494.

10 Millionth Exchange Line

The number of connexions linking customers to Britain's telephone system has reached 10 million.

The landmark rounds off a year of unprecedented growth in the telephone service with another record—the installation of 1·3 million new lines in a year, 250,000 of them provided in the past ten weeks. It is the highest yearly figure ever and the third successive year that the supply of new lines has topped one million.

The demand for telephones today has never been greater. To meet it the telephone business, in an ordinary working day—

adds more than 5,000 new exchange lines;
provides 9,600 telephone instruments.

A major contributing factor to this explosive demand is the emergence of a new generation which has been brought up to accept the telephone as a normal part of life, rather than something used only in emergencies.

Nowadays people also use their 'phones more, making 12,000 million calls a year, double the amount made seven years ago.

Seventeen out of every twenty customers are provided with service on demand, and more than 1,000,000 orders for work in customers' premises—from the installation of a new line to the provision of an extension—are undertaken by appointment. Six out of ten orders for exchange service are completed within 10 working days of orders being placed.

To meet the expansion of demand the telecommunications service is spending £3,000M over the next five years—more than £1,000 a minute.

In its modernization scheme the telephone service opens three new exchanges and ten exchange extensions every week; provides 100,000 extra circuits each year to carry calls between exchanges and over long-distance routes; has extended s.t.d. facilities to 92 per cent of customers; is reducing the number of calls which fail because of faulty equipment or congestion at peak hours. On self-dialled trunk calls, for example, the call failure rate has been reduced from eight to seven for every 100 calls handled, and it is hoped to reduce this to five in 100 by the mid 1970s.

The productivity record of Post Office Telecommunications compares very favourably with major industry. In the past six years the service has grown by 55 per cent, the workforce by only four per cent. The Post Office's aim is to double the size of the telecommunication system in ten years with a comparatively small increase in the workforce.

Post Office Cutting Transport Costs

To keep down the cost of running its 65,000-plus transport fleet, the Post Office is extending self-service refuelling and automatic vehicle washing, to save more than £3M a year.

For three years, the postal business has been allowing drivers of its fleet of 11,000 diesel mailvans to refuel their vehicles themselves, using automatic cut-off nozzles. Consumption records are kept on a fleet basis: because mail vehicles generally cover the same routes each day, reliable mileage and fuel-consumption figures can be worked out for each local group. This makes individual vehicle records unnecessary and fuel is made freely available, saving the postal business about £25,000 a year in clerical costs and attendants' time.

Trials of self-service refuelling for petrol-driven vehicles are now being carried out at selected depots in each postal region where, for two short periods each day, petrol is made freely available without individual records. These trials will show whether fleet-based arrangements are suitable for countrywide use, to obtain maximum savings from self-service refuelling.

With more than 41,000 vehicles, Post Office Telecommunications already uses about 170 self-service fuel dispensers—each saving about £2,000 a year in staff and waiting time. This represents a 200 per cent return on capital. A further 180 dispensers are to be introduced to cover all depots serving 50 or more vehicles.

Used mainly for engineering work—installing and maintaining subscribers' exchange and transmission equipment throughout the U.K. network—the telecommunication vehicles are scattered over the country in groups ranging from two or three to several hundred. Most set out and return at about the same time and with an average of three men to each two vehicles, queuing for fuel at these peaks wastes manpower.

Self-service refuelling is cutting queuing time drastically, eliminating manual recording and signatures and freeing pump attendants for other work. Each driver carries a small printed-circuit plate for insertion into an electronic reader near the pump; this switches on the pump and selects the individual indicator that records fuel issues for his vehicle, with automatic cut-off when the tank is full.

The Postal service is planning to use about 80 automatic washing machines, for fleets of 30 vehicles or more. It has developed, with the manufacturer, its own dragmat machine to fit the washing bays in its space-restricted city centre depots. With the two vertical brushes of the three-brush design, it has a hanging mat overhead instead of the third brush. This makes it possible to install the machines at depots where the smaller fleets operate.

Meanwhile, Post Office Telecommunications is cutting the cost of washing vehicles by hand—about £1½M a year—by installing 350 automatic machines at depots with at least 50 vehicles. The 120 so far installed are showing a 100 per cent capital return. These are generally three-brush machines but others are on trial. When machines have been installed at all major depots, the Telecommunications business will consider extending them to smaller fleets.

Post Office Sells Cable-laying Gear to Canada

The first production model of an improved machine which simplifies the laying of modern undersea telephone cables left Manchester Docks for Canada in April. It is a linear cable engine, developed by the Post Office Research Department and bought by the Canadian Government. On arrival it will be installed in the Coastguard ship *John Cabot*, the powerful ice-breaker/cable-layer which early next year is to lay the Canadian end of the new high capacity cable CANTAT 2. This will more than double undersea telephone links across the Atlantic.

Another engine of the same design is now under construction at the Wolverhampton works of Dowty Boulton Paul Ltd., who make it under licence from the Post Office. This machine is for the Cable and Wireless cable-layer *Mercury* which will lay the transoceanic section of CANTAT 2. Both engines are improvements on one that has operated successfully on the Post Office cable ship *Alert*: this has laid the U.K.-Spain, North Sea and English Channel cables—all similar to CANTAT 2.

The new engine cuts out problems caused by the repeaters when laying cable using earlier methods. The repeaters are heavy metal cylinders, up to 10 ft long and 14 in in diameter and in the past a scheme which allows them to by-pass the cable gear has been used. This meant slowing the ship to 1–2 knots and needed a team of several cable-hands. But modern high-capacity systems such as CANTAT 2 with repeaters every 6 miles make this method unwieldy. The new linear engine allows the repeater to pass straight through at about 4 knots, and eliminates all manhandling.

In the new engine, the cable passes between vertical pairs of standard motor-vehicle wheels fitted with pneumatic tyres having concave treads. Each wheel is mounted on the shaft of a hydraulic motor, which in turn is carried on the end of a pair of pivoted arms, linked by a double-acting hydraulic jack so that they open and close in line with the cable. The arms are normally closed, the tyres gripping the cable with a compressive load of about 2,000 lbf; a repeater housing passing through forces the wheels apart, opening the arms. This expels oil from the jacks into an accumulator and/or through a relief valve to maintain hydraulic pressure and grip on the housing. When the repeater has passed, oil feeds back into the jack, closing the arms.

The wheel motors can also operate as pumps to provide the braking action necessary when paying out cable and can rotate in either direction, driving or braking. When driven for hauling in the wheels can hold cable at tensions up to 30,000 lbf; at this tension, the engine hauls in cable at 0·5 knots. When braking to pay-out cable, the engine gives speeds up to 8 knots at normal laying tensions. Motor speed and direction is determined by the rate and direction of flow of the oil delivered by the main pumps. Motor torque (either driving or braking) is governed by oil pressure, controlled by pressure-relief valves.

The linear cable engine for laying CANTAT 2 is built up from basic modules of three pairs of wheels. Any number of modules may be assembled for installation at bow or stern. The engine for the *John Cabot* consists of six modules to be mounted on the foredeck. These are hydraulically interconnected to form three separate groups of two modules which can be operated separately or in concert, while individual pairs may be by-passed. For hauling or laying cable, the motors are usually connected in parallel for maximum traction, but they can be connected in series for handling chain or rope, to avoid bunching.

The wheel motors are the Fletcher Stewart development of the hydraulic ball motor invented at the National Engineering Laboratory. The stator is a steel ring with two adjacent tracks on its inner surface, each comprising four concave cam profiles. It is held in place by the outer casing of the motor. The rotor consists of a cylinder block with two rows of six radial cylinders and two axial bores: each radial piston ends in a hemispherical cup, which seats a ball-bearing running against the cam tracks. When oil is fed into the radial cylinders through a central distributor leading off the inlet axial bore, reaction between the ball and the cam profiles produces rotation. The profile, a computer-aided design, produces a constant output torque at a given oil pressure. The multi-lobe, multi-cylinder configuration means that the double-row motor has in effect, 24 working strokes per revolution, with smooth running at all speeds.

Oil flow to the motors for speed variation is controlled by manually-operated servo valves which adjust the swashplate angle of the variable delivery pumps. Variation in torque is provided by pressure-relief valves which are controlled by a single tension control valve capable of varying the relief valve pressure settings from 3,000 to 75 p.s.i. while maintaining fluid flow.

Massive Increase in International Telephone Facilities

The international telephone service of the Post Office in 1971–72 handled nearly 50 million international telephone calls. By 1976 it is forecast that the figure will have risen to nearly 130 million calls a year and rapid growth will be continuing throughout the decade.

In particular, entry into the Common Market is likely to stimulate the growth of calls and the Post Office must ensure that with entry into the Common Market the British business community is provided with the best possible communications with all their European operations and customers.

In 1970, the Post Office announced the placing of a £12M contract with the Plessey company for the provision of a "full facility" international switching centre for installation at Mondial House to augment the capacity of the Wood Street exchange, also provided by Plessey, which is now coming into service.

Because of building delays in the construction of Mondial House, the Post Office have taken firm measures to provide an alternative location for this equipment and are acquiring a 42-year lease on a large premises at Edgware. This will enable the provision of this international switching centre to be completed on schedule.

In anticipation of the rapid growth in international telephone calls the Post Office have now advised the Plessey company of their intention to place, at an early date, a contract for a further international switching centre identical with that already in production. When completed these two "full facility" exchanges, together with that at Wood Street, will represent the most versatile and comprehensive international switching system in Europe and will enable the Post Office to deal adequately with the vast volume of international calls requiring the full spectrum of facilities then being carried.

But this provision alone will not be sufficient to deal with the substantial growth of calls to the Continent.

Therefore, in parallel with the provision of these new switching centres provided by the Plessey company, the Post Office are, as a result of international competitive tendering, placing a £14M order with LM Ericsson (LME) of Sweden for supplementary switching units of a type designed specifically to provide the limited range of facilities required for international subscriber dialled calls on our main Continental routes. These units will also be installed at the new Edgware site.

The total capacity provided by the two new "full facility" international switching centres ordered from Plessey together with the "limited facility" supplementary units to be obtained from LME is 13,000 erlangs and will, by the completion of the total scheme in 1978, give the Post Office an international switching capacity four times that available to it today.

The total cost of this international switching plan, exclusive of buildings, will be £40M.

Modernizing the Coast Radio Stations Radio Stations over the Waves

Britain's coast radio stations, strung out round her shores to link her people with ships plying to and from U.K. ports, are being modernized. Under the Post Office's six-year £1·2M program—due to be completed in 1974—an up-to-date transmission system will make more frequencies available, giving more telephone channels to meet a demand doubling every 10 years. Also extra facilities being introduced should soon end the tradition of having to call ships at set times each day.

The system, known as single-sideband operation (s.s.b.), is being adopted internationally under a 1967 decision of the World Maritime Administrative Radio Conference. The Post Office is taking advantage of the change to s.s.b. to replace equipment that is nearing the end of its working life with some of the very latest transmitters and receivers.

One by one the 11 stations of the medium-range network are being re-equipped. These stations make radio-telephone contact with ships up to 200 miles from Britain, connecting them directly to inland or oversea callers on the telephone network. They also make wireless-telegraph connexion with ships up to 500 miles away.

The coast radio stations play a vital role in safeguarding all who sail in British waters—in the Safety of Life at Sea, Distress and Rescue Organization. On behalf of the Department of Trade and Industry, they maintain continuous watch on maritime distress frequencies, and rebroadcast distress messages on which U.K. emergency services can act. In rescue operations, they co-ordinate radio communication between casualties, and rescue vessels and coastguards.

The radiotelephone services which operate in the maritime band (1·6 to 3·8 MHz), are affected most by the modernization program: nearly all existing R/T transmitters and receivers are being replaced by new equipment. A contract, worth about £50,000, for more than 50 Eddystone receivers (EC958/1) was placed last year and deliveries have already started. Now the Post Office has let a £60,000 contract with Field Tech Ltd for 1kW single-frequency, s.s.b. transmitters for delivery starting later this year. It had earlier contracted with Marconi Communications Systems Ltd. for 11 multi-frequency s.s.b. transmitters. These have now been installed and are giving service in conjunction with some existing transmitters capable of s.s.b. operation. International regulations require coast radio stations everywhere to provide an s.s.b. service as soon as possible.

As a further aid to shipping, the new services will have the additional facility of selective calling, which avoids the need for fixed calling periods. Each ship will have its own internationally-agreed code and at the modernized stations the code will be translated into sound tones by an encoder coupled to the transmitter. The code is sent out by the coast station when it wishes to call a ship. Decoding equipment, coupled to the ship's receiver, recognizes only its own code, and automatically sets off a visual or bleep alarm. The ship's radio officer then contacts the coast station to take the call. This system provides an automatic 24-hour watch without tying the radio officer to his set. The Post Office's encoders are being supplied by Moore-Reed Ltd.

The internationally-agreed program for conversion to s.s.b. permits ships to install new equipment working on double sideband (d.s.b.) up to the end of this year. All new equipment put in after then must be s.s.b. Both systems can be used until the end of 1981, when d.s.b. working is to cease.

The internationally-agreed programme for conversion to s.s.b. permits ships to install new equipment working on double sideband up to the end of this year. All new equipment put in after then must be single sideband. Both systems can be used until the end of 1981, when d.s.b. working is to cease.

Some stations also provide a short-range VHF R/T service (156–174 MHz). Their equipment is being modified or replaced to comply with new regulations, with channel spacing reduced from 50 kHz to 25 kHz to increase the number of channels available for calls.

Telephone Charges

The Post Office is putting proposals to the Post Office User's National Council for an increase in some telephone charges. This is the first increase since July 1970 and will yield an additional 3 per cent in revenue. The total sum that the proposed increases will provide is £30M in a full year.

For twenty-one months the Telecommunications business has kept its prices steady despite considerable increases in wages and cost of services. In the last twelve months alone the total wage bill of the business has increased by £60M per annum but substantial productivity performance has yielded £10M per annum to help offset these very large increases in costs.

Demand for the telephone, particularly from the residential sector, is at a record level and, overall, is 30 per cent up on last year.

To meet this unprecedented demand every effort is being made to increase supply which, overall, is running 20 per cent higher than a year ago. To support this the Government has agreed to increase the already massive investment program by a further £100M, of which £60M will be spent over the next three years.

To implement this program in the field the Post Office has already recruited an extra 1,000 engineering staff and a further 2,000–3,000 jobs will be created over the next two years. Industry, to meet the enhanced program, will be increasing its labour-force, particularly in development areas.

By these measures the waiting list, which now stands at 200,000 will be contained and, subject to satisfactory delivery of equipment from industry, progressively reduced.

With a rising investment program already running at £500M a year and totalling £3,000M over the next five years it is essential that an adequate level of profit should be maintained and re-invested in the business, and it is with this in view that the current increases have been proposed.

The proposed increases raise the installation charge for new customers from the present maximum of £25 to £35. Present charges for taking over an existing installation remain unchanged.

The charges for installing extra lines and for transferring a telephone to a new address remain at £20. The present £5 reduction where internal wiring exists, is ended.

Telephone rentals, at present £24 a year business and £20 residential are to go up by £2 a year, adding 50p to the quarterly telephone bills of all customers.

The Post Office has turned to installation charges for a substantial part of the extra revenue because of the high capital investment needed for this sector. By the end of the present financial year the Post Office will have provided 1·3 million new connexions—the highest yearly figure ever.

Yet the demand for new telephones in the residential sector is not matched by their profitability. It costs over £150 in plant for every new telephone added to the system, but only one new residential customer in four uses it enough to offset the low rental and produce the overall 10 per cent return on capital required by the Government. Since about half of the Telecommunications business's capital investment is spent on equipment for new customers, the Post Office feels it is only reasonable that new customers should be asked to pay a more realistic charge. Otherwise an added burden would fall on existing customers.

In the financial year 1970–71 the Telecommunications business with a profit of £93·5M slightly exceeded its financial target. Despite a £10M productivity gain the wage increases granted of £60M per annum during 1971–72, coupled with charges to the customer being held steady over the same period, will inevitably result in a decline in profit. With the income from the proposed tariff changes the profit for 1972–73 is forecast at £65M. This will produce a return on capital of 8·6 per cent compared with the target of 10 per cent. Thus the proposed increases do not fully restore the financial performance of the business but are judged to be the maximum justifiable during the present period of price restraint.

Post Office Work on Transistors Recognized by Queen's Award

A Queen's Award has been won by the Post Office's Research Department. Given for "Technological Innovation" in the development and production of high-quality transistors for use in undersea telephone cables, it recognizes the Post Office's leadership in, and invaluable contribution to, worldwide international communication.

During the last 10 years the Post Office Research Department has perfected transistors—vital for boosting telephone calls along cables—so that they can work non-stop without failure for at least 25 years. And in addition their performance has been uprated so that the call-carrying capability of undersea cables—forming the backbone of international communication—has been raised dramatically.

Today the most modern submarine cable systems carry more than 1,800 telephone conversations simultaneously compared with only 100 or so in the early 1960s. Cables of even greater capacity—carrying up to 4,000 conversations at once—are on the way.

All this has been made possible by the pioneer work of Post Office research teams backed by U.K. industry not only in developing these vital components capable of working to performance tolerances and reliability never before achieved, but in perfecting a manufacturing process that can be used with a high degree of confidence.

In pioneering these production processes the Post Office established a special transistor manufacturing unit at its Dollis Hill Research establishment in North London. In conditions which are among the cleanest in the world—the smallest speck of dust will ruin a transistor—staff, gowned like surgeons, produce several hundred transistors ever week. The transistors are inspected and tested many times and are subjected to rigorous reliability checks. In the 10 years of their use no Post Office transistor has failed in any submarine cable system.

The advances achieved by Post Office research have been a major factor in enabling administrations throughout the world to keep pace with the exploding demand for international telecommunications services. Moreover, the work has helped to keep down costs. Today the cost of each telephone circuit on a submarine cable is only an eighth of what it was 10 years ago. This has been a significant factor in stabilizing, and even reducing, the cost of international telecommunication services.

These devices, with a guaranteed life of not less than 20 years, are the key elements in the submerged repeaters of international and intercontinental submarine cable systems. They determine the circuit capacity of the cable and the cost per circuit mile. In 10 years the number of circuits per cable has increased more than five-fold, through the introduction and progressive improvement of the transistors. There are 1,840 circuits in the latest CANTAT 2 system which use the 10A-type transistor, and 4,000 circuit may be possible when amplifiers using the new 40-type transistor are available.

In the same 10 years the cost per circuit mile in the submarine link has been reduced by a factor of eight.

The electrical performances of the earliest 4A-type, of the 10A-type and of the latest 40-type all compare well with their commercial contemporaries but the most important innovation is the achievement of ultra-reliability. The submarine system will fail if a single amplifying transistor, in a total of more than 3,000 in the longest cables, fails catastrophically, or if the mean gain change of all the transistors exceeds plus or minus three per cent. In addition the gain change of a single transistor must not exceed plus or minus fifty per cent. A guarantee is given that, in these terms, less than one transistor in 4,000 will fail in 20 years and that the mean gain-change specification will not be exceeded in the same period.

It has been possible to give this guarantee only through the adoption of a new, improved thermo-compression bond, by the adoption of better piece-part pre-processing and by the use of special stabilizing methods. In addition screening has been designed to exclude defective or unstable devices. Meticulous attention to all aspects of the technology and quality control procedures is demanded from every member of the staff engaged in this complex production effort. Critical product evaluation using overstress ageing assessment techniques on many transistors has enabled confident prediction of service life to be made.

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The *Journal* is published quarterly, in April, July, October and January, at 21p per copy: 31p per copy including post and packing (£1.24 per year) (3 dollars Canada and U.S.A., per year). Back numbers will be supplied, if available, price 24p (34p post paid) per copy. January and April 1969, October 1968, and all Journals earlier than July 1967 (except January and October 1966) are no longer available. Orders, by post only, to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, EC2V 7AG.

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Readers can have their copies bound at a cost of £1.87½p plus 24p (40p overseas) return postage, by sending the complete set of parts, with a remittance to Press Binders Ltd., 4 Iliffe Yard, London, S.E.17.

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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*.

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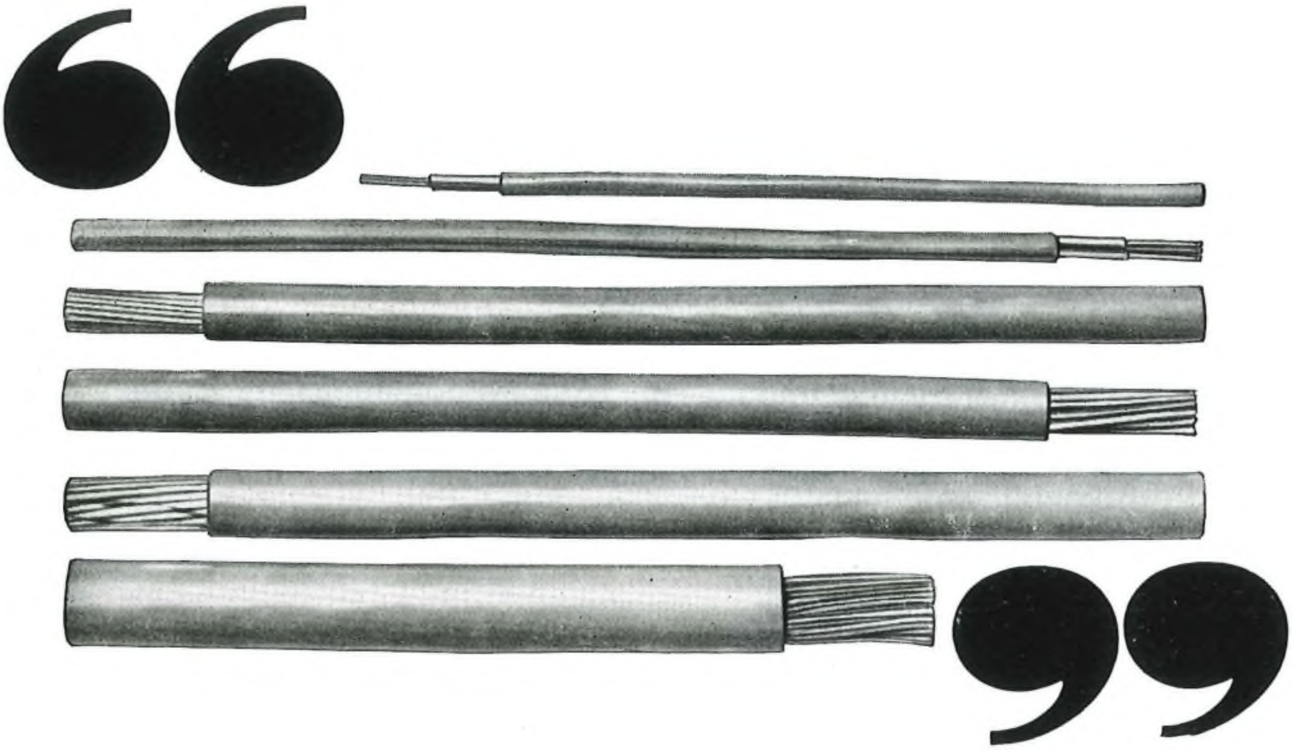

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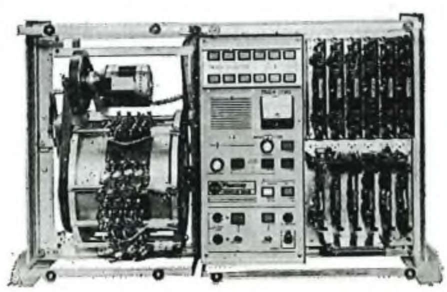

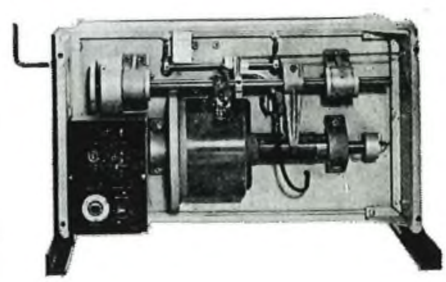

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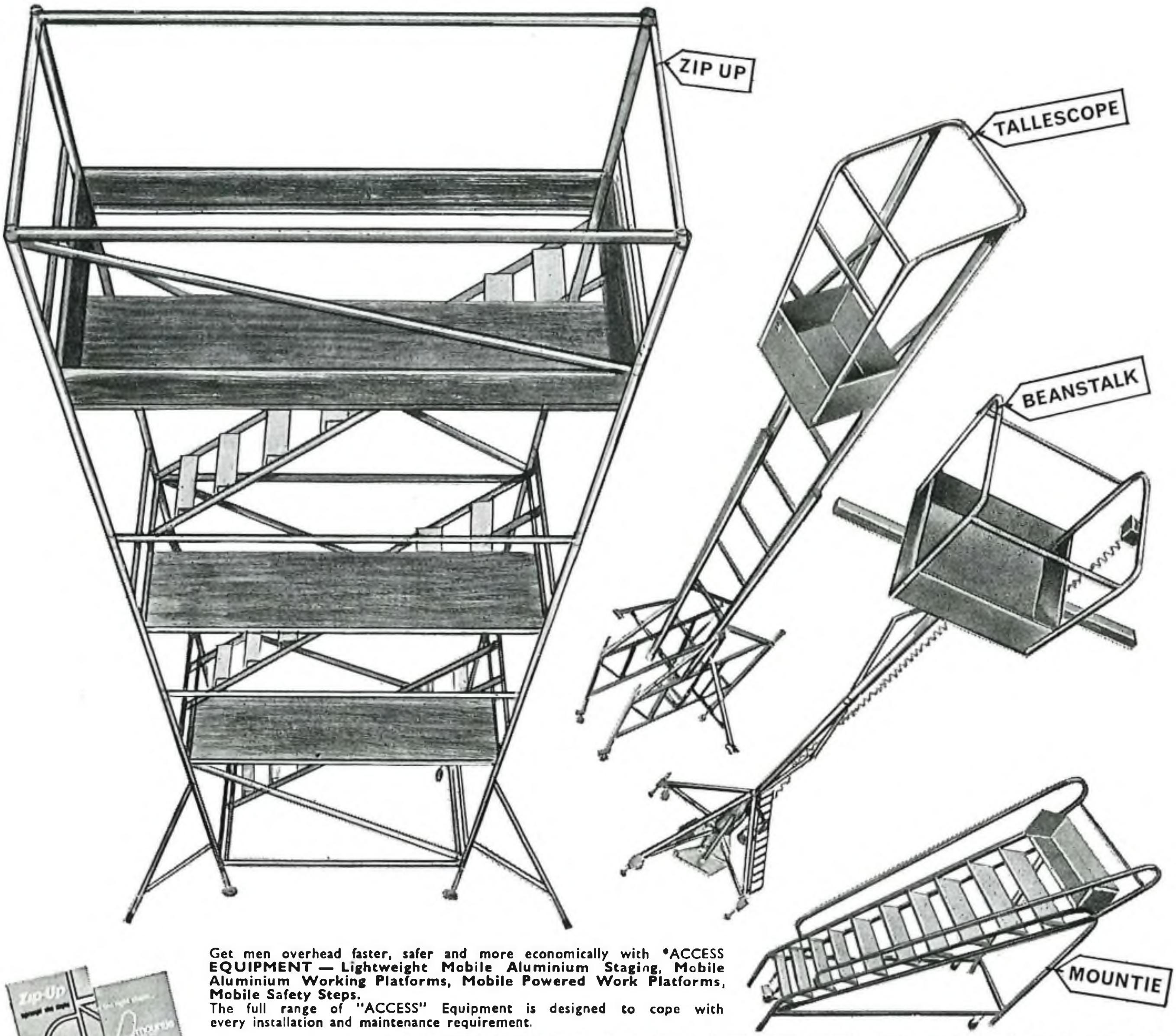

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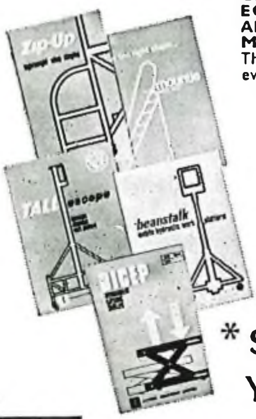

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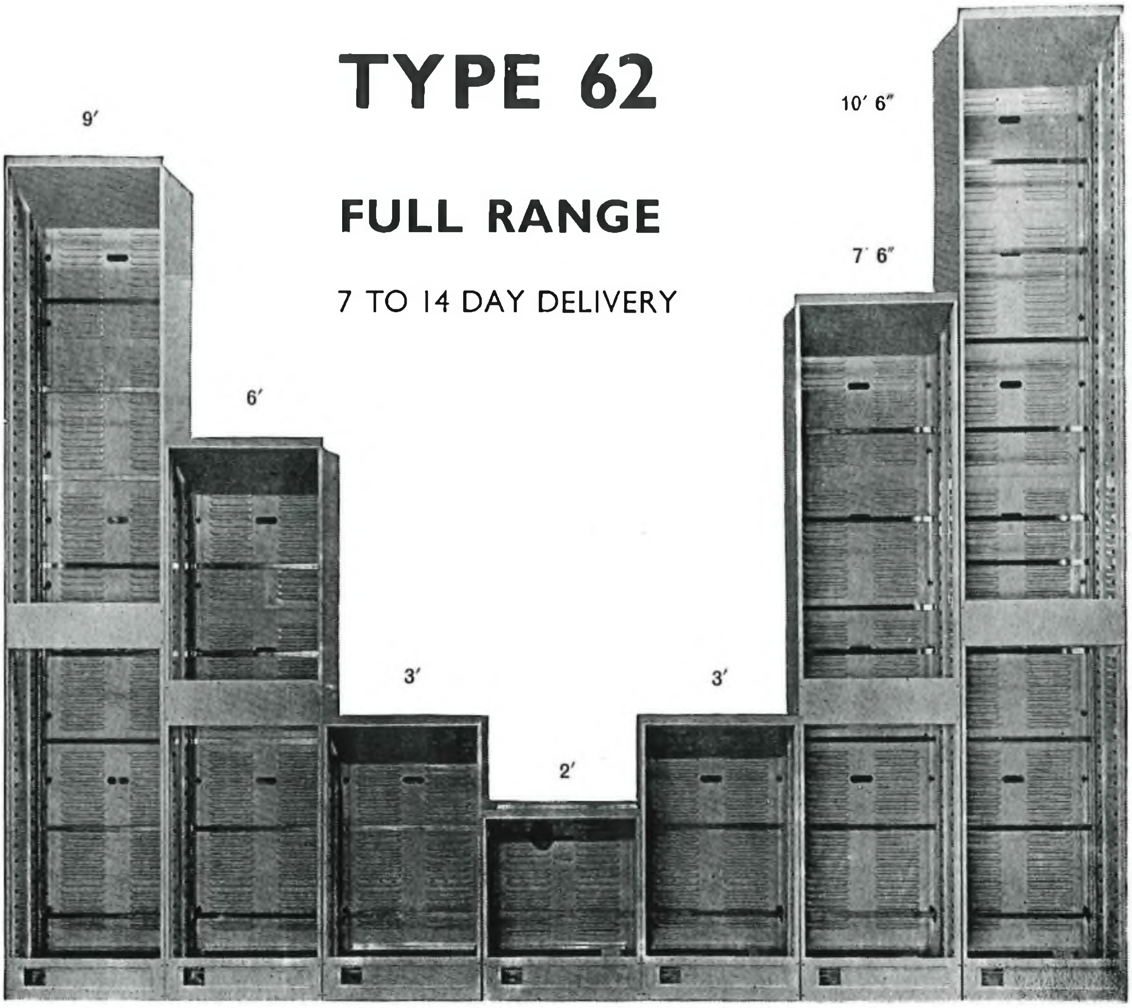

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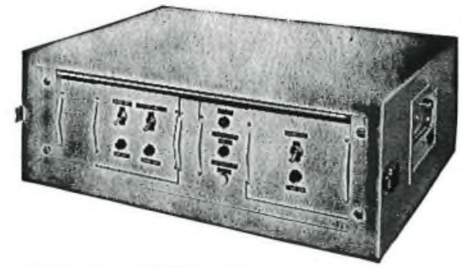

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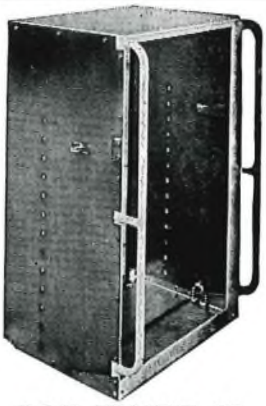

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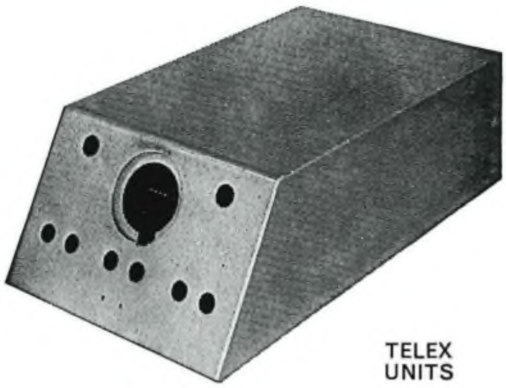
DATEL MODEM



TELEX UNITS

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