Mr. Roe PE12

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Contents

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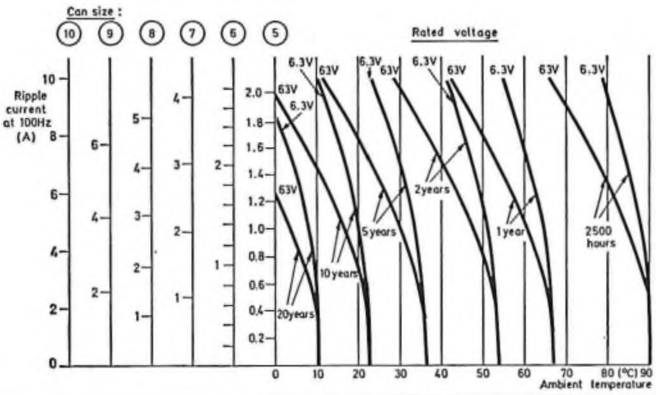

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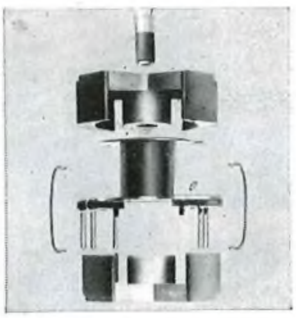

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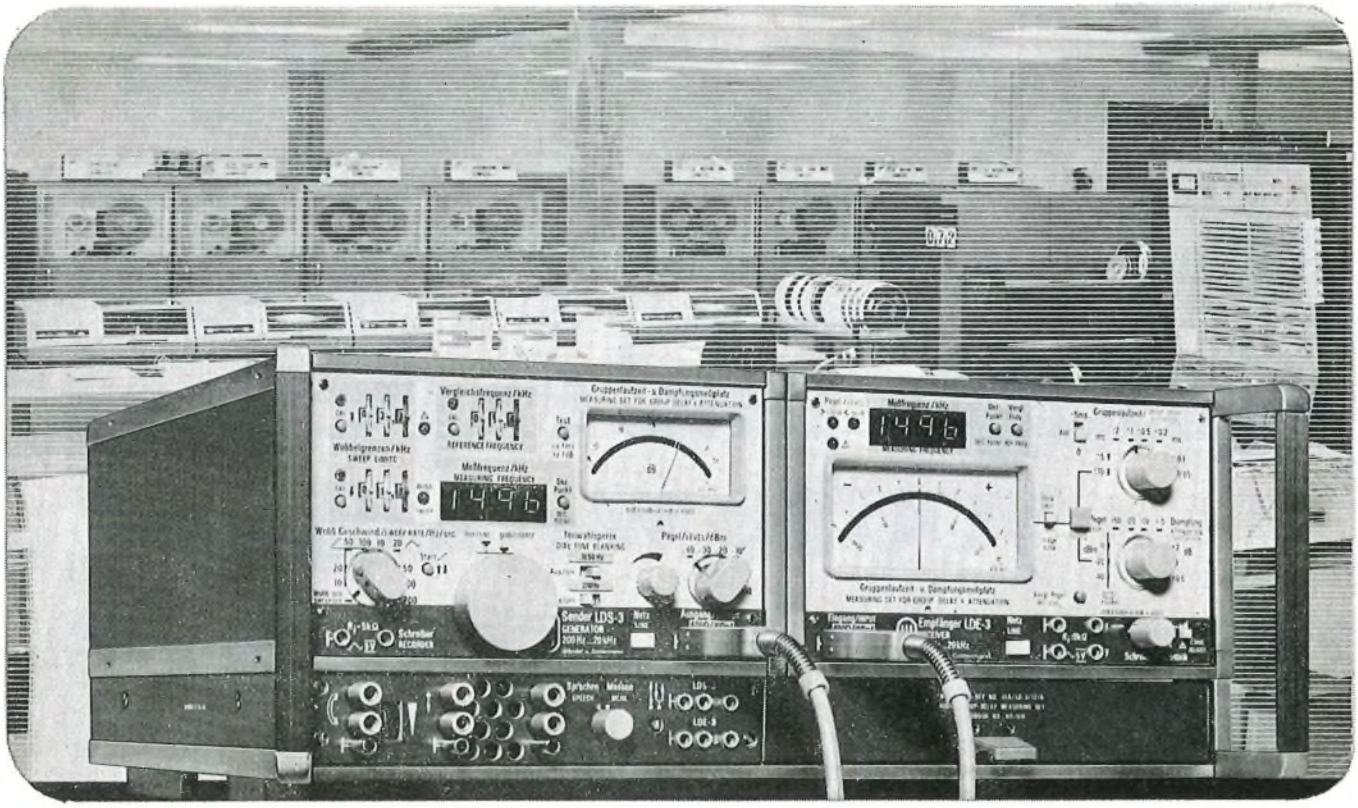

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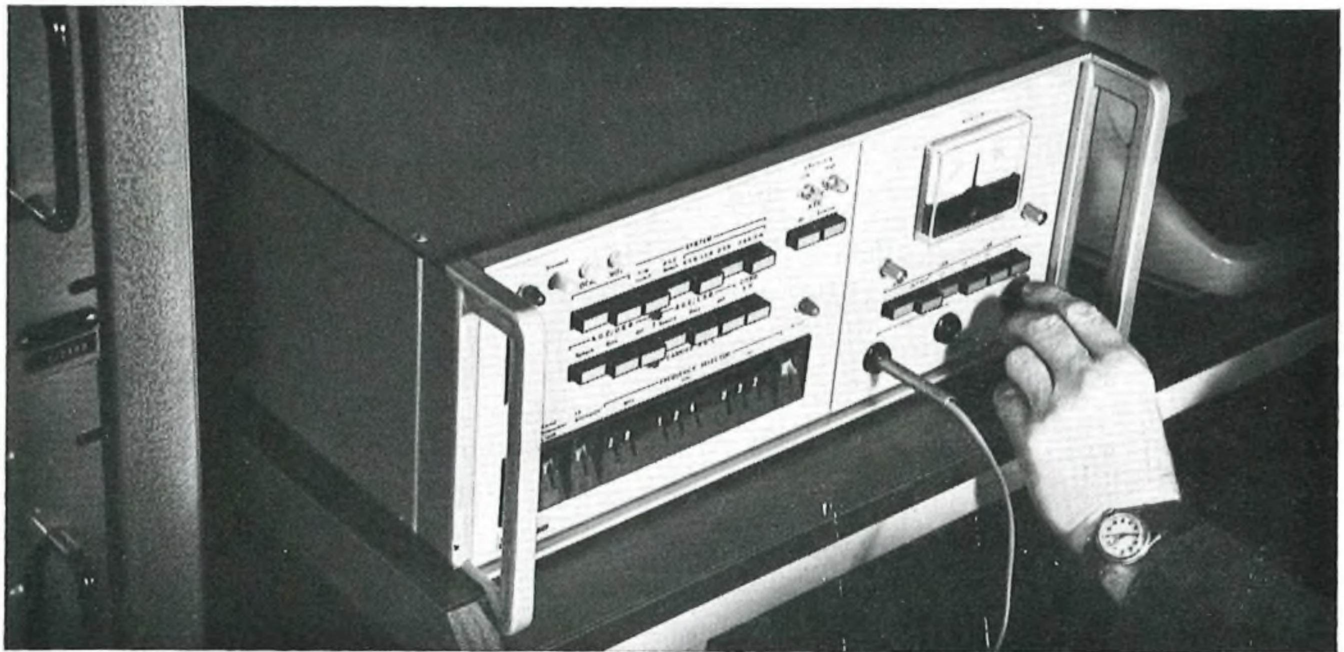

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The Post Office Electrical Engineers' Journal

EDITORIAL

The national press has recently given publicity to a spate of fraudulent long-distance telephone calls, some of which are of a scarcely-believable nature. It has been suggested, by at least one national newspaper, that the "phone phreaks", as the originators of the calls have been alliteratively dubbed, can obtain some of their data from the *Journal*. It is true that *Journal* articles sometimes include information that might conceivably be used for this purpose, but normally both author and editor are at pains to exclude sensitive material.

One of the purposes of the *Journal* is to disseminate technical information on telecommunications subjects to a wide range of interested readers. As in any other field there is some danger that such information will be misused by a very few dishonest individuals with a distorted and immature outlook. Against that must be set the immensely useful function of the *Journal* in promoting a better understanding of telecommunications developments throughout the world.

From time to time readers enquire if the earlier practice of publishing lists of promotions, retirements, etc. of I.P.O.E.E. members can be restarted. Unfortunately, the necessary information is no longer available in a suitable form from staff units and this, together with the large increase in numbers that would be involved, makes revival impracticable.

A New Code Translator for the Letter-Sorting System

Part 2—The Code-sort Translator: Design and Testing

K. H. C. PHILLIPS, C.ENG., M.I.E.R.E. and A. W. STURGEON, B.SC.(HONS.)†

U.D.C. 656.851 : 681.187

Part 1 of this article described the application of the Postcode and other address-coding techniques in the organization and control of mechanized letter sorting. This part deals with design and testing of a new code-sort translator which provides new facilities and offers scope for the sorting office management to rationalize sorting methods by using sorting machinery more effectively. The equipment forms the first "real time" application of computers to control systems in postal engineering.

INTRODUCTION

The letter code-sorting system was originally designed to function within the long-established manual letter-sorting and distribution framework. For machine sorting, the Postcode or other address information is encoded by the coding translator in the form of two codemarks which are printed on the letter; one codemark identifies the delivery town or district, the other, the address within that district. The original sorting-translation equipment was designed to control the operation of sorting machines using information derived from either the outward or the inward part of the Postcode, but not both simultaneously. The decision to concentrate mail sorting into a limited number of Mechanized Letter Offices (M.L.O.s) highlighted this limitation and showed a need for a new sorting translator which would be sensitive to both rows of codemarks.

This change in the sorting-translator function had repercussions on the facilities required of the coding translator. A study of these together with the desire to introduce some new translator facilities culminated in the decision to develop a second-generation coding and sorting translator system as a single unit. From an appraisal of the translator system requirements, and after investigation of a number of methods of realizing the objectives, it was decided that the use of a number of small "off the shelf" computers in conjunction with a magnetic-drum store and purpose-designed electronics would best suit the application. The primary design aims were to reduce the capital cost of translation equipment in each M.L.O. whilst providing a means of improving the cost effectiveness of mechanized letter sorting.

CODE-SORT TRANSLATOR FUNCTION

In the mechanized letter-sorting system adopted by the British Post Office, the address information used in the letter-sorting process is encoded and printed on each envelope in a form suitable for automatic reading by letter-sorting machines. The process of reading the address from the envelope is a manual task, and letter codemarking is carried out at operator-controlled letter-coding desks. At each coding desk, letters are presented individually to the operator, who copy-types the Postcode, or specified parts of the address, on a near-conventional keyboard. The keyboard code is then translated, by the coding translator, into one or two groups of codemarks which are printed on the face of the envelope. Automatic letter-sorting machines, each capable of handling up to 20,000 letters per hour, sort the codemarked letters into 144 separate groups. The phosphorescent codemarks are detected by the sorting-machine reader after stimulation by ultra-violet light and the information derived from them is then used to control the path of the letter through the sorting machine and into the selection box associated with the address.

In mechanized sorting, it is impractical and uneconomic to provide an individual sortation box for each of the 1,700 postal delivery districts in the United Kingdom, or even for each delivery point within the local postal distribution area. Also, it would be uneconomic to install sorting machines having fixed sorting methods. Thus, to secure sorting flexibility, it is necessary to be able to route letters bearing any codemark to any sorting-machine selection box. The conversion of the codemark data into sorting-machine command signals is implemented by the sorting translator.

On a codemarked letter (Fig. 1) the outward codemark identifies the delivery town or district; the inward codemark denotes the delivery location within the area defined by the outward codemark. Each 14-bit codemark (one start bit, plus 12 code bits, plus one parity bit) can identify 4,096 different locations. Thus, it is theoretically possible to identify one address in 16 million.[1]

The achievement of an optimum mechanized sorting arrangement is conditional on all the available codemark information being used for machine control at each sorting stage. The sorting translator to be described has been designed to meet these requirements through

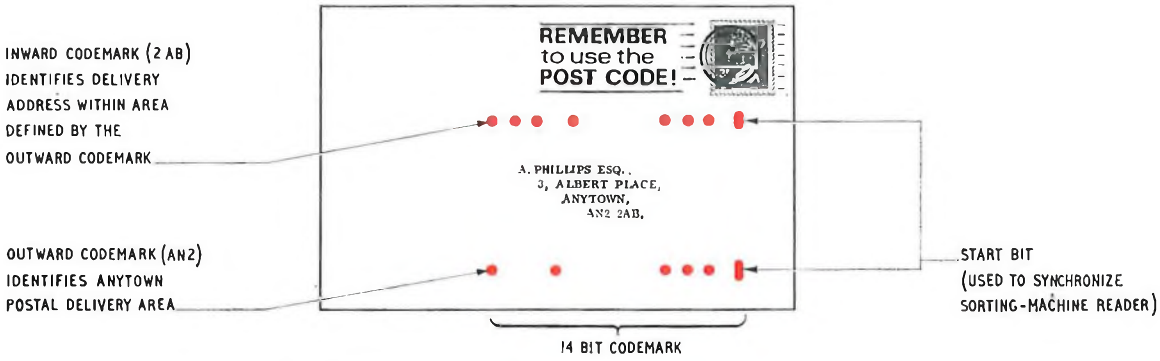
(*a*) being sensitive to both rows of codemarks (when present) at all stages of sorting, and

(*b*) permitting the alteration of the sorting-machine command signal, associated with each codemark, to facilitate alternative machine-sorting methods.

These features offer the means of equating the letter-traffic load of the sorting office to the sorting capability of the machines. This permits the number of sorting machines required to be minimized, thus reducing the capital investment.

Fig. 2 illustrates a simplified mail-flow arrangement within a mechanized letter-sorting office, and shows the function of the code-sort translator.

† Postal Mechanization and Buildings Department, Postal Headquarters.



Note: The codemark is printed in a phosphor which is normally invisible.

Fig. 1—A codemarked letter

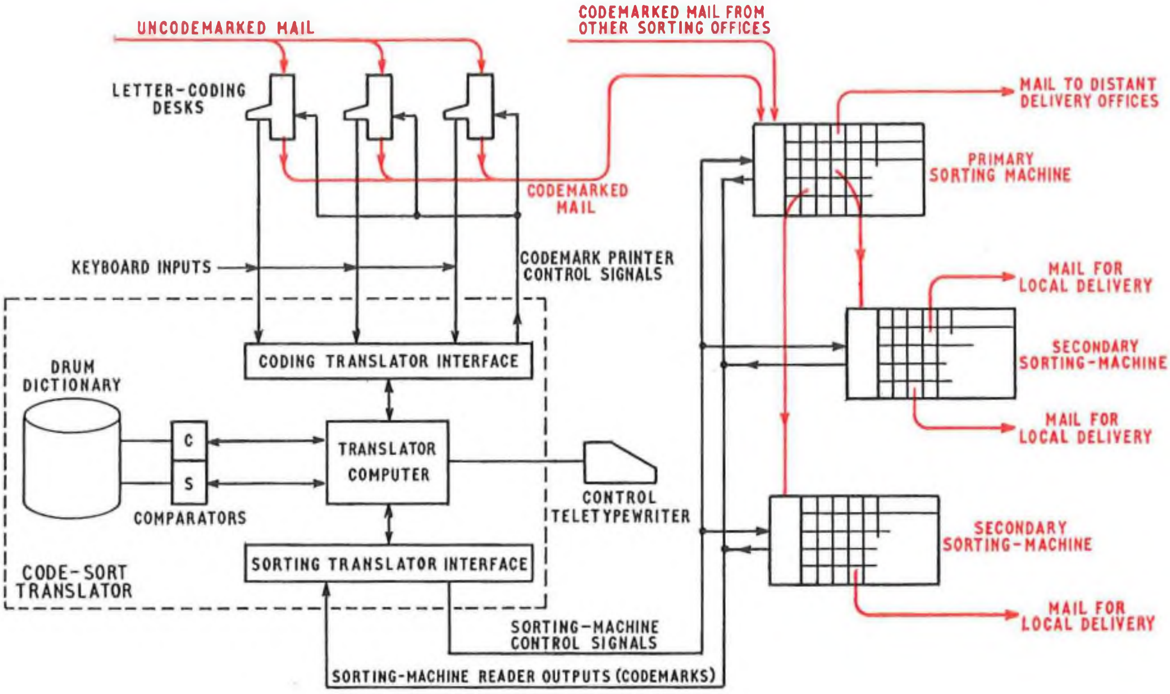


Fig. 2—Simplified mail flow arrangement in a mechanized letter office

DESIGN CONSIDERATIONS

The translator is required to operate reliably in the letter-sorting office where even short-duration system failures could result in significant disruption to the distribution and delivery of mail throughout the country. Consequently, sufficient redundancy has to be built in to allow continued operation in the event of partial equipment failure.

Since the number of coding desks and sorting machines installed in M.L.O.s can vary significantly, the equipment has to be modular in design and capable of serving, economically, the varying machinery complements within each M.L.O. The translator has to afford the sorting-office management with an effective means of organizing and controlling the flow of mail through the office, and must be capable of providing new facilities which might be needed in the future.

Data conversion can be achieved using a variety of techniques. The choice of method was influenced by the following factors:

(*a*) In both the coding and sorting translation processes, no direct relationship exists between the form of the input data and that of the translated output data.

(*b*) In the sorting process and, to a lesser extent, in the coding process, the translated information associated with a specific input is frequently changed—sometimes at short notice—to accommodate alterations to the sorting methods employed within the M.L.O.

(*c*) To allow the coding-desk operator to work effectively without distraction, the translation process must be completed without perceptible delay. Both to avoid frustrating the operator and to satisfy the existing (and possible future) sorting-machine control requirements, the translator must return an answer to each input question within 60ms.

The absence of an algorithmic relationship between the input and the translated output results in the need for a dictionary capable of storing all the reference and conversion data appropriate to the translation process. A store with a capacity of up to 3 million bits was needed and a magnetic storage drum, operating in parallel-read mode, was chosen.

SYSTEM REALIZATION

In the translator system, a number of small, relatively inexpensive (less than £4,000) computers were used in

From left to right this photograph shows two translator cabinets, a common-equipment cabinet and two magnetic-drum cabinets.

FIG. 3—The prototype translator equipment

preference to a single large computer, since this provides modularity and a means of achieving security of operation through computer interchangeability. The computers are identical and each has a memory of 4,096 16-bit words. The function required of a computer is governed by the program which is loaded. These separate system programs include

(*a*) translation control,
(*b*) system monitoring,
(*c*) magnetic-drum data loading and verification,
(*d*) translator dictionary updating, and
(*e*) maintenance diagnostics.

The translator equipment is shown in Fig. 3. There are two identical drum cabinets, each storing all the dictionary data for an M.L.O. The drum systems are interfaced to the translator cabinets via the common equipment cabinet. This cabinet also contains two computers, one of which normally holds the system-monitoring program but is loaded with programs (*c*) or (*d*) (above) when changes to the data stored on the drums are required; the other is a spare which is provided in larger installations. The translator cabinets are identical, and each is capable of carrying the traffic of 24 coding desks and 10 sorting machines. The number of translator cabinets fitted in the system is determined by the number of machines to be connected. Up to four translator cabinets can be accommodated with no modification to the system programs or electronics.

Since all the computers are interchangeable, the effects of one, or two, computer failures can be tolerated by using the spare, and even the monitoring computer, to secure full service. In the event of a major failure in a translator cabinet, changeover facilities enable all, or some, of the associated machine control to be transferred to the remaining operational equipment.

SYSTEM DESIGN

Outline of Translator Operation

The data conversion principle used in the translator can be likened to the process of looking up a word in an English–foreign-language dictionary. The word for which the translation is required is compared with all the other words until a correlation is found, and the corresponding translation is read out. In mechanized letter sorting two dictionaries are required. The two groups of information stored give the relationship between

(*a*) the operator-generated keyboard address code, and the corresponding codemark to be printed on the envelope, and
(*b*) the codemark information detected at the sorting-machine reader, and the sorting-machine command signals.

In the translator equipment, all the reference and conversion data necessary for the coding and sorting translating processes is stored on a magnetic storage drum. By loading the translation dictionary so as to present input question and corresponding answer information at the drum output in parallel, all translator reference information can be presented sequentially for interrogation during each drum revolution.

Dictionary interrogation is carried out by loading question data, originating from the coding desk or sorting machine, into a comparator. The comparator sequentially compares the question data with all the similar data stored on the drum. When exact correlation is detected, the associated answer data is copied from the drum and staticized in the comparator. The answer data is subsequently returned via the data processing and control equipment to the machine originating the translation request. Control of both coding and sorting translation operations is exercised by a common digital computer. A diagram of the translator system organization is given in Fig. 4.

Drum System

The magnetic drum provides a reliable and secure memory for the translator data and control information. By operating the drum store in parallel-read mode, the entire memory contents can be presented at the drum outputs in data formats convenient for high-speed interrogation. The maximum drum-data output rate in the translator application is equivalent to 100 Mbits/s.

The data associated with each group of dictionary information is connected to separate parallel drum data highways which serve the comparators in the translation equipment.

The processes involved in preparing the data, the method of loading and storing the dictionary information on the drum, and the magnetic-drum-store operating system are described in the concluding article of this series.

Translation Equipment

Since the input and output data formats pertinent to each translation process are different, the two dictionaries are interrogated via separate coding and sorting comparators. To service the inputs generated by a number of coding desks and sorting machines within the translator access time of 60 ms, a number of comparators of each type are required. The number of comparators connected to each dictionary data highway is determined by

(*a*) the translation-request rate generated by the coding desks and sorting machines,
(*b*) the mean access time of the magnetic-drum store, and
(*c*) the mean processing time of the translator computer.

The translator computer distributes the questions sequentially amongst the available comparators in each group. If all the comparators within a group are engaged, the computer queues the question inputs until a comparator becomes free.

Since all the comparators within each group are connected in parallel to the respective drum data highways, individual comparator occupancy times are determined by the time taken to detect data correlation. This can vary between a few microseconds and up to 40 ms. Drum interrogation is, consequently, controlled by the comparator, and the computer is concerned only with the allocation and loading of the

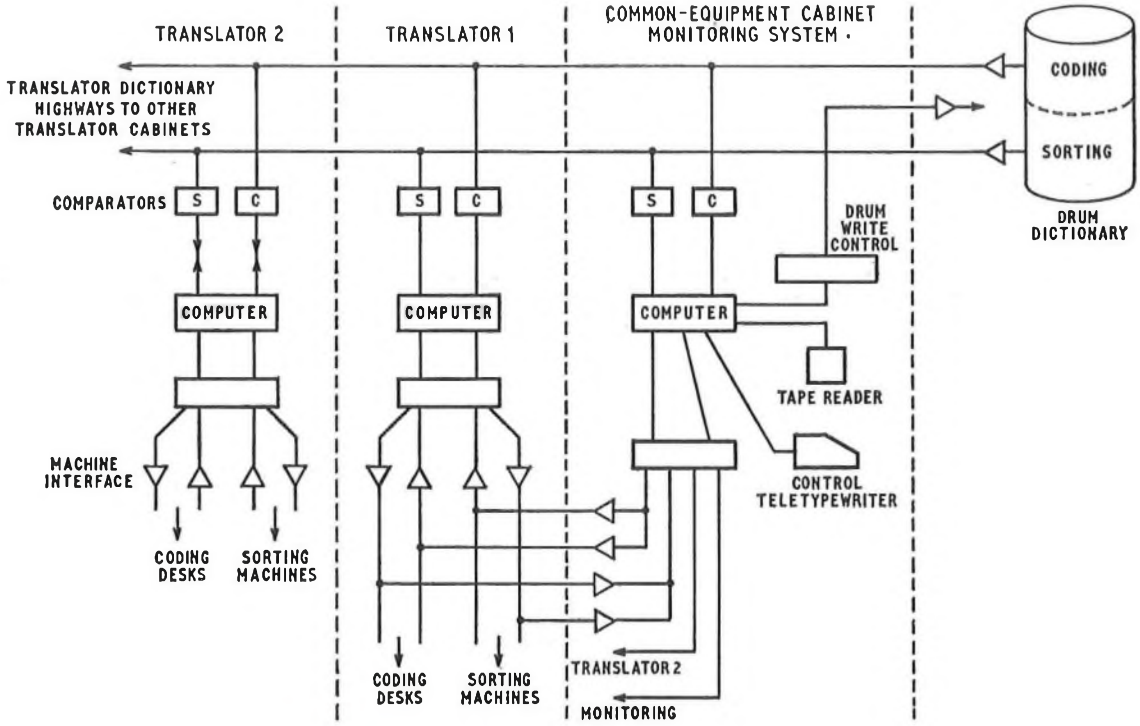


Fig. 4—Translator system organization

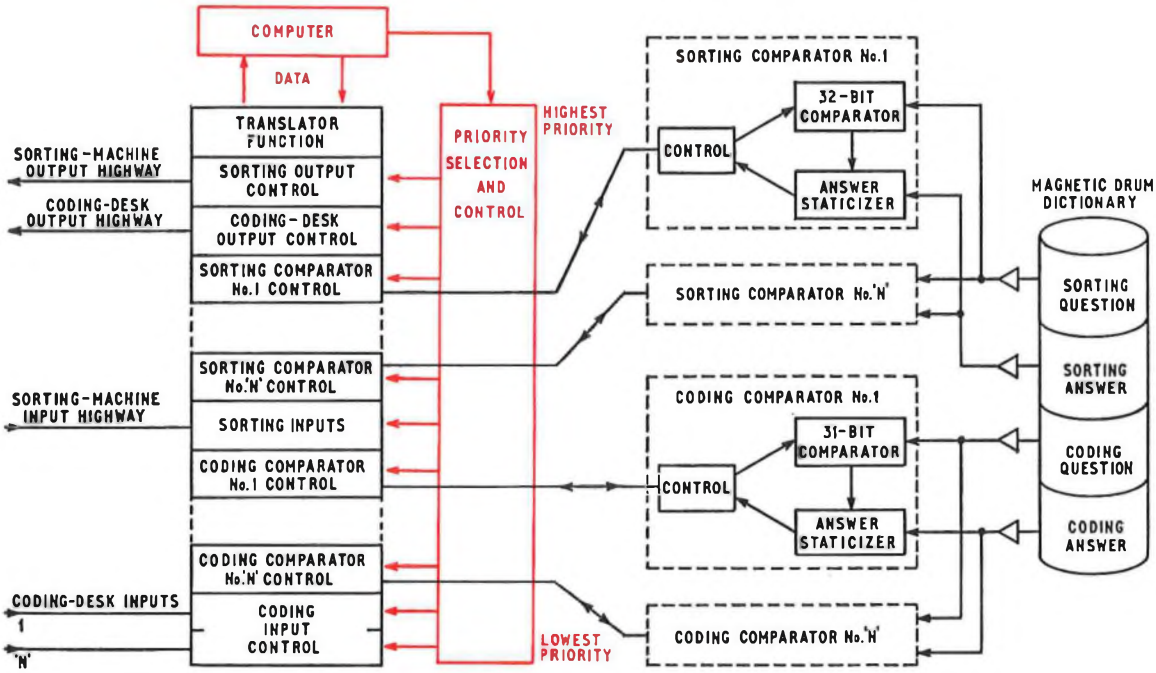


Fig. 5—Diagram illustrating translator functions and computer processing priorities

comparator followed some time later by unloading the answer. This feature ensures that the processing capability of the computer is used effectively.

The translator communicates with the letter-handling machines over parallel data highways, some of which are time-shared. Highway interface voltages (0 volts and + 12 volts) and data transmission rates (5 kHz) are chosen to minimize the effect of electrical interference within the M.L.O. A block diagram of the translator is given in Fig. 5.

Computer Processing Method

Within the computer, each translation process is treated separately although, in practice, the computer interleaves the processes concerned with both translation functions. Each computer executes data processing or control functions on demand. Each of these functions is assigned a servicing priority. When two or more requests for service are present, the computer deals first with the function having the highest priority, if necessary interrupting any current processing activity concerned with a lower priority function. Subsequently, the computer reverts to dealing with other processing requests in decreasing order of priority, eventually returning to the original processing activity. This mode of computer operation is referred to as *interrupt* working and, in the translator, is used to ensure that time-critical processing functions are implemented without significant delay.

CODING TRANSLATOR

Operational Features

In the letter-coding process, for each Postcode copy-typed by a coding-machine operator, the translator is required to provide two 14-bit binary codemark-printer-control signals. These cause the outward and inward codemarks to be printed on the envelope. When the postcode is not present, the keyboard code generated is translated into a single 14-bit code.

At the output of each coding desk, letters are separated into groups by means of a letter diverter which can be translator controlled. This feature provides a means of segregating the mail into two groups categorized by the code keyed by the operator, and enables mail to be sorted at the coding stage into groups convenient for further mechanized sorting. Up to five different modes of coding-desk sorting can be selected by the operating staff to suit the mail-flow arrangements required at any stage of mail processing.

System Description

The keyboard associated with each coding desk is connected directly to its own single-character store in the translator. The operator-generated keyboard codes are loaded asynchronously from each coding desk, one character at a time, into the translator computer store. The characters originating from each coding desk are compiled in dedicated areas within the computer store. On receipt of each character, the alphanumeric format of the currently-assembled code is checked until a data format corresponding to a complete, valid, address-code is recognized. Twenty-six different address- or question-code formats, assembled from 2–7 character codes, are acceptable.

After recognition of a valid question code, the computer sends the keyboard code to a free comparator. If the question code has a Postcode format, the question data is divided into outward and inward sections and loaded into separate comparators. Within the comparator, the question data is assembled into a 31-bit word. The computer notes the number of the comparator to which the question was directed, and the coding desk from which the input was received, and relinquishes control of the comparator. When the comparator detects a correlation between the staticized question code, and the identical code in the dictionary, the associated 14-bit codemark-printer-control answer is staticized. The current computer-processing activity is then interrupted to transfer the staticized answer into the computer store. If, after a complete scan of the dictionary, no correlation is detected, the comparator interrupts the computer and a *no-answer-found* word is transferred to the computer store. The comparator is then made available for further access by the computer.

The codemark-printer control data is subsequently format checked and associated with the number of the coding desk to which the answer is to be returned. If the answer received from the comparator forms part of the response to a Postcode-type question, the computer waits for the second comparator to answer before routing the two-part translation to the appropriate coding desk. The answer data is routed to the calling coding desk over a common time-shared output-data highway. Since the serial transmission rate over this 13-bit parallel highway is limited, to secure high noise immunity (pulse width 200 μs), it is sometimes necessary to queue the answer data on the output highway under computer control.

The translator computer can deal with traffic originating from up to 24 coding desks each making up to 2,000 translation requests per hour and giving a worse-case answer-back time not exceeding 60 ms.

SORTING TRANSLATOR

The codemark data detected by the sorting-machine reader comprises one or two groups of 14-bit codemarks. The 28-bit codemark-question data originating from all sorting-machine readers is sent in parallel over a time-shared input highway to the translator. This data is augmented by a 7-bit sorting-machine function word which defines the sorting method or plan to be implemented, and the method to be adopted in sorting incorrectly-codemarked mail. The transmission of data over the 35-bit parallel input highway is controlled by the computer. The translator accepts inputs over the data highway on demand from each sorting machine.

On receipt of each input, the computer checks the format and correct parity of the codemark data together with the *sorting-plan-selected* code. Inputs having incorrect parity in the outward codemark are automatically routed to the parity-fail selection box on the sorting machine. Inputs having incorrect parity on the inward codemark are either sorted, using the valid outward codemark, or routed to the parity-fail selection box as determined by the destination of the codemarked letter and the parity-fail sorting method selected by the sorting-machine attendant. Inputs having correct format are loaded into a sorting comparator where a 26-bit codemark word and 6-bit plan-selection word are assembled for comparison against the sorting dictionary. The two start bits associated with each codemark and the parity-fail sorting-control bit are not loaded into the comparator.

In the dictionary, a number of sorting-machine command signals are associated with each 26-bit codemark. The comparator seeks, initially, a dictionary correlation with the codemark data and, when one is found, a correlation with the sorting-plan data. When the double correlation is detected, the corresponding sorting-machine-control data is staticized in the comparator answer register. Subsequently, the comparator interrupts the computer and the 8-bit answer code copied from the drum is transferred into the computer memory. This 8-bit code is then converted by software into the 1 from 5 plus 2 from 10-bit form necessary to control the path of the letter into one of the 144 sorting-machine selection boxes. The translator sends the answer data to the sorting machines over a time-shared answer highway using the same transmission techniques as described previously.

As mentioned earlier, a 26-bit codemark combination read from the letter can identify 16 million delivery locations. In practice, the sorting dictionary stores only those codemark combinations which are necessary to the sorting of mail circulating through the office in which the translator is used. Since the address information contained within the outward codemark is, usually, sufficient to enable machine sorting to distant delivery offices, only the outward codemarks pertinent to distant sorting offices are stored. Letters bearing codemarks which are not held in the sorting dictionary in combination with the sorting-plan code are routed to a common sorting-machine selection box. Such mail is dealt with by the sorting office staff.

The translator computer can deal with traffic originating from up to 10 automatic letter-sorting machines, each sorting up to 20,000 letters per hour. The equipment translates any 26-bit codemark combination into sorting-machine control signals on up to nine different sorting plans (a capacity to accommodate up to 61 different sorting plans is provided).

SYSTEM MONITORING

In the mechanized letter office, the effect of a translator malfunction could misdirect mail, or introduce delays, and increase the proportion of letters requiring manual sorting. In order to minimize this, the system incorporates a number of self-testing and monitoring facilities.

The correct operation of the translator is verified by generating test coding- and sorting-translation requests and monitoring the responses. By careful selection of the test data used (a group of test questions and answers is written on to the drum), the majority of the translator-system hardware and software can be exercised fully.

Three levels of system monitoring have been incorporated and these are described below.

Routine Testing

All the comparators associated with one translator computer are cyclically tested by that computer. The operation of each comparator is checked by monitoring the replies to the test questions. When unscheduled answers are received the comparator is busied to normal traffic. The test program retests a busied comparator regularly and returns it to service when correct operation has been established. If a drum system fails, all comparators are busied sequentially to prevent the miscoding and mis-sorting of mail.

Performance Monitoring

The computer in the common-equipment cabinet is utilized to monitor the overall performance of the translator system. This is achieved by sending test questions to each translator equipment via any normal coding and sorting translator-input interface, and monitoring the replies at the appropriate output interface. Most of the translator system hardware and software is exercised in this way. The performance of the drum systems is checked using dedicated comparators associated with each drum.

Faults detected in the system are brought to the attention of the maintenance staff by a fault-indicator panel on the equipment. Descriptions of all current faults in the system can be obtained by the maintenance staff through a faults-report output on the system-control teletypewriter. Faults detected in the translator equipment are communicated to the monitoring computer over the normal translator output interfaces. In the event of a teletypewriter failure, all error conditions present in the system are stored in the monitor computer and an indication of the presence of each type of fault is given by indicator lamps on the computer control panel. In the absence of a monitor computer, fault indications are given on the control panels of each translator computer.

Manual Testing

The performance of the translator system can be manually checked using the control teletypewriter. In most manual testing operations, a conversational mode of communication is employed. Any coding or sorting translator input can be simulated and the answers are printed using a number of formats to aid maintenance. From the teletypewriter, the operator can select any translator or drum system, and even any comparator within any translator, and conduct a range of tests. For example, any selected input question can be routed, repetitively, to any comparator to facilitate checking of the translator circuitry. Any computer can be halted if it is found to be malfunctioning due to hardware or memory corruption fault.

TRANSLATOR TESTING

Since a real-time computer-based translator was to be used, it was deemed necessary to build a testing device capable of exercising the translator system as completely as possible. This presented a number of problems. The translator system is program-controlled, and program performance is not as easily checked as with a hardware-based system. In order to establish that the translator system was operating correctly and that the predicted performance of the equipment for different densities of traffic had been achieved, it was decided that the tester should take the form of a traffic generator. By simulating realistic traffic inputs to the translator from a number of coding desks and sorting machines, most conditions involving simultaneous requests for service can be presented to the computer operating system. Also, all the data and control paths through the system can be exercised. Though all the combinations of conditions which can occur within the system cannot be directly predicted, the probability that the system is fully exercised can be increased by conducting a number of tests, each generating large amounts of traffic. Individual test runs could be made to generate in the order of 100,000 requests for translations.

Additionally, the tester had to be used as a tool in debugging the translator programs. This necessitated a different emphasis on the type of testing required. Such a multi-functional tester is not easily realized using purpose-built hardware so, to achieve the required flexibility, tester control was implemented through a small computer of the type used in the translator. This computer can be programmed to produce a range of tests and present the results in any required form. Hardware had to be designed to interface the computer to the translator and simulate correctly the connexion of a number of sorting machines and coding desks.

Testing Facilities

The tester provides the following facilities:

(*a*) simulation of 12 coding desks and 10 sorting machines (to simulate the 24 coding desks necessary to test the translator, the traffic rate of the 12 coding-desk inputs was doubled),

(*b*) ability to produce all valid and invalid types of coding-desk and sorting-machine data,

(*c*) variable programmable translator calling rates,

(*d*) monitoring of all translator responses and detection of system malfunction,

(*e*) calculation of translator answer-back delay for each simulated input and presentation of this performance data in histogram form,

(*f*) a time-dependent record of all tester input and output operations,

(*g*) on-line production of error messages, and

(*h*) generation of simple tests to check translator input and output interface performance.

General Description

The sorting machines each send a 35-bit question to the translator and operate, typically, at a rate of 350 translation requests per minute. Coding desks can operate at speeds up to 50 letters per minute. Every letter requires a translation of a message consisting of a number of keyed characters, each comprising six bits of character data and three bits of mode information. To simulate the keyboard signals which go to make up a coding-desk message, inter-key depression times are simulated as being, typically, 200 ms with a minimum value of 35 ms. The time between completed keyboard messages, typically 450 ms, is also simulated.

To generate traffic realistically, the time between sequential outputs from the tester must be random. Three-groups of inter-output data are required; one for the coding-desk inter-character times, one for the coding-desk inter-message times, and one for the sorting-machine inter-message times. These time-values are stored in three separate tables in the computer, each time-value appearing a number of times. The number of appearances of each time-value is proportional to the ordinate of the standard Normal curve for any specfic inter-ouput time-value (see Appendix). A time-value is chosen from a table using the random number found in a suitable counter to determine the position in the table. Hence, the output characteristics of the simulated coding desks and sorting machines approximate to normal distributions of given means and standard deviations. This method was chosen because it minimized computer processing time. The data in the tables can be altered to vary the simulated traffic densities.

The tester has a system time-clock, the period of which is 1 ms. All outputs and calculations are made with respect to this clock. Each of the simulated coding desks and sorting machines has a number of program parameters which specify the position that the simulated coding desk or sorting machine has reached in its testing cycle, for example, whether it is

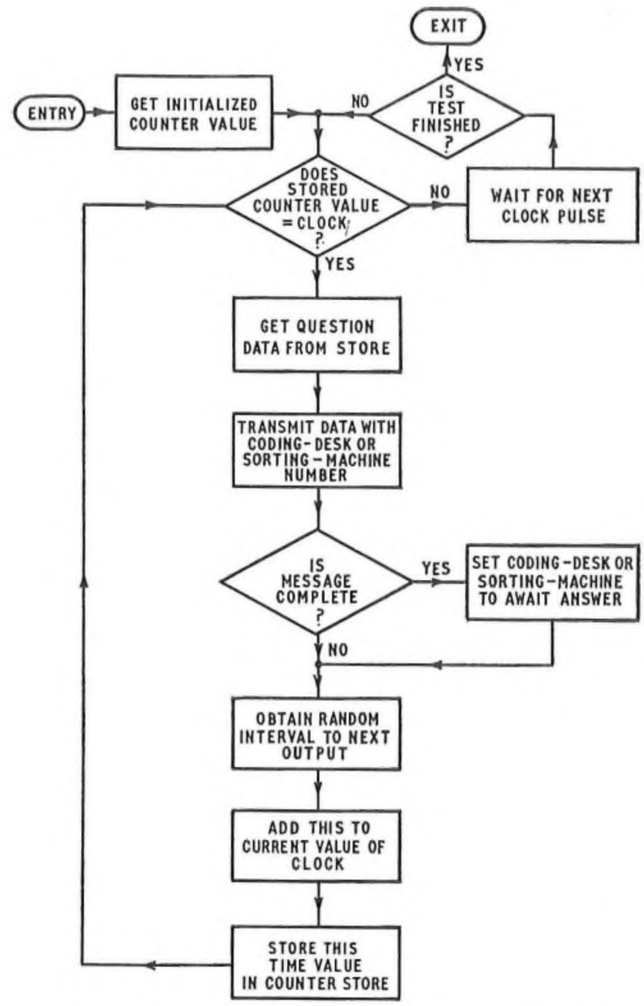


FIG. 6—Simplified flow diagram of coding-desk and sorting-machine question-output system

```
SM  TOTAL=100000
T      N
00   04680.***********************
02   04616.***********************
04   04691.***********************
06   04712.************************
08   04608.***********************
10   04848.************************
12   05120.**************************
14   04628.***********************
16   04624.***********************
18   04545.***********************
20   04863.************************
22   04754.************************
24   04787.************************
26   04416.**********************
28   04615.***********************
30   04346.**********************
32   04360.**********************
34   04759.************************
36   04449.**********************
38   04368.**********************
40   04352.**********************
42   01748.*********
44   00580.***
46   00377.**
48   00100.*
50   00046.
52   00008.
54   00000.
56   00000.
58   00000.
60   00000.
62   00000.
64   00000.
66   00000.
68   00000.
```

T is the time-delay in milliseconds.
N is the actual number of delays within the 2ms class of the histogram.
The asterisks represent the number as a percentage of the total, each asterisk representing 0·2 per cent.

FIG. 7—Printout of translator performance data.

waiting to transmit a question or waiting for a translator answer. One of these parameters is a counter value which is compared with the clock and, when the values are equal, the appropriate data is transmitted. The coding-desk and sorting-machine question/answer data is stored in the same manner, with minor modifications to identify the particular requirements of each equipment. There is a common store of questions and associated answers for all coding desks and all sorting machines. After sending each complete question, the answer parameter of the coding desk or sorting machine is set to the corresponding answer and its question parameter is incremented to the next part of the question data. The question parameter of the coding desk is incremented a number of times to produce a complete message.

There are approximately 50 different questions and answers stored for both the coding-desk and sorting-machine simulations. The contents of both these stores can be changed to suit test purposes. At the beginning of each test run the computer arranges a suitable mix of test questions which establishes a random start-up condition. A simplified flow diagram of the question-output system is given in Fig. 6.

Hardware Interface

When question data is sent from the computer it is associated with a coding-desk or sorting-machine number. This number is decoded by the interface to direct the data to the correct translator inputs. Similarly, the interface creates the correct coding-desk or sorting-machine number to be loaded into the computer with any answer data received from the translator.

Operation

To prepare the tester for a test run, paper tapes specifying the operating rate, and the question and answer data, are loaded. The number of coding desks and sorting machine inputs to be simulated is selected using the control switches on the front panel of the computer. Once the tester is running it can be stopped in a number of ways.

(*a*) A switch can be set on the computer which inhibits all further outputs and, after 100 ms, halts the computer by which time all answers will have been returned by the translator and processed by the tester.

(*b*) The system can be programmed to shut down automatically after a predetermined number of translation requests.

(*c*) The computer halts when an error state is found which could corrupt the computer program.

While the tester is running, it can produce a print-out of error messages as they occur. These messages usually specify the error type, the coding-desk or sorting-machine number, and other pertinent information, for example, the question asked, and the actual answer received to a particular translation request. The error types are

(*a*) an incorrect translation from the translator,

(*b*) no answer returned from the translator within 70 ms (the translator has been specified to return the answer within 60 ms), and (*c*) an answer directed to the wrong coding desk or sorting machine, or an answer returned after 70 ms.

A number of other error messages, concerned with the internal operation of the tester, are also available.

When a test run has been completed, the translator performance data can be printed by the teletypewriter. This is presented in histogram form as shown in Fig. 7. When a fault is detected in the translator, it is useful to be able to reconstruct the state of the traffic through the translator at the time the fault occurred. The computer keeps a record of all the input and output operations performed by the tester during the previous 120 ms. This record can be printed, if required, and specifies the time of the fault occurrence with respect to the computer's clock, the coding-desk or sorting-machine number and the actual question-data output or answer data received by the tester.

The performance of the translator was specified in terms of the number of times that the equipment failed to respond to a translation request under traffic conditions. A failure rate of one request in 10,000 inputs was considered acceptable. To check this, the tester was programmed to generate batches of 100,000 requests for translation at high traffic densities and monitor the system performance. During the testing period, program faults were encountered which would have proved difficult to find other than by exercising the translator under variable traffic conditions. In this respect, the tester proved to be an invaluable tool in locating faults under dynamic conditions.

CONCLUSION

This article has described an application of general purpose computers in a real time controlling function in the field of postal engineering. The design philosophy, the realization of the translator, and the system testing procedures used for design evaluation have been described.

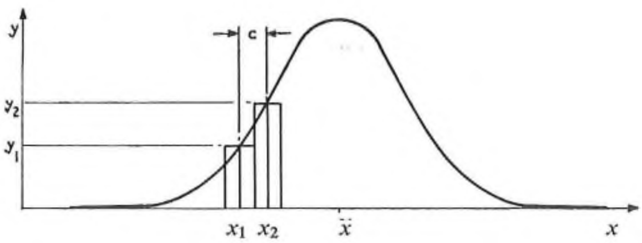
Reference

1 ANDREWS, J. D. A New Code Translator for the Letter-Sorting System. Part 1—Postcodes and their Use. *P.O.E.E.J.*, Vol. 65, p. 198, Jan. 1973.

APPENDIX

Normal Distribution

A histogram can be drawn from collected data by counting the number of occurrences of an event within a specified limit for a number of such limits. The mean and standard deviation can be calculated from the data and a Normal curve, with the same parameters, can then be superimposed over the histogram.



In this case, the histogram data is produced from a Normal distribution with predefined mean ($\bar{x}$) and standard deviation σ. The number of occurence (M_n) within a class (c), with a total number of occurrences (N), is proportional to the ordinate (y) of the Normal curve.

The ordinate of a standard Normal distribution curve is given by $y_n = f\left(\frac{|x_n - \bar{x}|}{\sigma}\right)$ and is readily accessible in tabular form.

The number of occurrences in the class can then be calculated from the formula $M_n = y_n \frac{cN}{\sigma}$ where M_n, rounded up or down to the nearest integer, gives the number of entries of a value x_n in a table of length N.

Book Review

"Signals." vii+100 pp. 67 ill. £1. "Networks." 104 pp. 67 ill. £1. F. R. Connor, Ph.D., M.Sc., B.Sc.(Eng.)Hons., A.C.G.I., C.Eng., M.I.E.E., M.I.E.R.E., M.Inst.P. Edward Arnold.

These are the first two books in a series of six. The other books, which are in the course of preparation, are: Vol. 3—Wave Transmission, Vol. 4—Antennas, Vol. 5—Modulation and Vol. 6—Noise. The author's intention is to prepare texts on introductory topics in electronics and telecommunication mainly for students who are preparing for degrees of L.U. and the C.N.A.A., examinations of the C.E.I. and for other qualifications such as H.N.C. and H.N.D.

Vol. 1—Signals

The main topics dealt with in this book are analysis of a signal, network response, transmission of signals, signal techniques and information theory.

The section on signal analysis is concerned mainly with the steady-state analysis of well-known waveforms using Fourier, the appreciation of bandwidth requirements for the transmission of these signals being the main objective. Network response is largely concerned with repetitive and non-repetitive waveforms applied to a network having a complex image-transfer function. To understand this, a knowledge of the Laplace transform is required. The sections on transmission of signals and signal techniques include principles of frequency- and time-division systems; the section on basic information theory includes the sampling theorem and also principles of redundancy in codes.

Included in the book are 14 worked examples, and there is also a list of references for further reading on the subject of Signals. It is just as well that these references have been provided because the scanty treatment given to one or two topics in the book will make it necessary for some students to do a good deal of supplementary reading.

The book could be useful to students studying for degrees and other professional examinations, and for those taking the Advanced Line Transmission examination of City and Guilds of London Institute. It could be recommended to planning/development engineers on digital transmission systems who need to revise on bit-rates and system bandwidth.

Vol. 2—Networks

The main topics dealt with in this book are one-port networks, two-port networks, prototype filters, m-derived filters and modern filter theory.

In the section on one-port networks, Foster's reactance theorem and the principles of circuit synthesis are covered. The sections on two-port networks and prototype filters deal with the transmission properties of passive networks of standard configurations; m-derived filters are included. Modern filter theory deals with the principles of Butterworth and Chebyshev methods and also mentions active filters.

Included in the book are 22 worked examples, and there is also a list of references for further reading on networks.

An important omission is Bartlett's bisection theorem in the sections on two-port networks and prototype filters. Its inclusion would have enabled the subjects to be treated on a half-section rather than a full-section basis, thus substantially reducing the amount of algebraic manipulation.

Generally, the book could be recommended to students studying for the professional examinations previously mentioned, and expecially to those taking the Advanced Line Transmission examination of City and Guilds of London Institute. J. F.

Time-Interval Measuring Equipment

A. H. ELKINS and A. S. DHANJAL, M.SC. †

U.D.C. 681.39: 519.2

Detailed statistics of telephone and data traffic characteristics are frequently required for theoretical traffic studies. In the past, information was collected using pen recorders or devices equipped with counting meters. Processing data, particularly from pen recordings, was tedious and time consuming. This article describes an electronic equipment with incremental tape recording, an arrangement which allows large amounts of data to be computer processed with minimum effort.

INTRODUCTION

For many years various purpose-built devices have been used by the British Post Office for recording the different parameters of telephone and data traffic. In the main, the output from these measuring devices has been to electromechanical counters (meters); extensive use has also been made of commercially-available pen recorders.

The results using meters may be in error owing to incorrect manual reading or transcribing and also, owing to sheer numbers, insufficient time may be available for these processes. Pen recorders, although automatic in operation, require considerable maintenance and operating attention and the subsequent evaluation of the results is a very laborious process.

For some purposes, large amounts of data must be recorded at short time-intervals and all types of measurement may need to be continued over long periods. There is, therefore, a need for a recording equipment suitable for unattended operation and which requires minimum effort to evaluate the results obtained. Such an equipment has been designed on the basic principle of recording events by measuring them as time-intervals from a fixed datum. It has been, accordingly, designated time-interval measuring equipment (t.i.m.e.).

A long-outstanding need is an improved and more widespread knowledge of the behaviour of different classes of subscriber, and the initial design of the t.i.m.e. was based on obtaining measurements of subscriber-dialling over a wide range of exchanges. It was envisaged that the first measurements would be made in electromechanical Strowger exchanges and, as the equipment was to be electronic in design, a feature of the development was the determination of its performance and the use of magnetic-tape recording in the environment of electromechanical exchange equipment. In this initial design the events recorded are

(*a*) the pre-dialling pause (p.d.p.),
(*b*) each digit dialled, and
(*c*) the duration of each inter-digit pause (i.d.p.).

The sequence of events which occurs during the set-up of a typical call is shown in Fig. 1.

GENERAL DESCRIPTION OF THE T.I.M.E.

Since convenience and accuracy in processing data are required, it is necessary to use an output medium suitable for direct input to a digital computer. Thus, magnetic-tape recording has been adopted and the instrument used is an incremental-type machine, i.e. tape movement only occurs when data is recorded. This technique conserves tape, thus minimizing the need for maintenance visits, a useful feature when recording in remote situations. However, for security reasons, for an early knowledge of the results obtained and for an even flow of work to the computer, it is usually desirable to replace tapes at regular intervals depending on the amount of data recorded.

In order to obtain the maximum amount of information in the shortest possible time, the connexion point for the t.i.m.e. is at the Strowger exchange first-selector stage, and provision is made for the connexion of up to 10 first selectors. Provided the t.i.m.e. is free, the first call to arrive on any connected selector is extended to the t.i.m.e. and the setting-up details of the call recorded. Since the equipment is measuring at

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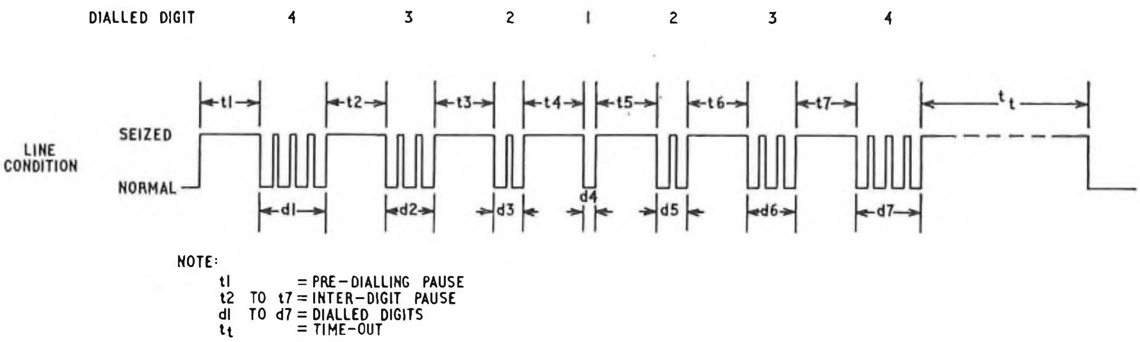

FIG. 1—Typical subscriber call set-up

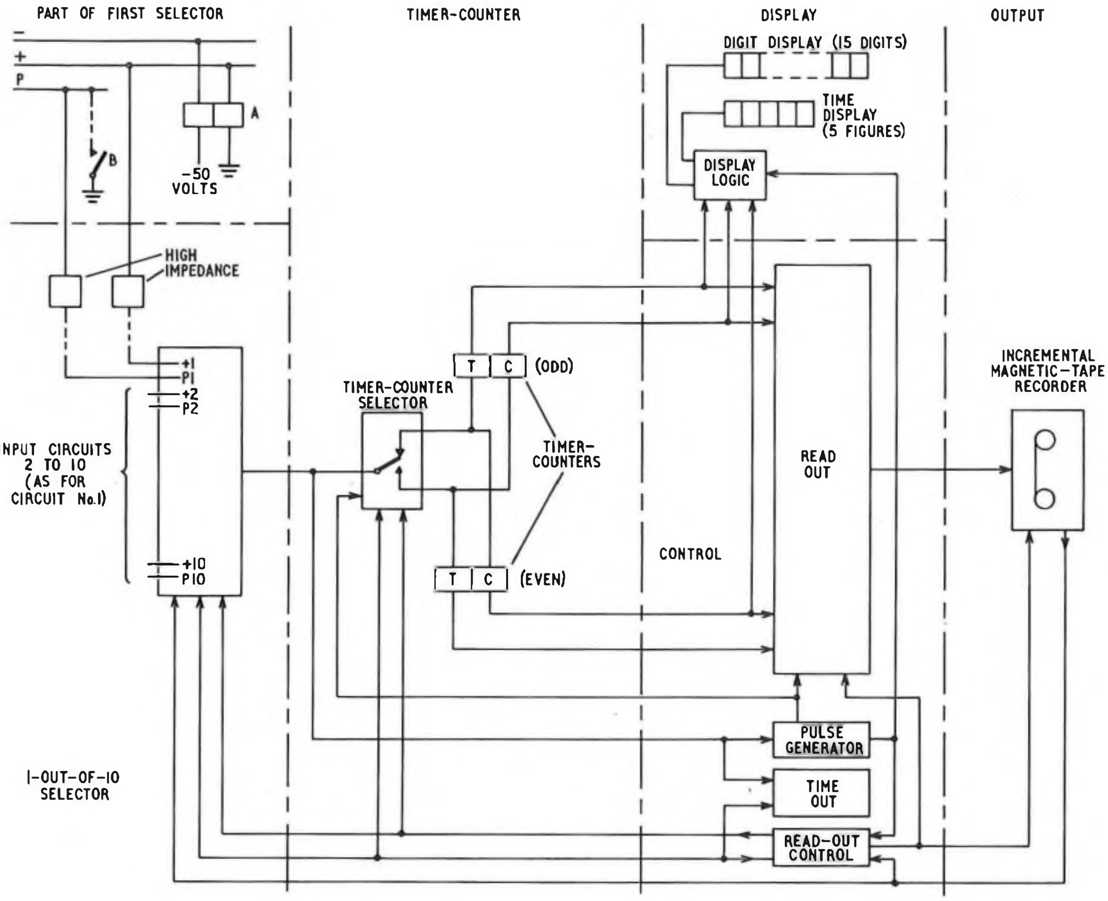

FIG. 2—Block diagram of the t.i.m.e.

the first-selector stage, an allowance has to be made to the pre-dialling pause measurement for the time that has already elapsed for the seizure signal to reach this point. The t.i.m.e. also disconnects itself from an input after a pre-selected time interval, thus further increasing the amount of seizure and dialling data which can be collected.

A visual indication is given of both the time intervals and the dialled digits which are being measured. This display facilitates the setting-up procedure and provides subsequent confidence of satisfactory operation. Without some such arrangement the results of a measurement would only be obtained following computer processing at the end of a recording period.

To understand the more detailed circuit arrangements it is necessary to appreciate the coding arrangements for the data recorded on the magnetic tape, Burroughs Computer Language (B.C.L.) code being used since processing is carried out on a Burroughs B5500 machine. This language code requires six binary digits (bits) for each character and one parity bit, i.e. seven-track recording.

The tape recorder used has a packing density of 200 bytes per inch (b.p.i.), a byte consisting of seven bits. Versions with higher packing densities are available, but in most situations regular tape changing is preferred to long periods of unattended operation and, therefore, in practice, the consequential reduction of potential storage capacity is acceptable.

In the tape format of a call, each time-duration is represented by five numerical characters and each dialled digit by a single numerical character. Time-durations and digits are separated by a single space, and there is a double space after each digit. The end of each call is signified by a time-duration indicating 00000 followed (after a single space) by digit 0. Calls are grouped into blocks of 10 calls by leaving an inter-block gap of 0·75 in after every tenth call. Using 1,200 ft spools, with the recording arrangement described, each tape has a capacity for approximately 3,300 calls each of seven digits.

Control of the tape recorder is by two forward signals generated in the read-out control and one backward signal sent from the tape recorder. In the forward direction a *write step command* (w.s.c.) signal causes the tape to advance by one increment and, when effective, generates within the tape recorder a *write data command* (w.d.c.) signal causing the data at the input of the tape recorder to be written as a character on the tape. The other forward signal is the *inter-block gap* (*i.b.g.*) *generate* signal. While the forward movement of the tape is taking place a backward signal, *i.b.g. in progress* is returned and is used to inhibit the inputs to the 1-out-of-10 selector (discussed later) until the forward movement which produces the gap has been completed.

The t.i.m.e., which uses commercially-available transistor-transistor-logic (t.t.l.) integrated circuits, has three main sections, apart from the subsidiary display section and the incremental tape recorder. The main sections are

(*a*) a 1-out-of-10 selector,
(*b*) a timer-counter, and
(*c*) control circuitry.

A block diagram of the t.i.m.e. is shown in Fig. 2 and Figs. 3, and 4 show photographs of the t.i.m.e.

The power supply for the integrated circuitry is derived from the public a.c. mains supply, which is also used to drive the tape recorder.

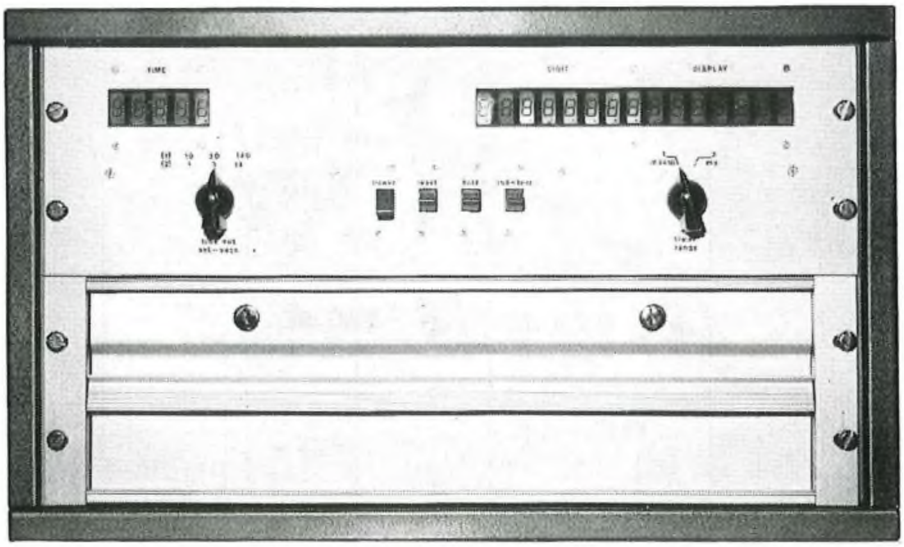

FIG. 3—Photograph of the t.i.m.e. showing the digital display

FIG. 4—Photograph of the complete equipment

THE 1-OUT-OF-10 SELECTOR

The incoming private wire (p-wire) and positive speech-wire of each of the exchange first selectors to be monitored are connected by high-impedance tapping circuits to the inputs of the 1-out-of-10 selector which provides for

(*a*) monitoring up to 10 input circuits,

(*b*) detection of a loop on a selector speech path followed by earth on its p-wire,

(*c*) connexion of the timer-counter to the first of the monitored circuits on which a call originates,

(*d*) isolation of the other nine input circuits while any one input circuit is connected to the timer-counter,

(*e*) transmitting the incoming loop-disconnect pulses to the timer-counter with a minimum of distortion, and

(*f*) the subsequent connexion of the timer-counter to the first input circuit to receive a call after its release from a previous monitored call.

A change of the p-wire potential to earth occurs at the beginning of a call and this event, together with the change in positive-wire potential, is used to ensure that only complete set-up conditions are recorded.

The monitoring of a call ceases after a pre-selected time-interval and the equipment then awaits the next call to arrive, an event which may occur on any of the input circuits.

The operation of the 1-out-of-10 selector can be described in terms of a call received on circuit No. 1, using the simplified circuit shown in Fig. 5 which illustrates the basic logic arrangements. With no call on any input, each of the bistable circuits (A) inhibits its associated nand gate (G). A change in line-loop conditions is presented via the inverter I1 to gate G1 where it remains inhibited unless accompanied by a change of p-wire potential to earth. When contact P1 closes, monostable circuit M1 operates, bistable circuit A1 changes over, thus removing the inhibition from gate G1 and, hence, extending the seizure condition to the timer-counter. At the same time, bistable circuit B1 changes over and extends an inhibit condition to gates G2 to G10 thus excluding any other call which may originate while the first call is being recorded.

Any further changes, due to dialling, of line-loop conditions of circuit No. 1 are repeated to the timer-counter. Finally, at a pre-determined time after the completion of a dialled digit, since end of dialling cannot be determined, the circuit is released and recording is terminated by a time-pulse from the time-out control. Bistable circuits A1 and B1 are reset and the inhibition placed by circuit No. 1 on gates G2 to G10 is removed. However, the gate of any circuit which has a call in progress remains inhibited since its own bistable circuit (A) is also reset by the same time-pulse; A1 inhibits its own gate G1.

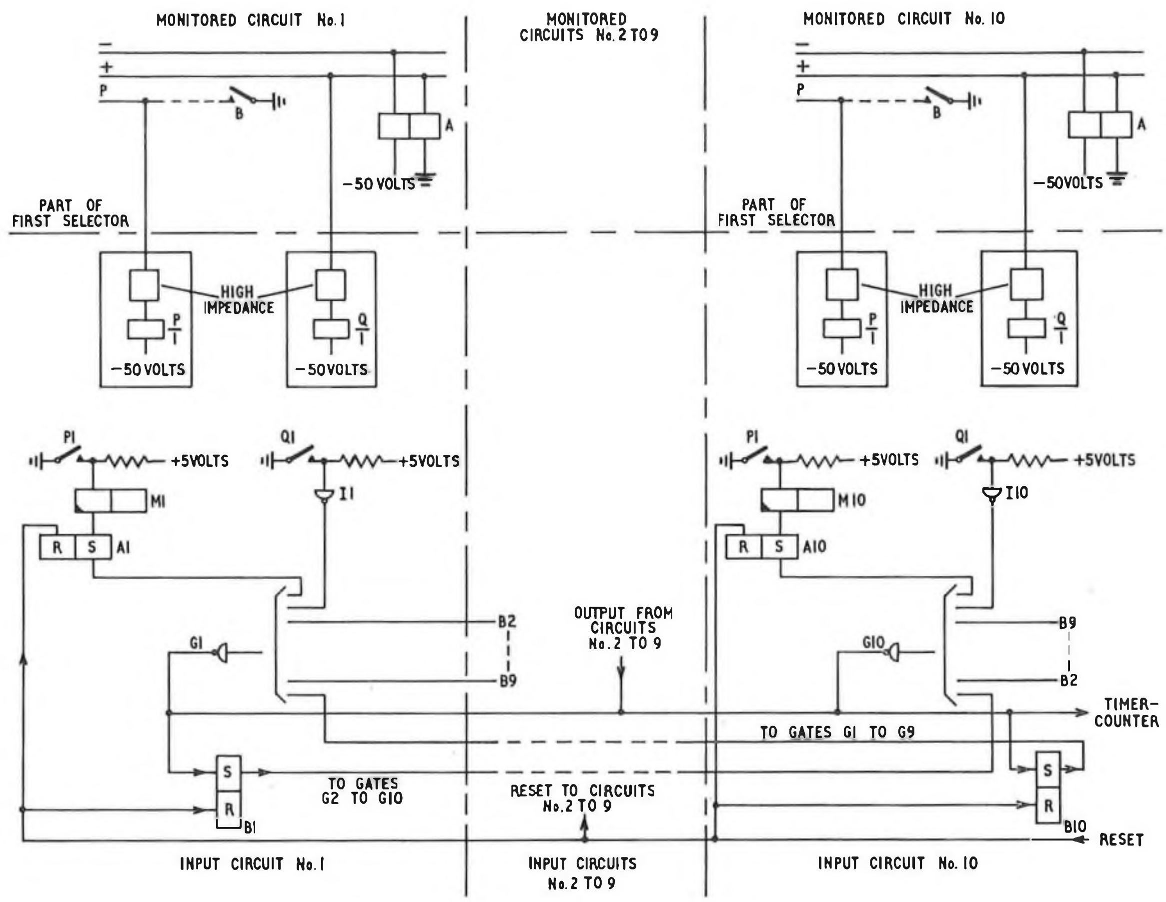

FIG. 5—Circuit diagram of the 1-out-of-10 selector

THE TIMER-COUNTER

The section of the t.i.m.e. which provides the timing and counting functions contains two identical timer-counters, odd and even, selected by a change-over arrangement; the timer-counter selector (see Fig. 6). The facilities provided are

(*a*) measurement of the p.d.p.,
(*b*) measurement of each i.d.p., and
(*c*) counting the pulses of each dialled digit.

The time-durations measured in (*a*) and (*b*) are recorded in five-digit numbers either as tens of milliseconds (i.e. 0 to 999·99 seconds) or in milliseconds (i.e. 0 to 99·999 seconds). The alternatives are preselected by an external control which changes over an internal pulse supply from 100 Hz to 1·0 kHz. For each timer-counter the first five elements are used for storing, in binary-coded decimal form, the five numerical characters of time durations Element 6 is permanently wired to provide the code for the space character, and element 7 stores the dialled digit.

The first two events of a call are the p.d.p. and the first dialled digit; these are registered in the odd timer and the odd counter, respectively.

The next two events, i.e. the first i.d.p. and the second dialled digit, are similarly registered in the even timer-counter. A change-over sequence between the odd and even timer-counters occurs for successive pairs of events.

The timer-counter selector initiates the change-over of timer-counters on detecting the first break period of the pulse train of a dialled digit. The counter is stepped by detecting the break periods while, concurrently, the duration of each make period is timed in the opposite timer. If a break period occurs within 70 ms of the beginning of a make period the timing is reset. Thus, at the end of a pulse-train, when there are no further break periods, the subsequent i.d.p. is timed in full. A change-over of read-out is effected immediately following the completion of a pulse train. Thus, whilst timing followed by counting is being registered in one timer-counter, the information already recorded in the other timer-counter is being read out to the tape recorder. The sequence of events continues until the monitored line stabilizes in the loop condition.

CONTROL

The control section provides the read-out and time-out facilities and incorporates a pulse generator to effect their control. The timing of the pulses relative to a call is shown in Fig. 7.

Read-out

The following read-out facilities are provided

(*a*) output compatible with the tape recorder,
(*b*) output-data coded in binary-coded decimal,
(*c*) transfer of the timer-counter information to the tape after each measurement.

The function of the read-out control is to extend the information stored in a timer-counter to the tape recorder whilst controlling the latter, in order that it may receive it. Each numerical character stored in a timer-counter as four binary digits is transferred as a six-bit B.C.L. character. Read-out is alternatively from the odd and even timer-counters under the control of bistable circuit F (Fig. 6), the correct read-out sequence being effected by strobe pulses obtained from a 10-bit shift-register used as a ring counter (Fig. 8) whose action is as follows. The 100 Hz supply provides

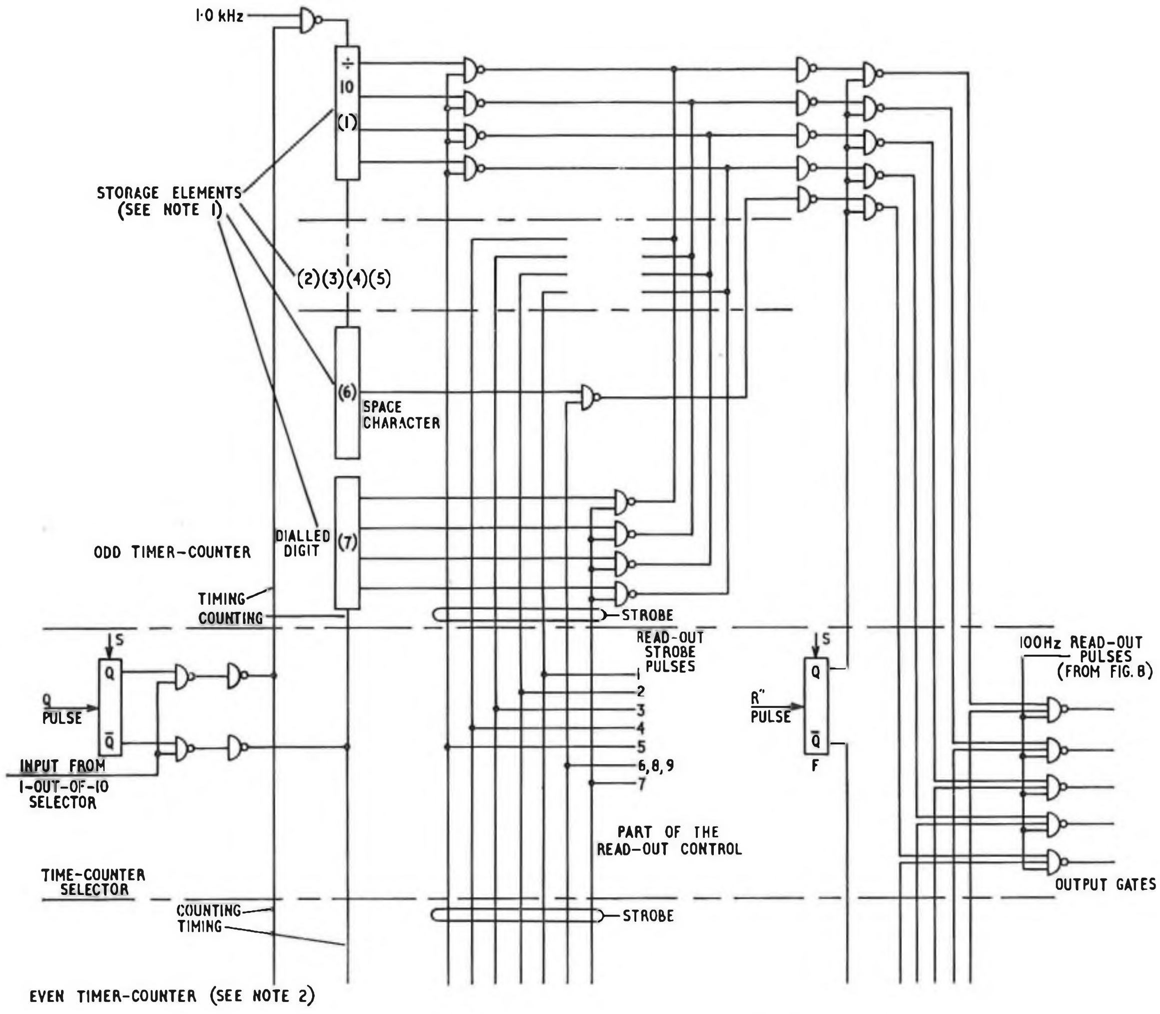

FIG. 6—Circuit diagram of the timer-counter

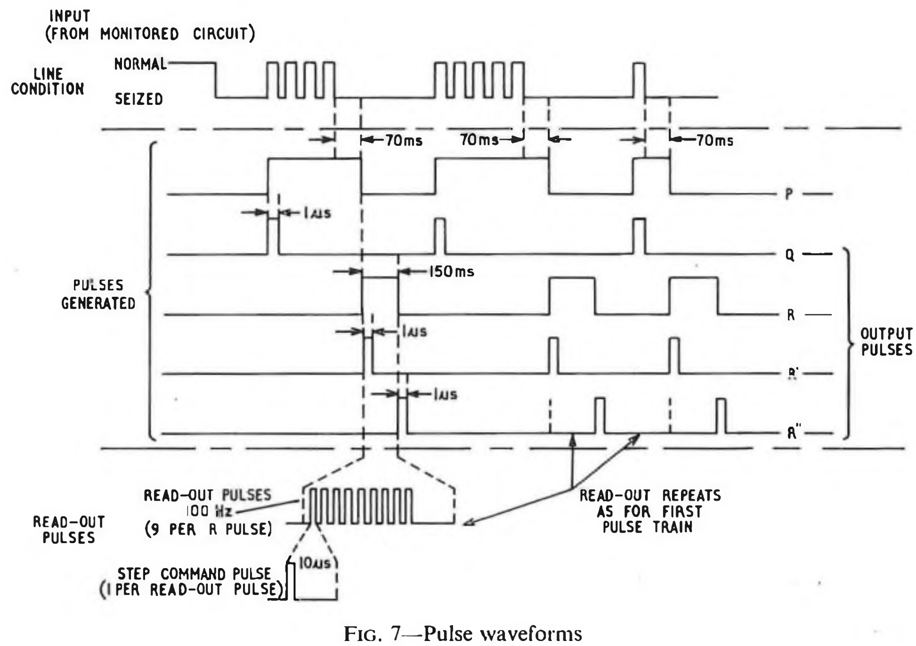

FIG. 7—Pulse waveforms

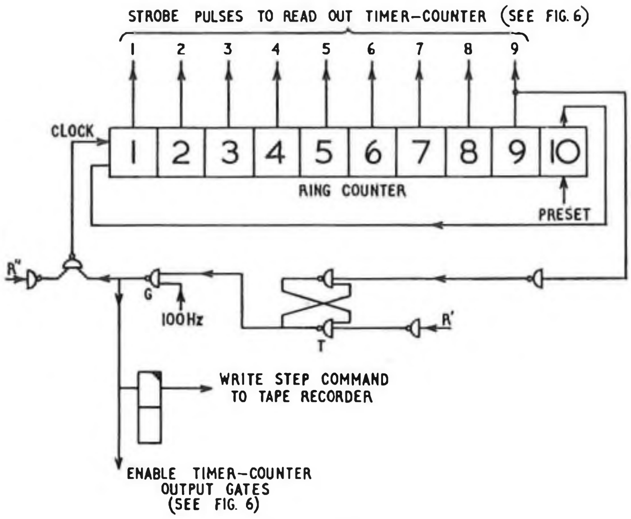

FIG. 8—Read-out pulse circuit and ring counter

clock pulses at a 10 ms periodicity which step the ring counter to give strobe pulses 1, 2, etc. At the same time these pulses open the output gates of the timer-counter (Fig. 6); the write-step command signals are also provided. The ninth strobe pulse, in addition to sending the last space character, also resets bistable circuit T (Fig. 8) thus inhibiting the associated nand gate G and cutting off the 100 Hz supply. This pulse supply is subsequently reconnected by an R′ pulse provided there is further data to be read out from the other timer-counter.

Time-Out

The timing facilities provided are

(*a*) generation of 100 Hz and 1·0 kHz pulses as a basis for timing measurements, and

(*b*) time-outs of one, three, 10, 14, 30 and 140 seconds.

The time-out pulses serve the three following purposes.

Forced Release.

There is no subscriber end-of-dialling signal and, to ensure that the equipment records the maximum amount of information, a monitored circuit is disconnected at a pre-determined time after receipt of a dialled digit. This time is variable in two ranges, pre-selected to give a time of one, three or 14 seconds in range 1, or 10, 30 or 140 seconds in range 2.

Detection of Clear-down.

Discrimination between the break period of a dial pulse and the release of a call is effected by timing the line disconnexion. The timing circuit provides a pulse after 110 ms and clear-down is assumed if the disconnexion has persisted for this length of time. The figure of 110 ms allows for dials of speed seven pulses per second and for the break period to be up to 80 per cent of the total pulse period.

Recognition of i.d.p..

As already described under the action of the timer-counter, timing is reset if a break period occurs within 70 ms from the beginning of a make period. The figure of 70 ms allows for dials of speed seven pulses per second and for the make period to be up to 50 per cent of the total pulse period.

Pulse Generator

The output waveforms of the pulse generator are shown in Fig. 7 and its circuit in Fig. 9. For completeness the pulses from the read-out pulse circuit (Fig. 8) are also shown in Fig. 7. Activation is by detection of the line-seizure condition when the 1-out-of-10 selector extends a call. The pulse train of each dialled digit initiates an internal pulse P, the length of which exceeds the pulse train by 70 ms i.e. the pulse is continued for 70 ms after the completion of the last break period of the pulse train. The output is a set of pulses Q, R, R′ and R″ unique to each dialled digit, having durations and relative timings as shown.

DISPLAY

Besides the necessity of a display for setting up a recording and also for confidence as discussed in the general description, immediate, if somewhat limited, results can be obtained by reading and manually recording the displayed information.

Provision is made for two groups of seven-segment display lamps. The first group with five lamps provides for time-duration display, and the second group with 15 lamps provides for digit display for calls of up to that number of dialled digits. Each time-display remains until replaced by its successor, although a manual control which permits retention of a

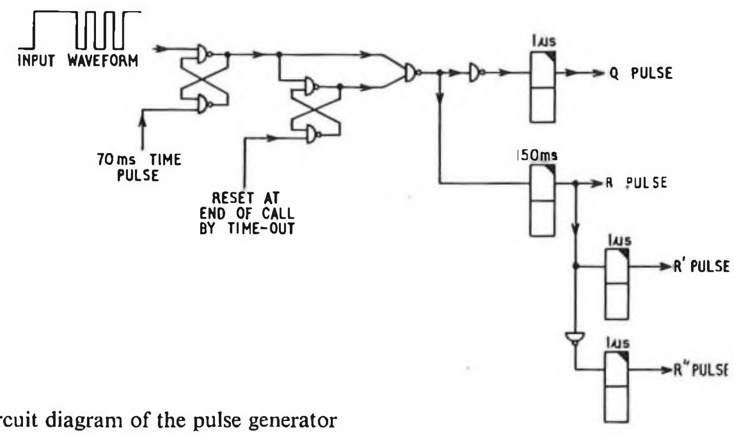

FIG. 9—Circuit diagram of the pulse generator

↓ Time duration ↓ Digit ↓ Time duration ↓ Digit End of call

02211 0 01003 5 00890 1 ↓ 01117 2 00858 2 01133 7 01084 3 018
33 7 01310 1 00784 1 00000 0 02313 0 00704 2 00719 2 01382
5 01377 2 00786 6 01287 6 00694 1 00845 5 00000 0 03283 1
01271 9 01025 2 00000 0 02599 7 01900 9 01779 0 01583 2 01
557 4 01761 1 01420 1 00000 0 01233 5 01218 3 00959 1 01229
0 01195 0 01146 6 01235 0 00000 0 01417 4 00947 5 00974 5
00896 2 00857 6 00790 3 00851 8 00000 0 01707 4 00802 9 00
842 3 00791 8 00759 8 01024 2 00776 7 00000 0

FIG. 10—Call format for part of one block

Serial No.	Digits Dialled	Pre-Digit-Pause	Inter-Digital Pauses					
341	637 1273	3193	1123	811	3601	674	793	748
342	946 7488	1441	1098	1233	1114	1012	2751	1342
343	946 7488	1143	981	1003	1189	1158	1339	1334
344	070 1781251	1337	1891	1337	920	1189	2257	10775
			1254	1076	1042			
345	046 4040008	1372	1145	1189	1208	1358	1007	1086
			1000	1148				
346	590 4824	1077	1193	1460	1164	1022	950	939
347	623 2030	6328	1231	1864	2426	1469	1260	1383
348	981 2587	4340	1337	1452	2264	1446	1910	1461
349	024 3321513	3224	947	1031	899	797	883	1284
350	142	2580	998	850				
351	051 2273711	2211	1003	890	1117	858	1133	1084
			1833	1310	784			
352	022 524615	2313	704	719	1382	1377	786	1287
			694	845				
353	192	3283	1271	1025				
354	790 2411	2599	1900	1779	1583	1557	1761	1420
355	531 0060	1233	1210	959	1229	1195	1146	1235
356	455 2638	1417	947	974	896	857	790	851
357	493 8827	1707	802	842	791	759	1024	776
358	010 411447711	3324	904	825	902	896	824	822
			894	894	898	899	823	
359	010 3110282700	1571	4891	797	662	520	457	787
			697	989	740	110	828	746
360	226 0547	758	711	896	1129	868	1008	1175

FIG. 11—Magnetic-tape record (edited) [see Fig. 10]

selected time-measurement, is provided. For simplicity in design, the displays are activated direct from the timer-counters, a method which, although having the disadvantage of not necessarily indicating that data is actually being recorded, does have the merit of obtaining results in the absence of a tape recorder.

RESULTS

The tape format of the calls recorded is shown in Fig. 10 and an edited version is given in Fig. 11. Some of the initial results obtained, relating to distributions of p.d.p. and i.d.p. are given in Fig. 12 and 13, respectively.

CONCLUSIONS

An equipment based on time measurement and using commercially available t.t.l. integrated circuits has been developed for use, initially, in Strowger electromechanical telephone exchanges. The output is passed to an incremental magnetic-tape recorder and subsequent tape processing is on a Burroughs B5500 computer. No difficulties have been experienced in using the equipment in Strowger exchanges.

Further development to provide interfaces allowing access to different switching and control equipments, and to permit detection of various tones and supervisory conditions, will enable this technique to be applied to a variety of traffic measurements including

(*a*) route and destination analysis,

(*b*) subscriber repeat-attempt behaviour, and

(*c*) holding times of calls and common-control equipment.

Cell (ms)	Frequency of Pre-digit-pause
1 : 500	7
501 : 1,000	58
1,001 : 1,500	168
1,501 : 2,000	173
2,001 : 2,500	112
2,501 : 3,000	76
3,001 : 3,500	55
3,501 : 4,000	38
4,001 : 4,500	30
4,501 : 5,000	16
5,001 : 5,500	12
5,501 : 6,000	7
6,001 : 6,500	9
6,501 : 7,000	8
7,001 : 7,500	5
7,501 : 8,000	9
8,001 : 8,500	6
8,501 : 9,000	5
9,001 : 9,500	5
9,501 : 10,000	4
10,001 : 10,500	6
10,501 : 11,000	4
11,001 : 11,500	3
11,501 : 12,000	3
12,001 : 12,500	–
12,501 : 13,000	4
13,001 : 13,500	1
13,501 : 14,000	1

Total = 825
Mean = 2,774·88 ms
Standard deviation = 2,254·94
Note: These results do not include the time that has already elapsed for the seizure signal to reach the measurement point.

FIG. 12—Distribution of Pre-Digit-Pause (ms)

Cell (ms)	Frequency of Inter-Digit-Pause
301 : 400	1
401 : 500	0
501 : 600	2
601 : 700	26
701 : 800	70
801 : 900	98
901 : 1,000	98
1,001 : 1,100	112
1,101 : 1,200	68
1,201 : 1,300	42
1,301 : 1,400	39
1,401 : 1,500	27
1,501 : 1,600	7
1,601 : 1,700	15
1,701 : 1,800	3
1,801 : 1,900	8
1,901 : 2,000	6
over 2,000	38

Total = 660
Mean = 1,164·40 ms
Standard deviation = 558·46

FIG. 13—Distribution of Inter-digit-pause (ms)

ACKNOWLEDGEMENT

The equipment was built in the Telecommunications Headquarters, Telecommunication Development Department Circuit Laboratory, and the authors wish to thank Mr. K. W. Coulson for his assistance with the physical design and his many valuable suggestions during construction and testing.

The incremental tape recorder used was manufactured by Messrs. Recording Designs (EMI) Ltd of Camberley, Surrey.

Book Reviews

"Principles of Carrier Communication." N. N. Biswas, Ph.D. (Eng.), A.I.I.Sc., D.I.I.Sc., B.Sc.(Hons.), S.M.I.E.E.E., M.A.S.E.E. Asia Publishing House. vii+ 232pp. 150 ill. £2·00.

This book is unusual in many respects. Firstly, because it is written by a former professor of an Indian university whilst at a university in the U.S.A., its language is always strange, often confusing and sometimes even amusing. Secondly, the range covered is enormous. In less than 250 small pages, with diagrams on almost every page, audio circuits and v.f. signalling, modulation theory, noise, carrier generation, all types of carrier systems, f.d.m., and p.c.m., microwave radio and line carrier systems are all treated—and sometimes ill-treated. Yet, it is easy to be too critical of this book. At the end of each chapter, there are numerous references to other works (mostly American) and a large selection of problems on which the student can test his knowledge. Nevertheless, it is not a book that I could recommend to the student. He would find it difficult to follow and sadly lacking, in places. For example, there is no clear explanation of the reason for the low-pass filters at the channel inputs of a p.c.m. system. As a reference book, for a person who already has a good knowledge of the subject, it would be much more useful. It is a pity that the book was not more carefully edited; it has more than the usual number of typographical errors, but these are of less moment than some of the errors of technical fact.

L. J. B.

"Thermistors." F. J. Hyde, D.Sc., M.Sc., B.Sc. Butterworth Group, Iliffe Books. 9+197 pp. 96 ill. £3·20.

This distinguished author has produced a comprehensive book on the properties and applications of thermistors. Both positive and negative temperature-coefficient type thermistors are dealt with and their characteristics are fully defined mathematically with equivalent circuits given where applicable. A wide range of practical applications are described, each fully defined by equations so that variants or adaptations can be made by the reader. A long list of references is given at the end of each of nine chapters, each chapter dealing with a related group of applications. The first four chapters deal with material aspects and theoretical considerations of thermistors, while the following chapters discuss practical applications. To those engineers not familiar with thermistors it may be surprising that they can be used to form phase-advancing and retarding circuits, low-frequency oscillators, direct-reading thermometers, a.g.c. circuits for amplifiers as well as a variety of the more usual regulator and limiter circuits.

This book will be found extremely useful by those interested in applications of this versatile device.

W. T. L.

A Fresh Look at Facsimile for Document Transmission

H. E. WESTAWAY†

U.D.C. 621.397.12

There has been a resurgance of interest in the use of facsimile for transmitting documents over the public switched telephone network. This article outlines the basic principles involved, examines the techniques employed to exploit these, mentions some of the problems encountered and looks at possible future developments.

INTRODUCTION

Facsimile transmission involves the transmission of a perfect copy. This is clearly rather ambitious, but the feasibility of transmitting a legible reproduction of a sheet of typescript over most circuits likely to be encountered in the British Post Office (B.P.O.) public switched telephone network (p.s.t.n.) can readily be demonstrated.

The principles of facsimile transmission have been known for more than 130 years, but despite many attempts to popularize it as a communication medium, its use has been limited to certain specialized fields. These include picture-telegraphy and meteorological-map transmission, where no alternative means of rapid communication is available. The apparatus used in these fields is of extremely high quality, which, coupled with the restricted market, has resulted in very costly hand-built equipment. The present range of document-facsimile machines owes much to the mass-produced office copier concept, and holds out the possibility of document transfer between offices without the aid of skilled keyboard operators, at a cost that is competitive with Telex.

The principles of operation are akin to those of television in that the picture to be transmitted is scanned as a series of lines and that the shade of the picture instantaneously encountered along the scanning line is used to control a signal sent over the communication medium. At the receiving end, a scanning system, carefully synchronized and phased with the send scanner, uses the incoming signal to vary the recording intensity and thus re-construct the picture.

The main difference between television and facsimile communication lies in the bandwidth employed and the time taken to transmit one picture. A facsimile transmission over a circuit of 3 kHz bandwidth takes from 3 to 20 minutes and a single picture is recorded in a permanent form. A television picture requires a much larger bandwidth and is continuously reconstructed on the face of a cathode ray tube.

PICTURE TELEGRAPHY

Facsimile communication is at present best known in its picture-telegraphy application, a system developed mainly for the newspaper industry. In this application, the picture to be transmitted is wrapped around a drum and secured by a longitudinal clip. The drum is then rotated at a constant speed and either it, or a scanning head, is moved axially so that the latter scans the whole picture. The scanning head consists of a photo-sensitive cell onto which light reflected from the spot on the picture being scanned is focused by a lens-and-aperture system. The scanning head normally has a lamp to illuminate the area of the picture around the scanned spot. The amount of light reflected at any instant from the surface of the picture being scanned causes the photo-sensitive cell to modulate an electric current which is used to control the transmitted signal

At the receiver, a sheet of photo-sensitive paper or film is secured to a drum similar to that used at the transmitter. To receive a picture, the drum is rotated in the same direction and at the same speed as that at the transmitter, furthermore, both drums must be correctly phased, i.e. the paper-securing clips must pass the reading and writing heads at the same instant. The maintenance of similar drum speeds is an onerous task as, unlike television, no synchronizing pulses are sent during the transmission of a picture.

The writing head, which must make a similar relative traversing motion to that of the reading head, consists of a modulated-light source which is focused into a spot on the photographic material fixed to the drum surface. The light intensity is under the control of the received signal and the provision of an optional inverting stage in the driving amplifier can result in the production of positive or negative copy, as required. Picture-telegraph equipment is operated mostly over private dedicated cable or radio circuits by skilled staff who select the most appropriate drum speeds, scanning pitches and modulation systems to achieve the best possible picture. The apparatus is carefully adjusted to give a linear reproduction of the half-tones.*

Phototelegraphy Standards

In order to facilitate interworking of equipments from different countries and manufacturers, a number of parameters have been defined as follows:

(*a*) index of co-operation – $\left(\frac{\text{drum diameter}}{\text{scanning pitch**}}\right)$,

† Telecommunications Development Department, Telecommunications Headquarters.

* Half-tone—image in which there is a continuous range of contrast between black and white.

** Scanning density, which is the reciprocal of scanning pitch, is often quoted.

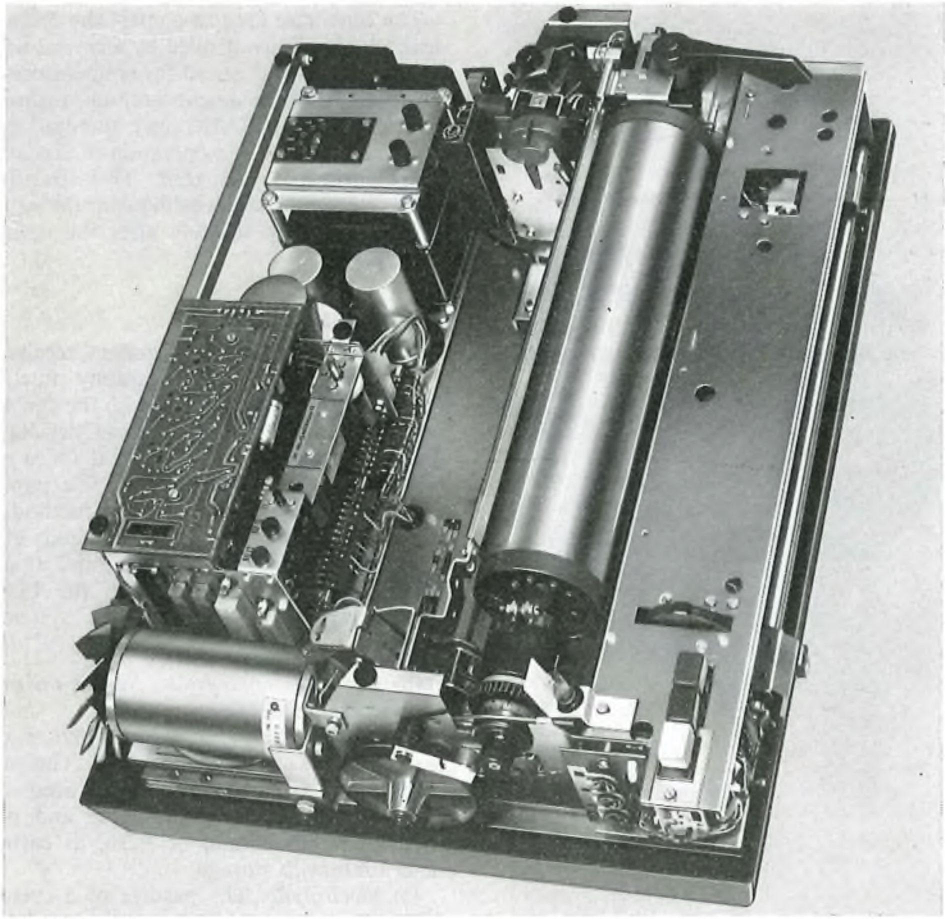

FIG. 1—E.M.I. *Emifax HF* 146·4

(*b*) drum speed—a range of standard speeds are prescribed,

(*c*) dead sector—the proportion of the drum circumference which may not be used (the difference between the whole line length and the effective line length, usually about 5 per cent),

(*d*) drum factor (the ratio of drum diameter to drum length),

(*e*) time-base stability—of the order of 1 part in 10^5—and

(*f*) phasing arrangements—pulses are sent preceding the transmission of a picture to align drums. Phasing is normally achieved in less than 15 s.

DOCUMENT FACSIMILE

There has recently been a resurgence of interest in the possibility of using facsimile principles to transmit documents containing little or no half-tone information. To provide a simple and reliable service, steps must be taken to overcome a number of problems associated with picture telegraphy. These include:

(*a*) reduction of equipment and materials costs,

(*b*) removal of the requirement for photographic dark-room facilities,

(*c*) simplification of operating procedure, and

(*d*) provision of access to other facsimile stations over a switched network, preferably the p.s.t.n.

A considerable relaxation in the quality of reproduction is permissible, in the limit it being necessary only to differentiate between black and white, although the ability to transmit a limited range of half-tones is advantageous. The main use envisaged for document facsimile equipment is to transmit sheets of type-written information, although line drawings and specialized symbols can be transmitted with equal facility. A surprisingly poor quality of reproduction can be accepted due to the high degree of redundancy in the presentation of each character, and also in the language of the text transmitted.

Document Transmitters

A number of variants exist, some based on the revolving-drum system of the phototelegraph machines and others which are classed as flat-bed machines. The latter seldom have truly flat beds and embrace types in which the document is laid in a concave tray, is drawn past a slit or is wrapped around a stationary drum. The distinction would seem to be in whether the scanning of a line requires the paper or the reading device to move. A further advantage of the so-called flat-bed type of machine is that no limit is placed on one dimension of the document to be transmitted, although time-base accuracy may prevent very long transmissions without intermediate re-phasing operations.

In most cases, loading the document to be transmitted has been simplified. Generally, it is necessary only to lay it in a tray or insert the end into a slot, and then to operate a control to initiate transmission.

The scanning reading-head is usually similar to that employed on phototelegraph machines, but the relaxed requirements for half-tone representation may permit photo-transistors or photo-diodes to be used in place of the expensive electron multiplier tubes used in more sophisticated equipment. In some cases, the illuminated area, including the line being read, is flood-lit by fluorescent tubes instead of a filament lamp coupled to the reading head.

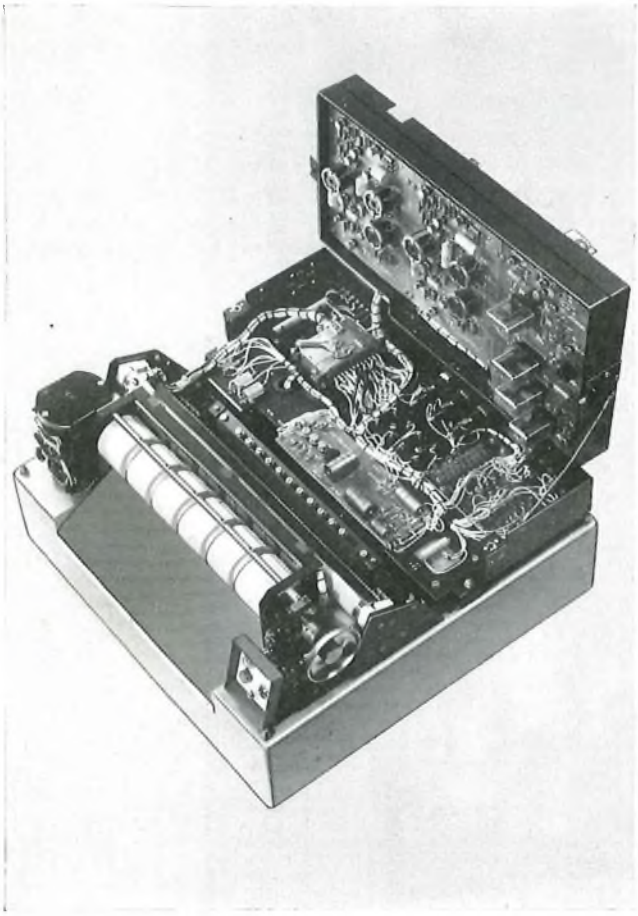

FIG. 2(*a*)—Muirhead *Courier K*-400-*D* (transmitter)

The time-base used to control the drum speed or scanning device is usually controlled by a crystal which gives adequate stability without the need for temperature-controlled ovens.

Most of the document-facsimile transmitters used in the United Kingdom (U.K.) have standard drum speeds of 180 r.p.m., an index of co-operation of 264 and a dead sector of approximately 5 per cent. They transmit, automatically, phasing pulses corresponding with the scanning of the drum-clip position for 10–15 s after the operation of the send control.

Document Receivers

It is in the field of document receivers that the major departures from picture-telegraphy practice are found. The use of photographic papers, with the consequent requirement for dark-room and wet-process development facilities, is quite unacceptable in the normal office environment, apart from the high cost of photographic paper. It is, therefore, necessary to employ alternative methods of recording the received signals. A number of methods exist, none of which is clearly superior to all others, and at present virtually all the machines being offered on the U.K. market employ different writing principles. These systems are summarized below.

(*a*) *Ink roller, percussion.* Writes on ordinary paper, but cannot record half-tones.

(*b*) *Carbon Paper, percussion.* Writes on ordinary paper through a sheet of carbon paper. The recording cannot be seen until the carbon paper has been stripped away. For best results, paired carbon-paper and paper sets must be used, and they should be fresh, as carbon paper tends to deteriorate with storage.

(*c*) *Electrolytic.* The passage of a current from a writing edge of stainless steel into a spot on special, damp, chemically-impregnated paper causes local blacking to occur. The image

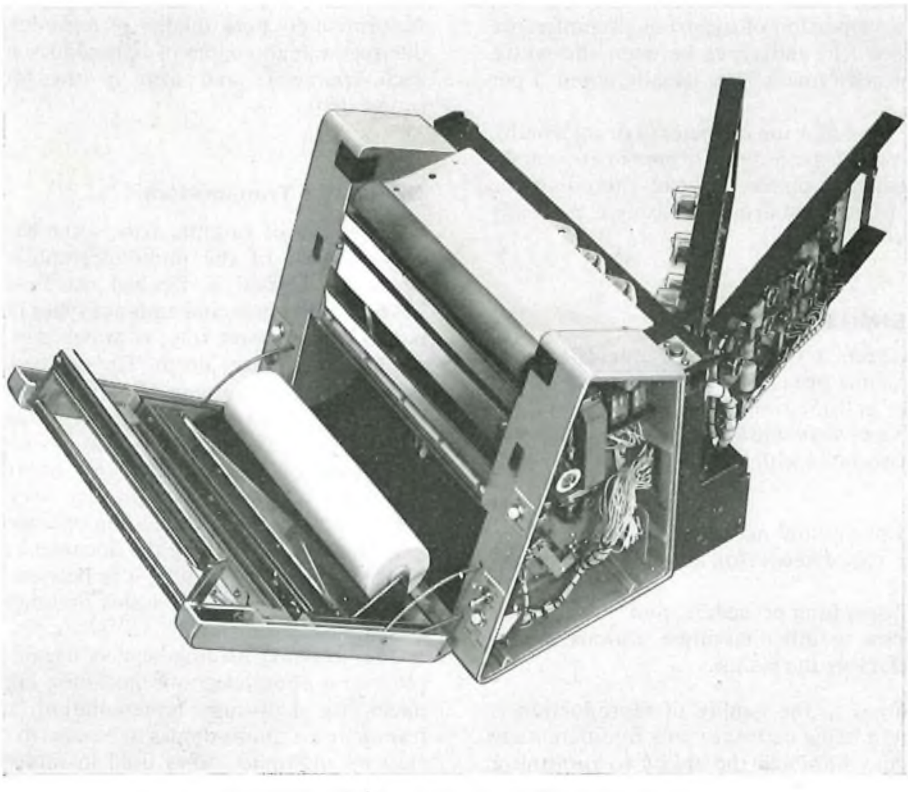

FIG. 2(*b*)—Muirhead *Courier K*-401-*D* (receiver) can be seen immediately after writing, but requires drying, and even then may deteriorate with age and may damage documents placed adjacent to it in a file. The unused paper also has a limited shelf life.

(*d*) *Electro-sensitive.* A white surface coating on the paper is locally destroyed by the passage of an electric current flowing from a scanning stylus, thus exposing a black sub-surface and recording a black mark. Some half-tones can be recorded. The special paper used is relatively expensive, is damaged by surface pressure and may emit objectionable fumes during recording. An alternative version makes use of paper having a thin surface-layer of aluminium deposited over a black sub-surface. The passage of recording current from the scanning stylus causes local melting of the aluminium to occur. The metal recedes under the influence of surface tension revealing the black sub-surface. This method of writing does not appear capable of recording half-tones, and the unconventional appearance of the documents may not be acceptable to some users. This method is, however, relatively cheap and is odourless.

(*e*) *Electrostatic.* A special paper with a dielectric coating is required to prevent dissipation of static charges deposited on the surface. A minute or so has to elapse after recording for the image to develop. Machines using this principle require a potential of several hundred volts. The paper may be difficult to write on with normal pens, and problems with charge leakage could be encountered when operating in humid conditions.

The foregoing writing principles may be applied to a variety of drum or flat-bed recording designs. Flat-bed machines can readily employ continuous rolls of paper, which facilitates unattended operation. Drum machines, however, require hand-loading with individual sheets, or the use of a hopper-feed mechanism with its attendant problems.

Drum Receivers. The scanning of a line is achieved by rotating the drum, thus drawing the paper attached to it past the recording point. Scanning of successive lines is achieved by traversing the recording point along the drum surface and parallel to its axis. This method has been employed in conjunction with the ink stylus and the electro-sensitive recording systems. It has the advantage that the receiving drum may be adapted from the transmitting drum, simply by substituting a writing point for a reading point on the same axial traversing carriage. Such machines, known as transceivers, are unable to send and receive at the same time, but apart from test operation this facility is seldom required. The drum-type receiver system suffers from the disadvantage that the received copy cannot be inspected until the drum is halted when reception is complete. Thus, it might not be possible to detect and interrupt a faulty transmission.

Flat-Bed Receivers. As with transmitters, the term flat bed is something of a misnomer. The distinguishing factor is that the scanning of a line does not require movement of the paper. Generally, however, the advance to subsequent scan lines is achieved by slowly moving the paper past the recording point. The writing methods employed are, percussion (carbon paper), electrolytic and electrostatic.

With the percussion method, the paper is laid in a semi-circular trough. The curved surface is then traversed alternately with one of a pair of percussive recording heads rotating on an axis placed at the centre of curvature. The paper is drawn slowly through the trough past the recording point whilst the heads rotate and cover the sheet with a succession of recorded lines reproducing the transmitted document. This method of recording necessitates a bulky machine requiring precision engineering, but although it is capable of acceptable reproduction quality it lacks high speed potential and is thought to be approaching obsolescence.

With the electrolytic method, the paper is drawn over a stainless-steel blade. Recording is achieved by traversing the opposite side of the paper with a second electrode. The scanning of a line is achieved by traversing the second electrode which may take the form of a stylus, or more usually a helix. This causes the spot of paper pinched between it and the blade to traverse a line across the paper. Successive line tracing is arranged by slowly advancing the paper. Peak white and peak black are less intense than with some other systems, resulting in poorer contrast, nevertheless, under favourable conditions, very satisfactory recording can be achieved.

With electrostatic recording, the paper is traversed by a stylus which deposits an electrostatic charge proportional to the density of the spots being scanned at the transmitter. The tracing of successive lines is arranged by slowly advancing the paper. As the paper advances beyond the recording point, it passes through a development process in which toner powder is attracted by the electrostatic potentials deposited on the surface by the scanning stylus. The coated paper is then passed over a heater-bar to fuse the adhering powder into the surface to provide a permanent copy. Electrostatic recording is the most recently evolved system and much development effort is still being concentrated on it, particularly in Japan. Even in its present state of development, good-quality recording can be obtained. It does, however, have the disadvantage that about one minute must elapse after scanning has taken place before the processed image commences to emerge for inspection by the recipient.

Modulation System

The output signal from the photocell at the transmitter consists of one potential representing the scanning of black, a second for white and intermediate potentials for half-tones. The signal is analogue in form, and, as completely black or white areas may occur in the document being scanned, the transmission of the photocell output directly to line requires circuits with a d.c. transmission capability. If it is desired to use the p.s.t.n. for facsimile transmission, it is necessary to modulate a carrier frequency in order to confine the signals within the normal telephone-channel bandwidth. Mainly because of the range of attenuation which may be experienced on a succession of calls over the p.s.t.n., frequency modulation (f.m.) has been recommended by the C.C.I.T.T.* and has been adopted by a number of manufacturers. There is, however, at least one manufacturer who is a firm advocate of amplitude modulation (a.m.) for this purpose. A.M. systems require reference-level pulses to be sent by the transmitter to adjust automatic-gain-control circuits at the receiver.

LINE TRANSMISSION

The p.s.t.n. was constructed and is maintained to provide satisfactory telephone speech communication at a reasonable cost. Certain transmission impairments which have no noticeable effect on speech communication can adversely affect the transmission of facsimile and data signals. Facsimile transmission can be seriously affected by group-delay distortion introduced by filters and loading coils. Listener echo with delay times of only 2 or 3 ms may also impair received copy.

Equalization can be provided at the receiver to compensate for delay distortion, but on the p.s.t.n. the latter varies from circuit to circuit, and equalization is always a compromise. A further constraint on the use of the p.s.t.n. is the necessity to choose modulation systems and frequencies which avoid interfering with in-band signalling equipment on long lines.

It is probable that acceptable document facsimile communication can be achieved over most circuits which are encountered on calls over the p.s.t.n., but it is difficult to be dogmatic about the point at which a document ceases to be considered

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

TABLE 1

Machine Characteristics

Machine Designation	Country of Manufacture	Type of Machine	Recording Process	Index of Co-operation	Scanning Pitch (m.m.)	Scanning Rate (lines/min.)	Useable Portion of Whole Scan Line (per cent)	Modulation System	Frequencies Used (Hz)
E.M.I. *Emifax HF* 146.4	Germany	Drum transceiver	Inked stylus percussive on ordinary paper	264	0·265	180	90	f.m.	2,100 (white) 1,300 (black)
Muirhead, *Courier K*-400-D & *K*-401-D	U.K.	Separate flat-bed transmitter and receiver	Helix and writing edge on damp electrolytic paper	264	0·28	180	92	f.m.	2,100 (white) 1,300 (black)
Plessey, *Remotecopier KD* 111	Japan	Flat-bed transmitter and receiver mounted in same cover	Electrostatic charge, deposited by stylus on electrostatic sensitive paper	296 or 198 (operator selectable)	0·265 or 0·395	180	88	f.m.	2,100 (black) 1,500 (white)
Rank-Xerox 400 *Telecopier*	U.K.	Drum transceiver	Electrosensitive paper, marked by current flow from stylus	264 or 176 (operator selectable)	0·265 or 0·395	180	94·9	f.m.	2,100 (black) 1,300 (white)

satisfactory. This is influenced by the message content, and is very much a matter of personal judgement.

OPERATIONAL PROCEDURE

To send a document, it is first necessary to establish telephone communication with another telephone station which has a compatible facsimile machine. When the call is established, the calling operator asks the receiving station to switch to facsimile whilst he connects his facsimile machine to line in place of the telephone. The operator who wishes to transmit a document then starts his machine. For the first 10–15s the send machine sends phasing pulses each of approximately 5 per cent line-scan duration repeated at line-scan rate. On detection of these pulses the receiving machine starts but runs at a modified line-scan rate until the received phasing pulses coincide with the dead sector of the receive scan, whereupon the receiver line-scan is restored to the standard rate. Alternatively, an electro-magnetic clutch can be operated by received phasing pulses to couple the receiver scanning mechanism in the correct angular relationship to the transmitter. Transmission of the document commences automatically as soon as the phasing period has expired, and continues until the image has been passed. Controls may be provided at the transmitter to define the length of document to be sent. On completion of transmission, the receiving machine senses the cessation of information flow, comes to rest and indicates by an alarm that reception is complete. On some machines, supervisory tones outside the main signalling bands are exchanged between sender and receiver before, and at the end of a transmission to ensure correct interaction between machines.

At the completion of a call, the operators at both ends switch back to telephone, and having certified acceptable reception, the call is cleared in the normal manner. Most of the machines at present being offered for p.s.t.n. service transmit an A4-size document in 6 minutes, which whilst appearing slow, compares favourably with Telex which requires at least 9 minutes to transmit a full 60-line page of 600 words.

DOCUMENT-FACSIMILE TRANSMISSION STANDARDS

Facsimile transmission over the p.s.t.n. lacks much of its potential attraction if the machines used are able to communicate only with those from the same manufacturer. It is recognized that compatibility between all makes of machine is necessary if the service is to grow, yet at present there is virtually no compatibility between machines from different manufacturers and often little within a single manufacturer's range.

A large measure of agreement exists—that f.m. should be employed, that the drum speed should be 180 revolutions/minute and that the index of co-operation should be 264. There is some controversy as to whether the upper frequency of the f.m. signal should be 1,900 Hz or 2,100 Hz, and the lower 1,300 Hz or 1,500 Hz. The major point of contention is as to whether the higher or lower of the two frequencies should be transmitted where black is scanned at the sending machine. The majority usage at present is for the higher frequency to represent black, but the C.C.I.T.T. recommends the transmission of the lower frequency for black. No clear advantage for either system has been demonstrated but theoretical arguments favouring the higher frequency for black have been advanced.

Agreement on supervisory signalling arrangements are also necessary if interworking is to be achieved, even between machines with compatible modulation systems.

A list of the principal characteristics of four machines at present being offered for use over the p.s.t.n. is shown in Table 1. The machines, with covers removed to show the internal layout, are illustrated in Figs 1–4. All use f.m. for their line signals, and despite the inversion of black and white frequencies on two machines, they may be considered potentially compatible.

FUTURE DEVELOPMENTS

The quality of a facsimile copy for a given design of machine is directly related to the channel bandwidth and the time taken

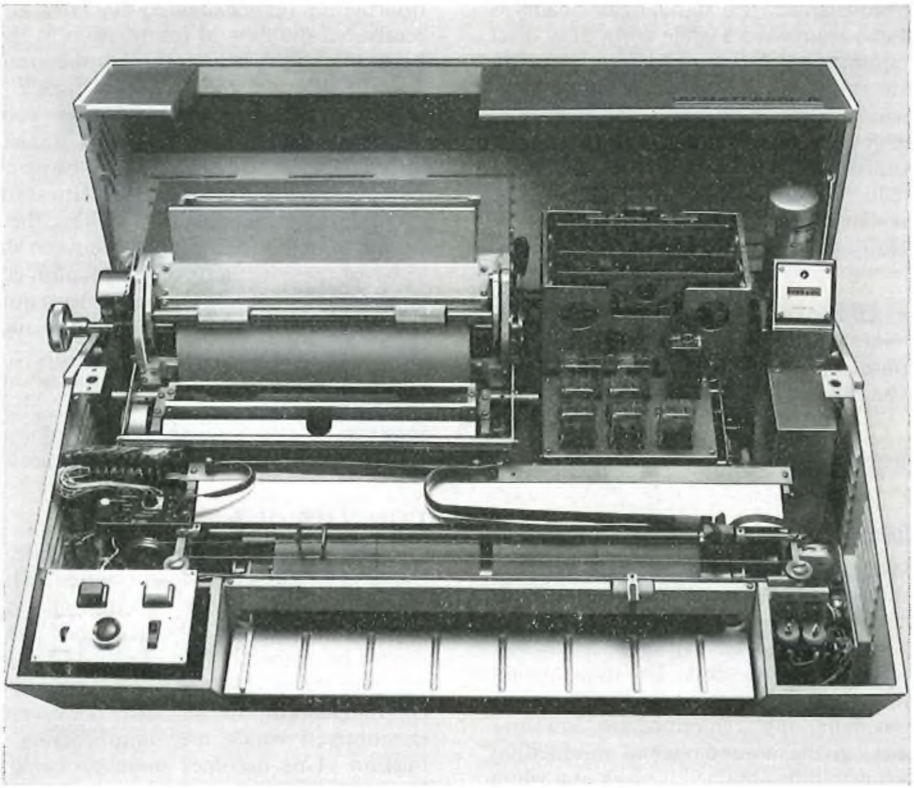

FIG. 3—Plessey *Remotecopier KD* 111

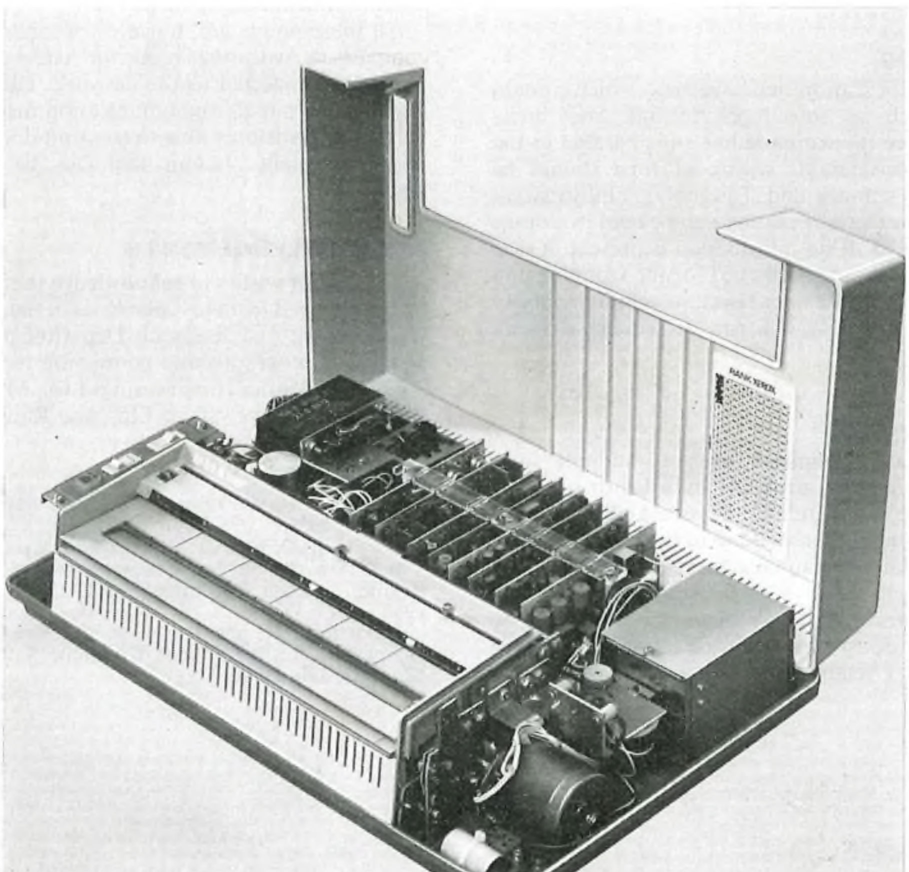

FIG. 4—Rank-Xerox 400 *Telecopier*

for transmission over the channel. If a standard of quality is set, such as the ability to transmit a legible copy of a sheet of typescript, then, if simple modulation techniques are used, and the bandwidth available is that provided by the p.s.t.n., the time for transmission will be fixed and is approximately 6 minutes on the machines discussed. This period, although competitive with transmission time by Telex, appears long to the sender, and the reduction of this period to possibly less than one minute is the aim of many researchers.

There are three possible ways in which transmission time can be reduced:

(*a*) the use of a more efficient signal-modulation technique,

(*b*) the skipping of lines containing no information, and

(*c*) the redistribution of the information within a scanned line to give a more even flow of signal transitions fed to the modulator.

These are discussed further below.

More Efficient Modulation

Techniques have been proposed which should enable a greater amount of information to be passed over a given bandwidth in unit time. Typical of these is a system in which alternate high and low-frequency signals represent black, and an intermediate frequency represents white. The transmission of a white, black, white, black, white sequence results in the transmission of intermediate, high, intermediate, low and intermediate frequencies, giving a fundamental modulating signal of half that which would be obtained if black and white were represented by single frequencies. This system, which is akin to the alternate-mark-inversion technique employed on some pulse-code modulation systems, usually precludes the transmission of half-tones and requires a transmission system having a higher signal-to-noise ratio.

Blank-Line Skipping

Most documents to be transmitted have areas which contain no information, such as inter-typescript-line and inter-paragraph gaps. Where the scanning line runs parallel to the typescript lines, a considerable saving of time should be possible. Each line is scanned and if it contains information it can be re-scanned or the information can be held in storage before being transmitted. If no information is present, a skip signal is sent to line, and time is allowed for the scanning and writing devices to advance one line. This time requirement can present problems, particularly if a run of sequential blank lines is detected.

Information Compression

In most documents transmitted over a facsimile link, black or white predominates, probably by a factor of 10 : 1 or even more. There is, therefore, considerable scope for saving time by speeding the transmission of the predominating shade. Still further economy can be achieved by speeding the transmission of either shade and pausing only where a transition is to be transmitted. Various methods can be employed for this purpose, but it is necessary to provide either variable-velocity scanning, or storage of one line of information (approximately 800 bits), at both transmitter and receiver if the flow of information to the modulator is to be kept near to the maximum that the circuit can convey.

An alternative method is to inspect blocks of line information in, say, 10-element blocks, and if all elements are black or white a simple code is transmitted, otherwise the information is transmitted as scanned. This method also requires storage or variable-velocity scanning.

Other methods include signalling the length of any block of one shade, or the intervals between shade transitions.

All of these methods of information compression introduce considerable complexity into the equipment, and this is reflected in cost and reliability, and most imply black-and-white transmission only. Furthermore, one of the factors which permits facsimile communication over the p.s.t.n. is the large amount of redundancy present in the original message. If this is considerably reduced then the ability to communicate may be seriously impaired.

CONCLUSIONS

The feasibility of document-facsimile communication over the p.s.t.n. has been demonstrated. The equipment can be simple to operate and avoids the requirement of special skills, such as the ability to touch-type. Document transmission should be well within the capacity of any office junior. Working over the p.s.t.n. ,which is designed primarily for speech communication, means that occasionally circuits will be encountered which are unsatisfactory for facsimile transmission. This becomes more probable when long-distance international calls are attempted. There is considerable scope for improvement of the recording equipment to give good contrast and definition whilst avoiding objectionable features such as odours or unstable copy, to reducing the time taken to transmit a document and to arranging for unattended operation of the equipment.

All these points are, however, secondary considerations in comparison with the need for compatibility between all machines connected to the network. Facsimile is unlikely to grow into a popular communication medium whilst any one facsimile user is only able to transmit documents to a fraction of the facsimile stations that can be contacted over the p.s.t.n.

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Construction Practice for Transmission Equipment

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U.D.C. 621.395.461

Evolution of equipment construction practice is closely related to component and system advances. An outline of historical development is given and the present standard form of construction used by the British Post Office is described. Any studies related to future equipment practices must take account of already-established trends towards higher component-packing densities, higher power dissipation and a greater degree of automation in production.

INTRODUCTION

British Post Office (B.P.O.) transmission systems are required to meet exacting requirements for stability, reliability and maintenance over a service life which often exceeds 25 years. Many modern electronic components are, however, essentially delicate, both mechanically and thermally, so that achievement of the objectives is, to a large extent, bound up with physical design, involving considerations of mechanical engineering, properties of materials, thermal design, electrical connector techniques and manufacturing technology.

A standardized system for physical design of a whole range of equipment, facilitating its interconnexion with other equipment, is generally known as an equipment practice. Whilst many such equipment practices are possible, there are economic and service advantages if the transmission systems which are supplied to the B.P.O. by a wide range of manufacturers are designed and produced using a common equipment practice.

The article reviews the historical development of standard equipment practices for B.P.O. transmission equipment and indicates the reasons for some of the changes that have taken place in the physical form of equipment. The need to meet frequency-division multiplex (f.d.m.) channel equipment requirements economically has invariably been the primary reason for the development of new forms of construction to complement advances in electrical component technology and availability of new materials. Apart from improved overall performance, the chief benefits derived from the advances have been reduced initial cost and increased reliability of equipment. Each new equipment practice has also had an impact on maintenance techniques, generally leading to reduction in costs and improvement in service.

As circuit operating speeds increase towards and into the nanosecond region, fundamental limitations are imposed on the spacing of circuit elements, and this adds impetus to the already established trends to higher-density circuit configurations and increased penetration of the various types of integrated-circuit techniques—monolithic, hybrid, thick and thin films. This could lead to relatively high levels of power dissipation and consequently to excessive temperature rises within equipment units which could impair system performance and reliability if insufficient attention is paid to thermal design. The problems can be tackled economically by the present standard form of construction for the time being, but in the future, alternative approaches may well be needed.

HISTORICAL DEVELOPMENT OF TRANSMISSION EQUIPMENT PRACTICES

The form of construction used prior to the early 1950s comprised strong vertical steel sections, carrying metal panels on which electrical components were mounted. Panel wiring and components were accessible for maintenance adjustment, fault location and repair, after removal of steel dust-covers. There was, however, little possibility of using centralized repair-centre techniques on a large scale since panels could not conveniently be removed from the rack for servicing. Overhead cabling between racks terminated on tag blocks at the tops of racks and rack cabling was via vertical rack channelling to tag blocks on equipment panels which were mounted on both sides of the rack. It was often difficult to provide rack wiring to panels subsequently added to an installed rack.

During this period, components were comparatively bulky, and packing density was low so that generally there were no particularly onerous problems of heat concentration. By about 1950, however, valves and components of greatly reduced size, improved performance and better reliability were available and a new form of construction was necessary to obtain an economic packing density consistent with the need for high reliability and improved maintenance facilities.

51-Type Construction

A form of construction which became known as B.P.O. 51-type[1] was developed by a contractor and introduced by the B.P.O. as the standard practice for transmission equipment. The rack-side was of folded sheet steel and panels were of the jack-in type, being connected to the rack wiring by means of U-links engaging with rack-side and panel sockets. The rack was permanently wired from rack-side connectors to connexion strips at the top of the rack where station cabling terminated. Racks were usually placed back to back in suites.

Perhaps the most significant innovations, apart from the method of manufacture and appearance, were that the permanent cabling down rack-sides could be carried out in the factory and individual panels could readily be removed from the rack without disturbance to permanent cabling. This innovation, facilitated by the rack-side connectors, enabled improvements to be made in maintenance methods. Service could rapidly be restored using spare panels, faulty items being removed for fault location remote from the rack, often at specialized repair centres.

56-Type Construction

Component technology advanced rapidly during the 1950s and it was clear that semiconductor devices would replace the thermionic valve as soon as development reached a stage when reliability and performance were considered adequate for long-life telecommunications equipment. The 51-type form of construction was not ideally suited to fully exploit the new

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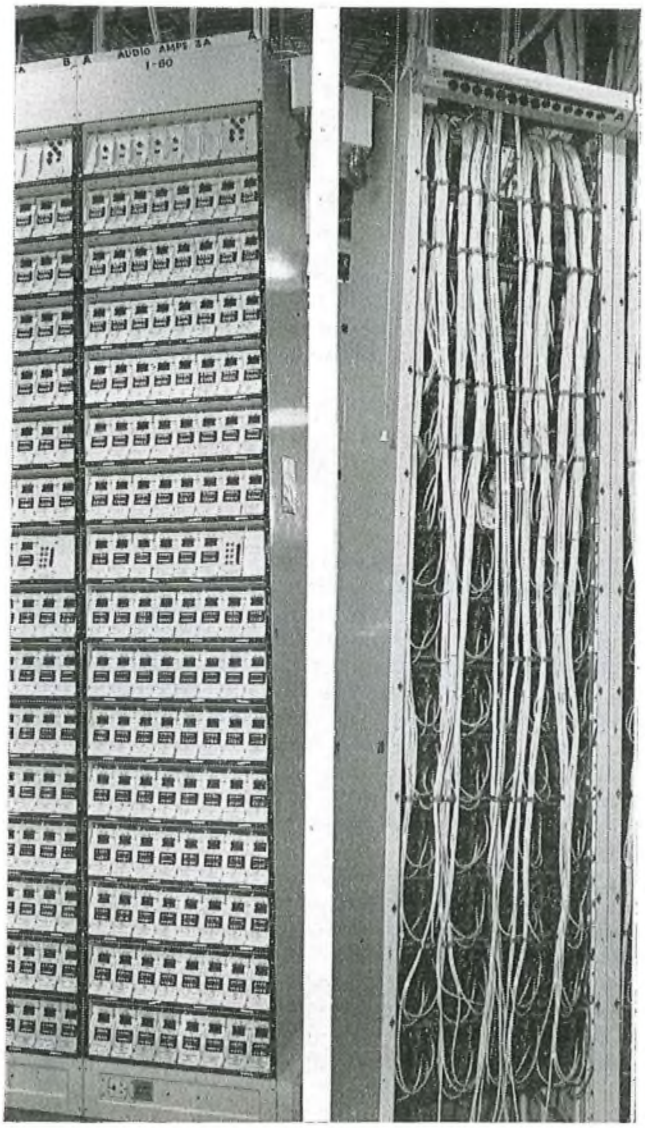


(a) (b)

(a) Front view showing general appearance
(b) Rear view with covers removed showing cabling and maintenance access

FIG. 1—62-type rack

potential for size reduction and a development, known as B.P.O. 56-type, was introduced. This practice, which utilized the basic 51-type rack, enabled several separate equipment units to be placed side by side across the width of the rack. Individual equipment units were connected to permanent shelf wiring by U-links and could be readily removed for maintenance etc.

The construction was more complicated mechanically than 51-type, but it was possible to achieve lower equipment cost due to higher packing density and better space utilization in repeater stations.

62-Type Construction

During the early 1960s the B.P.O. made careful study of equipment practices being developed by a number of suppliers, and after consideration of alternatives, one of these was adopted as the new standard equipment practice for transmission equipment and designated 62-type by the B.P.O. This form of construction, the present standard, is designed specifically around the use of printed-wiring-board techniques and high reliability connectors between permanent rack-wiring and individual equipment units. 62-type racks conform to internationally established dimensional requirements and are compatible with older types of rack.

A description of the practice is given below.

EQUIPMENT COSTS

The cost of transmission equipment has fallen steadily over the years. This is due to a number of favourable trends but advances in equipment practice have had a part to play, principally in the direction of increased packing density to exploit modern technology and materials and to facilitate more economical manufacturing methods. For f.d.m. channel equipment, for example, the greatest capital cost reductions have tended to coincide with the introduction of a more advanced equipment practice to complement advances in component technology and circuit techniques. Equipment practice advances have also given rise to other savings, principally due to more efficient space utilization in repeater stations, and improved maintenance methods which lead to improvements in service.

The capital cost of f.d.m. channel equipment has continued to fall in the period since 1964 when the 62-type equipment was introduced and there is every prospect that the favourable cost trends will be perpetuated with equipment now under development.

62-TYPE CONSTRUCTION

With earlier forms of construction, the rack was the basic unit for planning purposes. Partially-equipped racks could be installed but it was often difficult subsequently to cable the remainder of the rack without disturbance to working equipment. Alternatively, if partially-equipped racks were fully cabled at the outset, it was difficult subsequently to accommodate different types of equipment on the same rack. The space economy which is obtained with modern components and printed-wiring boards readily permits the quantity of equipment which might formerly have required a whole rack or more to be housed on a single shelf within a rack. In the 62-type form of construction the shelf is therefore the basic unit of provision. Station cabling terminates directly onto connectors at the rear of the shelf with no intermediate connectors or soldered joints so that separate rack cabling is largely eliminated.

Any number of shelves, up to the maximum determined by the rack height, may be provided at the outset, and there is no restriction on the future provision of remaining shelves or on the type of equipment they are to house, nor is there any disturbance to existing shelves when this subsequent work is carried out. Individual shelves may be factory wired and supplied fully or partly equipped at the outset, any additions or alterations subsequently being made without disturbance

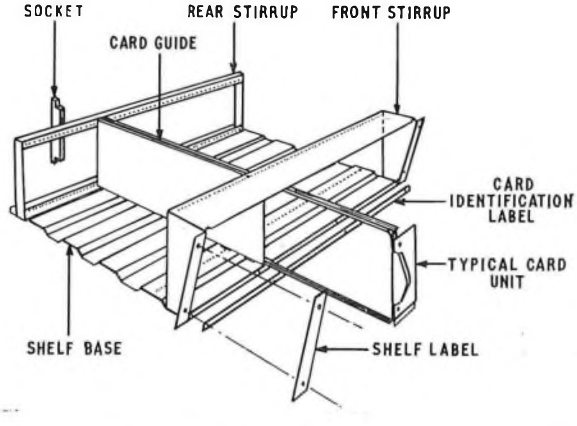


FIG. 2—Typical 62-type shelf assembly

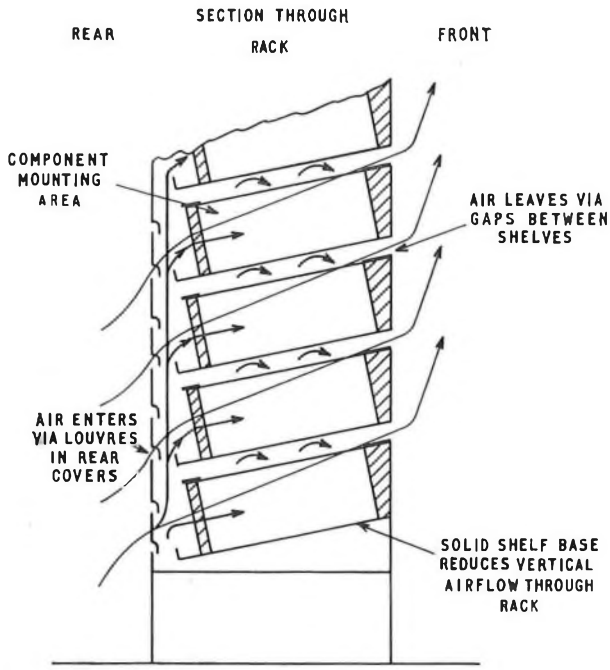


FIG. 3—Air flow through 62-type rack

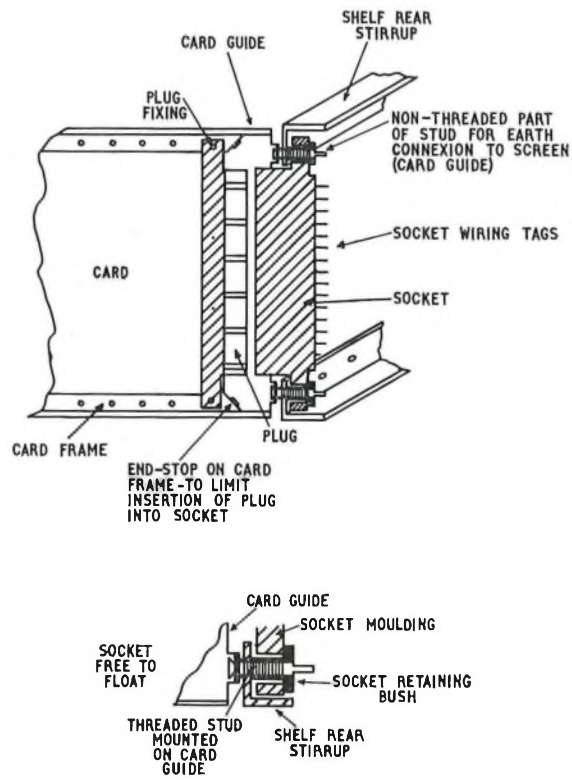


FIG. 4—Details of socket mounting on 62-type shelf

to working equipment. This flexibility is largely facilitated by the single-sided nature of the rack whereby one whole face (the rear) can be exposed by removal of covers, thus giving excellent access to all cabling which runs vertically from overhead ironwork and can utilize the whole width of the rack, as shown in Fig. 1.

Cabling upwards from floor level can be accommodated if required.

The Rack

The rack which is illustrated in Fig. 1 comprises two formed sheet-steel sides (1·6 mm gauge) 450 mm deep and in a range of standard heights up to 3·23 metre, 2·74 metre being standard for repeater stations. The sides are bolted to top and bottom members which give the rack a total width of 520 mm. Accommodation is made in the sides of the rack for the fitting of shelf-supporting slides, the positioning of which is flexible in 50·8 mm vertical increments. The base of the rack has facilities for provision of power for test equipment and soldering irons etc. The top of the rack is connected to the overhead ironwork which carries power distribution and inter-rack cabling etc.

A fuse unit for d.c. power distribution within the rack is mounted at the top rear of the rack. Power from the station bus-bar is connected to this unit by an individually-fused cable from an end-of-suite distribution unit which also serves the other racks in the suite.

The Shelf

The shelf comprises a base and a front and rear stirrup as shown in Fig. 2. The standard shelf height is 152 mm but other heights in multiples of 50·8 mm can be accommodated.

Shelves are usually inclined at 15° to the horizontal and this helps to increase airflow over the components. (Shelves which mount horizontally are also available.) Air enters the rack via louvres in the rear covers and passes over the components housed in the shelf and is then discharged at the front (top) of each shelf as shown in Fig. 3. Each shelf has a solid-steel base for strength and also to encourage the flow of air from rear to front, thus minimizing vertical air flow and temperature rise in the rack.

Metal card-guides, which also serve to a certain extent as electrical screens, are fitted in appropriate positions in the shelf. The positioning of the guides is determined by location holes in the front and rear stirrup at 5·08 mm centres. Studs on the rear of the card guides project through the holes in the rear stirrup and serve for mounting the socket onto which station cabling is terminated. The arrangement is shown in Fig. 4. There is, thus, a close relationship between the guidance system for cards and the socket. The socket mounting is such that there is a certain amount of free movement or float to accommodate tolerances in the guidance system. A useful facility from a maintenance and service viewpoint is that any socket can be removed from the rear of the rack without disturbing adjacent cards.

Cards and Chassis

Printed-wiring boards are mounted on steel card-frames which also mount the plug for electrical connexion to the shelf-mounted socket. A front plate and handle with any necessary test points and controls is also fastened to the card frame.

Larger items are often constructed in the form of a chassis which connects with sockets at the rear of the shelf as for smaller units, but within which the designer is largely free to determine the particular mechanical arrangements. An individual equipment unit can be of any width from 15·2 mm up to the full width of the shelf, in increments of 5·08 mm. A typical 62-type card unit is illustrated in Fig. 5.

Cards and chassis can be replaced very rapidly by simply withdrawing the unit out of the guides after lifting a simple gravity-operated retaining strip which prevents inadvertent removal of units. It is necessary to be able to withdraw certain cards, for example fuse cards, without disconnecting the circuits, and arrangements exist for this facility. Suitable

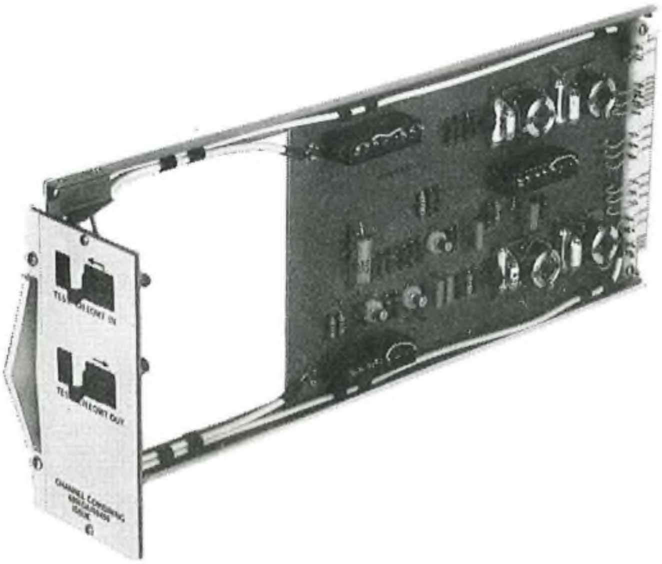
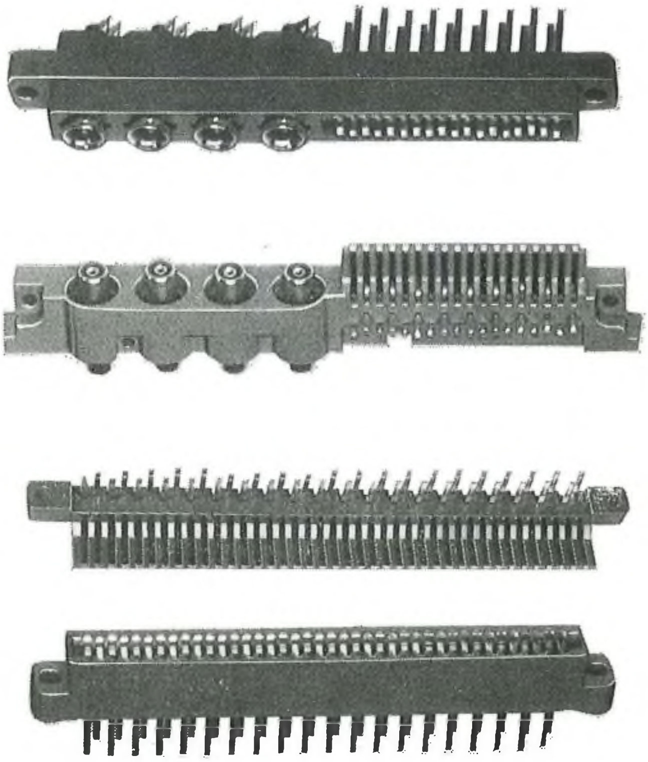
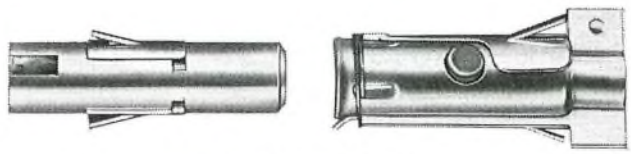


FIG. 5—Typical 62-type card



(*a*) Typical connector mouldings



(*b*) Coaxial connector inserts

FIG. 6—62-type connectors

adaptors are available to facilitate in-service adjustments and fault finding on individual cards.

Connectors

Some of the types of connector used with 62-type equipment are illustrated in Fig. 6. Contact springs are typically of phosphor bronze or beryllium copper, plated over mating surfaces with hard gold about 5·0 microns thick, to give low contact resistance (less than 5 milliohms) and durability. Contact pressures are consistent with limits for insertion and withdrawal forces for equipment units—equivalent to 14 kg and 8·25 kg + 0·25 times unit weight, respectively (for 15° inclined shelves). Termination of rack cabling onto sockets can be by soldering or wire-wrapping. The maximum number of connexions with the standard connector is 40. Also available are composite connectors which have a maximum of six coaxial and eight single connexions. For economy, and to keep insertion/withdrawal forces low, only the number of contact springs or coaxial inserts acutally required are fitted.

Moulding materials used to hold contact springs and coaxial inserts are, typically, glass-filled polycarbonate and di-allyphthalate (various proprietary names are often used for these materials). Materials are selected for dimensional stability and hardness, and for the socket, resilience to prevent damage when the plug is inserted many times over a long life. The degree of insertion of the plug into the socket is positively limited by an extension of the card frame which touches the shelf rear stirrup when the plug and socket are fully engaged (Fig. 4). This arrangement prevents damage to sockets if an equipment unit is inserted into position with excessive force.

The electrical and mechanical interface represented by the connector is of prime importance in determining overall reliability of the equipment practice and hence of transmission systems. It is not surprising, therefore, that great attention is paid to the aspects of design which directly influence the reliability of this interface.[2, 3]. The assessment includes systematic consideration of:

(*a*) dimensions and tolerances of parts which determine positioning of the plug and socket and of the assembly of these parts,

(*b*) dimensions and tolerances of plugs and sockets,

(*c*) properties and performance of materials used,

(*d*) results of tests to determine long-life capability of parts. These tests are aimed at determination of the effects of exposure to repeater-station environment over the life of the equipment, say 25 years. The method is to accelerate the effects by exposure to highly deleterious atmospheres, rapid cycling between extreme temperatures and damp heat, etc., and

(*e*) results of special testing for certain parts, e.g. determination of hardness of gold on mating parts of connector, study of sections by microscope, electrical testing of connectors etc.

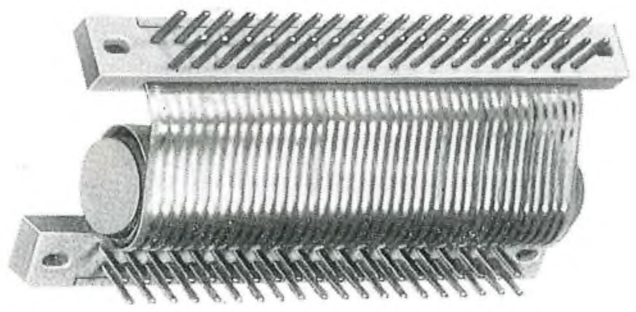
Design and Manufacture

The equipment practice is specifically designed for printed-board equipment. It allows flexibility in equipment layout while at the same time requiring a relatively small number of standard parts. Inevitably in a system aimed at long life and high reliability some parts have to be designed and constructed to relatively close tolerances. This particularly applies to those parts associated with the plug and socket interface.

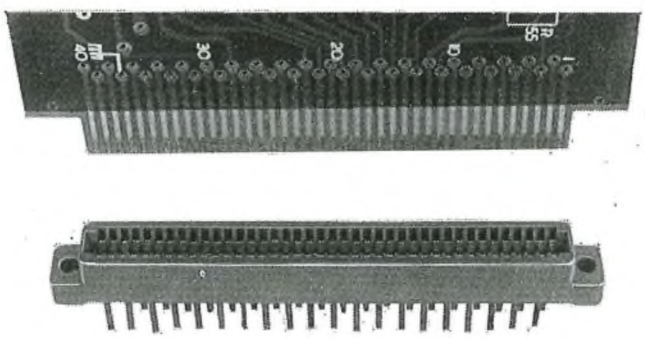
Fabrication is mainly from standard gauges of sheet steel and production accuracy depends primarily on tooling rather than assembly operations which are operator dependent. An empty rack is designed to have sufficient strength to withstand stresses incurred during handling and installation and is also strong enough to support up to 135 kg of overhead ironwork and cabling if required. When the rack has been fitted with a complement of shelves the strength is such that it may be equipped to a total weight not exceeding 540 kg.

B.P.O. design evaluation encompasses dimensional tolerance analysis, assessment of strength and stability of materials and suitability of finishes. Testing for compatibility of parts from different sources is also most important to ensure continued acceptability of parts from several sources. Thus, once design and tooling have been approved, consistently high conformity with dimensional requirements is achieved and parts from different sources are readily interchangeable.

Availability of racks and parts from a number of manufacturing sources enables equipment designers to exploit the practice with adequate assurance of production supplies.



(*a*) Flexible retractile connector



(*b*) Printed edge connector

(*c*) Crimped coaxial connector

FIG. 7—Recent developments

Recent Developments

The standard practice is highly successful in the transmission field with its features such as economy, suitability for purpose, flexibility and ready availability. There are also an increasing number of applications for the practice in the telephone-exchange environment, for example, pulse-code modulation (p.c.m.) transmission and junction-signalling equipment, trunk signalling equipment, wideband alarm schemes, and electronic directors.

The seven or eight-year period since the introduction of the standard form of construction has seen unprecedented advances in component technology, materials and circuit techniques. Adaptation of the equipment practice has ensured exploitation of these advances, and development of the next generation f.d.m. and p.c.m. multiplex equipment will no doubt see further adaptation. Some recent developments include the following:

(*a*) horizontal and inclined standard-width shelves, card guides and frames all having reduced depth (89 mm shorter) giving a higher ratio of cabling space to equipment space on a rack. These items will be used on the test access and gain adjustment racks (t.a.g.a.r.) being developed for use with next generation f.d.m. channelling equipment,

(*b*) wide shelves and housings (673 mm wide) to take reduced-depth equipment for fitting on certain existing types of racks in Strowger telephone exchanges,

(*c*) special rack enclosures for transmission and data equipment fitted in customer's premises. These racks, 2 m high, have a high standard of finish making them suitable for use in computer rooms, offices and other prestige areas,

(*d*) security covers for racks and housings

(*e*) integral gold-plated edge connectors on printed-wiring boards instead of the use of a separate plug (Fig. 7). This can lead to economies in production and elimination of all conventional wiring from the printed-wiring board,

(*f*) flexible retractile connector (Fig. 7). This allows a unit to be withdrawn without disconnexion and exploits modern flexible-wiring techniques, and

(*g*) crimped coaxial connectors having superior electrical properties making them suitable for use at the higher frequencies now being exploited (Fig. 7). Crimping can also lead to savings in production compared with soldered-type coaxial connectors.

There are still some flexibility features not yet exploited, for example, only one shelf height (152 mm) has been found necessary up to the present but other heights, in increments of 50·8 mm, will be allowed if they become necessary.

Metrication

The 62-type practice documents are now in metric terms and metric materials will be employed as soon as they are available. It is expected that industry will cope with the changeover with little difficulty.

THERMAL DESIGN

The thermal design of telecommunication equipment must aim at providing satisfactory working temperatures for electrical components, consistent with acceptable room conditions. This involves relating equipment dissipation firstly to the room environment and secondly to ambient conditions within the equipment itself and to component temperatures. These considerations are clearly not mutually exclusive but it will be convenient to consider them separately here.

Room Conditions

Rack dissipation is limited to a level which can be economically handled by natural ventilation within the rack, coupled with standard schemes of room environmental treatment to maintain acceptable room temperatures. For planning purposes, in the case of 62-type equipment, this is achieved by setting a 400 watts limit to rack dissipation and providing the necessary room cooling arrangements on the assumption that a certain proportion of racks will actually dissipate 400 watts, the remainder of space being occupied by non-dissipating equipment, e.g. distribution frames. Generally, adherence to this limit is not unduly restrictive on designers but there are certain equipments, particularly those involving line signalling, where vacant spaces must be left on racks in order to keep within the limit. Immediately apparent alternatives to accommodate higher rack dissipation are:

(*a*) to provide more room cooling plant. This approach could cater for marginally-higher dissipation but would involve higher capital and running costs for the extra cooling plant. This plant could, moreover, take up some of the space gained in the equipment area, albeit in a different room, and

(*b*) place fewer racks in a given area and use the space gained for purposes not involving heat dissipation.

The room-cooling approach will maintain staff comfort conditions but care is necessary to avoid excessive within-rack temperatures which could impair equipment reliability and possibly performance.

Equipment Conditions

Performance, reliability and life of many components are adversely affected by high operating temperatures. Every effort is made to minimize dissipation by good design, and in some cases dissipation on a per-function basis has fallen an order or so in recent years. Unfortunately, however, this has often not kept pace with size reduction achieved, nor does it seem likely that there will be any reversal in the trend towards greater dissipation per unit volume as operating speeds and the use of integrated circuits increase.

Having established a dissipation limit for a rack consistent with satisfactory room temperature, the thermal design of equipment aims to optimize heat transfer from heat-producing components to the room so that excessive component temperatures are avoided. It is also important for safety of personnel that the temperature of external surfaces is kept low. In the case of 62-type equipment, cooling is principally by natural convection of air over the components and radiation and convection at external surfaces (Fig. 3). Because the shelf is the basic provision unit, shelves in a rack can house a variety of equipment, perhaps from different suppliers. Cooling air is therefore deliberately ducted through the shelves to be exhausted at the rack front and discouraged from travelling vertically through the rack. The ambient temperature within a shelf can be estimated from the empirical formula:

$$\text{temperature } (^\circ\text{C}) = T_{room} + 0{\cdot}3\,P_a + 0{\cdot}18\,P_b + 0{\cdot}105\,P_c + 0{\cdot}06\,P_d,$$

where P_a = power dissipated in shelf in question (watts), and

P_b, P_c, P_d = power dissipated in shelves below, in order (watts).

T_{room} = room ambient temperature (°C),

The temperature rise from a shelf four or more below is usually negligible. The overall heat-transfer efficiency from components to the ambient air in the shelf space ultimately determines component temperatures. The transfer usually involves elements of all three modes of heat transfer—radiation, convection and conduction, and an analytical approach is necessary for an accurate evaluation of conditions in an equipment unit[4]. A proper understanding of heat transfer problems becomes most important as circuit-packing density and power dissipation increase, although intuitive and experimental assessments have often served in the past.

Some methods of improving heat transfer from components are as follows:

(*a*) *Use of heat sinks.* Many materials used in modern equipment are poor thermal conductors. A heat sink will effectively increase component surface area and sometimes will also provide a path of good thermal conductivity to say equipment framework. Heat is first conducted from a component to the heat sink and is removed by convection, radiation and sometimes conduction from the larger body. It is important that the thermal resistance between the component and heat sink is kept low, and this is often achieved by increasing contact pressure between the two and/or the use of grease compounds having good thermal conductivity, which tend to fill any voids at the joint.

(*b*) *Increase in convection air flow.* This is achieved by suitable design to ensure that large components do not block air flow over smaller heat-dissipating components or by providing larger inlet and outlet apertures for cooling air etc. Alternatively, air flow can be increased by provision of blowers on racks. This latter course has up to now largely been avoided in telecommunications equipment since the reliability of the cooling apparatus could become a major element in determining the reliability of a transmission system. The ancilliary equipment would of course also cost money and take up some space.

(*c*) *Use of heat exchangers.* Again, cost, space, and possibly reliability considerations are involved, but these methods could be adapted to deal with hot-spots, i.e. components dissipating a high power on a rack which would not otherwise require special cooling.

FUTURE DEVELOPMENTS

The use of semiconductors and high-reliability connectors and the refinement of printed-wiring techniques have been key influences on circuit and equipment-practice design during the past 15 years. Indeed, at the present time, all equipment practices involve the use of these elements in one form or another. Packing density has been such that natural ventilation of racks is both practical and economic and circuit performance objectives have been adequately met.

There is a close relationship between circuit design and physical design. This is particularly so as circuit operating speeds increase to the microsecond and nanosecond range, when satisfactory circuit operation often depends directly on physical design. For example, spacing of components becomes critical to performance and the control of electrical and magnetic interaction between elements, so that interconnexions must be kept short or a prescribed length related to the circuit operating speed. In many cases integrated circuits, both monolithic and film type, present an ideal solution since they are of very small size, amenable to batch processing, accurately reproduceable and of low cost. The increased use of such circuits in the future will lead to further substantial reduction of equipment volume and consequent saving in space. Any cost savings from greater packing density must of course be related to the cost of extra cooling required.

To make maximum use of the potential for space saving, any new equipment practice should be able to deal with levels of dissipation about an order higher than present limits. Such levels could not be dealt with solely by natural ventilation within the rack so that enhanced cooling capability of one form or another would be an important optional feature. The reliability of the cooling arrangements would of course be of paramount importance.

Weight Concentration

Higher component densities in the future could lead to problems of weight concentration, even though individual components may be of reduced size and weight. The solution could require new mounting and interconnexion methods to cater for the increased weight distributed within the rack. From a planning point of view, floor loading limits might have to be modified and this could be reflected in increased building cost. Alternatively, serious consideration should be given to reducing the height of racks for telecommunications equipment to, say, 2 m. This would produce a number of benefits such as, building requirements simplified due to reduced floor loadings and lower ceiling requirements, improved access to equipment for maintenance from floor level without need for ladders, etc., and lower heat dissipation per unit floor area.

Automation in Production

There is obviously a close connexion between the design of an equipment practice and the method of manufacture. This is becoming more so with increased use of new materials and new device technologies. New forms of construction should be amenable to automated production methods such as automatic machining, drilling, component insertion, wiring, testing, etc., to keep manufacturing costs low.

The use of computers[5] for the design of printed-wiring boards and integrated-circuit layouts is already established and it is foreseen that their use could be steadily extended to cover the whole process of physical design and production.

FUTURE EQUIPMENT PRACTICE REQUIREMENTS

Any new form of construction practice should ideally possess all the features of accessibility for cabling, flexibility, maintenance facilities, reliability etc. possessed by the present form of construction and should also be compatible with present designs from a station planning point of view. The construction must be suitable for long service life, have high heat dissipation capability and offer prospects of reduced cost per function compared with present practice. Attention should also be given to appearance and external design features and standard requirements for safety, including earthing.

Mass production of accurately-reproducible parts from basic materials should be possible by simple processes or by automation methods. Costly on-site work will be kept to a minimum if much of the wiring and testing is carried out in the factory by automatic machinery.

Equipment should have sufficient strength to withstand shock and vibration during shipment to site and installation.

CONCLUSION

The article has briefly reviewed development of equipment practice in the transmission field and highlighted the close relationship between component and material developments and form of construction. In the past, major changes have been made when the scope for adaptation within an equipment practice has become exhausted and limiting features identified. The 62-type practice has proved very versatile and adaptable to changes which have occurred since its inception, and continues to facilitate economical and reliable housing for the latest transmission system developments. More recently, because of its technical suitability and ready availability, it has been adopted for use in the telephone-exchange environment, and this emphasizes the growing similarity between the needs of switching, signalling, transmission and data equipment.

The tendency for equipment to become even more compact will continue, not necessarily because size reduction is required, but because development of components will govern the size of circuitry which is cheapest to manufacture. In certain cases involving high speed circuits, however, high packing density will be dictated by technical necessity to achieve a required performance objective, and the equipment practice must cater for this.

Some emphasis has been given to the problems which stem from increased packing density because these will be central to any study of possible new equipment practice techniques in the future.

ACKNOWLEDGEMENTS

The 51-type and 56-type equipment practices were developed by S.T.C. Ltd. The 62-type equipment practice was originally developed by G.E.C. Telecommunications Ltd. Assistance from colleagues in preparation of the article is gratefully acknowledged.

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Book Review

"Radio Communication." J. H. Reyner, B.Sc., A.C.G.I., D.I.C., C.Eng., F.I.E.E., Life Member I.E.E.E., and P. J. Reyner, M.A.(Cantab.), C.Eng., M.I.E.E. Pitman Publishing. xi + 864 pp. 569 ill. £5·00 (cased), £3·75 (paperback).

The authors state that the basic coverage is that required for the City and Guilds Telecommunication Technician Course. Despite the rapid development of solid-state devices for use in radio communication, thermionic devices are retained in the book on the grounds that they still play an important role in certain applications, and will continue to do so for many years. This also conforms to the requirements of the City and Guilds radio syllabuses.

The chapters of Part I are much the same as those of the 1967 edition although certain obsolete matter has been omitted and some new material included. Part II of the book, which deals with practical applications, likewise is very similar to the earlier editions, but there are extended sections on the subjects of transistors and television. Also, two new chapters have been included on solid-state switching and control circuitry, and specialized communication techniques. These chapters are the best in the book.

The main criticisms are as follows.

(*a*) The book is too bulky. It would have been preferable if the subject matter had been spread over two or three volumes. This would have catered more directly for the needs of those who only intend to study specific parts of the radio syllabuses.

(*b*) The authors have attempted to cover too much ground in the space of one volume. They start with basic concepts such as Ohm's law, alternating currents and then progress through 19 chapters to deal with about 90 important items. This wide coverage makes it impossible to give every item adequate treatment with the result that the book is patchy.

(*c*) At the end of the book, there are about 100 questions with answers provided. It would, however, have been better, from the students point of view, if some of the more difficult questions had been fully worked-out and included in the main text at appropriate points.

The book can be recommended for reference purposes, but, students of the City and Guilds radio syllabuses should have no difficulty in finding other books which cover the ground more effectively.

J. F.

Efficiency in the Telecommunications Motor Transport Fleet

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The telecommunications motor transport fleet is used mainly in the provision and maintenance of the telephone system and, thus, faces different problems from those which beset the conventional large-fleet operator. This article discusses some of the methods used to improve the efficiency of the fleet and the service that it provides.

INTRODUCTION

To provide and maintain the public telephone system in the United Kingdom requires a motor transport (m.t.) fleet of considerable size. The British Post Office (B.P.O.) telecommunications business has a fleet of about 47,000 vehicles and trailers with a net book value of £24M; it runs 270M miles and uses 13M gallons of fuel a year. In addition, employees in Regions and Telephone Areas using their private cars on telecommunications work run 97M miles a year which is equivalent to 12,000 6 cwt vehicles.

The vehicles range from 6 cwt to 10 tons payload and in complexity from what is, virtually, a manufacturer's standard van as shown in Fig. 1 to a pole-erection unit, as shown in Fig. 2, which is equipped with a pole-hole borer, extensible-jib crane and various hydraulically-operated tools. The more complex vehicles and trailers, such as the pole-erection unit, are known as vehicular mechanical aids (v.m.a.s). Vehicles which can be used for a number of different functions carrying men, stores, and equipment are known as utility vehicles. Table 1 shows the composition of the fleet.

TABLE 1

M.T. Fleet Vehicles and Trailers

Type		Number
6 cwt vans		16,200
15 cwt utilities and stores carriers		13,800
1–2 ton utilities and stores carriers		5,800
Over 2 ton utilities and stores carriers		900
Articulated vehicles	motive units	50
	semi-trailers	60
V.M.A.s and trailers		7,700
Various special-purpose vehicles including passenger cars		2,400
Total		46,910

The fleet is, notionally, divided into engineering occupational group sub-fleets, i.e. mainly installation, maintenance and construction, and the vehicles are manned by technicians* working singly or in small parties of up to, exceptionally, four men. While the technician drivers are responsible for minor daily servicing such as the checking of water, oil and tyres, other maintenance is carried out by the m.t. organization. Both the telecommunications and postal businesses of the B.P.O. have m.t. organizations which provide and maintain their respective fleets. The two businesses operate over 600 workshops which are about equally apportioned between them and, where it would be uneconomical to do otherwise, provide a repair agency service for each other.

The United Kingdom is split into 10 Telecommunications Regions sub-divided into 62 Telephone Areas. Fleet utilization is controlled by the Areas via the heads of occupational groups with general oversight by the appropriate regional efficiency groups; an Area Transport Control Officer (A.T.C.O.) acts as a liaison point in the Area for all transport matters and assists local management in controlling the number, suitability and efficient use of vehicles. The m.t. maintenance organization, however, is directly controlled at regional level by a Regional Motor Transport Officer (R.M.T.O.).

About 3,600 staff are employed by the Telecommunications business on vehicle design, provision and maintenance. The total cost of providing, running and maintaining the m.t. fleet is about £27·6M a year of which about £4·6M is spent on the employee's cars mentioned earlier and £7M is invested in new vehicles and capitalized plant and equipment. These sums are small by the standards of the Telecommunications business but huge by those of the road-transport industry. They justify considerable monitoring effort in ensuring that maximum fleet effectiveness is achieved at minimum cost, the primary objective being to ensure that fleet economics do not impair the efficiency of the telecommunications service as a whole.

FLEET EFFICIENCY

The conventional m.t. fleet exists to carry loads from point to point. It is being operated efficiently when its annual fixed charges can be divided by a high average mileage to give a low cost-per-mile figure. Judged by this yardstick, B.P.O. Telecommunications vehicles are not operated efficiently since they are mainly used to transport men, stores and equipment to the place of work where the vehicle lies idle. The more effective working time a technician has in a day

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* Technician is used here in the general sense, not as a rank.

FIG. 1—Bedford HA 6 cwt van

FIG. 2—Pole-erection unit

the lower is the mileage on the vehicle he uses. This results in a low average annual mileage and higher costs per mile. The Electricity and Gas Boards are examples of other fleet operators whose efficient operation cannot properly be measured by the conventional means; the B.P.O. uses a technique which provides average vehicle-type costs quarterly on a moving-annual basis.

Efficient operation depends also on efficient maintenance. Whilst minimum acceptable standards of mechanical maintenance are set by the requirements of the law, the B.P.O. sets, above these, its own standards which are determined by the level of serviceability of the fleet. One aspect of maintenance which is arbitrary is the standard of vehicle cleanliness. As a commercial organization with a public image to maintain, this standard is set accordingly.

CONTROL STATISTICS AND COSTING

A working party was set up in 1969 to decide what information was required to show, at Area, Regional and national levels, the effectiveness and cost of m.t. services both as a whole and in enough detail for effective management of all aspects of provision, operation and maintenance. A scheme, based on the recommendations of the working party, is now undergoing a field trial in two Regions to determine its workability.

The trial has been running since April 1972 and the first set of statistics are now being collated. The scheme is designed to produce the information three times a year to coincide with the budgetary forecast periods and the statistics will be on a moving annual basis. Experience has shown that this is the best basis for the control of m.t. in terms of performance and cost. It is important that such statistics should be produced regularly, quickly and at minimum cost; because of this they will eventually be compiled by automatic data processing and the system was designed with this in mind.

The statistics which the system presents to management are divided into seven basic groups.

(*a*) *Overall costs*—includes overheads, agency working between posts and telecommunications, depreciation and interest, fuel, licences, use of employee's cars for telecommunications work and maintenance and cleaning, including that done by the driver.

(*b*) *Disposition of staff and vehicles*—statistics concerning numbers of technicians, numbers of vehicles (including reserve vehicles and employee's private cars), ratios of reserve vehicles to those in service, and numbers of m.t. staff, authorized and in post.

(*c*) *Indices of operating efficiency*—statistics indicating how well vehicles are being used by showing how staff numbers vary with vehicle numbers, total costs per effective day and the days vehicles stand idle. Each day the vehicle is in use is considered to be an effective day.

(*d*) *Indices of m.t. maintenance efficiency*—maintenance costs and m.t. manhours spent per effective day, and a weighted vehicle/mechanic ratio which allows for vehicle type variations and work done by contractors.

(*e*) *The national cost index*—enables Areas and Regions to compare their costs with the national cost for a fleet of similar composition.

(*f*) *Vehicle type costs*—costs in the form of £ per vehicle per annum. For this purpose, vehicles are divided into four main types by payload.

(*g*) *Standing charges*—provided annually for each of the four main types.

First reports indicate that the field trial is progressing well and it is hoped that the information provided during 1973 will be adequate for the development of a national scheme in time for introduction in 1974.

Vehicle Age-Related Costs

Vehicle age-related costs are an important factor in determining a replacement policy. To facilitate the collation of such costs, every vehicle has now been allocated a 9-digit number divided into three groups; the first two digits indicate the year of manufacture, the next three provide the vehicle-type code and the last four identity the vehicle individually. For example, 72 314 0812 indicates the 812th Commer 15 cwt utility vehicle (code 314) supplied in 1972. The change was introduced retrospectively and will result in full age-related costs for all vehicle types being available one year from the completion of the changeover.

Vehicle Records

A primary document from which much of the basic information on vehicle performance and utilization is derived is the vehicle log sheet. A new-style log sheet, designed to suit the new cost-control system, was introduced in March 1973. It calls for fewer entries to be made than the old sheet, is presented at monthly intervals, instead of weekly as previously to the Area vehicle records centre, and is expected to result in considerable savings in clerical effort.

Local Control Procedures

To help the A.T.C.O. in his duties, a control system operating on the principle of management by exception has recently been introduced. The system is based on serviceable-not-required (s.n.r.) time and mileage. Serviceable not required is a term used by the B.P.O. to identify the period when vehicles are fully serviceable and available, but are not used. Because of the relatively-low-mileage characteristics of the fleet, mileage alone cannot be used as the measure of effective vehicle use; it is, however, useful to be able to identify those vehicles whose mileage is exceptionally high or low. The system therefore highlights, monthly, individual vehicles having s.n.r. times, or low or high mileages, which are outside the limits set by local management. Generally, the limits are set so that the system highlights between 5 to 10 per cent of the fleet.

From the figures provided, A.T.C.O.s may investigate cases of apparent under- or over-utilization and, subsequently, make the appropriate recommendations to Area efficiency engineers. This system also provides the A.T.C.O. with information concerning the mileage of employee's cars used on telecommunications work. Where this mileage is high, in relation to the circumstances, the A.T.C.O. might recommend the use of a B.P.O. vehicle which would be more economical above a certain level of mileage, currently about 8,000 miles a year.

FLEET UTILIZATION

Vehicle Pooling

One of the most important proposals for improving efficiency is the pooling of vehicles. The principle of vehicle pooling is based on the fact that, for any group of workmen, there will always be absentee time, e.g. time spent on holiday, on sick leave, and attending courses. Where the vehicles are provided on a one-man/one-vehicle basis which, hitherto, has been standard practice for the majority of B.P.O. telecommunications vehicles, there are always some vehicles not being used due to the absence of technician drivers. A detailed study at a number of Telephone Engineering Centres, has produced information which indicates that vehicle pooling is justifiable in certain circumstances.

The basic requirements for pooling are that

(*a*) the staff concerned should all perform a similar type of work,

(*b*) the vehicles should be equipped with a standard layout of tools and stores, and

(*c*) normally, a minimum of ten units or working parties is required in the group.

Field trials, concerning the operation of telephone installation staff and their vehicles, have shown that, for a Telephone Area, a vehicle/working party ratio of 0·86 is workable. This means that, normally, a minimum of ten vehicles must be employed on the same class of work at a centre before a vehicle can be saved by pooling. In practice, this ratio varies according to local circumstances and it would be the responsibility of local management to adjust the ratio to suit.

The most important point to guard against in this exercise is the wasting of a technicians' time which, currently, is worth about six times that of vehicle idle time, depending, to some extent, on the vehicle type.

A further difficulty in interchanging staff and vehicles is the loss of pride of ownership which exists in the one-man/one-vehicle system. To overcome this problem in a pooling scheme the vehicles would be allocated to the senior men in the group who would be regarded as regular drivers, the junior men making use of the vehicles made spare by the absence of the regular drivers. Other problems are the responsibility for the tools and equipment on the vehicles and the workman's pride in the care of what may be classed as personal tools. This would be overcome by dividing the tools and equipment into two categories

(*a*) small personal tools and equipment which would be kept in a special container and moved from vehicle to vehicle with the man, and,

(*b*) the remaining tools and equipment which would be recorded as part of the vehicle and for which the technicians would not be held closely accountable.

The extension of the pooling scheme to all types of work at present involving the one-man/one-vehicle ratio would undoubtedly result in worthwhile savings of vehicles and, hence, their standing costs; the running costs would mainly be transferred to the remaining vehicles. The disadvantages of pooling, which will need to be carefully weighed against the obvious advantages already mentioned, are the risk of wasting the technicians' time and the increased local-management load which results from the loss of flexibility. These factors have already been taken into account in draft instructions which are currently being negotiated with the staff associations concerned.

Specialist Vehicles

Over the last few years there has been a steady increase in the number of v.m.a.s from 7·4 per cent of the fleet in 1968, to 16·3 per cent at the present time. The two main types are, currently, the pole-erection unit and the rodding-and-light-cabling vehicle. The pole-erection unit enables two trained technicians to install or renew poles in almost any circumstances. The rodding-and-light-cabling vehicle, with its highly-sophisticated power-operated equipment, enables its crew of two men to rod ducts and install or replace cable of up to 100 pairs. Although these vehicles are very expensive they result in high increases in manpower productivity.

The opposite of the specialist vehicle is the utility vehicle. These are relatively cheap and are extremely flexible in use. The advantages of the utility vehicle can be easily overlooked when consideration is being given to the need to specialize the fleet. To maintain the flexibility that is required there will always be a need for such vehicles and a balance between the two types provides for the most efficient working.

Increased Fleet Utilization in the Future

Seventy-four per cent of the fleet is comprised of 6, 15 and 20 cwt payload vehicles of the general utility type. By varying the binning and equipment carried, these three vehicle types cover 14 classes of work which, in turn, occupy about 61 per cent of the engineering work force. This, as previously mentioned, produces problems when attempting to pool vehicles and to loss of time when changing over tools and equipment from service to reserve vehicles, e.g. when the service vehicle requires overhaul.

One way of partly overcoming this problem is to use the principle of containerization, one of the latest techniques in the transport industry. At present, this system is based on using demountable bodies which can be easily removed, complete with contents, from the vehicle chassis and stored on supporting legs. This is a very flexible system because a number of bodies may be used with each chassis. The system could only be applied to the larger of the three types of vehicle currently available, i.e. the 20 cwt types which comprises about 9 per cent of the fleet. To extend it to include the smaller vehicles would need a special exercise to design and develop a container which could be adapted to the needs of the various classes of work and which might be used within a conventional van or carried on a pick-up truck. In either case it would need to be waterproof because, when not in use, it would be stored fully equipped. Both aspects of this project are currently under consideration.

A further project for the future may be to investigate the possibility of having the stock of materials carried in telecommunications vehicles replenished by somebody other than the technician driver—perhaps, for example, by staff normally responsible for the issuing of stores. This type of system would benefit from a containerization scheme but would of course, introduce problems, not the least of which would arise from the present design of stores accommodation and the approach thereto.

M.T. WORKSHOP PRODUCTIVITY

The m.t. organization's primary function is to ensure that the operational fleet is maintained so as to achieve maximum availability for use by the technicians. To this end, it is necessary to provide a suitable range of reserve vehicles and to organize the work on the basis of preventative maintenance carried out according to a predetermined program. The program used by the B.P.O. consists of safety checks at 1,000 miles or two months, full inspection at 3,000 miles or six months, and a major service, known as a *dock*, at 12,000–24,000 miles or two to four years, depending on the size and complexity of the vehicle. To run such a program efficiently and economically requires very careful consideration of optimum staff levels.

The system used to determine the staff complements of m.t. workshops is based on work-unit values for each vehicle type. The work-unit values are reviewed annually from information built up from workshop primary documentation and an assessment of the effect of predetermined vehicle replacement programs. This system is simple and facilitates changes in authorized complements resulting from policy changes, e.g. a change in the average age at which a vehicle type is replaced. Such changes can be reflected in the complementing of workshops by adjustment of the relevant work units. Other changes, such as increased annual leave entitlement, can be catered for by the use of an overall correction factor.

The nature of the system is such that the m.t. staffing of one year is based, broadly, on the performance of the previous year. This means that the existing situation, including inefficiencies and inadequacies, tends to be perpetuated instead of being progressively improved. Further, it has the disadvantage of setting a common labour productivity standard throughout the United Kingdom regardless of any variations in operating and maintenance conditions which may exist. In practice, however, allowance is made for operational variations by the granting of limited local discretionary powers and the exercise of engineering judgement by the R.M.T.O. and, thus, a trend in the right direction is maintained.

There is a need for some independent scale against which the performance of m.t. workshops can be measured and monitored—perhaps some form of work-study—but difficulty has been experienced in finding a suitable technique. The conventional type of work-study, involving the measurement by stop-watch of the time taken to complete jobs, is viewed with suspicion by those observed and, consequently, often produces untypical and unreliable results. However, one technique which does appear to be suitable is the Method Time Measurement (MTM) technique. This is a well-established procedure widely used in production work and many other activities involving repetitive processes. It has been successfully applied in several spheres in the B.P.O. MTM-2 is the current version of the technique, and a special application of it to maintenance work is known as the MTM-2 Maintenance Data System.

One advantage of the system to the m.t. organization is that it enables standard times to be assessed which take account of variations in local circumstances and the types of vehicles maintained. This facilitates the assessment of the performance rating of a particular workshop and, consequently, the setting of targets for improvement.

A report based on a relatively small sample made by consultants specializing in MTM indicated that, while the B.P.O. m.t. organization is operating relatively well, there is a need for better management-control information on the utilization of staff and, consequently, on productivity. The report indicated that the MTM-2 Maintenance Data System is likely to be the one most suited to the m.t. organization and that there is a potential for a marked improvement in labour productivity. However, the report recommended that the highest level of improvement would only be attainable if strong incentives in the form of local, direct, and immediate pay bonuses were paid. This is not a practicable idea in the B.P.O. due to the national pay scales and agreements. An alternative was offered in the report that it might be possible to increase labour productivity by a lesser but, nevertheless, substantial extent without differential bonus schemes but with some form of national incentive scheme, if the MTM-2 system were to be fully applied. Since the report was based on a small sample, it would be necessary to substantiate the claims in the report by applying the system to a large sample such as a whole Region. There is one problem which prevents this at present, that is, that the control scheme is not worth its running cost unless the consequential substantial productivity increase can be taken advantage of without resulting in staff redundancies. Since the growth rate of the m.t. organization is too slow and natural wastage inadequate and too uncontrollable to meet this problem, the only solution would seem to be to take on work from outside the B.P.O. Action of this sort is fraught with problems which would need to be solved before a trial could be introduced to a whole Region.

VEHICLE CLEANING

Vehicle cleaning can be time-consuming and costly for a large-fleet operator. To wash large numbers of commercial vehicles manually consumes many manhours and can require considerable space. To achieve savings in this respect the B.P.O. is installing automatic vehicle washing machines (a.v.w.m.s) at centres with at least 50 vehicles. The program calls for 350 machines to be installed by 1976 and, so far, 120 have been supplied. When this program is complete, consideration will be given to extending provision to centres with a smaller number of vehicles. Six different makes of a.v.w.m. have been tested, all similar in construction and mode of operation. In general, the machines consist of a large frame containing three rotating brushes, two vertical and one horizontal, and a series of high-pressure water jets overhead and at the sides. The brushes automatically follow the contours

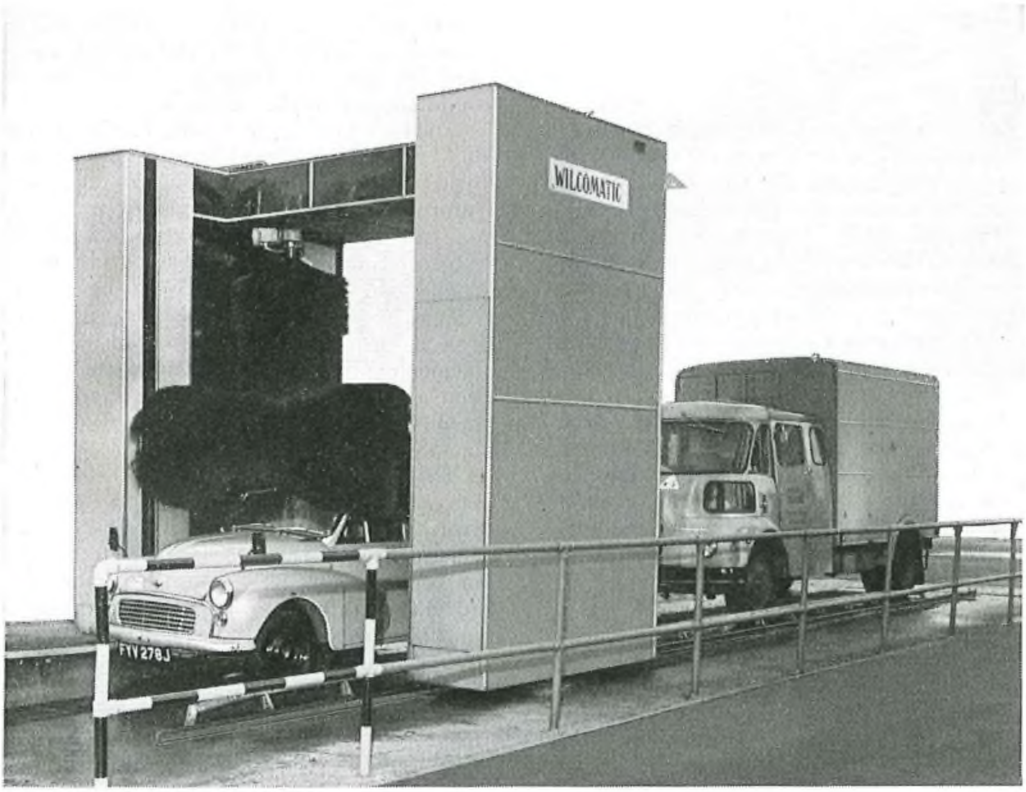

FIG. 3—An automatic vehicle-washing machine in operation

of the vehicles which can be up to 10 ft 6 ins high, 8 ft wide and 36 ft long. The ability of the machine to accommodate vehicles of various sizes can be seen from Fig. 3.

A small kiosk housing the control panel (Fig. 4) is sited so that the operator can watch the progress of the machine. For vehicles with awkward projections a series of over-ride controls is incorporated to allow for a certain degree of manual control. However, vehicle design has been modified with a.v.w.m.s in mind to enable the machines to operate fully automatically as much as possible. For example, ladder racks on utility vehicles have been redesigned and awkward projections such as driving mirrors are spring loaded so that they yield to allow the brushes to follow the contour of the vehicle as closely as possible.

The washing procedure is extremely fast and simple. The vehicle is parked in the wash area in a marked position and the operator presses a button to start the washing cycle. The frame moves over the vehicle with the jets cascading detergent solution over the top, sides, front and rear. Simultaneously, the brushes revolve and maintain contact with the surface of the vehicle, the horizontal brush cleaning front, top and back and the vertical brushes the sides. Finally, this sequence is reversed, using clean water, to complete the cycle. Wherever possible, the machines are sited to provide a drive-through facility, usually in the open and with side screens to confine the spray. The whole washing cycle takes only 2½–3½ minutes, depending on the length of the vehicle. Where there are large concentrations of vehicles, the machine is operated for some of the time by m.t. staff so as to avoid time being wasted by several drivers having to wait to clean their vehicles. When fully effective, the machines will produce a 100 per cent per year return on capital on the basis of cleaning telecommunications vehicles only. Even so, the machines still have spare capacity which is being exploited by allowing other fleet users access to them for a realistic charge.

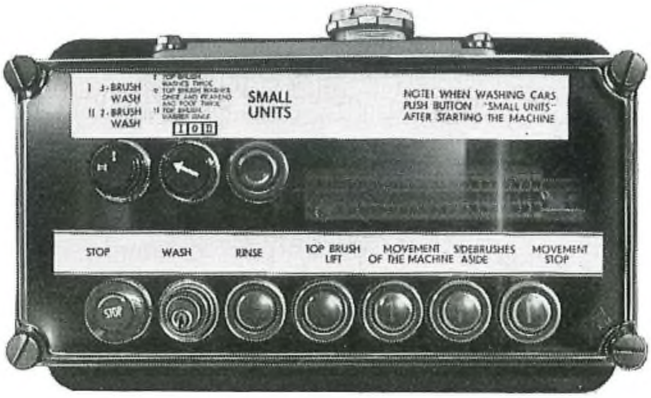

FIG. 4—The control panel of an automatic vehicle-washing machine

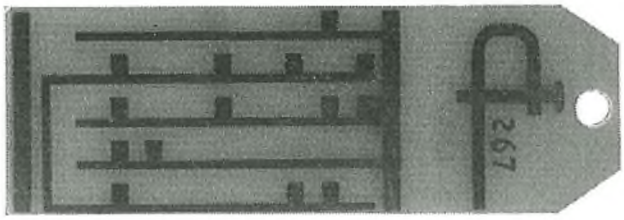

FIG. 5—Key used to operate a self-service fuel dispenser (actual size)

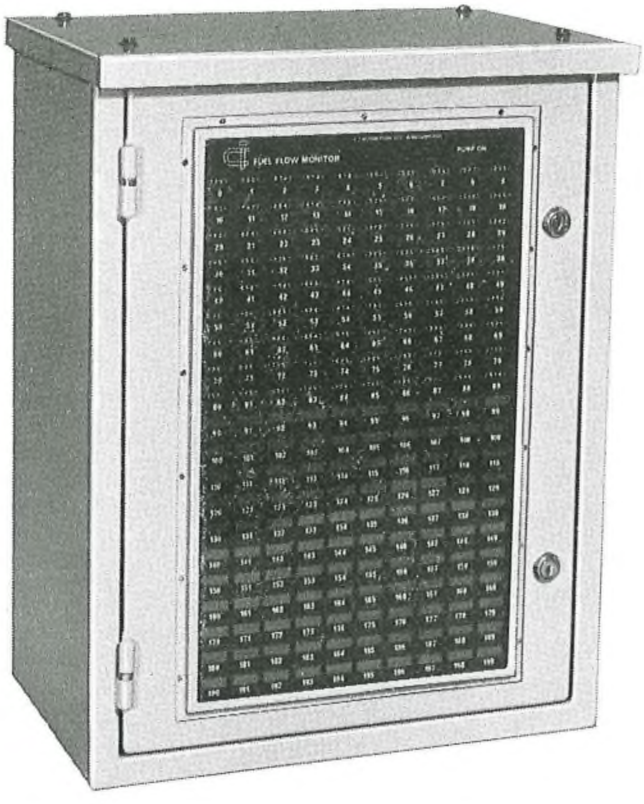

FIG. 6—Bank of counters used to record individual fuel issues.

VEHICLE REFUELLING

Most telecommunications vehicles set out from, and return to, their headquarters at approximately the same time. In some centres there are several hundred vehicles. The normal procedure for obtaining fuel requires a pump attendant who operates the fuel pump and records the issue. The driver must also record the fuel issue and check that the figures recorded agree with those of the pump attendant. Ideally, the pump attendant should only be available at the peak times when vehicles are leaving or returning to the centre. This system results in congestion in the centre due to vehicles queuing for fuel and, therefore, a waste of manpower.

To overcome this problem, self-service fuel dispensers have been introduced. There are already 170 dispensers installed with another 180 planned thus covering all engineering centres serving 50 or more vehicles. Self-service installations are available for dispensing fuel at any time and no pump attendant is required. It is estimated that each installation saves about £2,000 a year, in staff and waiting time, representing a 200 per cent return on capital. Where these installations are used each driver carries a small printed-circuit plate (an example is shown in Fig. 5), which is exclusive to his vehicle. When refuelling, the plate is inserted into an electronic reader to switch on the pump and select the individual counter and, thus, the fuel issued to the vehicle is recorded. The counters are arranged in groups as shown in Fig. 6. To speed up refuelling and avoid spillage, an automatic cut-off switches off the pump when the tank is full. This form of refuelling cuts queuing time, eliminates manual recording and signatures, and frees pump attendants for other work. It has been well received in the field.

CONCLUSIONS

The total annual cost of m.t. is very high and, therefore, justifies close control by all concerned with its use. Managers, however, need to assess relative priorities and it is in this context that there is an apparent conflict between the importance of the facility and the control of its cost. In the terms of current account and capital expenditure, the cost of transport is about two per cent of the total and the major problem facing management, especially at first-line level, is that of achieving an optimum level of provision.

An efficient m.t. organization is vital to the productivity of the business. The introduction of a.v.w.m.s. and self-service fuel dispensers are outstanding examples of the service provided in that they result in more efficient and economic working by increasing the time that drivers and m.t. staff can spend on useful work. The new m.t. costing and performance control system, which is in the early stage of experiment, should provide managers at all levels with useful control statistics. Although the first complete set of statistics has yet to be produced, the information so far available is already proving to be of value.

Acknowledgements

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F.D.M. Multiplex Equipment

R. W. E. BLACKHALL†

U.D.C. 621.395.46: 621.315.212

The methods used to assemble telephony channels into frequency spectra to suit the various types of transmission system are described, together with the techniques used by the translating equipments which carry out this function.

INTRODUCTION

Before 1932 all United Kingdom long-distance telephony was provided by single-channel physical circuits which required heavy-gauge copper conductors. The introduction of audio amplifiers enabled the size of conductors to be reduced but it was not until the introduction in 1932 of the Carrier System No. 1 (a one audio channel + one carrier channel system) that any increase in the number of channels per physical circuit was obtained. This system was followed by others[1] which provided an increased number of channels. All these systems transmitted the channels over twisted-pair cables of various types.

The London–Birmingham No. 3 cable system,[2] installed in 1938, marked the introduction of coaxial cables, which allowed wide-band systems to be provided.

The exploitation of these wideband systems required equipment which enabled a large number of channels to be multiplexed. This equipment was developed using frequency-division multiplexing (f.d.m.) techniques—the only practicable system available at the start of development. This article describes the pattern in which the multiplexed channels are assembled.

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CHANNEL TRANSLATING EQUIPMENT

The first standard assembly of channels is the twelve-channel group. The method of assembling larger blocks of channels follows the same pattern, and a description of the equipment which assembles the channels is used to introduce and define some of the terms used, and to show the general arrangement of equipment design. This equipment is called channel translating equipment (c.t.e.).

Each channel is made to occupy a separate frequency band. This function is carried out in a modulator, a non-linear device which has two inputs and one output. The channel-band signal (f_s) is applied to one input and the carrier signal (f_c) to the other. The result of mixing these signals in a non-linear device is to produce a complex waveform which, when analysed, can be shown to contain two major modulation components, the upper and lower sidebands. These have frequencies of ($f_c + f_s$) and ($f_c - f_s$), respectively, and the lower sideband is selected for transmission. There are also many additional products, having the form ($xf_c + yf_s$). Some of these, e.g. ($f_c - 3f_s$) fall in the wanted-signal range and give rise to distortion, in the same channel, or crosstalk, in a different channel. By careful design, e.g. by using suitable operating levels, these can usually be kept to a low level.

The lower sideband is referred to as an inverted sideband in which an increase in the input frequency results in a decrease

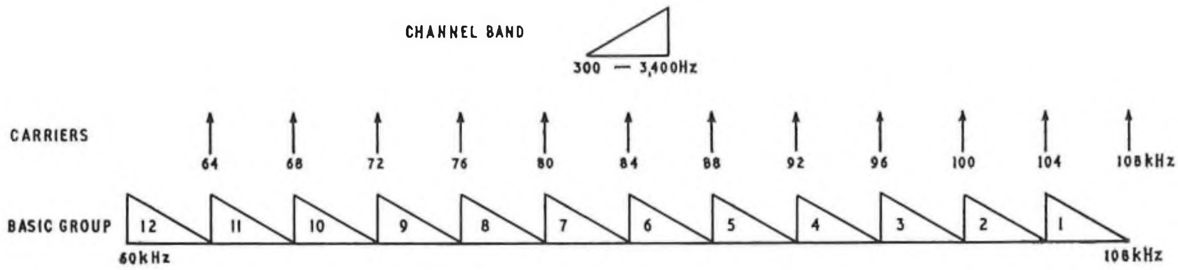


FIG. 1—Channel translation

of the sideband frequency. This term is used to describe any sideband in which this relationship occurs. Similarly, a sideband where an increase in the input frequency results in an increase of the sideband frequency, is an erect sideband.

The selection of the wanted sideband and the suppression of the majority of the unwanted products is accomplished by filters. The main requirement is that the filter should suppress the unwanted sideband. In the c.t.e. the frequency gap between wanted and unwanted sidebands is only 600 Hz, and very steep-sided crystal filters are used to achieve adequate separation.

The twelve channels are modulated from the audio frequency range (300–3,400 Hz) using twelve separate carriers spaced at 4 kHz intervals in the range 64–108 kHz. (See Fig. 1.). The twelve lower sidebands, after selection by means of filters, are then combined to form a twelve-channel group in the range 60–108 kHz. This assembly is called the basic group.

In equipment designed before 1965, the sidebands were combined by means of hybrid transformers. Since then, increasing use has been made of a low-impedance combining technique. (Fig. 2). This technique, which has become popular because transistors provide cheap and reliable amplification, is one in which the signals are combined by means of a resistance network. The filter outputs are each terminated in a separate series resistor each having a value equal to the characteristic impedance of the filter, and a common low resistance. The latter can be the input impedance of an amplifier which compensates for the loss in the resistance network. This method of combining has the advantage of economy and easier filter design as the hybrid transformers are replaced by resistors and transistors and the filters can be designed to operate between resistive impedances. The removal of one filter does not affect transmission through the other paths, and this assists maintenance.

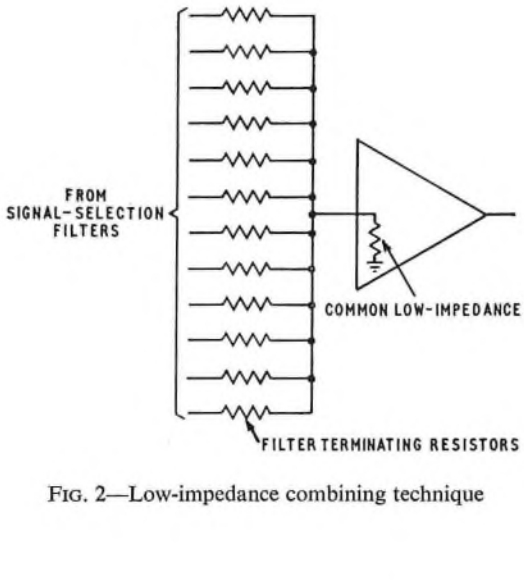


FIG. 2—Low-impedance combining technique

THE FORMATION OF LARGER MULTICHANNEL ASSEMBLIES

One obvious method of increasing the number of assembled channels would be to use a c.t.e. of higher capacity to fill the available frequency spectrum. The main objection to this method is the increasing difficulty of filter design at higher frequencies, and to avoid this problem, a number of twelve-channel groups are each modulated a second time so that

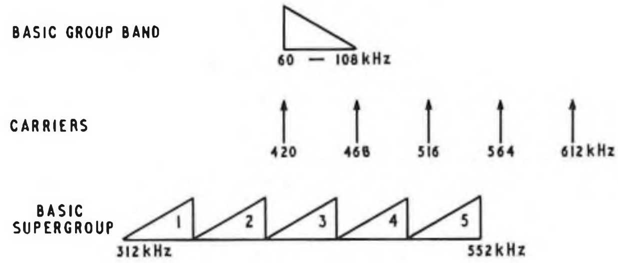


FIG. 3—Group translation.

each group occupies a different frequency band. This assembly is known as a supergroup. The equipment which performs this function is the group translating equipment (g.t.e.) in which five basic groups are modulated with carriers of 420, 468, 516, 564 and 612 kHz. The lower sidebands are selected and combined to form the basic supergroup in the frequency range 312–522 kHz. (See Fig. 3.)

At each stage, the basic assembly is used not only as the building block for the next larger assembly but also to provide an assembly of channels for transmission over a high-frequency (h.f.) system of appropriate bandwidth, e.g. a supergroup can be used on a 60-circuit carrier-on-deloaded-audio system in the band 12–252 kHz. This is provided by a supergroup modulating equipment which modulates a basic supergroup using a carrier of 564 kHz.

The next stage in the basic assembly process takes place in the supergroup translating equipment (s.t.e.) which modulates and combines 15 or 16 supergroups to occupy the band 60–4,028 kHz. (See Fig. 4).

An assembly of any number of supergroups is called a hypergroup, but the assembly of fifteen supergroups in the band 312–4,028 kHz is called the basic hypergroup.

The largest assembly of channels currently in use is formed by the hypergroup translating equipment (h.t.e.) which assembles 2,700 channels for transmission over a 12 MHz line system (Fig. 5). The h.t.e. accepts three basic hypergroups and modulates two of them using carriers of 8,432 and 12,648 kHz. The lower sidebands are then combined with the third basic hypergroup to occupy the range 312–12,336 kHz.

FLEXIBILITY AND INTERCONNECTION

To allow circuits to be provided economically, interconnection between transmission systems is performed at the

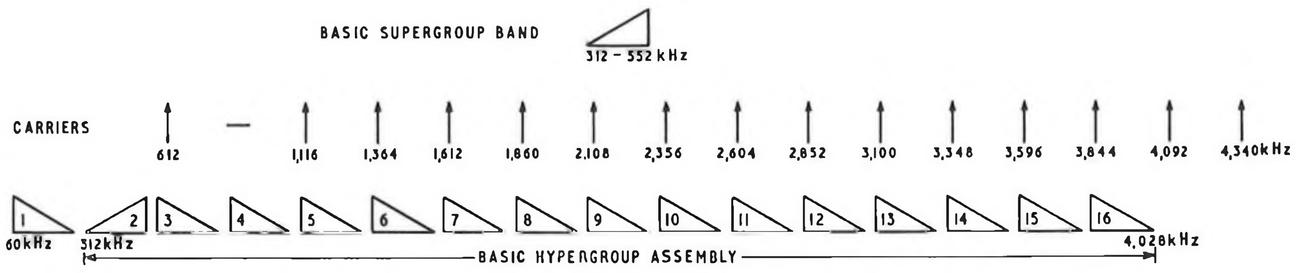


FIG. 4—Supergroup translation

basic group[4] or supergroup stage, e.g. the basic group input on a g.t.e. may come from a c.t.e. or the basic group output of another g.t.e. (See Fig. 6). As the g.t.e. is basically designed for working into and from a c.t.e., it does not provide enough suppression against the unwanted signals present at the output of the g.t.e. to permit through connexion, and additional filtration is required. This is provided by through-group filters. A similar problem occurs when basic supergroups are through-connected, and a through-supergroup filter is provided.

In a typical h.f. repeater station (Fig. 6) these interconnexions are made on the group and supergroup distribution frames (g.d.f. and s.d.f. respectively).

In a network which is expanding and altering, flexibility is an important consideration and the existance of the g.d.f. and s.d.f. readily permits alterations to be made to the routings of the multichannel assemblies.

PRESENT DEVELOPMENT

To meet the increasing demand for telephone circuits, a wideband transmission system operating at a maximum frequency of 60 MHz is being developed.

For this system it is proposed to assemble twelve hypergroups into the range 4,404 – 59,580 kHz (Fig. 7). The assembly used as the building block is not the basic hypergroup but a hypergroup in the range 8,620–12,336 kHz, i.e. the highest of the three hypergroups used in the 12 MHz system. In addition to technical advantages, such as a reduction of difficulties in the design of the filters, there is also a commercial advantage. This hypergroup, which is used

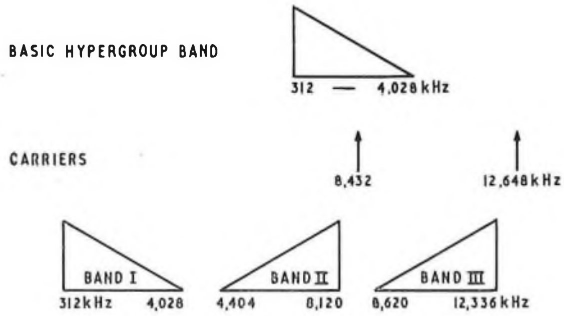
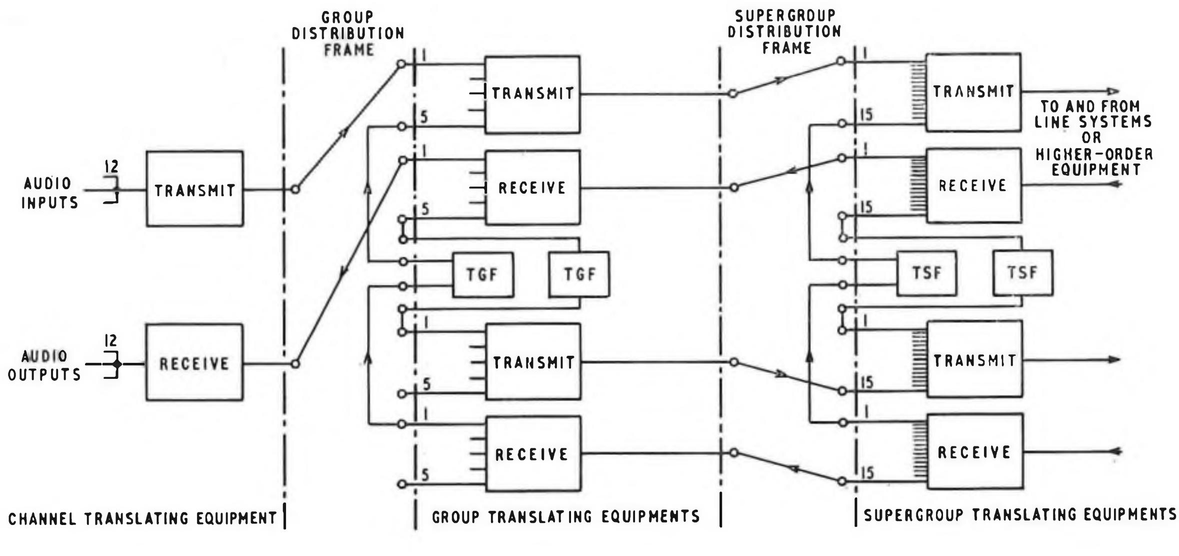


FIG. 5—Hypergroup translation

by many overseas administrations, is approximately the same as the basic super-mastergroup (8,516–12,388 kHz, see Appendix 1) and it may be possible to design an equipment capable of handling both assemblies and hence having a wider market. The frequency allocation, which has been agreed on an international basis, has been arranged so that a system using four, eight or twelve hypergroups can be used if required. The carriers used in this equipment are multiples of either 124 kHz or 2,200 kHz.

In addition to providing increased numbers of circuits, current developments are taking into account the changing nature of the traffic. With the increasing use of various types of non-speech signals such as data and facsimile, a requirement has arisen for circuits having bandwidths greater than that provided by a speech channel. These can be provided by



TGF—Through-group filter
TSF—Through-supergroup filter

FIG. 6—Typical group and supergroup distribution frame interconnexions

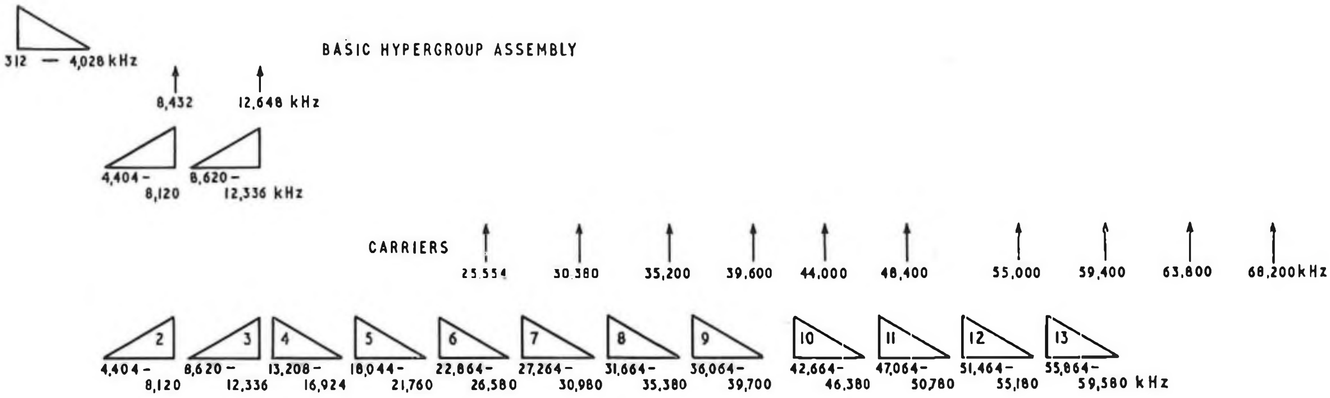


FIG. 7—Translation of 15-supergroup assembly to 60 MHz band

means of group and supergroup links which are extended to the subscribers premises. One of the chief requirements of such links is freedom from spurious signals. It can be seen from Figs. 3 and 4 that the g.t.e. and s.t.e. carrier frequencies fall in the frequency band of a nearby group of supergroups. It is therefore essential to ensure that any carrier-frequency signal appearing at the output of an equipment is kept at a very low level. The versions of g.t.e. and s.t.e. recently developed provide this clean-band facility.

CONCLUSION

This brief outline deals only with the translating equipments used in the network. Associated equipment such as carrier generating equipment,[6] gain control equipment[7] and the specialized types of equipment used on international circuits[8] has been previously described in the *Journal.*

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APPENDIX

An alternative pattern of assembling channels, as used by some other administration, is as follows:

12 channels are combined to form a basic group	(60–108 kHz),
5 basic groups are combined to form a basic supergroup	(312–552 kHz),
5 basic supergroups are combined to form a basic mastergroup	(812–2,044 kHz), and
3 basic mastergroups are combined to form a basic super-mastergroup	(8,516–12,388 kHz).

The basic super-mastergroup approximates to the top hypergroup in the 12 MHz system, i.e. 8,620–12,336 kHz.

Maintenance of Trunk Transit Routes

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U.D.C. 621.395.74.004.5

The introduction of the new inter-register signalling system S.S.M.F. No. 2, using multi-frequency codes for digit transfer, into the inland trunk network for transit and certain direct links has necessitated changes and additions to the test equipment provided for trunk circuit maintenance. This article reviews circuit maintenance methods and briefly describes the new testing equipment.

INTRODUCTION

In the United Kingdom, the network provided for carrying telephone trunk traffic, 83 per cent of which is customer dialled, comprises some 400 main network switching centres (m.n.s.c.s) interconnected by over 120,000 long distance circuits utilizing a range of transmission and line-signalling systems. Collectively, the equipment involved represents a large part of the total investment in telecommunications plant and the income from a fully utilized circuit is high. From the business point of view, it follows that when the demand for circuits is heavy the maximum possible number of installed circuits should be available for carrying traffic and that each of these should be in good working order. The maintenance purpose is to achieve maximum serviceability on trunk routes at minimum cost. These objectives begin to be realized at the equipment design stage when system performance standards, security requirements and maintenance facilities are specified. The first aim is to obtain a satisfactory order of reliability in the engineering of the individual items of equipment and then to ensure, as far as possible, that performance variations are automatically corrected and failures affecting service automatically indicated at a maintenance point so that prompt repair action can be taken.

Trunk routes utilizing modern transmission systems and modern line-signalling systems, therefore, include a number of in-built monitoring features which combine to bring quickly to maintenance attention many defects of a service affecting nature, hence the quality of service, as seen by the customer, is improved. Other defects are detected by supplementary tests applied frequently by automatic test-equipment. Failure detection, in itself, does not achieve good route serviceability. An effective location and repair capability is also essential to minimize the outage time per fault and to restore equipment to service quickly so that more calls result in ring tone rather than equipment-engaged tone or congestion announcement.

Maintenance of transmission terminal equipment and line-signalling equipment is a function of repeater station and exchange staff, respectively. Day-to-day control of the overall serviceability of trunk circuits and routes, switching point to switching point, is vested in trunk maintenance control centres (t.m.c.c.s) located in or near m.n.s.c.s. These t.m.c.c.s may be considered as operating at the interface between the switching equipment and the line plant, and are equipped to

(*a*) monitor and test the circuits controlled,

(*b*) localize faults down to an item of equipment or section of line plant for attention by the appropriate maintenance staff, and

(*c*) progress repair.

The circuit surveillance and maintenance methods adopted apply, in general, to all trunk routes, but with the introduction of the inter-register signalling system, Signalling System Multi-Frequency No. 2 (S.S.M.F. No. 2), into the inland trunk network and the application of 4-wire switching in transit switching centres (t.s.c.s.), the testing equipment in t.m.c.c.s and m.n.s.c.s has been augmented to accommodate the new systems.

The maintenance of a typical route utilizing S.S.M.F. No. 2 is outlined in this article.

SYSTEM FEATURES

For maintenance purposes, a trunk route consists of a number of trunk circuits connecting switch outlets in one m.n.s.c. to switch inlets in another m.n.s.c. Included in this traffic path are elements of the transmission system or systems utilized, the line-signalling equipments at each end interfacing the transmission and switching systems and items of switching equipment directly associated with each trunk circuit. A transit connexion between two group switching centres (g.s.c.s) switched through a t.s.c. is shown in block form in Fig. 1. Typically, the two interconnecting circuits may take into use channels in frequency division multiplex line systems and be terminated by the inband single frequency line-signalling system Signalling System Alternating Current No. 11 (S.S.A.C. No. 11) relay-sets or junctors necessary to convert direct current connexion, control and supervisory signals in both directions into a form suitable for transmission over the line system. Line signalling is on a link-by-link basis with repetition of signals in d.c. form at intermediate switching points. Numerical and information signals passing between registers during call set-up are in multi-frequency code (m.f.c.) and are, therefore, suitable for direct transmission to line. The multi-frequency senders and receivers used during call set-up are associated with registers at each switching point in the connexion.[1]

Reliable performance of the system as a whole depends on the maintenance of circuit transmission levels at specified points, the correct functioning of the line-signalling equipment and the correct operation of the register equipment and

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switching-control equipment common to the trunk circuits connected. The usefulness of the completed connexion depends on the overall, customer to customer, transmission quality it provides. Some of these operational requirements are automatically monitored by in-built features, others are controlled by supplementary maintenance measures.

Line Transmission System

Using pilot-tone monitoring techniques, changes in line-section transmission gain due to variations in the attenuation/frequency characteristics of the coaxial cable-pairs with temperature are, to a great extent, automatically compensated by the regulators built into the line system. Changes in the overall gain owing to cumulative residual regulation-errors, together with changes in gain in the parts of the transmission path outside the regulated section, are held within acceptable limits by additional automatic-gain-control equipments associated with each group of 12 channels within the system. Should these control limits be exceeded for any reason, an indication is given at the receive end of the group affected. This indication is arranged to give an alarm in the repeater station and in the t.m.c.c.

The circuit-group-fail signal is further utilized to automatically busy to traffic those circuits outgoing with respect to traffic direction, from the alarm point, and is to be used to act on the group pilot in the transmit direction so as to effect busying of all circuits utilizing the group.

The t.m.c.c. and repeater station staff subsequently co-operate to determine the cause of failure and to restore circuits to service. In the event of major damage to line plant or multiplexing equipment which could result in prolonged route outage, use is made of alternative routes or the service protection network, as co-ordinated by regional and national network co-ordination centres, to restore service quickly.

Line Signalling Systems

Excessive transmission loss in individual channels, as well as particular line relay-set misoperations, are automatically detected during the normal circuit release sequence which comes into operation when the caller clears. During this sequence, if the clear-forward signal is not recognised by the incoming line relay-set or the release-guard signal in the reverse direction fails to be recognised by the outgoing line relay-set, the circuit remains busied to traffic and the condition is indicated in the t.m.c.c. for attention. This sequence also serves to ensure that equipment at the distant end is fully released before the circuit is marked as free for use at the outgoing end. The clear-forward signal is automatically repeated at intervals to avoid continuing to hold circuits in the busied state as a result of some transient condition which could have disturbed the initial clear-down sequence.

In the event of a relay-set or channel developing a fault of this type when in the idle state, the first call attempt taking the circuit into use is likely to fail but the circuit will then be automatically busied to subsequent attempts through failure to complete the release sequence.

Inter-Register Signalling

In most controlling register-translator (c.r.t.) configurations, loss or mutilation of numerical and information signals between registers during call set-up results in

(*a*) the release of the S.S.M.F.No. 2 equipment taken into use,

(*b*) the release of the connexion forward of the outgoing line-signalling relay-set (types 2, 3 and 4 c.r.t.) or register-access relay-set (type 5 c.r.t.), and

(*c*) automatic initiation of a second call attempt in which there is a high probability of different trunk circuits being selected.

This feature safeguards service against intermittent discontinuities or transients in the connexion path and specific equipment misoperations during the critical call set-up period.

MAINTENANCE MEASURES

The system features outlined, automatically monitor and control circuit transmission levels between line multiplex equipments and serve to identify individual circuits in which the line-signalling equipments may have failed or in which the circuit transmission levels have deteriorated to a point where the exchange of line signals between relay-sets fails.

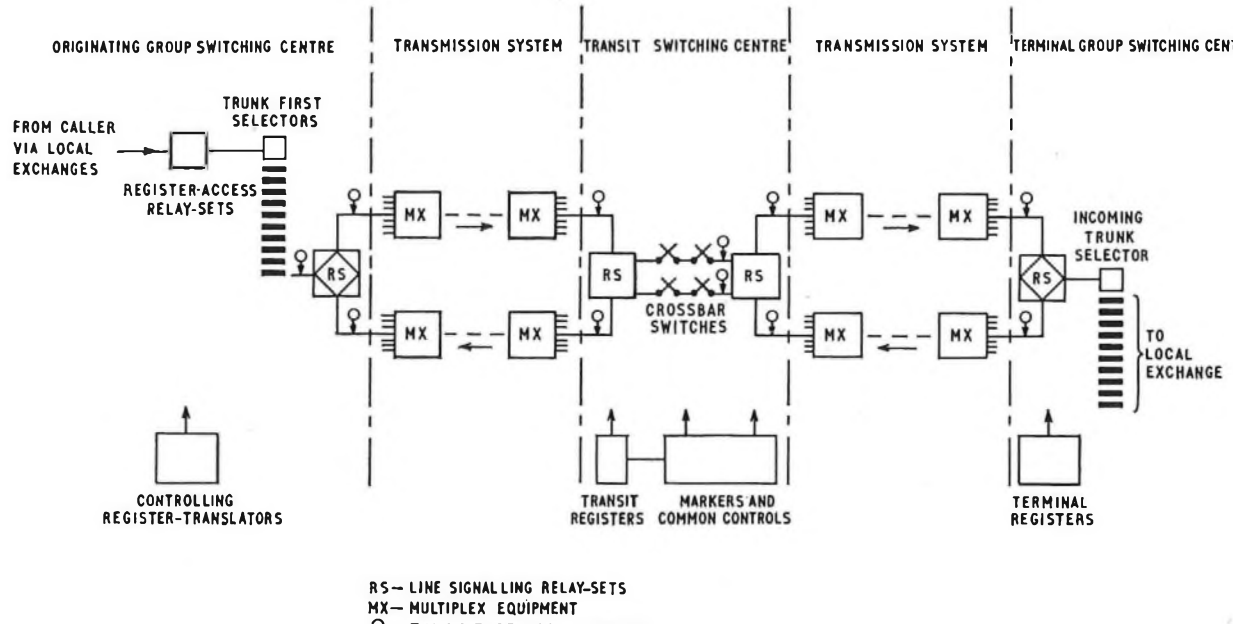

FIG. 1—Connexion path for a g.s.c.—t.s.c.—g.s.c. routing

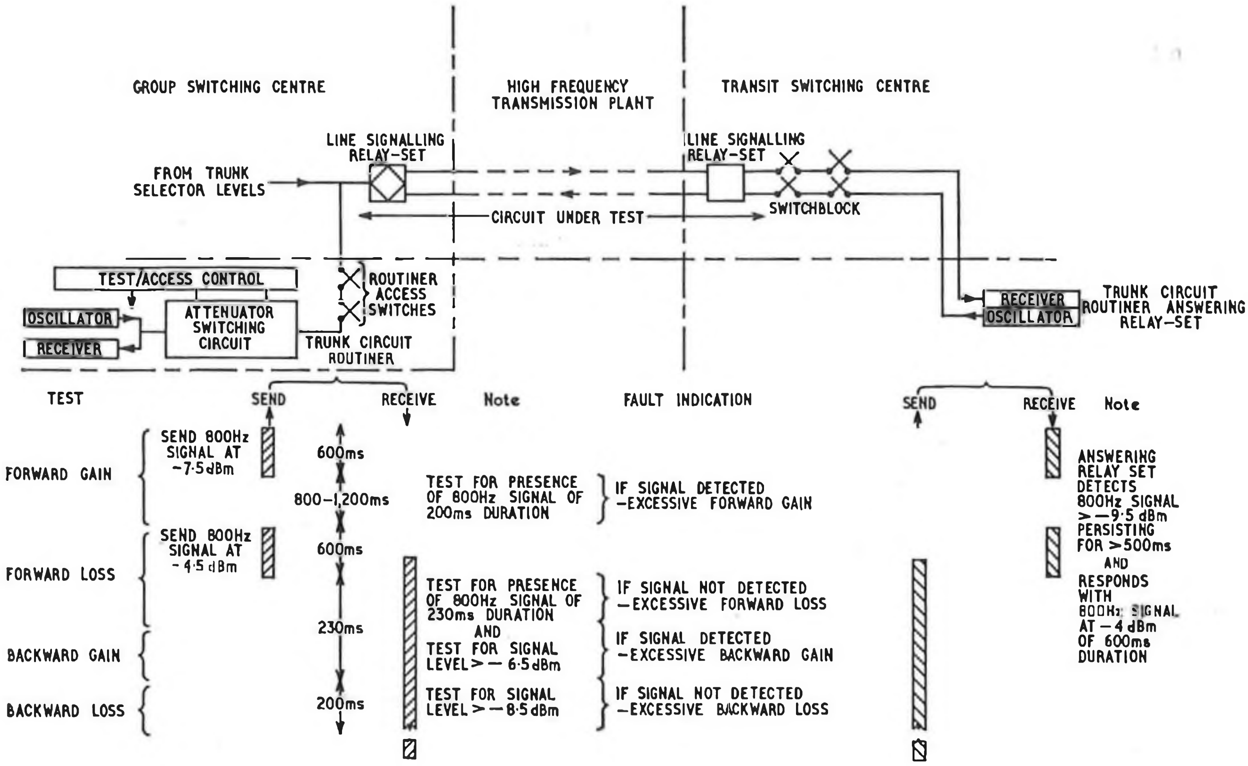

FIG. 2—Trunk circuit routiner transmission test sequence

Note: Nominal 3·5dB circuit loss, test tolerance ± 1dB assumed.

Other defects in relay-sets, some of a marginal nature, can occur which would not be brought to maintenance attention by these features, e.g. failure to apply a seizure signal, failure to busy on seizure or under line-fail conditions. These defects could degrade service and are best checked by comprehensive tests applied directly to individual relay-sets.

In addition, the overall transmission loss or gain of individual trunk circuits requires to be checked to close limits between switching points to ensure that speech transmission on any connexion which, in the trunk transit network could include up to five circuits in series, will be satisfactory. Maintenance testers are used to provide control over these functions and parameters.

Line Relay-Set Testers

Depending on the size of each installation, an automatic routiner or manually-operated tester is used to apply comprehensive tests under limiting conditions to individual line-signalling relay-sets. Each testing device is arranged to connect directly to the input and output leads of the relay-set under test, thereby excluding external equipment from the test path. Routiners are arranged to start on receipt of a clock pulse and to test automatically relay-sets in sequence, usually during the night when the number of circuits engaged by normal traffic is at a minimum. Faults are automatically recorded for the attention of equipment maintenance staff on the following working day. The objective is to busy manually all faulty items as soon as possible, thus minimizing call loss arising from defective equipment, and then to repair the relay-sets and to restore the circuits to service before the onset of the peak traffic period. Existing routiners and testers have been modified to test S.S.A.C. No. 11 relay-sets in g.s.c.s whilst new testers have been provided for use in t.s.c.s in which S.S.A.C. No. 11 relay-sets and junctors are entirely 4-wire.

Trunk Circuit Routiners

Trunk circuit routiners are provided in g.s.c.s. and are used to verify that a call can be established to a distant answering relay-set over each outgoing trunk circuit in turn and that the transmission loss between switching points is within maintenance tolerance in both the transmit and receive directions of transmission. This routiner is also operated under clock control during the night with automatic recording of faulty and busy circuits and during the day under manual-control to detect faulty circuits and circuits marked as busy but which are not carrying traffic, the latter condition may be caused by a held connexion or simply human failure to restore a circuit to service after work has been done. Existing trunk circuit routiners, designed for loop-disconnect sending, are not suitable for testing routes utilizing S.S.M.F. No. 2. A new generation of trunk circuit routiners has been developed which caters for all current types of trunk circuit; a 4-wire version is provided in t.s.c.s.

The new trunk circuit routiners check for excessive transmission gain as well as excessive loss on circuits, so catering for the more exacting requirements on transit routings. The rejection limits may be selected by key operation. Earlier designs of routiner were arranged to wait on a circuit testing busy and to print a *busy* docket if the circuit did not become free during the waiting period. Experience has shown that since the network carries traffic well into the early morning hours the maintenance time spent the following morning giving attention to such dockets printed during the night test cycle is considerable. The new routiners meet this situation by following the *busy* test by a check for speech and/or answered conditions on the circuit, if either are detected the identity of the circuit is stored and the access stepped on. After a further 100 circuits have been tested, or when the store is full, the circuits in the store are automatically re-tested and a docket is printed for any circuit found busy on this re-test.

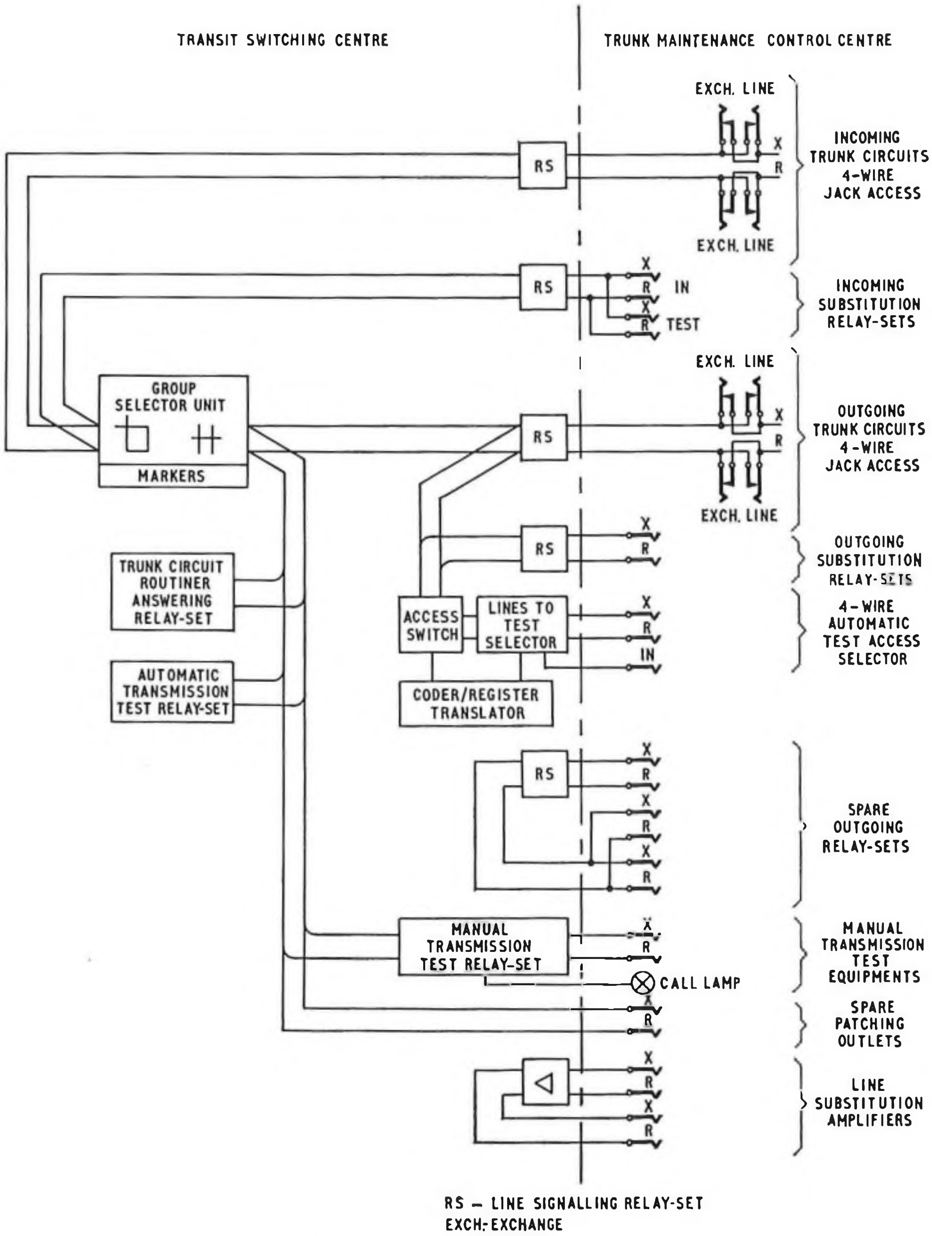

FIG. 3—Trunk circuit testing facilities in t.s.c.s.

The routiners also provide for a noise test to be applied on each test connexion established, the extent of the use of this facility is currently being considered by the Service Department of Telecommunications Headquarters.

Trunk circuit routiners are programmed to establish a test connexion over each circuit to a routiner answering relay-set connected to switch outlets in the exchange at the incoming end of the circuit and to interwork with this relay-set to check repetition of called-subscriber-answer conditions and transmission levels. The test sequence on accessing an answering relay-set is shown in Fig. 2. New solid-state answering relay-sets have been developed for use in g.s.c.s and t.s.c.s. The t.s.c version provides for 4-wire connexion and for correct multi-frequency response signals on seizure in addition to the test sequence described. The new equipment is more stable than earlier designs using thermionic valves, thus permitting improved control over circuit transmission levels between virtual switching points.

T.M.C.C. TESTING FACILITIES

Twelve-circuit group and higher order line transmission system failures are indicated in the repeater station for attention. However, to ensure effective follow-up by t.m.c.c. staff on circuits indicated as faulty or reported as being the cause of service difficulty by operating or engineering staff the t.m.c.c. should be able to

(*a*) gain testing access to trunk circuits, and

(*b*) be equipped with test equipment with which to localize failures.

The testing requirements for routes using S.S.M.F. No. 2 coincide with those for existing circuits. These requirements are

(*a*) automatic monitor and test access to the exchange side of any outgoing trunk line signalling relay-set, by code dialling from a test position,

(*b*) signalling relay-set substitution facilities,

(*c*) monitor and test access at the line-side of the signalling relay-set with facilities for testing towards the line and exchange, usually provided by 4-wire test jacks located in the t.m.c.c., and,

(*d*) circuit busying facilities.

It is also required to establish test calls over the circuits to verify correct operation and to gain access to automatic transmission test-number equipment in the distant exchange. This equipment has been augmented to provide for S.S.M.F. No. 2 signalling.

T.M.C.C. Test-Register

The 2-wire and 4-wire automatic test-access provided in g.s.c.s and t.s.c.s, respectively, allows the t.m.c.c. to gain access to the exchange side of the outgoing line-signalling relay-set. A call is established by associating a test register with the access which accepts the dialled routing code and subsequently seizes the line circuit and interworks with the distant register in m.f.c. to establish the connexion required. The arrangement is shown in block form in Fig. 3.

Automatic Transmission-Test Relay-Set

The automatic transmission-test relay-set is combined with the trunk-circuit routiner answering relay-set and its response is determined by the separate paths of entry. When accessed by the transmission-test code-number from a test desk it responds to a 800 Hz tone of the appropriate level on the receive pair by returning a 800 Hz tone for six seconds at −4dBm level on the transmit pair. The level of this tone is measured by the testing officer.

Manual Transmission-Test Relay-Set

Where testing co-operation is required between t.m.c.c.s, a connexion is established over the circuit to be tested to the manual transmission-test relay-set which terminates on test jacks on the distant t.m.c.c. test positions. The relay-set provides for speech, the exchange of test tones and for a tone to be applied to the transmit pair for as long as is required by the calling t.m.c.c.

CONCLUSIONS

The service security features embodied in the design of the transmission systems and line-signalling systems used on trunk transit routes, combined with the form of information signalling used and the crossbar switching techniques applied in t.s.c.s, to protect the customer from the majority of equipment misoperation, thereby increasing the percentage of calls successful at his first attempt. The improved trunk-circuit routiners and associated answering equipments enable transmission levels to be controlled within closer limits resulting in a consistently acceptable quality of transmission on all multi-link trunk calls.

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[1] Miller, C. B., and Murray, W. J. Transit-Trunk-Network Signalling Systems, *P.O.E.E.J.*, Vol. 63, p. 43, Apr. 1970, p. 91, July 1970 and p. 159, Oct. 1970.

Book Review

"Communications Systems Analysis." P. B. Johns, B.Sc.(Eng.), M.Sc., C.Eng., M.I.E.E., and T. R. Rowbotham, B.Sc.(Eng.), M.Sc., C.Eng., M.I.E.E. Butterworth Group. x + 207 pp. 65 ill. £3·40.

This book covers a number of aspects of modern communications problems. The authors, one of whom is with Research Department of Telecommunications Headquarters and the other who was formerly with the Post Office but is now a lecturer at Nottingham University, have evidently set out to bridge the gap which they found to exist between the published literature on mathematical theory of communication systems and the requirements of the practising system design engineer.

The authors describe their work as an "undergraduate level book" and it is true that aspects of the presentation, such as, the inclusion of worked examples in the text and the problems at the end of each chapter do make it a valuable learning aid. However, it would be misleading to suggest, on the one hand, that the practising communications system designer would not find the book a useful reference work in certain areas, or, on the other hand, that the undergraduate will necessarily find the material to be within the scope of the normal curriculum. It might, however, prove valuable when the student wishes to delve a little more deeply, such as, in project work.

For a proper understanding of the book, many readers would no doubt need to revise their understanding of some of the basic theory of frequency modulation (f.m.) and also to brush up on their mathematics, particularly in the use of the Fourier transform. Chapter 1 of the book does cover the main mathematical concepts used in the subsequent text, but is not in sufficient detail for those who are not already reasonably familiar. The Appendices summarize some of the useful mathematical results and good references are also given for more comprehensive reading.

The areas which are dealt with in considerable detail are the analysis of interference between analogue modulated systems and the analysis of non-linear devices. It is in these areas that the book has its greatest value. The treatment of interference between analogue systems will be particularly useful for those concerned with the design of f.m. systems. A number of methods are presented on how to determine the spectra of modulated signals and how these are used to determine the baseband interference level. The work on frequency modulation is continued in the treatment of the effects of delayed echo and of non-linear phase characteristics (a.m. to p.m. conversion). Both these effects can arise in modern microwave systems, satellite and terrestrial. The chapter on non-linear devices is a comprehensive treatment of the effects of various types of amplitude non-linearity on various types of signal. This material is of interest in many situations where a signal plus noise or several signals pass through non-linear stages such as power amplifiers or limiters.

In addition to these detailed treatments, the book contains a chapter on thermal noise and another on digital-modulation systems. These chapters appear to be aimed at a somewhat lower level and may be of less interest to the readers of the rest of the book but, nevertheless, useful to undergraduates and to those who require an introduction to these subjects.

A. K. J.

Development of Group-Delay Measuring Sets

B. N. S. ALLEN†

U.D.C. 621.317.74

The introduction of data transmission facilities over the U.K. telephone network has resulted in the need for certain transmission properties of the network to be more closely controlled than was hitherto necessary for the transmission of speech. This article describes the development of group-delay measuring sets introduced to measure one such transmission property.

INTRODUCTION

In the early 1960s, data transmission facilities became available to customers using the U.K. telephone network as the transmission medium. To make the data signals suitable for transmission over the telephone network, modems were provided to translate the data signals into analogue signals. It was evident that, with the proposed increases in data speeds, the relative phases of the received analogue signals must be controlled to avoid transmission errors. An earlier article[1] explains the basic problem and the nature of group delay. Even so, it may be useful in an article on group-delay measuring sets to review the transmission property to be measured.

PHASE DELAY AND GROUP DELAY

The phase shift of a circuit can be measured at each discrete frequency by comparing the wave at the input and output simultaneously, and determining bywhat angle the two differ, provided that the input and output terminals are not widely geographically separated.

If the circuit has a phase-shift/frequency characteristic as shown in Fig. 1 and is used to transmit a complex wave consisting of frequency f_1 (angular velocity ω_1 rad/s) and frequency f_2 (angular velocity ω_2 rad/s) where $f_2 = 2f_1$, then the waveform at the sending end is as shown in Fig. 2(*a*). At the receive end the component at frequency f_1 is shifted in phase by β_1 rad and the wave is changing at ω_1 rad/s. Therefore, the component at frequency f_1, is delayed by $\frac{\beta_1}{\omega_1}$ s, that is, the phase delay at frequency f_1. (See Fig. 2(*b*)).

Similarly, for the component at frequency f_2, the phase delay is $\frac{\beta_2}{\omega_2}$ s, as shown in Fig. 2(*c*) and the received complex wave is the sum of these two. (See Fig. 2(*d*)). The received waveform differs from that transmitted because each component has a different phase delay.

Let $\tau_1 = \frac{\beta_1}{\omega_1}$ s, and

$\tau_2 = \frac{\beta_2}{\omega_2}$ s, then, in the example,

$\tau_2 = \frac{3\beta_1}{2\omega_1} = \frac{3}{2}\tau_1$, since $\beta_2 = 3\beta_1$, and

$$\omega_2 = 2\omega_1.$$

† Telecommunication Development Department, Telecommunications Headquarters.

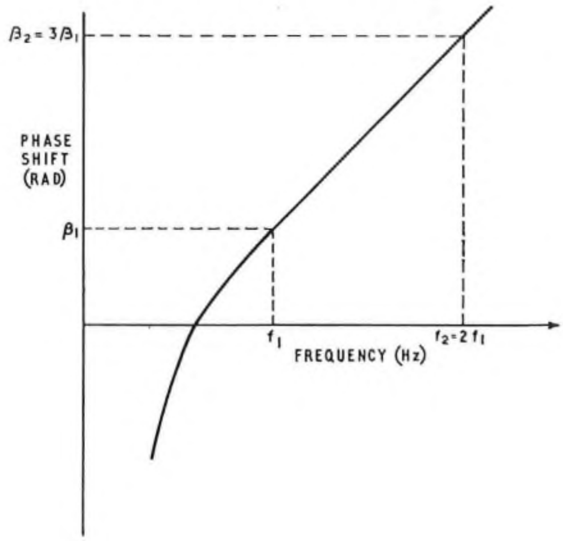


FIG. 1—Typical phase-shift/frequency characteristic

For distortionless transmission, the phase delay must be constant at all transmitted frequencies and this is not the case in the example shown in Figs. 1 and 2. For constant delay with frequency the phase-shift/frequency characteristic, when plotted on a linear scale, must be such that

(*a*) a single straight line may be drawn through all the points, and

(*b*) this line when extended to the phase-shift (β) axis must intersect at 0 rad or $2n\pi$ rad where n is any integer.

Condition (*a*) may be determined by a group-delay measuring set which measures the rate of change of phase with respect to angular velocity. Condition (*b*) is a measure of phase-intercept distortion. A phase-delay measurement covers both conditions.

Now suppose the circuit is used to transmit a signal of frequency f_m (angular volocity ω_m rad/s amplitude modulated on a carrier frequency f_c (angular velocity ω_c rad/s).

When a signal $A \sin \omega_m t$ is modulated onto a carrier frequency $\sin\omega_c t$, two side frequencies are produced in addition to the carrier. The input signal is, therefore, given by:

$$V = \sin \omega_c t\,(1 + A \sin \omega_m t),$$

$$= \sin \omega_c t + \frac{A}{2}\cos(\omega_c - \omega_m)t - \frac{A}{2}\cos(\omega_c + \omega_m)t.$$

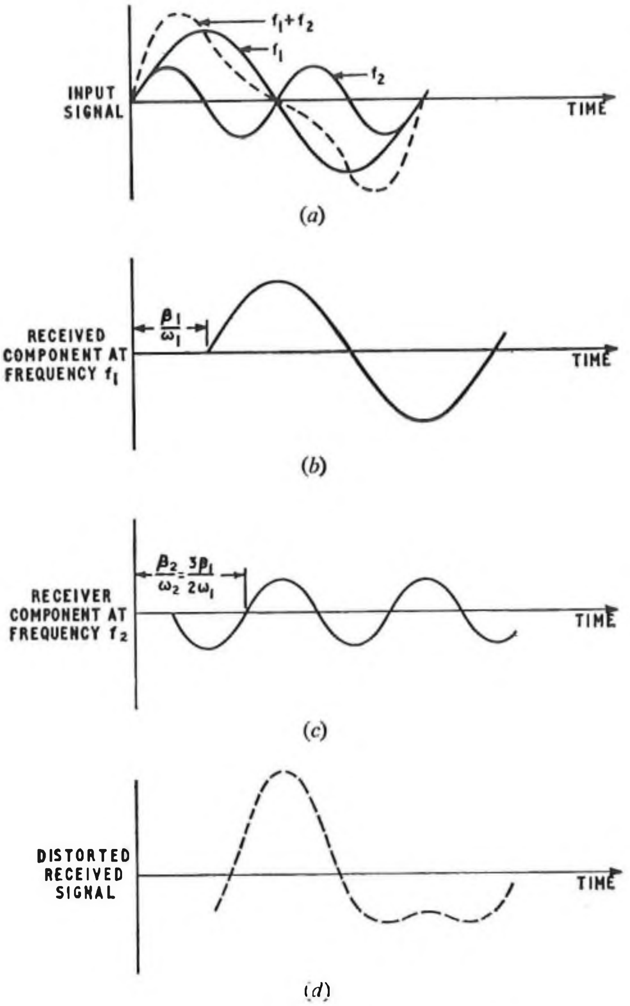


FIG. 2—Effect on complex wave of characteristic in fig. 1.

The phase of each frequency component, that is, $f_c, f_c - f_m$ and $f_c + f_m$, is shifted by a different angle as shown in Fig. 3.

The received signal (V_r) is, therefore,

$$V_r = \sin(\omega_c t + \beta) + \frac{A}{2}[\cos\{(\omega_c - \omega_m)t + \beta_1\} - \cos\{(\omega_c + \omega_m)t + \beta_2\}],$$

$$= \sin(\omega_c t + \beta) + A\left\{\sin\left(\omega_c t + \frac{\beta_1 + \beta_2}{2}\right)\sin\left(\omega_m t + \frac{\beta_2 - \beta_1}{2}\right)\right\}$$

If f_m is very much smaller than f_c so that in the region $f_c - f_m$ to $f_c + f_m$ the phase characteristic is linear, then

$$\frac{\beta_1 + \beta_2}{2} = \beta.$$

Therefore, $V_r = \sin(\omega_c t + \beta)$

$$+ A\left\{\sin(\omega_c t + \beta)\sin\left(\omega_m t + \frac{\beta_2 - \beta_1}{2}\right)\right\},$$

$$= \sin(\omega_c t + \beta)\left\{1 + A\sin\left(\omega_m t + \frac{\beta_2 - \beta_1}{2}\right)\right\}$$

Comparing the received signal with that transmitted, it will be seen that the received modulating signal (that is, the information) is displaced by $\frac{\beta_2 - \beta_1}{2}$ rad.

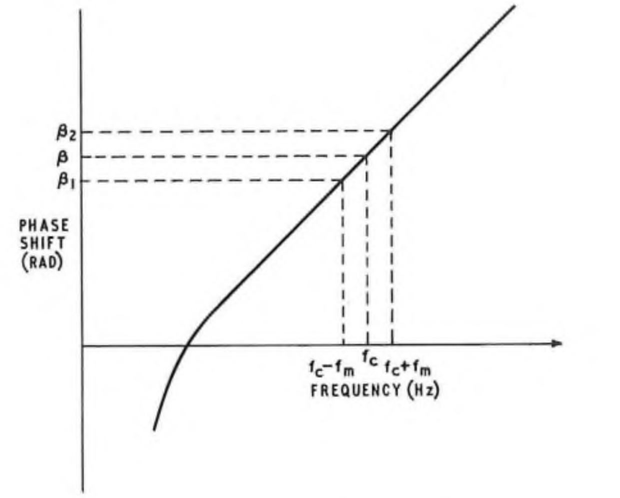


FIG. 3.—Effect of typical phase-shift/frequency characteristic on amplitude-modulated signals

Therefore, the phase delay of the received modulating signal

$$= \frac{\beta_2 - \beta_1}{2\omega_m}\ \text{s.}$$

However, $\frac{\beta_2 - \beta_1}{2\omega_m}$ is the slope of the phase characteristic shown in Fig. 3.

Thus, the limiting value of phase delay $= \frac{d\beta}{d\omega}$ as ω tends to zero. The phase delay suffered by the received modulating signal as ω_m tends to zero, is the group delay.

The carrier frequency is delayed by $\frac{\beta}{\omega_c}$ which is the phase delay at frequency f_c. The group delay may be numerically the same as the phase delay such as when the phase characteristic is linear and passes through the origin but this is generally not the case.

When the input and output terminals of the network or circuit under test are widely separated geographically, the group delay can be measured relative to the value at a chosen reference frequency. Phase delay and absolute group delay cannot be readily measured under these conditions. Relative group delay is, therefore, a useful measurement of the performance of a circuit which is to be used to transmit carrier signals modulated, for example, with teleprinter or computer data, since it gives the relative delay of the various frequencies carrying the information.

Group-delay measuring sets normally attempt to measure the rate of change of the phase-shift/frequency characteristic by using a low modulation frequency as proposed by Nyquist and Brand.[2] The maximum range of group delay that can be measured with certainty is dependent on the periodic time of the modulation frequency. For a modulation frequency of 20 Hz, the range is $\frac{1}{20}$ second.

If the circuit is used to transmit a carrier frequency with a high modulation frequency, the group delay is different from the group delay with low modulation frequencies unless the phase characteristic is very linear. This is illustrated in Fig. 4 in which T_1 is the rate of change of the phase-shift/frequency characteristic (group delay) at the carrier frequency f_c. However, T_2 is the group delay that would be measured using a high modulating frequency f_m. The two values of group delay will only be equal if the phase-shift/frequency characteristic is linear and the group delay is' therefore, constant with frequency.

Where there are ripples in the group-delay/frequency characteristic being measured and the ripple periods extend over only a small change in the measuring frequency, the effect of the measurement is to smooth out the characteristic. Fig. 5 shows the theoretical response of a group-delay

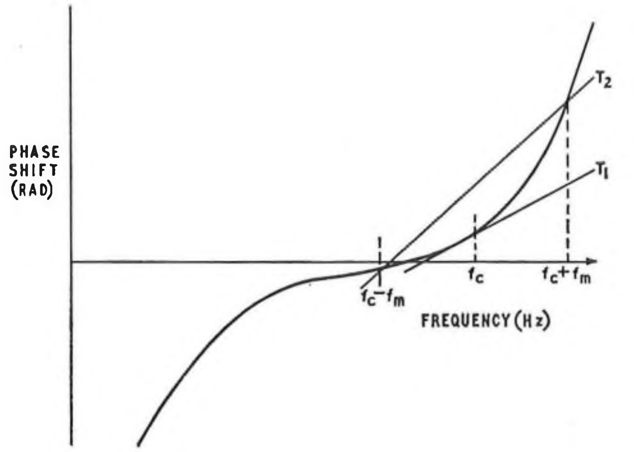


FIG. 4—Variation of measured group delay with modulating frequency

measuring set with a modulation frequency of 41·66 Hz when measuring group-delay/frequency characteristic having ripple periods corresponding to changes in measuring frequency of 10 Hz to 10 kHz.

It can be seen from Fig 5 that this type of set has eight blind spots* for ripple periods above 10 Hz change in the measuring frequency and comes within 90 per cent of the actual delay at ripple periods greater than 340 Hz. However, this effect, which is inherent using the Nyquist principle, causes no difficulties in most practical applications.

The foregoing description of the group-delay measuring technique is in terms of an amplitude-modulated carrier signal although frequency modulation can also be used. If the modulation index is small, there are only two prinicpal side frequencies and the line signal is very similar to that produced by amplitude modulation.

* Blind Spots. Specific variations in group-delay/frequency characteristic not measured by group-delay measuring sets occurring at ripple periods corresponding to changes in the measuring frequency of twice the modulation frequency and its sub-harmonics.

RELATIVE GROUP DELAY

Although group delay is an absolute quantity, in most practical methods of measurement it is only possible to measure group delay at one frequency relative to that at another. This restriction causes no difficulty in measuring group delay/frequency distortion but leads to measurements being referred to a reference frequency. Since the reference frequency may not be the frequency of minimum group delay, this makes negative relative values possible.

HISTORICAL SURVEY OF EVENTS

By 1965, specifications had been prepared by the British Post Office (B.P.O.) detailing the performance requirements for two group-delay measuring instruments, namely, a low-frequency (l.f.) set (200 Hz to 20 kHz) covering the audio and music frequency bands and a high-frequency (h.f). set (10 kHz–600 kHz) covering the basic group and supergroup frequency bands. These specifications detailed the performance requirements for measuring accuracy, stability of measurement, measuring range, power supplies, the working conditions and form of construction. However, the measuring principle, which is so important for compatibility between instruments on end-to-end tests, was not detailed because of foreseen difficulties in meeting synchronization requirements between instruments. It was decided that whatever signals were needed for synchronization purposes should be sent over the circuit under test and, to this end, invitations to tender were sought from prospective suppliers to demonstrate their designs. As a result, in 1967 the B.P.O. adopted a set, shown in Fig. 6, based on the stable-oscillator measuring principle.

STABLE-OSCILLATOR MEASURING PRINCIPLE

The stable-oscillator measuring principle is illustrated in Fig. 7 from which it can be seen that the chosen measuring frequency (carrier frequency) is modulated by a low-frequency signal (modulation frequency) and the resulting waveform is transmitted to line. At the receive end of the circuit, the

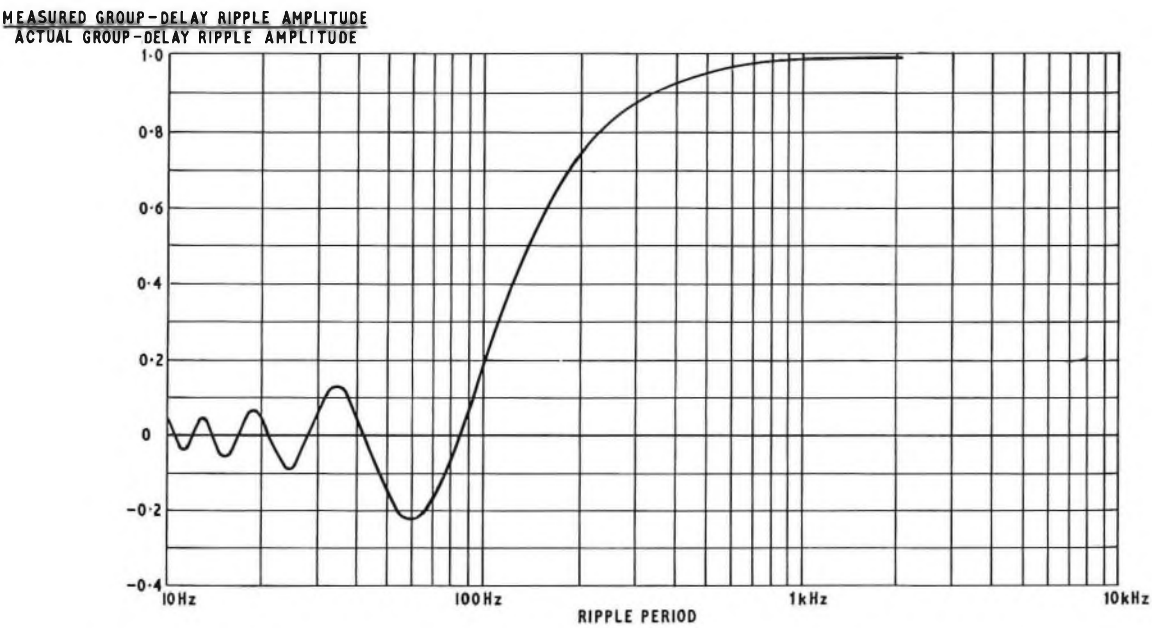


FIG. 5—Variation of measured group-delay ripple with ripple period

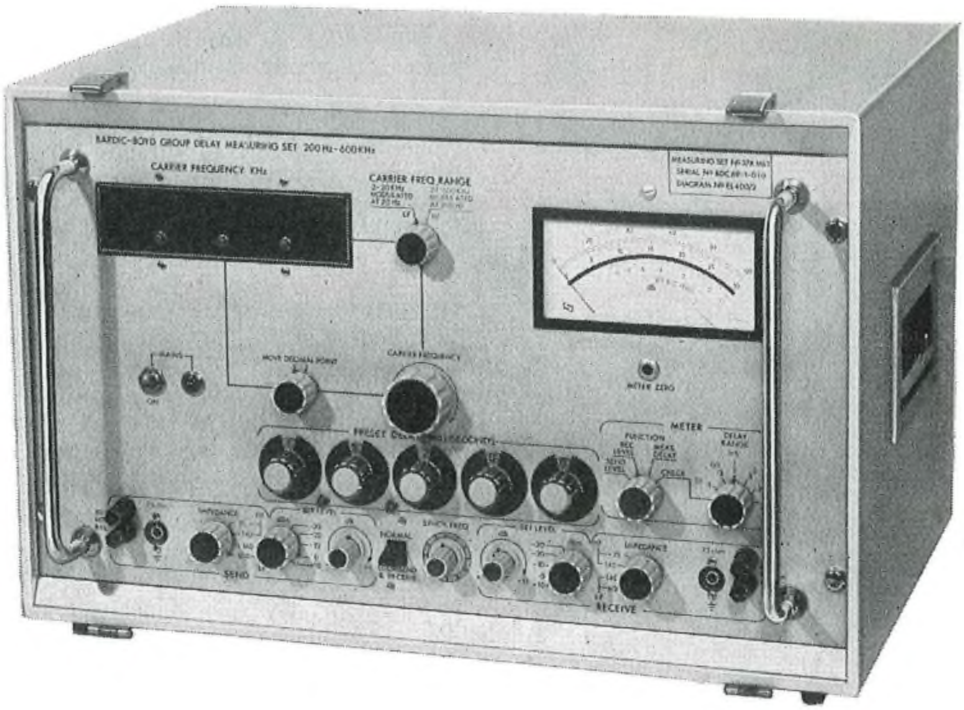


FIG. 6—First stable-oscillator group-delay measuring set

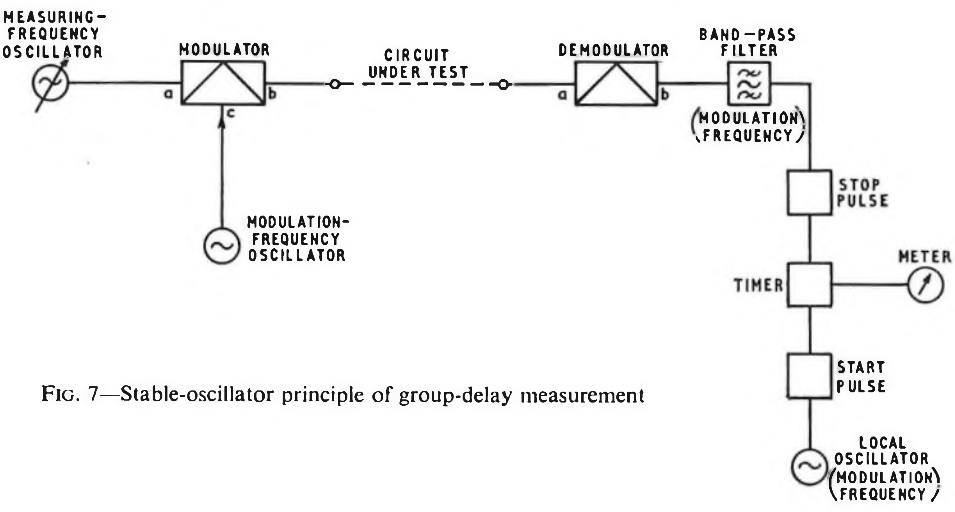


FIG. 7—Stable-oscillator principle of group-delay measurement

modulation-frequency signal is recovered from the delayed received waveform and a pulse is generated at the start of each cycle. This pulse is used to stop a timer circuit which is started previously by a similar pulse derived from a local oscillator of the same modulation frequency. Hence, the period during which the timer is running is a reference measure of the time difference between corresponding points on the waveforms of the local signal and the recovered modulation-frequency signal at the chosen measuring frequency. With a constant modulation frequency modulated onto different measuring frequencies any change in time difference from that at the reference measuring frequency is indicated on the meter and is a measure of the variation of the group delay of the circuit at the measuring frequencies relative to the reference measuring frequency. The stability of the frequency and phase of the local modulation-frequency oscillator with respect to the sending modulation-frequency oscillator is particularly important during the measuring period and hence, the title stable-oscillator method.

SECOND GENERATION GROUP-DELAY MEASURING SET

The second generation of group-delay measuring set supplied to the B.P.O. in bulk is illustrated in Fig. 8 and is also based on the stable-oscillator method. However, the mechanical arrangements of the case and chassis have been improved and active filters have been incorporated which replace ferrite-core tuned-circuits previously used, resulting in improved phase-shift/temperature characteristics.

Five switched modulation-frequencies are provided to meet various user requirements, these being 20 Hz, 25 Hz, $83\frac{1}{3}$ Hz, 200 Hz and 250 Hz. To enable the user to check readily the relative group-delay distortion at a known frequency within the band of interest without readjusting the main measuring-frequency control, facilities have been provided on the send part of the set to switch to one of three preset reference measuring frequencies, these being 1·8 kHz, 85 kHz and 432 kHz. Another new feature which has been provided is the remodulation facility.

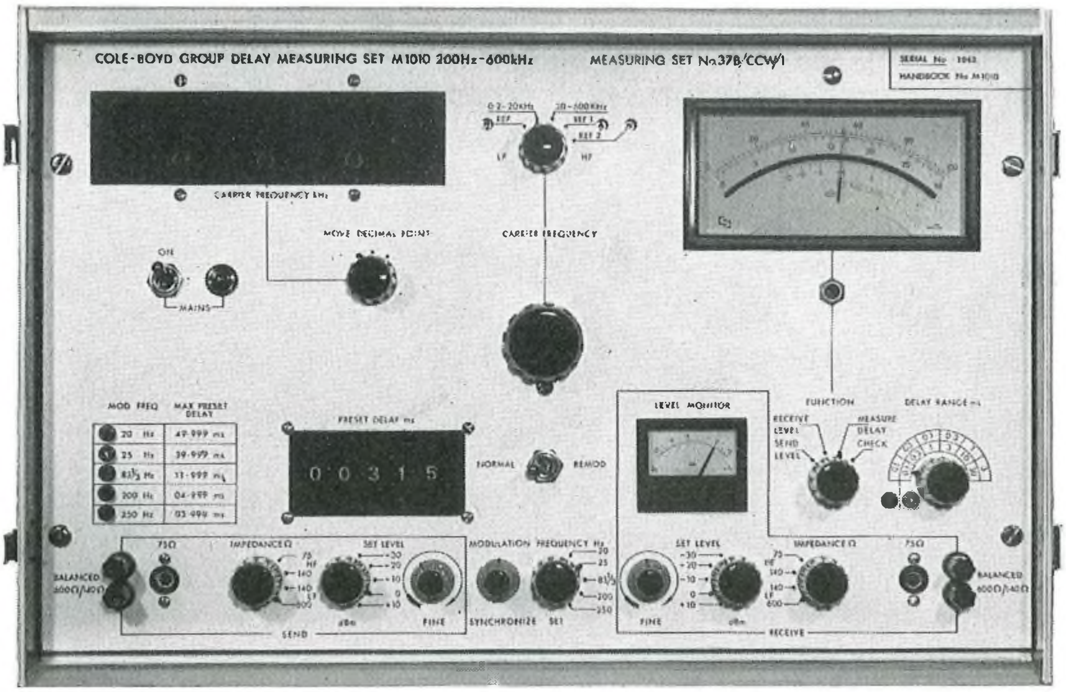


FIG. 8—Second generation stable-oscillator group-delay measuring set

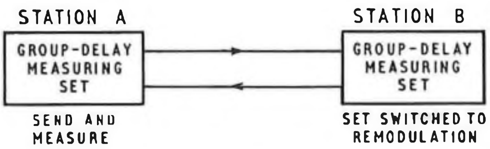


FIG. 9—Remodulation facility

Remodulation Facility

This facility enables the transmitting set at Station A (see Fig. 9) to be used to measure the relative group-delay distortion of the line in the A-to-B direction provided a return channel is available. To provide this facility, the set at Station B is switched to REMODULATION and adjusted to transmit at a midband measuring frequency, say 1·8 kHz for audio circuits. At each measuring frequency transmitted from Station A, the set at Station B extracts the modulation containing the relative group-delay distortion information of the circuit in the A-to-B direction and returns this information modulated on its own transmit measuring frequency (1·8 kHz). Because the measuring frequency transmitted in the B-to-A direction is constant, the measurement at Station A is unaffected by the B-to-A group-delay/frequency distortion and enables the operator at Station A to measure the relative group-delay distortion of the line in the A-to-B direction. Once adjusted, the set at Station B may be left unattended during the test.

FUTURE DEVELOPMENTS

To ensure compatibility between instruments when measurements are made on international circuits, the C.C.I.T.T.* has recommended the requirements for the characteristics of a group-delay measuring set for audio circuits based upon the time-division principle of measurement.[3] The B.P.O. has decided to adopt this set for audio group-delay measurements of both overseas circuits and inland circuits. A specification has, therefore, been prepared and contracts placed for the development and provision of audio group-delay measuring sets based on the time-division principle, first deliveries being expected in 1973.

Instruments employing the stable-oscillator method will continue to be used at frequencies above 20 kHz at least until international agreement has been reached on the basic specification for a high-frequency group-delay measuring instrument, at which time the position will be reviewed.

TIME-DIVISION METHOD OF GROUP-DELAY MEASUREMENT

In the time-division method of group-delay measurement, illustrated in Fig. 10, the modulation frequency (41·66 Hz) alternately modulates the measuring frequency (200 Hz–20 kHz) and a reference frequency (1·8 kHz) at a switching rate of 4·166 Hz. If the circuit under test has different group delay for the measuring frequency and the reference frequency, a phase surge occurs at the changeover point which can be detected and measured by the receiver of the measuring set.

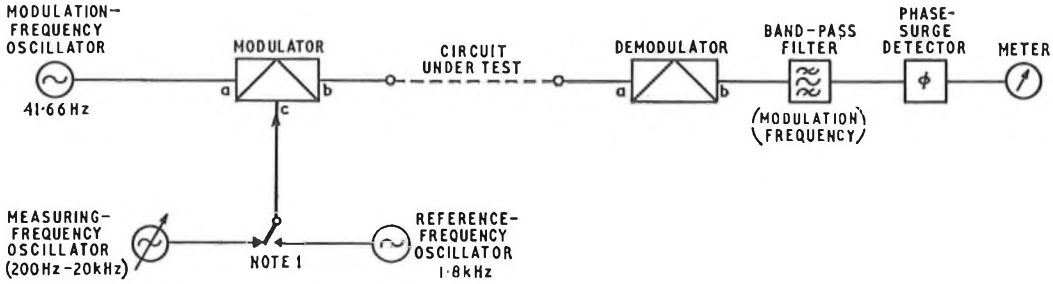
To ensure compatibility between instruments, the line signal has been rigidly defined. The reference frequency is identified from the measuring frequency by an identifying signal of 166·6 Hz which is transmitted during the last 24 ms of the reference frequency signal. The various signals used to generate the composite line signal are shown as a function of time in Fig. 11.

Additional Facilities

Additional facilities are being provided by the group-delay measuring set being developed for the B.P.O. and these are outlined below.

(*a*) Because the insertion-loss/frequency characteristic of a circuit is also important for the transmission of distortionless signals, it has been decided to incorporate in the group-delay measuring set, the ability to measure the level of the measuring frequency. This facility will reduce the number of separate test instruments required for the commissioning and subsequent maintenance of line circuits used for data

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



Note 1: Contact continually changing the measuring-frequency and reference-frequency oscillators.

FIG. 10—Time-division method of group-delay measurement

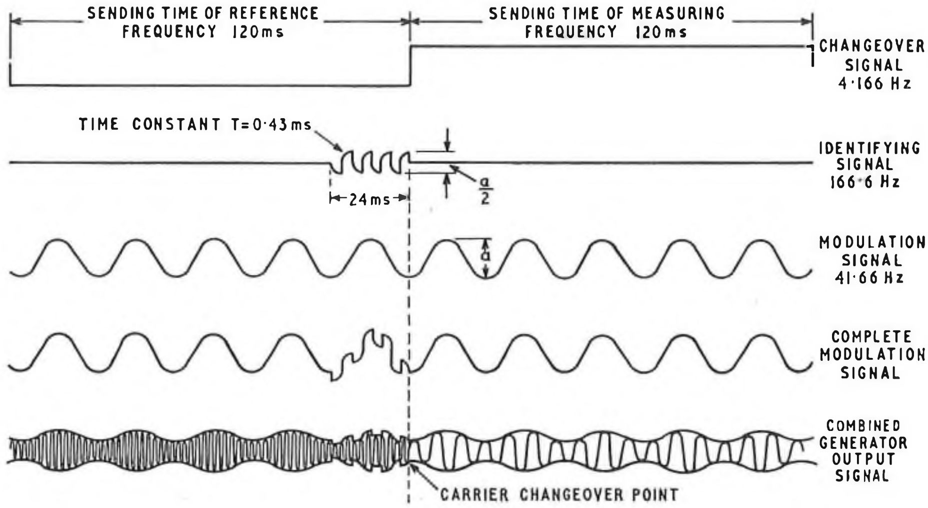


FIG. 11—Line signals transmitted in time-division method

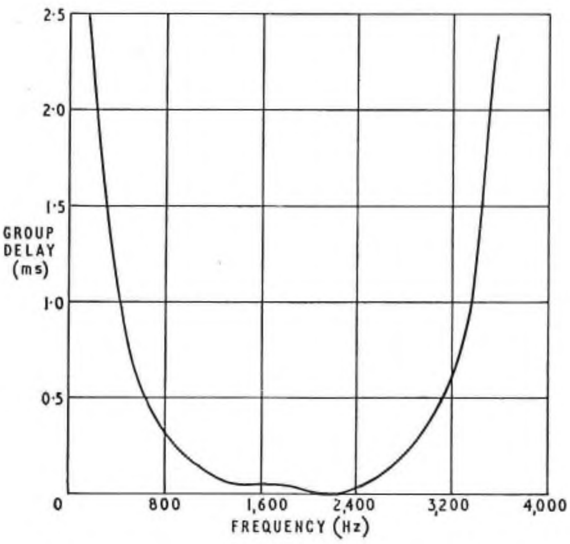


FIG. 12.—Typical group-delay frequency characteristic of an audio circuit

transmission, this being important where test equipment has to be transported to customers' premises.

(*b*) A means whereby the measuring frequency can be swept automatically for both group-delay and level measurements has been included, together with measuring outputs for association with an X–Y plotter. These facilities will reduce the time taken to measure the characteristics of the line circuits and provide a permanent record of the results.

A typical response of the group-delay/frequency characteristic of an audio circuit routed over carrier plant is shown in Fig. 12.

(*c*) Speaker facilities have been incorporated to allow the test operators to be in telephonic contact over the circuit to be tested. In addition, hold facilities are provided to enable the set to be used on the public switched telephone network.

CONCLUSIONS

Facilities to measure group-delay distortion in the telephone network have been provided. This article describes the present position with respect to the development of group-delay measuring sets.

During 1973, there will be a gradual penetration into the telephone network of audio group-delay measuring sets based on the internationally-agreed time-division system which will not be compatible with the existing sets based on the stable-oscillator measuring principle. Care will need to be taken by users during the period of change to ensure compatibility between instruments on end-to-end circuit tests.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance given by his colleagues in Telecommunications Development Department in preparing this article. Acknowledgement is also made to Cole Electronics Ltd for permission to publish Fig. 8.

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A Progress Report on Heavy Cabling Equipment

A. E. LUND C.ENG., M.I.MECH.E.†

U.D.C. 621.315.235:65.011.54

The problems involved in heavy cabling work are described briefly and an account is given of the equipment which has been developed to mechanize the work and improve productivity.

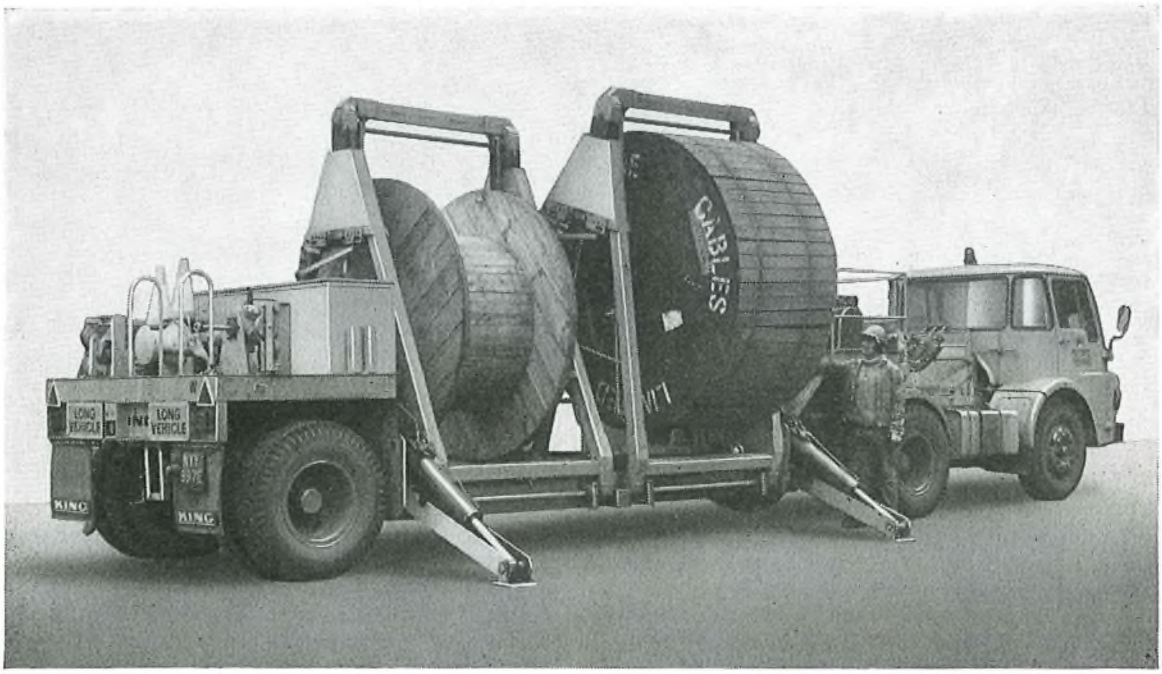

FIG. 1—Cable-carrier vehicle

One of the most laborious jobs in the external field of operations in the British Post Office is the laying of large underground cables. Basically, the task is that of pulling a cable through a duct between one manhole, or joint-box, and another. Because the cables are large, they are heavy and the tractive force required is high. Often, the mouth of the duct is many feet below ground level and it is difficult to keep the pull in line with the duct-mouth, as is necessary to reduce friction and prevent damage to the cable. Often, the presence of other cables in the manhole limits the space available for the provision of pulling tackle. The work nearly always has to be carried out in the open and extremes of weather have to be allowed for. All these factors describe a job which is heavy, dirty, labour-intensive—and, therefore, expensive.

Also to be taken into account are the problems of transporting large, heavy drums of cable to the site, of setting up the drums to permit the cable to be pulled from them, of providing facilities for storage of tools and equipment and—very importantly—facilities for the men to take meals and store their protective clothing.

The first attempt to obtain a rationalized solution to the problem led to the development, by Civil and Mechanical Engineering Branch of Telecommunications Development Department, of equipment aimed at reducing the manual effort involved and increasing productivity. A field trial of this early equipment in Birmingham clearly demonstrated the feasibility of the concept but showed that greater reliability was required. A second generation of equipment was, therefore, developed and put on field trial in London Telecommunications Region (L.T.R.) in 1971–72.

These two trials showed that a mechanized approach to heavy cabling could increase productivity significantly but that further improvements to the equipment were needed,

† Telecommunications Development Department, Telecommunications Headquarters.

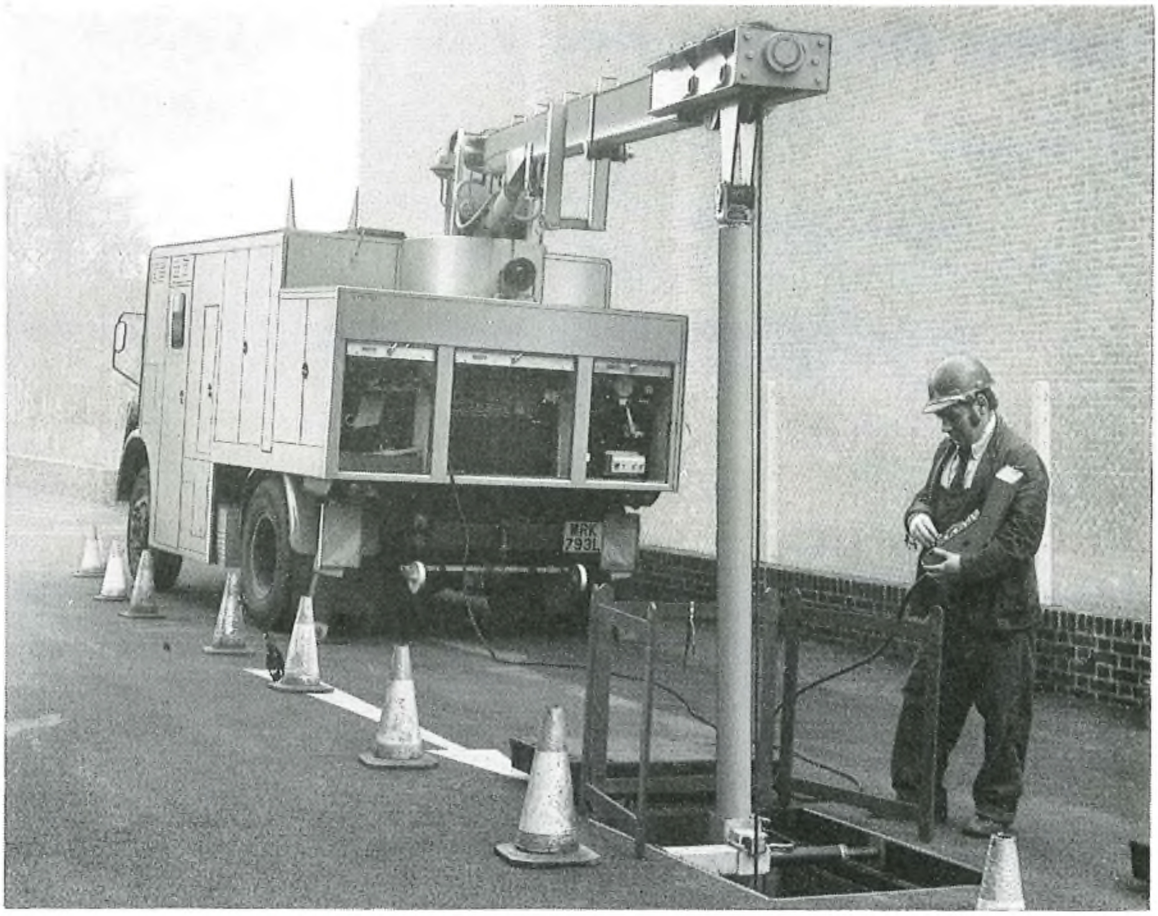

FIG. 2—Pulling-in unit

particularly to improve the facilities and accommodation for the crew. The outcome of further development was the Mark 3 equipment presently on trial in the L.T.R.

The equipment consists of two vehicles—a cable carrier and a pulling-in unit, shown in Figs. 1 and 2 respectively. In use, the two vehicles are positioned at opposite ends of the length of duct to be cabled. Using the drawrope existing in the duct, the winch on the cable carrier is used to draw in the steel winchrope of the pulling-in unit. The cable is attached to the winchrope and pulled into the duct by the winch on the pulling-in unit. Radio communication between the vehicles assists in synchronizing operations.

The cable carrier is an articulated low-loader which can carry two four-ton cable drums on its dropped deck. The drums are supported in frames which can be lowered to the ground by extensible hydraulic arms to permit easy loading and unloading. An auxiliary engine powers the hydraulic system which serves a 1,000 lbf, 300 ft/min winch and a 2 kVA 110-volt generator as well as the loading mechanism. The generator provides power for a submersible pump.

The pulling-in unit is basically a hydraulically-operated, vehicle-mounted winch incorporating a rope-guiding system in the form of a tower-mounted telescopic boom with a 25 ft outreach. At the end of the boom is pivoted a telescopic drop-arm carrying, at its lower end, a large-diameter cabling sheave which can be lowered into a manhole by operation of the boom controls. Recent and final development work on the unit has consisted of improving the reliability and efficiency, both mechanically and electrically, and providing more sophisticated methods of control. As now designed, the unit can exert a pull of 8,000 lbf at 150 ft/min.

The pulling-in unit is provided with lockers specially designed and located to hold all the tools and equipment which have to be carried. Directly behind the driver's cab is a crew compartment with a separate door on the near side of the vehicle. This compartment is fitted with a folding table, bench seats, a gas ring, small personal lockers for the men and a space for them to hang clothes and stand boots. Natural light is admitted through a translucent roof and a fluorescent tube is fitted.

Trials of the earlier versions of the pulling-in unit showed the need for a fine degree of control of the hydraulic equipment. This has been achieved, in the latest unit, by extensive use of electro-hydraulics in which control is exercised by electric switches rather than by manually-operated hydraulic valves. The speed at which the selected service or function operates is governed by potentiometer control of the servo system which, in turn, regulates the output from the main hydraulic pump. The switches and potentiometers are mounted in a control box which is linked to the relays and connexion strips on the vehicle by a flexible cable. By carrying the control box, an operator can stand close to a manhole entrance and control the unit from up to 30 ft away from the vehicle.

Specifications are being prepared for the purchase of 15 cable carriers and pulling-in units to be distributed amongst Regions in accordance with an agreed plan and programmed to go into service during 1974.

Regional Notes

London Postal Region

Commissioning of Mail-Processing Equipment

The installation and commissioning of the largest group of automatic letter-sorting machines installed to date in a British post office has been successfully completed by British Post Office staff. This code sorting installation is at the New West Central District Post Office, New Oxford Street. The provision of power supplies and signal highways for the code/sort equipment and the commissioning of the coding desks, translators and 17 sorting machines has taken 18 months.

Commissioning the system requires a large amount of mail passing through the machines in order to set them up and then run a meaningful trial. Since all the items have to be coded and subsequently analyzed it is not practical, at present, to use live mail and a large quantity of dummy mail, to test specification, was made available for local addressing and coding. The total number of items was about threequarters of a million, or looked at another way about six tons. This has very small residual value, and disposal was as scrap.

Since the office was operational during most of the commissioning, it was necessary to make the area out-of-bounds to normal office staff. This was done most economically by roping off the area with a single rope on standards about one metre high, this was effective and gave separation without isolation.

A specialist commissioning team, led by an Assistant Executive Engineer, was used for the testing and commissioning work. As the job progressed, the team became very experienced and effective, proving the value of this approach.

R. NEW

The Regional Engineering Training Centre of the London Postal Region

The recently completed Regional Engineering Training Centre of the London Postal Region, is located at Garrett Street, London E.C.1. The building, which has been completely modernized, contains approximately 16,000 ft^2 of accommodation arranged on four floors.

The training accommodation comprises two large lecture rooms (24 students), one of which also serves as a cinema, one smaller lecture room (12 students) and two demonstration rooms, together with the following workshops:

> hand tool, machine tool, welding, sheet metal and heat treatment, electric light and power, electrical machinery and electronic and light electrical.

The building also has a library and a conference/interview room as well as office accommodation for the training staff.

Welfare facilities include a students' tea bar and lounge, a games room and a staff lounge. Showerbaths have been provided in addition to the usual first aid, washing and toilet facilities.

Provided primarily to meet the formal training needs of the three-year T.T.A. training program, including the preliminary recruitment selection texts, the centre has complete facilities for the following range of T.T.A. courses:

> induction, hand tools, electric light and power and hot water fitting, machine tools, advanced equipment, drawing office familiarization, heat treatment and welding and sheet metalwork.

From time to time there will be capacity available which will be utilized for London Postal Region adult training requirements, which include courses on pulse clocks, relay adjustment, electric light and power wiring, electronics, and lifts.

I. W. S. BERG

London Telecommunications Region

Provision of Emergency Radiophone sets for use at Disasters

During October 1972 the London Telecommunications Region (L.T.R.) made available an emergency communications facility using portable radiophone sets. These provide immediate access to the public telephone network at the scene of a disaster, wherever the location, in advance of any other communication which might be provided. The service is intended for use by police and rescue services, and not by the press or public. It may also be used to provide skeleton communication where, for example, a hospital is isolated by loss of normal telephone services.

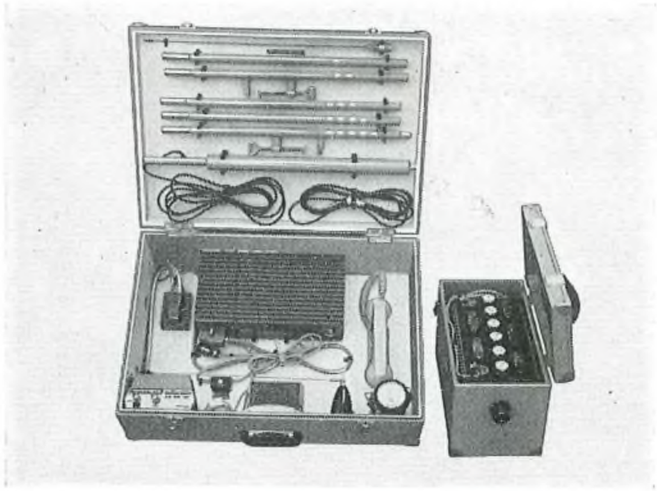

FIG. 1—An emergency radiophone unit complete with battery and aerials. The lid containing the aerials is removed before use.

FIG. 2—An emergency radiophone unit ready for use in a vehicle. Sufficient table space is available for two units to be operated simultaneously.

Two portable radiophone units are held at North Central Area Emergency Fault Control, Karen House. Each unit comprises two wooden cases with carrying handles, a jointer's tent and a table with hinged hanging brackets for use in the tent. A J4-type 15 cwt planning vehicle is available for transportation.

The radiophone equipment (system 3) is compactly housed in the two specially-adapted wooden cases for easy transit. One case contains the radiophone equipment and the other a 12-volt battery (Fig. 1).

The radiophone components comprising the transceiver, control unit, handset and loudspeaker are fixed inside the case which is normally operated in an upright position, after

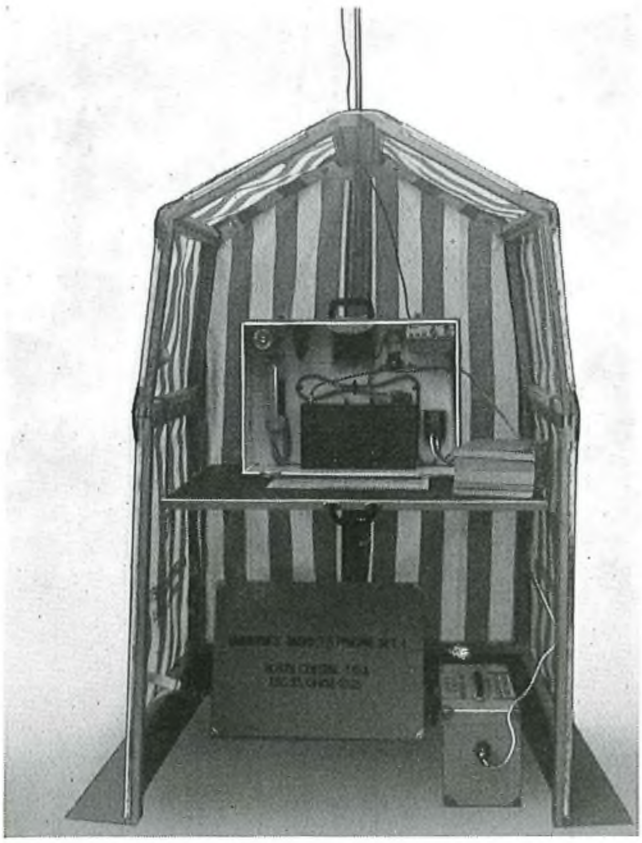

FIG. 3—An emergency radiophone unit ready for use in a jointer's tent. For clarity one tent section only is shown.

the lid has been removed. The case also contains a removable battery-operated hand lamp as well as inbuilt illumination powered from the radiophone battery supply, a removable magnetic-adhesion aerial and a card with guidance notes on operating procedure. The lid of the case houses the aluminium mast sections and aerial for use if a tent is used, and also feeder cables for both aerials.

The battery in the battery case, when fully charged, has a capacity for 24 hours of continuous service. Separate battery leads are also provided in the case to enable the radiophone equipment to be operated from the planning vehicle battery or any other available car battery.

In disaster situations, the radiophones will normally be operated on the table surface in the vehicle which conveys them (Fig. 2), or on the table provided in each jointers tent (Fig. 3). When operated in the planning vehicle, the magnetic-adhesion aerial is used and is positioned on the roof, which then acts as a ground plane.

When operated in a tent, a sleeve dipole aerial plus five mast sections are assembled and fixed to the end of the tent by the clamps provided.

A set of London Postal Area and Outer London Telephone Directories with writing paper and clip boards are included with each set of equipment.

Whilst it is hoped that the need to use the equipment will be minimal, experience has shown that there have been occasions when rapid access to and from the public telephone network at the scene of a disaster would have proved invaluable.

This emergency facility was called for by the Directing Board of the L.T.R. and the project was executed by its Service Divisions. The Operations Division of the L.T.R. was responsible for co-ordination of the project and issue of all relevant instructions covering call-out procedure and operation. The Maintenance Division of the L.T.R. designed the sleeve dipole aerial and this was constructed in its Development Workshop, which also designed and constructed the portable equipment, incorporating commercial radiophone units.

R. CLEGG

Midlands Telecommunications Region

National Westminster Bank Computer Centre

National Westminster Bank opened their new computer centre recently and became the first British Post Office (B.P.O.) customer to have multipoint private circuits and out-of-area standby exchange lines connected over pulse code modulation (p.c.m.) links. The centre is on the site of a building purposely build for a previous computer concern at Kegworth and the B.P.O. was able to use a large existing equipment room. This room houses the main distribution frame, the equipment for seven p.c.m. systems, two racks of single voice-frequency signalling relay-sets, miscellaneous equipment for key and lamp units, and a private automatic branch exchange (p.a.b.x.). In an adjacent room are the rectifiers and batteries for the B.P.O. equipment and the p.a.b.x. Standby power is provided by the customer should the mains fail.

Because of the large amount of traffic involved, and the need for security, every possible precaution is taken to provide the customer with alternative routing in the event of a catastrophic failure of cables and equipment. Sixty out-of-

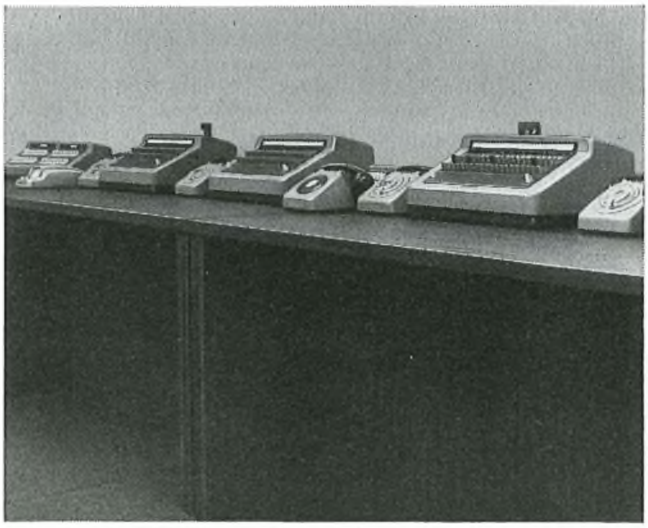

FIG. 1—DT 102 switchboards in the teleprocessing area

FIG. 2—Seven 62-type racks mounting Datel Modems 1D

area standby exchange lines are provided over four p.c.m. systems routed between Kegworth and Leicester, with alternative routing in two cables. An additional 20 out-of-area standby exchange lines are provided over the remaining three p.c.m. systems between Kegworth and Nottingham. These are at present routed in one cable, but an alternative routing is planned for the middle of 1973. The alternative routing requirement also necessitated the provision of two separate spurs from the computer centre to the main cables giving security in the event of damage to one duct track. Signalling is achieved by single voice-frequency relay-sets at the group switching centres at Leicester and Nottingham, and at the customer's premises.

Under failure conditions of the private circuits, the bank's branches are connected over the public switched network and the standby exchange lines to four DT102 switchboards sited in the teleprocessing area adjacent to the computer hall (Fig. 1). Operation of keys on these switchboards connects the standby exchange lines to modems via the control racks. A complex of 30 key and lamp units is also provided in this area for general data transmission enquiries.

The modern installation sited in the computer hall for the Datel 600 service comprises 14 62-type modem racks mounting 128 Datel Modems 1D (Fig. 2), and three control-racks for patching and testing. All the equipment, the six initial private circuits, and 20 standby exchange lines were to be installed for a ready-for-service date of 1 September 1972, and because some of the accommodation was not ready until the middle of May the Leicester Area was committed to a very tight schedule. With the exception of the p.c.m. equipment the work on site was planned and co-ordinated by the recently formed Area Customer Works Group in co-operation with Telecommunications Headquarters and Regional Headquarters. Access to the equipment room was made available in late February and work commenced there soon afterwards. Accommodation for a workshop was provided by the customer and this proved invaluable for constructing and wiring the modems and control racks, and in removing the modems from their normal cases and refixing them in shelves on the racks. In spite of this being the first installation using 62-type modem racks attempted by the Leicester Area, the 14 modem racks and three control-racks were ready for positioning and fixing in the computer hall on 15 May, the modem installation and DT 102 switchboards were completed by the middle of June and commissioning of the modems to the datel test centre was commenced. By the middle of July the relay-set installation at Kegworth and Leicester and the 30 key and lamp units were completed. The 60 out-of-area lines to Leicester were connected and tested by the middle of August followed soon after by the provision of the 20 remaining lines to Nottingham. The initial six multipoint tariff S3 circuits and a Datel 48k bit service to London were provided by the ready-for-service date.

The project was a major achievement for Leicester Area and the co-operation and assistance given by Telecommunications Headquarters and Regional Headquarters staff and all in the area who participated, is gratefully acknowledged.

E. G. Wilson
D. J. Wortley

Scotland Directorate

Lochboisdale Exchange Fire

Lochboisdale is the romantic-sounding name of a small manual exchange located in remote South Uist, one of the misty Isles of the Outer Hebrides. However, there is nothing romantic about an exchange fire, particularly when the exchange happens to be a single-position CBS No. 2 switchboard located in the house of the caretaker-operator. In addition, the exchange is a vital link in the life of the local community and the three adjacent communities of Bornish, Southboisdale and the island of Eriskay, which are served by country-satellite exchanges. More important, the exchange is located in an area not served by a regular full-time fire service.

The fire occurred within the switchboard at about 17.30 hours on Friday 24 November 1972 and only the prompt action of the exchange staff with the willing assistance of nearby volunteers prevented major damage to the house. Fire extinguishers alone could not contain the flames and ultimately sand and water had to be used to complete the job. By 18.00 hours the house had been saved but the switchboard was a blackened, ruined, shell. While clearing up was in progress, emergency action was being taken by the local maintenance staff and by midnight temporary service had been given to all emergency subscribers, using a 10 + 50 private branch exchange switchboard. Work continued through the night and by Saturday afternoon temporary service had been given to about half the subscribers.

On Saturday, a combined operation was mounted in the General Manager's Office which resulted initially in a 10 + 30 switchboard being flown from Glasgow to South Uist. This was installed by Sunday afternoon by the maintenance staff and temporary service given to more subscribers. A replacement CBS No. 2 switchboard and associated equipment were obtained and loaded into a 15 cwt vehicle which on Sunday started a 300-mile journey by land and sea to Lochboisdale. This was driven by two construction engineers who would form part of the team for permanent restoration. On Monday a joint Traffic, Engineering Planning and Construction team flew by charter plane, through force nine gales, to South Uist and timing was such that the equipment and full team arrived together at Lochboisdale in the afternoon.

Installation work started at once and by the following Thursday service was restored to those subscribers who had so far been without service since the fire. By Saturday 2 December all the subscribers' lines on one of the temporary switchboards had been transferred to the new switchboard and the next day those on the other temporary switchboard were changed over. Service to the country satellites had been given by means of single telephones located at suitable places in the areas concerned and these were also restored to full service.

The cause of the fire is not known and may never be. The switchboard was of an old pattern using Resistors Spool No. 1 and waxed cable forms, but the exchange staff were not aware of any prior sign or smell of over-heating.

The above is a brief summary of the actions of many who were involved, but the most important action was undoubtedly that of the exchange staff in their prompt handling of the fire. Without this the Lochboisdale subscribers would probably have been without service for a much longer period.

G. C. Dick

South Eastern Telecommunications Region

Prototype Datel Test Console

The Service Division of South Eastern Telecommunications Region has produced a prototype datel test console in conjunction with Telecommunications Headquarters and the firm of Trend Electronics Ltd.

The console is a 2-position suite and each operator can connect any of a range of standard British Post Office modems in the 2-wire mode to any of the exchange lines terminating on the console. There is also a facility for extending modems in the 4-wire mode to a patching jack field remote from the console. Switching is based on conventional key and lamp circuitry, with the necessary modem switching performed by reed relays.

In addition to a comprehensive range of modems, each operator has exclusive use of a Datel Tester 1C, a frequency counter and a loudspeaker. The two positions also share access to a Datel Tester 2C, audio transmission measuring equipment and an oscilloscope.

The modems can be accommodated in the rear of the console or separately if preferred. Removable pigeon holes provide space on the facing panel for additional equipment if desired.

R. Bayfield

Wales and the Marches Region

International Subscriber Dialling

On the 6 November 1972 international subscriber dialling (i.s.d.) was introduced to 18 exchanges in the Cardiff and Barry charging groups serving some 78,000 customers.

Although i.s.d. facilities have been available in the larger director areas for some time, Cardiff is the first exchange to use the new type of equipment developed for non-director areas. The initial installation consists of 14 international registers, 56 international call-timers and associated control and testing equipment. Fourteen direct circuits between Cardiff and Wood Street international exchange are in use. The equipment provides facilities for routing traffic over the trunk transit network.

The contract for the provision of this equipment was placed with Plessey Telecommunications Ltd in January 1970, and the installation commenced on the 22 February 1971.

All the i.s.d. and associated equipment was installed and ready for acceptance testing by the British Post Office (B.P.O.) in November 1971. Being prototype equipment, many design difficulties were encountered during the next six months, but owing to the excellent co-operation between Telecommunications Headquarters, Plessey and local B.P.O. staff, these problems were overcome. During these six months, many direct labour works associated with this contract, and also modifications to existing equipment, were completed.

It is interesting to see how the critical path analysis (c.p.a.) charts prepared by the Wales and the Marches Telecommunications Board staff helped our progress. The c.p.a. charts pin-pointed the areas of difficulty and helped with staff allocation to the numerous direct labour works required to be completed before i.s.d. could be brought into service.

Since the Cardiff i.s.d. equipment would use the outgoing Signalling Systems Multi-Frequency No. 2 group switching centre (g.s.c.) transit portion of the equipment it was essential that the g.s.c. transit call-through test be completed before the i.s.d. call-through test could start; this was achieved by the 30 June 1972.

The call-through test for the i.s.d. equipment was divided into three stages

(*a*) to prove that every controlling register within its own unit had access to every international register,

(*b*) to prove that international calls could be made from every register-access relay-set and that the metering and call barring facilities were correct, and

(*c*) to prove that international calls could be made from all the outlying exchanges and that metering and call barring facilities were correct.

The first two stages were carried out in the quiet periods i.e. calls to America were made between 07.00 hours and 12.00 hours and to Europe between 06.00 hours and 09.00 hours and the results were excellent.

Stage 3 tests were carried out by both engineering and traffic staff and the results from these proved to be above the national service-observation figures.

Traffic recordings over the Christmas period showed that on several occasions the traffic was over the design figure of 7·7 erlangs.

The provision of i.s.d. at Cardiff was an excellent example of teamwork. We would take this opportunity to thank all the staff in the Cardiff Area, Telecomminucations Headquarters and the International and Maritime Telecommunications Region for their interest and help in overcoming the many problems.

B. G. Hill

Associate Section Notes

Aberdeen Centre

So far this session the Centre has had one day visit, one evening visit and two talks. The first of the talks was on "Town planning and the history of Aberdeen" while the second was on "Mountain rescue". Both talks were illustrated by excellent slides and proved to be very interesting and informative.

Our first day visit took place on 10 October 1972. Twenty-three members went on a visit to the South of Scotland Generating Board Power Station, Longannet, in Kincardine. The station was very impressive, the visit being worthwhile and enjoyed by all who attended.

We had an evening visit to the Marine Laboratory on 6 December. This was a return visit and on this occasion we saw the Aquarium, following two short films and a talk on exhibits in the Demonstration Hall.

J. H. McDonald

Bournemouth Centre

Our summer 1972 season started in June with the annual general meeting, followed by a film show, with films kindly loaned by the Ford Film Library.

In July a very successful evening was held, with our General Manager Mr. B. H. Berresford giving a most interesting talk, and taking the opportunity to meet many of our members. We completed the evening with a buffet organized by members of the committee.

After a quiet August and September, due to the peak leave period, we started the Autumn program on 5 October with an interesting talk on the T.X.E. No 2 Exchanges, given by our local guest speaker Mr. M. H. Woodsford.

On 14 October, 18 of us visited the Police Driving School at Devizes, each member being taken out in a Police car, and also given practical instruction on the skid pan.

On 24 October some of our members attended a lecture and demonstration of the latest techniques in hi-fi. The guest speaker was Mr. B. J. Webb a frequent contributor to Hi-Fi News. This was at the invitation of the Graduate and Student section of the I.E.E. who also invited us to lectures in February and March 1973.

A party of 19 of our members visited British Broadcasting Corporation Radio Solent at Southampton on 9 November, where we spent a very interesting and informative evening.

At the end of January 1973 a visit was made to Mullard of Southampton.

G. H. Seagroatt

Colchester Centre

The Colchester centre began its winter session of meetings with a talk on "Alaska" by a member of the staff of British Petroleum. The theme of the talk was the country, its inhabitants and climatic conditions. The climate ranged from near sub-tropical in the south, during the summer months, where 150 inches of rain is not unknown, to the snow mountains in the north with temperatures of 50° below zero during the winter months.

Our winter program continues with a demonstration of hi-fi stereo equipment and talks on:

Fibre glass by the Strand Glass Co., submarine cables by Mr. T. Emery, big game fishing by Mr. L. Moncrieff, ending the session with a talk on the use of triacs and thyristors by Westinghouse.

The summer visits included a tour of the Shellhaven refinery in Kent and visits to the Police Driving School Chelmsford, Booths distillery and a lunch and tour of the Mullard valve factory.

A visit to a National Coal Board mine had to be postponed and will take place during the early summer next session.

During last summer, one of our committee members, M. T. Shanks, a long-standing holder of the honorary secretaryship of the local centre, retired and was made an honorary member of the local centre.

In addition to our normal winter program, the committee have agreed to put on a concert of classical records for those members interested. The first was an experiment and went down quite well, although there was a shortage of members, as always.

R. L. E. Durrant

Dundee Centre

During the first half of our 1972/73 Session we have enjoyed a varied and interesting program. On a visit to the Department of Civil Engineering, Dundee University, we were shown how tests were made on many different materials from soil samples to road-making aggregates. Special interest is being taken in the Tay Estuary, measurements being taken to determine among other things the flow of water and pollution; a really worthwhile evening.

A visit to the museum gave us an insight behind the scenes, allowing us to see how items are prepared for exhibition. The changes envisaged by the director show the forward view taken by the management of the establishment nowadays.

Our first talk was "North sea oil" by Mr. Kenny of Aberdeen and as anticipated proved to be most interesting. The lecture, suitably illustrated by film, slides and samples was first class.

The second lecture was given by Mr. W. Crook, Scottish Telecommunications Headquarters, and his subject "Post Office statistics" left those attending a bit wiser as to the reasons behind all the facts and figures which play such a large part of our day-to-day life in the British Post Office.

R. T. Lumsden

London Centre

The London Centre are having a very successful session so far. Attendances at the monthly talks have been much better this year and are improving each time. The Tower quiz trophy competition final was held in November and South Eastern Region held the trophy after narrowly beating London Telecommunications Region's (L.T.R.) South West Area in a fine quiz. We have many interesting projects underway at the moment and some fine workshops are being built up in the L.T.R., a good example being in the South Central Area.

Our program of visits is comprehensive and is being enjoyed by our members. The L.T.R. have adopted a lapel badge and, as with our ties, they may be purchased by any associate member. The London general secretary may be contacted for further information.

P. L. Hewlett

Oxford Centre

The present session's meetings are marred by very low attendances but the faithful band of members who regularly come along are enjoying a very interesting program.

This began with a talk and demonstration of amateur radio equipment when two stations were set up in a local public house by the Oxford Radio Club.

In December we visited the Nuffield Orthopaedic Centre to hear about artificial limbs and invalid cars.

Our next talk, in February, was on submarine cables by Dr. Bray, our Associate Section President, and in March one of our members spoke about his hobby, photography.

If our talks have been sparsely attended our visits to local places of interest are always very popular.

This year we visited Didcot power station, the Thames Valley Police Headquarters and the new presses of the *Oxford Mail and Times*.

We hope those of our members who find it difficult to leave their armchairs and television sets will realize what they are missing and attend at least one meeting next session.

D. A. Green

Swansea Centre

It is very pleasing to report that, after a period rather in the doldrums, the centre at Swansea has now become very much alive. At the annual general meeting on 8 November 1972 Malcolm Connor was elected Chairman and Phil Evans, Secretary, together with other officers and committee. This was followed by a talk on appraisements and promotion by E. S. Armstrong, Area Engineer, Swansea. On 7 December there was a visit to the Royal Naval Reserve (R.N.R.) Headquarters at Swansea for a quiz and darts match. The R.N.R. proved very hospitable and it was a most enjoyable visit.

For the new year a full program has been arranged including a visit to the A.T.V. Studios at Birmingham.

Perhaps the most encouraging aspect is that during the last few months the membership has increased from 52 to 141.

P. Evans

Notes and Comments

Publication of Correspondence

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

Letters of sufficient interest will be published under "Notes and Comments". Correspondents should note that, as it is necessary to send copy to the printer well before publication date, it will only be possible to consider letters for publication in the July issue if they are received before 25 May 1973.

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.

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.

Letters to the Editor

Dear Sir,

Mr Laver's letter published in the January 1973 issue reminds me that many years ago I read that when poles were being introduced into urban areas it was customary in "better class residential locations" for poles to be painted not creosoted. To further improve their appearance they were fitted with turned wooden finials instead of bent metal roof shapes used elsewhere. More recently of course trials of hollow steel poles were carried out.

Presumably additional cost and/or reduced durability terminated both these approaches.

Yours faithfully,

T. D. BEASOR

Telecommunications Headquarters,
Purchasing and Supply Dept,
207 Old Street,
London EC1V 9PS

Dear Sir,

Reading Mr. Laver's letter in the January edition brings to mind another problem relating to the Post Office image in the urban landscape. This is the increasing size of telephone exchange buildings. If I may extend Mr. Laver's metaphor, many urban telephone exchanges have grown into large oaks compared with the small acorns of Sir John Gavey's day. Consequently, town planners consider that the urban landscape is being disfigured by our tall buildings, with their 15 ft storey heights.

Storey height and rack height are related, but it is not clear which one came first. It would be of interest to know the origin of the 10 ft 6 in high standard apparatus rack and I would be grateful if any reader can supply the answer. One theory is that some of the independent telephone companies installed equipment in old warehouses prior to take-over and standardization by the General Post Office. The 15 ft storey height then applicable to warehouses seems to have lingered on ever since.

The services of architectural design consultants have been employed from time to time but even the most ingenious and pleasing architectural schemes still seem alien to an urban or rural background where lower storey heights are common.

The question therefore arises as to whether it is not time to consider a shorter equipment height in our modernization plans, thereby reducing storey height for TE buildings? This would accord with the urban rather than the industrial landscape into which many environmentalists would wish to place our telephone exchanges.

Yours faithfully,

P. CANNONS

Eastern Telecommunications Region,
Director's Office,
St. Peter's House,
Colchester,
Essex CO1 1ET

Dear Sir,

Mr. Laver, in his letter on telephone poles, has missed one or two vital points. The first is that the pole has changed considerably since the days of Sir John Gavey. Does he really believe that the introduction of ring-type distribution was a regressive step when compared with the old single or double poles, carrying 4, 6, 8 and even 10-way arms? The second point is that the distribution pole had its aesthetic uplift a few years ago, with the streamlining of drop-wire and pole fittings, which enabled light poles to be used for subscribers' distribution.

No one will dispute that underground service is better aesthetically, and the Post Office will provide underground service if the local authority or estate developer is prepared to help pay for this amenity; at present 80 per cent of all dwellings on new estates are served by underground distribution. However, we must have poles for many years to come, as overhead drop-wire distribution is normally the cheapest and most suitable way of providing telephone service. Perhaps Mr. Laver can suggest how the pole can be improved at a reasonable cost, so that the resulting design is sufficiently elegant to overcome most pole-objectors dislike of overhead distribution?

Yours faithfully,

D. E. FAGG

Telecommunications Headquarters,
Operational Planning Dept,
Lutyens House,
1-6 Finsbury Circus,
London EC2 M 7LY

Dear Sir,

The following extract from the *Fermanagh Times*, Enniskillen, dated September 1907 is of interest in view of the comments made by Mr. K. S. Laver.

> "Our fastidious Town Improvement Committee have been most careful to exclude from the main thoroughfares the ordinary tall poles which are to carry the telephone wires soon to be erected in our midst. They have not banished the lines, but they have relegated their supports to the least conspicuous positions. Now a factory has just been opened in Germany for the manufacture of glass poles which are to take the place in our progressive world of the old and clumsy wooden arrangements which have been so long in evidence. These I fancy would be quite an ornament to the streets in which they are located. They will probably be coloured in various light and handsome hues; in fact different fanciful devices may be interwoven through them according to the taste and artistic yearnings of the Municipalities utilizing them. Could not our City Fathers insist upon this most admirable substitute being employed here; might not they call upon the Telegraphic Department to make what would really be a chrystal colonnade along our leading footpaths from bridge to bridge? Quite a charming idea is it not? and quite practicable too seeing that the Improvement Committee has for its chairman, a venerable and Nationalist M.P.!"

It would appear that over 65 years ago there was concern being expressed about wood poles.

Needless to say the engineers at that time paid due regard to the suggestion and did a cost study and evaluation of this revolutionary pole. The conclusion reached was that the new pole was not an economic proposition. This was in the days when a 24 ft light wood pole (creosoted) was quoted in the Rate Book at 7s. 3d. whilst the estimated cost of the glass pole was 25s.

Production of the glass pole never got off the ground as the Germans found that the cost of setting up a production line was prohibitive.

In the ensuring years, generations of external engineers evaluated alternative types of poles, e.g. concrete, asbestos cement, steel, iron, glass fibre reinforced, etc., and even today are investigating other possible alternative materials.

There are many reasons why after all these trials and often tribulations (remember the sheet steel pole) we have to admit that the wood pole has many virtues which modern man-made materials lack.

When looking for a suitable substitute one must consider,

Cost—Wood poles are still relatively cheap, considering that the poles are obtained from the far North of Finland.

Handling—Wood poles can take a lot of hard knocks during loading and unloading without apparent damage or ill-effect.

Weight—Concrete, steel and iron poles are generally much heavier for the same strength characteristics as those for a wood pole. They also have to be handled with greater care.

Long life—Wooden poles last for up to 50 years and there are no doubt many still around older than this and still in good condition.

Timber of course is an easy material to make attachments to and offers flexibility for a change of use during the life of a pole, e.g. open-wire or armed poles are easily converted to ring type, cable dropwire poles. Man-made poles on the other hand have to be very carefully designed to ensure that all our fitments can be accommodated without further expensive drillings and fittings.

The real solution to all overhead problems is of course to put all the services underground, which is of course being done whenever possible on new housing estates, but the cost of doing this restrospectively for all the existing overhead plant is prohibitive, bearing in mind that the present U.K. pole population is in the order of some 3·5–4 million poles and annually the Post Office purchases some 125–128 thousand new poles.

In spite of this, however, there have been great improvements in overhead distribution, with the change from open-wire construction to the present cable dropwiring construction, particularly in urban areas. Together with this has been an increasing practice of burying cable directly in the ground by mole-ploughing techniques in the rural areas.

I am sorry that Mr. Laver fell back on the old or is it new cliche, "employ a design consultant." It is possible that they might recommend that the branches are left on the poles to improve the landscape, but I doubt whether they would produce an economic alternative to the humble wooden pole, with any more success than the present and past external engineers have done to date.

Yours faithfully,
L. CLARK

Telecommunications Development Dept,
Carlton House,
Carlton Avenue East,
Wembley,
Middlesex HA9 8QH

Press Notices

Electronic Exchanges go Mobile in New Attack on Waiting List

The B.P.O. has placed a £3m order for mobile electronic telephone exchanges as part of its campaign to beat the waiting list for telephones.

Between 30 and 40 mobile electronic exchanges, capable of providing service to a total of 45,000 customers, are to be supplied by Plessey Telecommunications.

Work has already begun on the construction of about 80 purpose-built caravan-type housings to carry the exchange equipment—a mobile version of the TXE2 exchange. Delivery will begin in May, and all the new electronic exchanges will be ready for service by September 1974. They are believed to be the first mobile electronic exchanges in the world.

The B.P.O. already has an extensive fleet of conventional mobile exchanges which deal with up to 400 customers each. These new exchanges are considerably bigger—25 have a capacity of 1,000 lines each and 10 of 2,000 lines each.

Mobile telephone exchanges form an important part of our short-term program to provide service as quickly as possible to people waiting for 'phones. This new order—the fourth this year for mobile exchange equipment—is a further indication of what the B.P.O. is doing to tackle the waiting list problem, which arises from the massive increase in public demand for telephone service.

The new mobile exchanges are being fitted with electronic equipment which has already been working successfully since 1966 in permanent electronic telephone exchanges, of which there are now more than 250 in service.

Like the B.P.O.'s fleet of conventional mobile exchanges the electronic units will be moved around the country pick-a-back on low-loader trailers. Once on site they can be brought into service in about six weeks. The new electronic units can be used to augment service at most types of telephone exchange.

Two major uses are planned:

- bringing immediate relief to areas, particularly in towns, where the waiting list is large; and
- temporarily replacing a permanent exchange which is being re-equipped or refurbished—this would speed re-equipment programs and avoid interrupting service while work is in progress.

At present the B.P.O. has 250 conventional mobile exchanges. Because of maintenance and transit, not all are in service at once, but more than 60,000 people who would otherwise be waiting are now on the 'phone because of these exchanges.

More than 350 mobile exchanges—including the new electronic units—are now on order and in various stages of production, boosting the eventual size of the fleet to more than 600 exchanges. During the next three years about 200,000 customers will be connected to the telephone network by mobile exchanges.

To help people get 'phones faster, the B.P.O. also uses portable racks of equipment which can be fitted into existing telephone exchanges. More than 600 racks, each providing service to 200 people, are already in service providing a total of 120,000 lines. A further 300 racks—capable of providing 60,000 extra lines—are in production or on order.

Transportable TXE2 exchanges are housed in trailers 27 ft long, 9 ft 4 in wide and 13 ft 4 in high externally. They use normal TXE2 equipment mounted on racks of the same width and depth as standard racks—3 ft and 22 in—but only 8 ft 1½ in high (standard rack-height is 10 ft 6 in). Each rack is supported between the floor and overhead ironwork by eight coil-spring anti-vibration mountings to avoid damaging the electronic equipment when the unit is on the move. While the trailers are moving the equipment is held in place by aluminium bars across the rack faces.

A 1,000-line exchange will be housed in two trailers: a line and switching trailer housing line units, A, B, C and D switches, supervisory relay sets, meters, distribution and trunk connexion frames; and a control trailer with the control equipment, registers and power plant, with batteries providing 10-hour standby; it will also have a workbench and test equipment. A 2,000-line exchange will comprise two line/switching trailers and one control trailer, with five-hour battery standby.

All the mobile units will be equipped with heating, ventilation, and fluorescent lighting.

For moving on and off the low loaders and for manoeuvring on site each unit has four detachable wheels fitted with solid tyres.

Trailers will be linked by cables, in metal trunking terminating on sockets for connexion with plugs mounted on the trailer housings.

The mobile TXE2 exchanges will be largely self-sufficient, needing only a mains power supply for operation once connexions have been made to the local cable network and to the junction cables between the mobile exchange and selected permanent exchanges. This independence enables the mobile unit to operate as an unattended automatic exchange—where necessary completely replacing an existing exchange. It will cater for p.b.x.s, single lines and coinbox lines and provide s.t.d. facilities.

The local telephone numbers of the subscribers connected to a mobile TXE2 may be of four, five or six digits. When it is used as a relief exchange the numbers given to the subscribers will not usually need to be changed when lines are transferred to a permanent exchange.

Dial up Datel 2400

A new service for sending computer data over the public telephone network for the cost of a telephone call has been introduced by the B.P.O.

Known as Datel 2400 Dial-up, the new service enables computer users to send data in binary form—a stream of rapid pulses—at 2,400 bits (binary digits) per second, faster than ever before over the U.K. switched telephone network.

In the new service, customers are able to gain advantage from using many types of data terminal equipment—including visual display units, remote batch terminals and front-end processors—which were previously restricted to use over special private circuits or at lower operating speeds over the switched telephone network.

As with existing Datel 200 and 600, users of the new service have a modem (modulator/demodulator) associated with their telephone to convert the digital data to a form suitable for telephone lines. They set up calls by dialling in the usual way and then switching over to data transmission.

Datel 2400 Dial-up uses a modified version of the B.P.O. Datel 2400 modem that has already been well proved in service over private circuits. The modified modem provides synchronous transmission of serial binary data at 2,400 bits per second (bit/s) in one direction at a time over the public switched telephone network. The modem can be switched to operate at half or quarter speed where difficulties are experienced at 2,400 bit/s.

Transmission at 2,400 bit/s is possible on a large proportion of calls over the public network: of hundreds of trial calls made by the B.P.O. during the last year between points scattered throughout the country, between 80 and 90 per cent were successful. In addition to these proving trials Datel 2400 Dial-up has been tried out over the past six months by computer users in London, Edinburgh, Birmingham, Nottingham and Teesside. All who took part expressed satisfaction and willingness to take the new service.

The charge for the Dial-up service is made up of a connexion charge of £50 and a modem annual rental of £280. The cost of transmission is the same as for a speech call over the same distance for the same time. Users, like Datel 200 and 600 customers, are able to take advantage of the Midnight Line service, in which, for £200 a year, they can make unlimited free dialled calls within the U.K. between midnight and 6 a.m.

At the end of March 1972 there were 19,060 Datel terminals in use in Britain compared with 15,093 a year earlier—an increase of 26 per cent.

Same Trench for 'Phone and Power Cables

Telephone and electricity cables serving new housing projects are to be laid side by side in the same trench under an agreement reached between B.P.O. Telecommunications and Britain's Electricity Boards. Cables laid in this "twinning" scheme will be protected to ensure that there is no danger of electric shocks for telephone users.

Whenever possible, the Area Electricity Board will excavate the trench and lay the telephone cable at the same time as its own cable, sending a bill to the B.P.O. Telecommunications Region in whose area the work is carried out. (The Board may employ a contractor.) Twinning the two services cut costs, speeds the provision of service, and reduces inconvenience to the public.

Agreement on cable twinning follows successful 18-month trials by four B.P.O. Telecommunications Regions—London, Eastern, South-Eastern and South-Western—and the South Eastern and Southern Electricity Boards. It will now be possible for the B.P.O. to conclude agreements with all other Area Electricity Boards. The agreement sets out the main contractual and administrative requirements; detailed arrangements and charges will be negotiated between individual telephone areas and electricity boards. Replacing a variety of local twinning arrangements over the past five years or so, the agreement extends the twinning principle over the whole country.

Cost of the work to the B.P.O. is expected to be about 30 per cent lower than when separate trenches are used and there will be similar benefits to Electricity Boards.

Cable twinning first became possible when B.P.O. studies showed that modern telephone cables and low or medium voltage (440-volt or 660-volt, three-phase and neutral) electricity cables could make random contact without affecting the safety and reliability of either service. The protection for the telephone cables consists of steel wire armouring over the polyethylene sheath which protects the telephone pairs, with a second polyethylene sheath over the armouring. When the telephone cable is laid by an electricity board, the jointing of the cable will still be carried out by B.P.O. technicians.

Twinning arrangements are a limited form of co-ordinated installation of underground services: full co-ordination between all services—electricity, telephone, radio and TV relay cables, gas, water, and sewage pipes, in a common trench—has been studied since 1966 by an Advisory Committee set up by the then Ministry of Public Building and Works (now Department of the Environment). The Committee has issued two reports on the technical and management problems involved. These are published as R. & D. Bulletins, available from H.M.S.O.; copies of both have been supplied to all Regions by Post Office Telecommunications to provide general guide lines for co-operation with other services.

Trials carried out under Advisory Committee principles have shown that full co-ordination is of greatest advantage for major projects such as new towns, or large municipal housing estates. The more modest schemes benefit from twinning arrangements with two comparable services, such as electricity and telephone cables, sharing the same trench.

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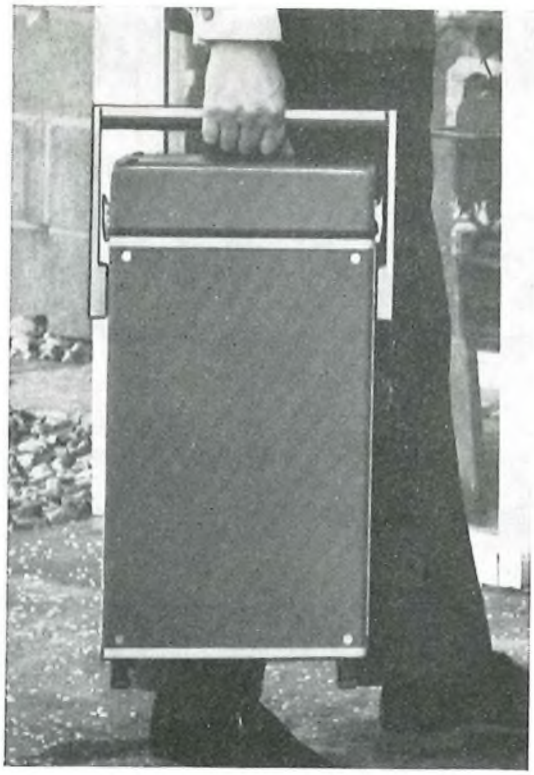
Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.



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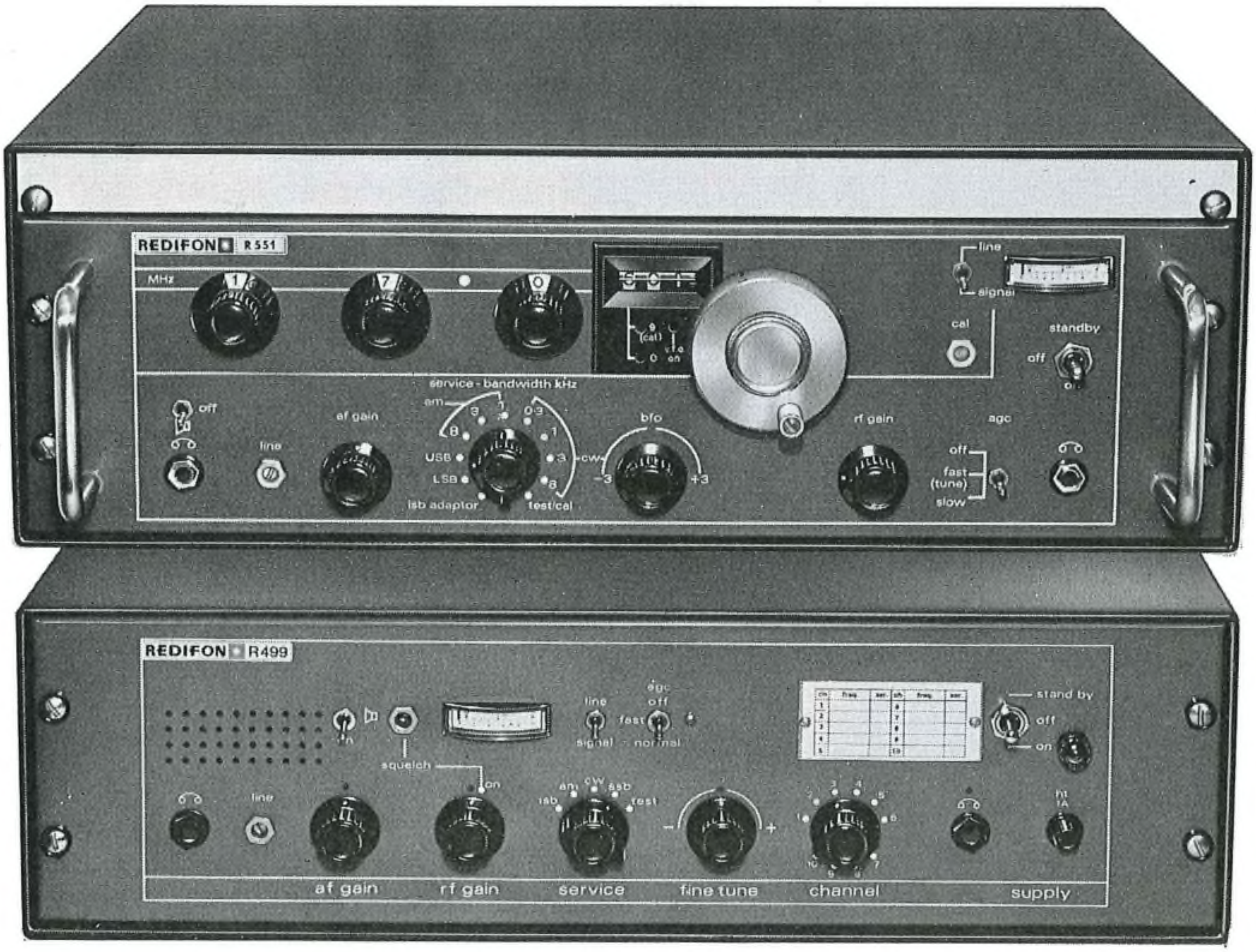

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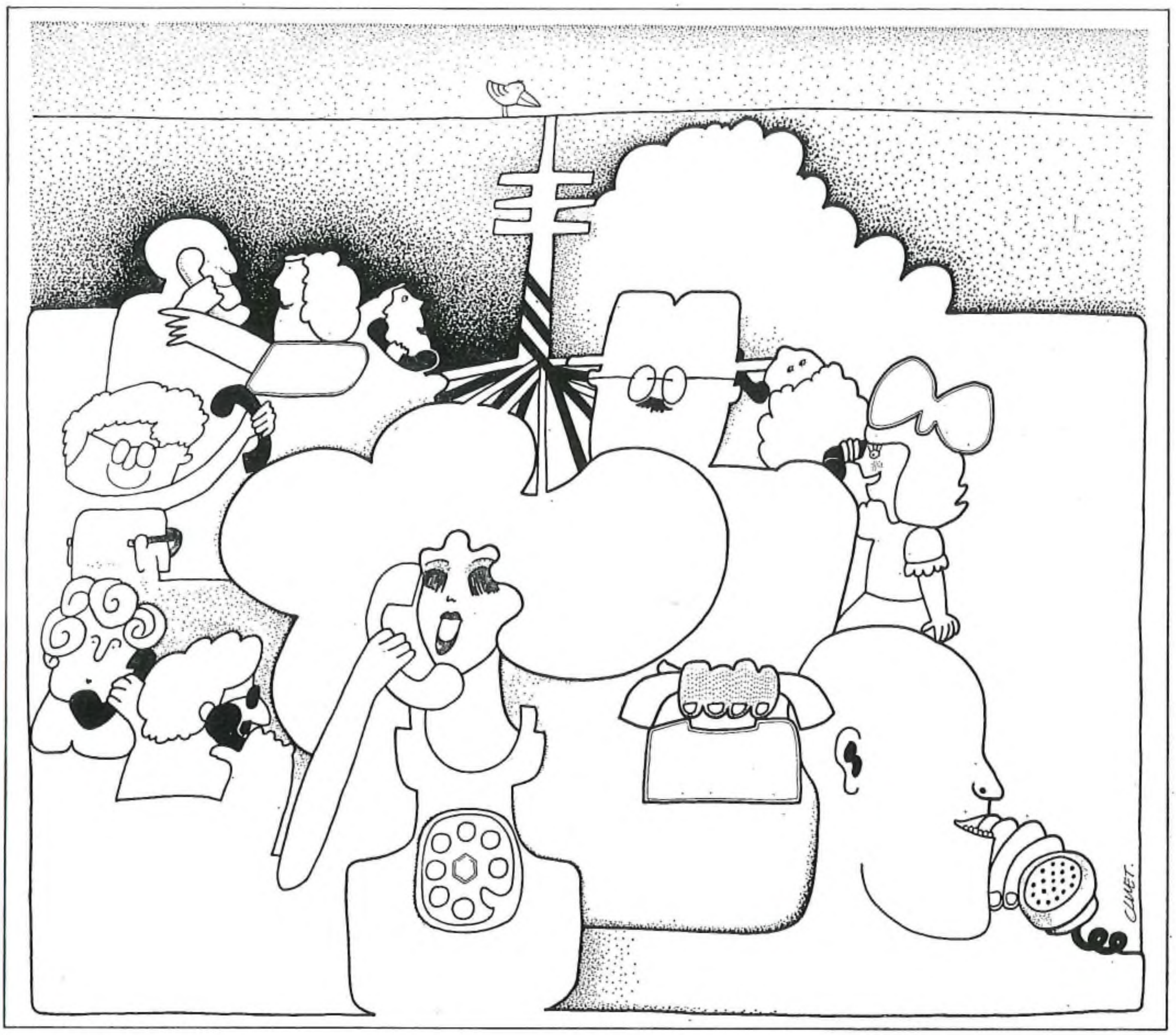

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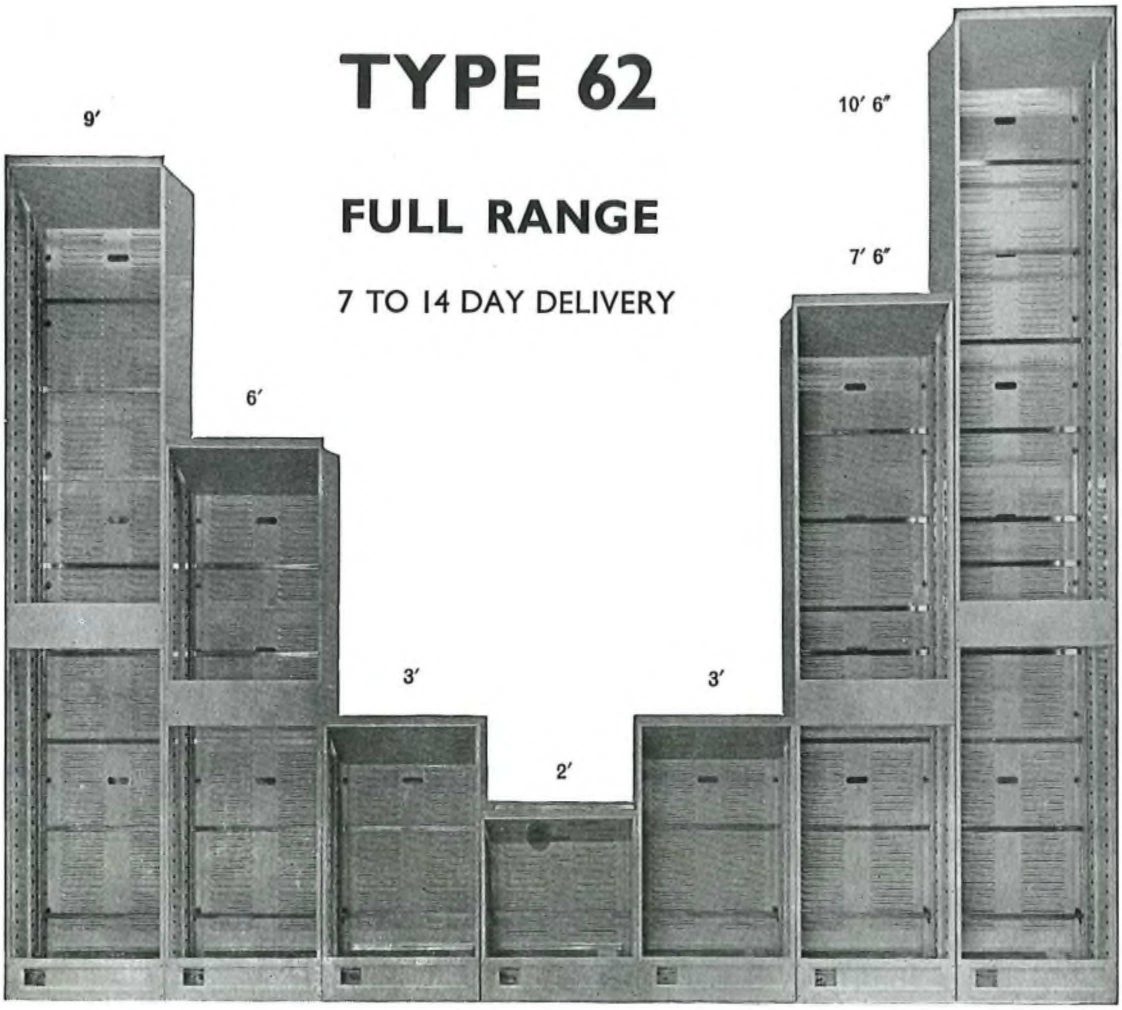

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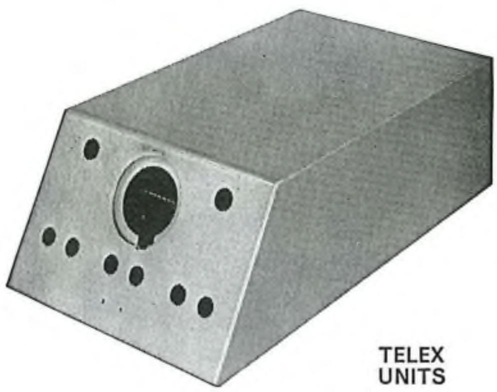

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