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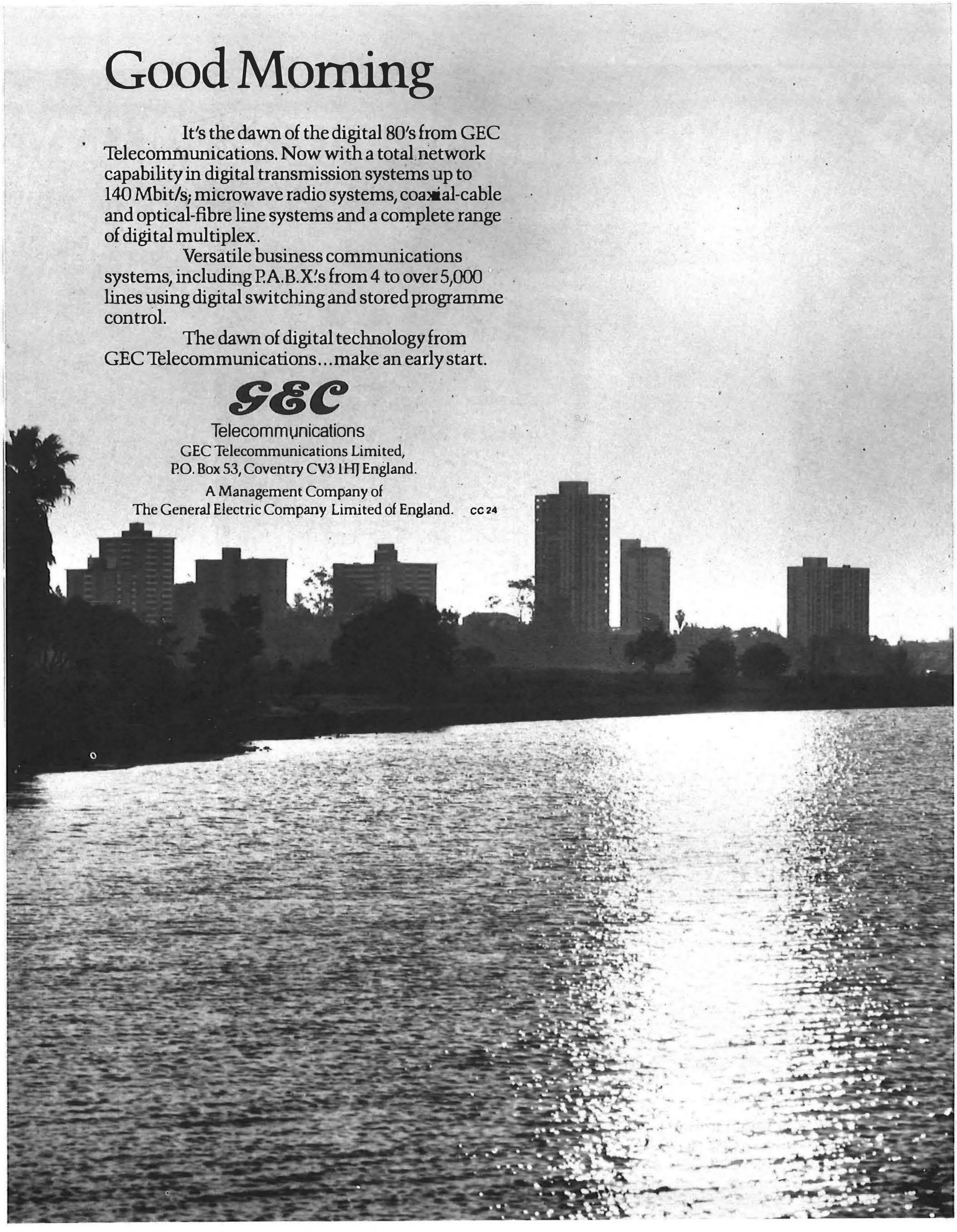
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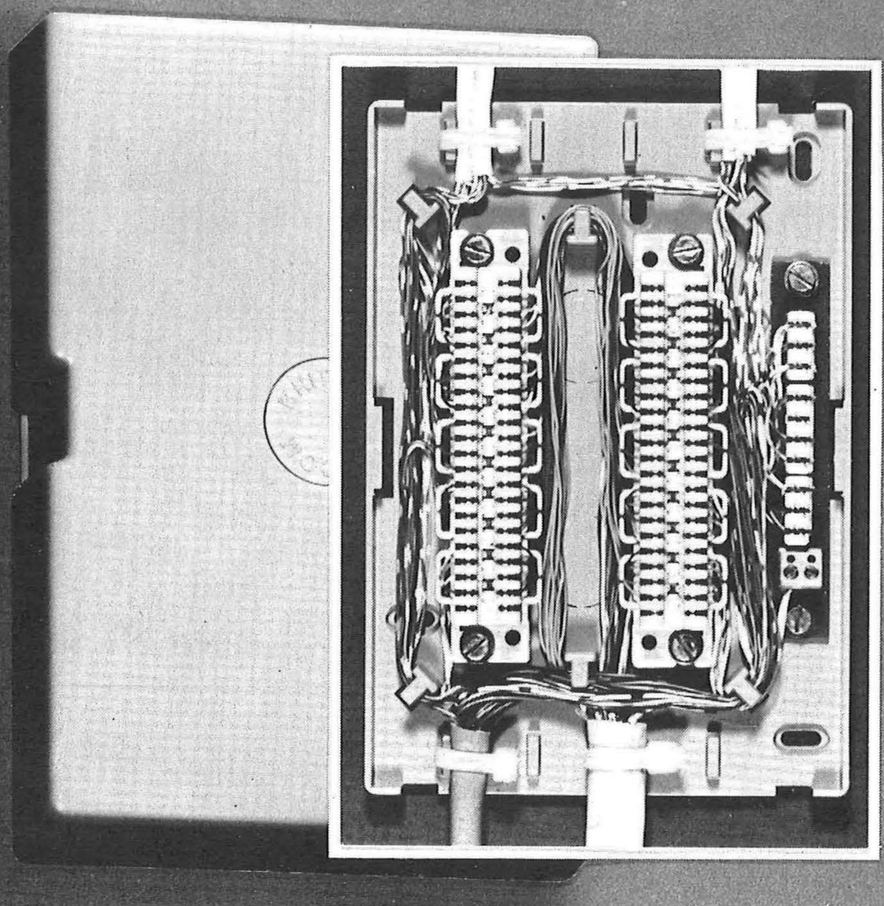

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EDITORIAL

In September 1982, British Telecom will be host to the sixth International Conference on Computer Communication, which will be held at the Barbican Centre, London. The theme of the conference—*Pathways to the Information Society*—reflects the convergence of the technological evolution of computer systems and telecommunications equipment. A prime factor in this evolution is the development that has taken place in micro-electronics. Over the past 10 years, micro-electronic devices have increased considerably in complexity, yet their cost per function has drastically reduced. The use of such high-technology components in the manufacture of computer and communications equipment, however, poses many problems for the manufacturer. In particular, the reliability of the final product depends on the correct operational performance of the devices used. Thus, an important stage in the overall strategy for testing the equipment is the initial testing of the individual devices before the manufacturing process begins. The testing of these devices, particularly when highly-complex large-scale integrated circuits are involved, is often a difficult and time consuming process. Some of the problems associated with testing these complex devices are discussed in an article on p. 64 of this issue of the *Journal*.

The Problems of Testing Large-Scale Integrated Circuits

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The increasing penetration of large-scale integrated circuits into telecommunication systems places a high premium on the performance and reliability of these very complex components and requires, in particular, that they should be adequately assessed for their task. Testing poses major problems related to both the design of the integrated circuit and its process technology, and this can be tackled only by using powerful computer-driven test equipment.

INTRODUCTION

Much has been written in the popular press of the capabilities of the silicon chip. The changes in this electronic technology are accelerating and affecting the production techniques for all electronic equipment, especially in telecommunications. In Strowger exchanges, raw materials, mainly metal sheet, bar and wire, accounted for only 10% of the cost. Current exchange production uses simple integrated circuits, referred to as *small-scale integrated (SSI) circuits* and *medium-scale integrated (MSI) circuits;* in these, the cost of raw materials has increased to 75% of the total cost. In the near future, a much larger proportion of complex integrated circuits, referred to as *large-scale integrated (LSI) circuits*, will be used. These parts will contain most of the complex functional hardware, and give extended benefits in terms of new sophisticated facilities at little or no added cost. The standard of performance and the reliability of future equipment depends on the equipment designer's ability to understand all the subtleties of these complex parts in relation to the needs of the system. In addition, it is particularly important that a comprehensive testing strategy is adopted.

The equipment manufacturer needs a comprehensive testing strategy for all stages of the system manufacture[1], to minimise the cost of the manufacturing process while maintaining high operational performance and reliability. The cost of rectifying faults in systems caused by component failures at the final testing stage, or during service, is very much greater than the cost incurred if these faults are detected at an early stage of manufacture. Part of this strategy is the testing of the integrated circuits before assembly. This is comparatively straightforward for SSI and MSI circuits, but the task takes on a new dimension where LSI circuits are concerned.

It might be supposed that component testing is the component vendor's problem and, indeed, this activity exercises them greatly. Some component vendors claim that 30% of the cost of production is spent on the testing of some LSI circuit types. Not only are the complex parts extremely difficult to test, but also it is impossible to determine when sufficient testing has been completed to allow a component to be marketed. In these circumstances, the vendor often relies on the number of faulty parts returned by knowledgeable equipment manufacturers to determine whether quality standards are high enough. If users and suppliers of telecommunications equipment are to remain competitive by using state-of-the-art components, they must be involved in this feedback loop. The component vendors are striving to improve the quality of their more mature products with the aim of achieving a failure rate at incoming inspection as low as 10–100 parts per million; at present, though, typical failure rates found at a number of equipment manufacturers are in the range of 0·1–5%.

The testing of LSI circuit components is difficult and complex, and requires the use of general-purpose software-controlled automatic test equipment. The technological problems associated with LSI circuit components require a high level of engineering activity to generate the appropriate software and hardware. Complete functional testing of most LSI circuit components is impractical because of the number of the possible combinations of stimuli[2]. Thus, sensible compromises have to be made to keep the test time low, while achieving a high test coverage—the ability to find faults.

Personal experience with such items as pocket calculators, and even personal microcomputers, might encourage the belief that complex integrated circuits are immune from problems with their operational performance and reliability. As will be demonstrated, however, they are in reality vulnerable to a whole range of defects and, like any other product, cannot be taken for granted. Indeed, their very complexity means that, unlike simpler electronic devices, the component vendors are quite unable to deliver products that can even remotely be described as *fully tested.*

Some of the features of test equipment for LSI components are described below, together with typical faults that have been discovered. A strategy for component testing and assessment is then outlined.

TEST EQUIPMENT

There are a number of key features that are required in general purpose LSI circuit test equipment; these are

(*a*) comprehensive functional testing capability at the speeds and in the conditions used in the component applications,

(*b*) high-quality interfaces to the device under test, allowing control of timing edges, input levels, monitoring levels, and power supplies,

(*c*) programmable software to allow testing of a wide variety of components,

(*d*) diagnostic software tools to allow fast analysis of testing and component problems, and

(*e*) measurement capability to allow marginal testing.

† Research Department, British Telecom Headquarters

Functional testing is achieved by applying streams of logical data called *test patterns*, which are inevitably very long, and special facilities are required to generate them. For SSI and MSI circuits, the functional test can be written into the tester in terms of ones and zeroes, and is only a small extension of the truth tables declared in the product descriptions. For a medium complexity microprocessor, a typical, though not exhaustive, functional test is written as 4000 lines, each containing 50 ones or zeroes, and with additional special sequencing and looping controls on each line. Each of the bits of data on a line forms a 50 bit word or test vector. When the functional test is executed, the looping and sequencing controls allow any line to be used repeatedly, making the total test length equal to 12 000 test vectors. Microprocessors, in common with a large proportion of digital circuitry, have their fastest logical operation controlled by a clock signal which, in the test pattern of this example, has the same period as a single test vector. Such a pattern would be totally unintelligible to a programmer without a means to generate the tests from simple mnemonics. This conversion from mnemonics to the test pattern must be written in the tester's own high-level language.

The length of the functional tests is not the only difficulty. The number of important specified parameters, such as timings and voltage levels, for an LSI circuit device is significantly more than for SSI and MSI circuit components; in addition, the tester capabilities and accuracies required are greater. Most SSI circuit transistor-transistor logic devices were only occasionally used close to their maximum specified speeds, and were very rarely checked against the full specification thoroughly, particularly for timing values. This is not true of LSI circuit memories and microprocessors, where the system designs frequently necessitate quite narrow timing margins to obtain the correct system operation and the best performance.

Test Equipment for LSI Circuits

All testers are expensive, but the system cost is only a small part of the cost of ownership because of the many skilled man-hours necessary for the preparation of a test program. The choice of a suitable system is therefore influenced by the availability of programs, even though they may have to be modified for each user's particular needs. The first equipment to be described is used extensively throughout the components industry, and probably has more programs available than any other system. Fig. 1 is a photograph of this tester (Sentry VII), showing: from left to right, a liquid nitrogen dewer, an automatic device handler, one of the test heads where the device is tested; near the back, in the large cabinet, the main tester section; and, on the right, a second test head. The liquid nitrogen is used for cooling devices during low-temperature testing.

The tester, shown as a functional block diagram in Fig. 2, uses a stored-response technique; that is, a test vector of binary data from the random data generator, or the algorithmic data generator, is applied in parallel through the pin-electronics cards to the device under test. The test vector contains both the data stimulus and the expected response. The pin-electronics cards convert the test vector into either pulses to stimulate the device under test, or to data for comparison with the response of the device. The pin-electronics cards receive control signals to set up the applied power, reference voltages, and the timings for the pulse edges.

The device under test is plugged into a performance board (shown in Fig. 3), which makes the final connection between the tester and the device. A functional test of, typically, many thousands of test vectors is applied at the working speed of the device under one set of operating conditions, the result being a pass or fail condition. During the functional test, the error-detection facility can be programmed to be very thorough, allowing very small noise signals and timing errors to be detected. Repeated application of these functional tests, for varying sets of conditions, allows a component to be checked over the full operating range. Measurements of the operating margins can be made by performing repeated pass/fail tests. Simple DC analogue parameters, such as input leakage, are measured by connecting the analogue measurement unit of the tester to a particular device pin.

From the block diagram in Fig. 2, it can be seen that the programmer has to define the tests in some detail. The functional logic stimulus and expected response is stored in a high-speed buffer store in the random data generator although, for memory testing, the functional pattern is generated by a special hardware module—the algorithmic data generator. The details of the format of the applied waveforms, the position of the timing edges, logic levels and applied power supplies are controlled by the program, and are changed according to the test. The logical data rate can be up to 10 MHz, but the timing edges can be programmed with a resolution of 160 ps and an accuracy on one pin of ± 1 ns; the voltage level can be programmed to a resolution of 2 mV. The minor inaccuracies in the tester, the number of pins and the

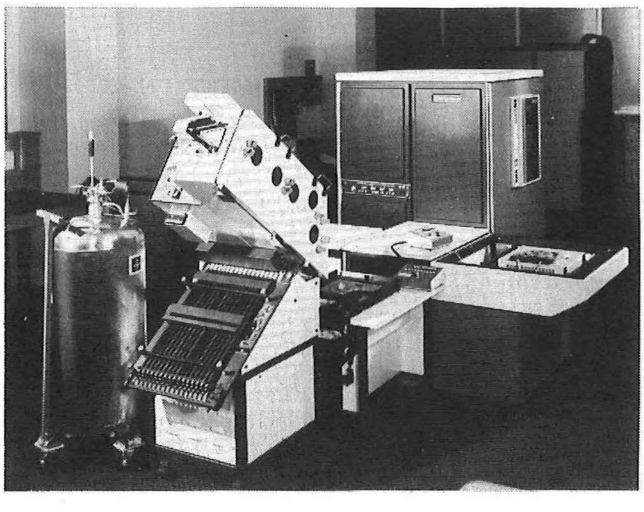


FIG. 1—An LSI circuit tester—Sentry VII

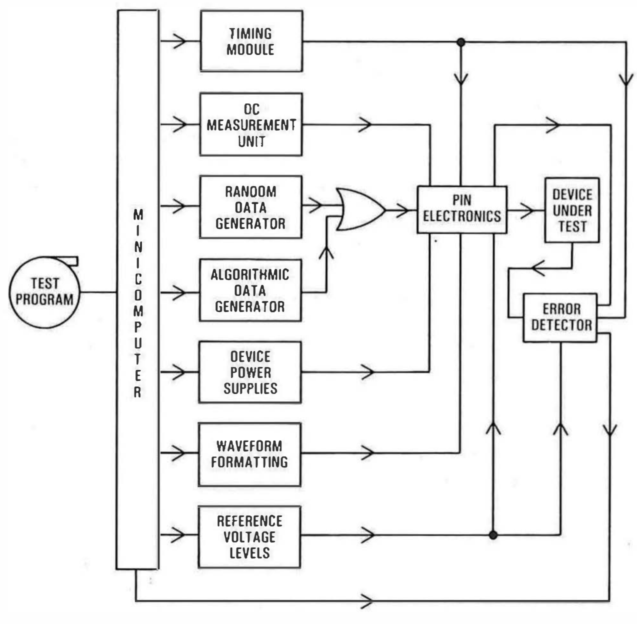


FIG. 2—Block diagram of an LSI circuit tester

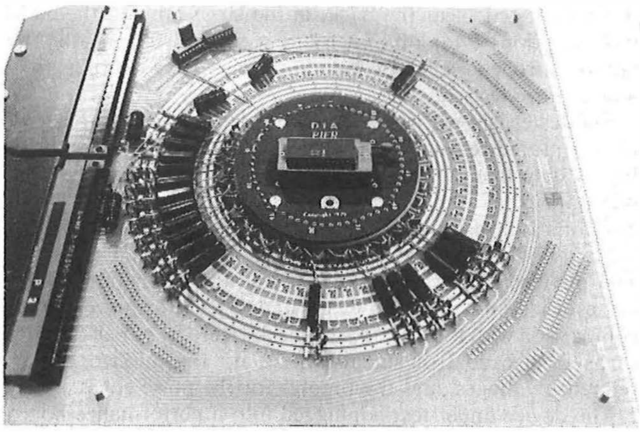


FIG. 3—Connection of the device under test to the LSI circuit tester by means of the performance board

problems of interfacing the tester to the component all add significantly to reduce the overall accuracy on devices to about ±4 ns on timings and ±30 mV on voltage levels.

An individual performance board (Fig. 3) is designed for each particular device or device family. It contains wire links between the tester and the device under test, which allow any device pin to be connected to any tester pin. Test loads are connected via reed relays that can be controlled from the test program. This fixture must be designed to a high standard, with high-frequency layout techniques adopted to preserve the accuracy of the tester. Although most LSI circuits do not have exceptionally high data rates, some can be sensitive to noise signals that have high-frequency components; thus, the timing edges must be accurately placed to within ±1 ns, and the pulse shapes must have a high integrity. Performance boards are now being constructed as 4- and 8-layer boards.

Typical test times vary significantly with the complexity and thoroughness of the testing, and the type of the component. As an example, for a popular microprocessor, a single pass through the functional test of some 12 000 test vectors takes 3·5 ms, where every instruction and control function is checked under one set of conditions. An incoming goods test for the same part, checking 90% of the timings, the DC limits, and the functional capability at various worst-case drive levels takes 7 s. To measure and record the parameters that are checked in the incoming goods tests, so they can later be analysed, takes 50 s. These times are approaching the maximum that can be tolerated because of costs.

The Sentry system just described is a purely digital tester which, while having great power to measure most of the currently available components, cannot satsfactorily cope with exceptionally high data rates or mixed analogue and digital components. Recent advances in device technology have enabled complex digital and precision analogue circuits to be incorporated on the same chip; for example, in coder-decoder (codec) devices, which convert the analogue signal from a telephone handset to digital signals, and *vice versa*. The speech quality of the future digital network depends on ensuring adequate performance of this component. However, it needs another type of tester, which incorporates special hardware for analogue testing, ultra high-precision digital-to-analogue converters, waveform generators and filters. The digital capability needs to be of a similar standard to the Sentry testers.

Codec testing is difficult because the function performed normally takes a significant time. Testing time in general-purpose testers is very expensive, and a large effort is made to ensure that maximum efficiency is achieved. Typical economic test times can be no longer than 9–12 s.

Test Programs

The foregoing operations are all carried out under the control of a test program, which allows the tests to be controlled in detail, is flexible and is transportable to another similar system. However, as with all software, care is required to ensure that programs can be understood and developed by several engineers. Program generation is a slow and difficult process. Many modern computers now have advanced support in the form of very-high-level compilers and operating systems that can significantly speed the program generation process. This software support is produced by the computer manufacturer. In this case, however, the tester manufacturer must produce the advanced support, and this is not always forthcoming because he cannot spread his development costs over a large number of systems.

There are further problems with test systems because the device under test can interact in unforeseen ways with the test system, and the device or the tester hardware can be damaged by inadvertent programming. A programmer, working on normal data-processing tasks, can expect to achieve a high degree of confidence in his code as it is a purely logical task and can be checked with established techniques. However, the tester programmer must check the physical functioning of his code, in addition to the logical sequence and structure. Hidden behind a high-level computer language is the need to ensure that the tester meets all the physical requirements of the device. For example, the rise time of the power supplies must not be too fast or too slow, and relays must be allowed sufficient time to settle, but not too long or the test times become too long.

Typically, the program is checked by testing a variety of parts from as many sources as possible, by taking special measurements during the test execution, and by checking carefully the hardware functioning using the tester's utilities and an oscilloscope. At the time of generating the test programs, the programmer has only a limited number of devices available to him; typically, he can write a program that reliably tests only the available devices and ones very similar. In practice, experience has shown that sometimes new batches, or later versions using a new mask or from a new manufacturer, will fail the tests. This failure is not due to the parts being out of specification, but because the test does not allow for small changes in component performance within the specification. These problems can occur even after the program has been in use for several years.

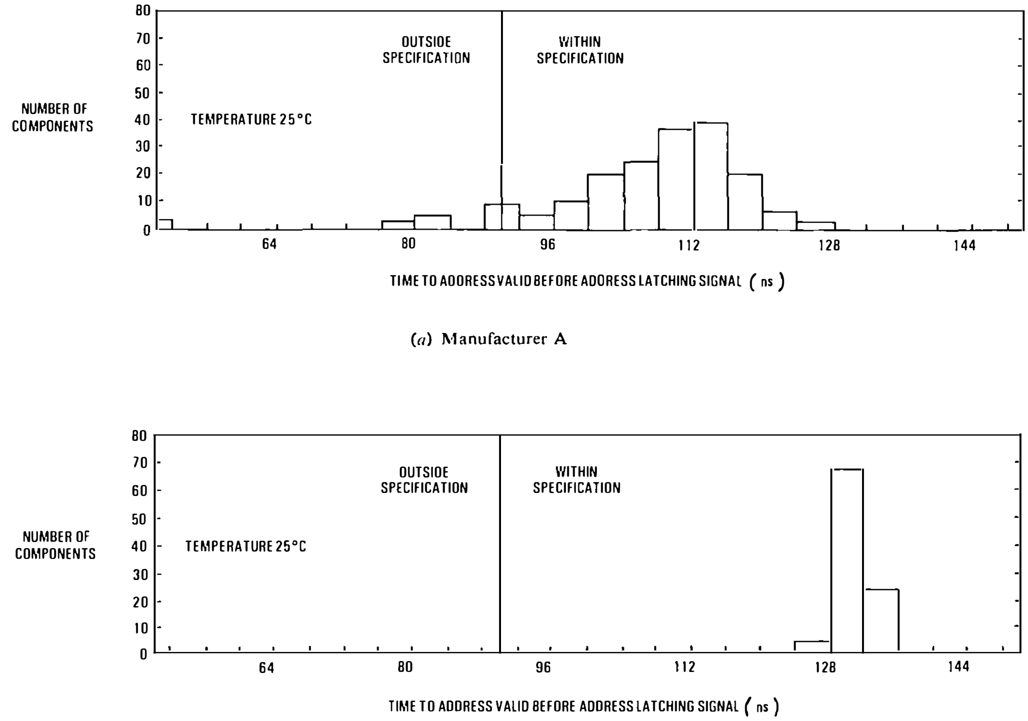
Test programs are written not only by the tester owner, but can also be obtained from other machine users. The standard of test programs obtained can vary considerably, and some modifications are normally necessary. Programs from the component manufacturer are useful, because they give a good understanding of their standards of testing and normally provide a good basic program.

DEFECTS IN LSI CIRCUIT COMPONENTS

Experience with the systems described has exposed many defects to which LSI circuits are vulnerable. These can be classified as manufacturing faults, marginal faults, design faults, and technological problems, and are discussed below.

Manufacturing Faults

Parts having faults that escaped the final test procedures of the component manufacturer or that become faulty between outgoing and incoming inspection are classified in the manufacturing faults category. There are many examples, such as faults arising because of insufficient testing, electrostatic discharge, bent pins, cracked or chipped packages, incorrect labelling and shipment errors. Electrostatic damage frequently manifests itself as a component with short-circuited inputs or outputs.



(*a*) Manufacturer A

(*b*) Manufacturer B

FIG. 4—Distribution of a timing parameter of the 8085A microprocessor for 2 manufacturers

Marginal Faults

Components displaying marginal faults function satisfactorily over part of their operating range, but not over the full specified range. An example is shown in Fig. 4 for a popular microprocessor—the 8085A. Measurements on 100 components of a timing parameter (the time between address valid to address latch signal) show distinctly different distributions for 2 manufacturers: manufacturer B has a good performance with each component falling in a small distribution well above the specification; manufacturer A has some components below the specified minimum. The shape of the distribution indicates that the component vendor must carefully screen this parameter to guarantee meeting the limit.

The distribution shows that a small variation in the specification can change the percentage of rejected components significantly. The question then arises as to whether the component is faulty or the test procedures are inadequate. The test procedures must be determined from a technical interpretation of the device specifications. The margins shown in the histogram of Fig. 4 emphasise that the tester must be very accurate to distinguish this class of faults.

Design Faults

Included in the design faults category are those problems associated with poor implementation of a design on the chip, and insufficient or inadequate specifications which can affect all the components of a particular design.

The first of 2 examples was found in the 8085A microprocessor when it was used with a particular driving condition. When the loading on one input pin was greater than a small capacitance of about 10 pF, the internal circuitry stopped working. The problem did not occur on all parts from the same vendors, nor on samples from other manufacturers. If a system designer used this component on a printed-wiring board (PWB) using this faulty driving condition, it would probably be found to work very satisfactorily in the laboratory. However, when in quantity production, the fault would soon become evident, and would greatly increase the production costs. Any consequent redesign or field change can be extremely expensive, both in cost and the time taken to complete the corrective action.

The second problem on the same microprocessor arose because of noise sensitivity. A particular input had been designed to make it less sensitive to noise. The design achieved the opposite effect: the input responded to the smallest noise. As an expedient, appropriate precautions at the PWB design stage minimised the problem to make systems that functioned satisfactorily. However, the narrow operating margins provided by the expedient PWB design might not be able to cope with variations in component properties during the production phase. For example, improvements are always being made to the component fabrication process; one such development in a new batch of the microprocessors increased the speed of operation of the internal transistors, giving improvements in performance. However, the faster device caused faster changes in the current through the pins of the component; because of the small inductances of the surrounding circuitry, this produced larger noise spikes. These noise spikes, which could activate the noise sensitive input, were more difficult to overcome in the PWB using the previous expedient design techniques.

Technological Problems

Various technological problems are found as different component manufacturing techniques are used, and some examples are described below.

Intermittent Errors

Integrated circuits are the origin of some of the intermittent system errors that are always extremely difficult to find and diagnose. A typical example is found in recent memory designs, where the small size of the cell is sufficient to allow alpha particles (radio-active emissions) to change the stored information[3]. Alpha particles are emitted naturally from many materials, including many of those used in component encapsulation. If the alpha particle has the right range and energy, it can create enough electrons in the chip to change the state of the storage cells and hence the data. The effect on a memory system is to create faults that are completely random. If data is written to a cell that has changed its data because of an alpha particle, the new data will be stored correctly.

Pattern Sensitivity

High circuit complexity can cause problems where only very specific sequences of data expose faulty operation; a phenomenon known as *pattern sensitivity*. It has been known for some time that memories suffer from pattern sensitivity and failures can be detected only by particular, usually very long, functional test sequences. When the number of cells in memory components was small, it was practicable to apply test sequences that would thoroughly test the component. In very large memories, this amount of testing is no longer practical; instead, efficient tests must be designed from an understanding of the types of failures that can occur in a particular memory design.

Pattern sensitive problems can be caused by various physical conditions, the simplest to understand being found in memory designs when control signals interact, perhaps by capacitive coupling. Fig. 5 shows a simplified dynamic memory cell where data is stored as a one or a zero, dependent on the charge on the storage capacitor. The bit line is used to read or write to the cell when the access transistor is turned on. The access line determines which of the memory capacitors is selected. In this example, a fault is assumed to cause a stray capacitance between the bit line and the access line. Signals on the bit line should not affect the charge on the storage capacitor, but the stray capacitance transfers spurious signals to the access line, and improperly turns on the access transistor. However, a succession of bit line signals may be needed to accumulate charge before the data is changed. This fault is thus pattern sensitive because the incorrect data on the storage capacitor occurs only when there is a particular sequence of operations using the bit line before the data in the cell is read.

In the early stage of LSI development, random-logic devices, such as microprocessors and their peripherals, were more immune from these problems because the chip design used larger tolerances. However, now that the techniques of memory design are better understood, and competition is encouraging the component companies to put more logic on a silicon chip, pattern sensitivities are being detected in random-logic devices[4].

One example of pattern sensitivity was found in a single-chip microcomputer[5]. The cause was traced to the layout of the power-supply conductor tracks on the surface of the chip. A ground connection was made round the periphery of the chip, but was connected to the package at only one point. When large currents flowed in the conductor, the potential difference between one end and the ground connection was raised, causing a failure of part of the circuitry. The instruction sequence, the data sequence and the input voltage conditions could all change the total current flowing in the conductor, and cause the microcomputer to work or fail according to the details of the functional sequences applied.

Pattern sensitivity is important because it is extremely difficult to design a low-cost screen for such faulty operation. The problems can be minimised in several ways. The component manufacturer has the primary responsibility to design his circuit so that, using existing standard equipment, thorough tests can be performed in a time that is economically acceptable. Component design rules can be used to avoid common problems that have been known to cause pattern sensitivity. In addition, adequate testing and assessment procedures must be used by any large purchaser to ensure that the component manufacturer maintains sufficiently high standards. Despite these precautions, and because complete functional testing is an impossibility, it is inevitable that some of the subtle pattern-sensitivity problems will appear in the field where, unfortunately, they are difficult and costly to locate.

TEST STRATEGY

From the foregoing studies, a test strategy has been evolved for the manufacturer of System X by the 3 participating firms—GEC, Plessey and STC. A key element of the approach is that all parties should acquire the same make and model of the tester already described (the Fairchild Sentry VII). A testing and assessment strategy for LSI circuit components has evolved in which there are 2 major stages: the component assessment and the incoming goods tests. The incoming goods tests will be performed on all LSI circuit components and will allow a continual surveillance to be kept of the component quality. The test programs will be developed from the assessment procedures.

During the assessment of the components, several tasks are undertaken as follows:

(*a*) electrical characterisation,
(*b*) reliability studies,
(*c*) package tests, and
(*d*) visual inspection and evaluation of the technology.

To reduce the cost of assessment of a particular component, only those manufacturers considered to be commercially acceptable, and likely to be capable of supplying parts of sufficient standard and quality, are considered.

Electrical characterisation, which follows the idealised flow chart of Fig. 6, is a critical task because a test program is

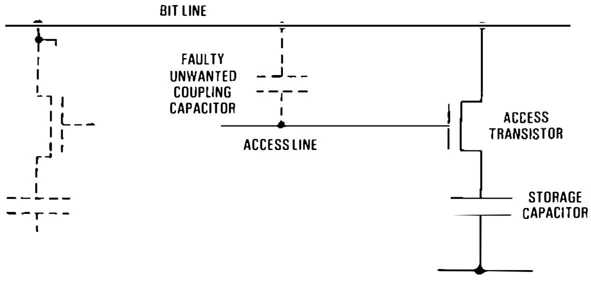


FIG. 5—Simplified circuit of the storage cell in a dynamic memory

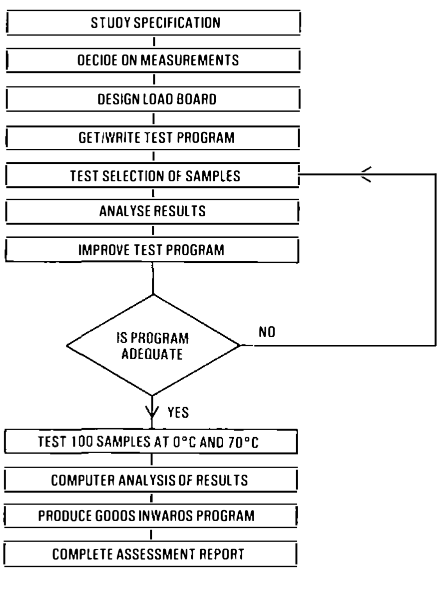


FIG. 6—Flow chart of electrical characterisation process for LSI circuit components

developed during this part of the exercise. The first task is the understanding of the performance specification which, for many advanced devices, is a significant part of the work-load. For one microprocessor, an intensive 2-week course was used to help understand 3 manuals describing the component and its use, each several hundred pages long. In recent years, there has been a very notable increase in the introduction of new concepts and jargon into the field of LSI circuit components, making the task of the test engineer in understanding the devices extremely difficult. The understanding is made more difficult by different manufacturers introducing their own new words for the same concepts.

Decisions are then taken as to the extent of the measurements and tests required, and an attempt is made to obtain a program from other users. If a program is found, it is modified to make the minimum of required measurements.

During the initial stages of program development, much is learnt about the detailed operation and margins of the component. Many design faults and limitations are detected at this stage, and initial comparisons can be made between the different manufacturers. The ability of the tester to make measurements under the direct control of the test engineer (referred to as *manual analysis*) is crucial at this stage. As the possible measurements are endless, the engineer has to apply a scientific approach of hypotheses, experimentation and interpretation. The information learnt is written into new test procedures to provide a thorough measurement program. This is an important advantage of using common general-purpose testers; information is not committed to a report and largely forgotten, but exists as a test that will ultimately be applied to all the devices used in exchange systems.

When a full measurement program has been written, the properties of a large batch of samples are measured. Batches of typically 100 components, taken from at least 2 separate weeks of production, are obtained from each of the possible manufacturers. The results are analysed, by using computerised data-reduction facilities, to produce distributions, averages, maxima and minima, and to identify exceptional parts requiring further investigation. This process can reveal defects and omissions in the test program. The measurements during characterisation are quite extensive—typically, 200–300 measurements per device on 100 components at temperatures of 0°C, 25°C and 70°C, giving a total of 60 000–90 000 measurements per manufacturer. A larger quantity of data may be produced during the reliability studies. The need for computer data-reduction facilities is obvious.

An incoming goods test program can be produced from the characterisation program by removing measurements that prove to be unnecessary when the characterisation measurements are analysed. The time taken to perform an incoming goods test can be significantly reduced because the tester can make comparisons against predetermined limits, as opposed to the values measured during characterisation. The characterisation program can be used for the generation of a reduced program for use in the reliability studies. However, to complete the studies in reasonable timescales, a version of the program is normally produced before the characterisation has been completed.

The costs and complexities of this test strategy are also experienced by other large LSI circuit component users, many of whom are actively co-operating to share their results, techniques and test programs.

CONCLUSIONS

The rapid advances in component technology bring many advantages in the facilities that can be provided in future exchange systems, but they also bring many pitfalls and hazards. The use of general-purpose test equipment has shown that LSI circuit components have many faults and limitations, which are subtle and hard to detect. The standard of performance and reliability of the hardware of future exchange systems depends on the ability to test and measure advanced LSI circuit components; this is a very complex and demanding task, which requires expensive test systems. To keep the costs and work-load at a manageable level, close collaboration in testing and test methods is necessary between the telecommunications equipment manufacturers and other similar parts of the electronics industry. Common test equipment has been purchased by BT and the System X participating firms, so that the testing task and development of test techniques, expertise and knowledge can be shared.

The assessment and incoming goods test procedures can provide cost savings in the equipment manufacturing process by removing faulty parts as quickly as possible from the manufacturing procedure.

New advances in components and technology can make test systems obsolete, despite the efforts of the test equipment manufacturers to ensure their testers are sufficiently flexible to enable any component to be tested.

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British Telecom Transhorizon Radio Services to Offshore Oil/Gas Production Platforms

Part 2—Radio Techniques and Networking Arrangements

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This 2-part article describes the provision of communication services to the UK's offshore oil/gas installations. Part 1 of this article discussed the choice of transmission media for the offshore services and examined some of the principles of tropospheric-scatter propagation. This second part illustrates the techniques used and reviews the existing and planned radio links serving the UK's North Sea area.

INTRODUCTION

In the first part of this article[2], a description was given of the scenario that led up to BT's involvement with transhorizon radio services to offshore oil/gas production platforms. The various aspects of tropospheric-scatter radio communication were discussed, some of the salient features were highlighted, and the limitations of a single tropospheric-scatter radio path were identified.

This concluding part indicates how the limitations of a single radio path are overcome and outlines the main items of equipment that make up a transhorizon radio terminal. It also illustrates the application of multichannel transhorizon radio techniques so as to provide services to oil/gas production platforms and shows how microwave line-of-sight radio links are used offshore to extend these services to other platforms. The existing and planned radio links serving the offshore oil/gas production platforms are reviewed and the article concludes with a brief look at the future.

DIVERSITY TECHNIQUES

To overcome the severe fading of a single tropospheric-scatter radio path, it is necessary to use diversity techniques that combine the received signals from 2 or more independent and largely uncorrelated radio paths in order to produce a steady signal at the receiver output. This process of combining the signals may be carried out either before or after the demodulation process. Both methods of combination give an improvement in the signal-to-noise ratio at the receiver output, but carrying out the combining process before demodulation has the additional advantage of improving the radio frequency carrier-to-noise ratio and, as a consequence, the system availability is enhanced because of the increase in signal level relative to the receiver threshold.

Quadruple Diversity Signal Combining Methods

With quadruple diversity signal combining methods, 4 diverse, independent and largely uncorrelated radio paths, each subject to random amplitude and phase variations, are combined to produce a steady signal at the receiver output.

Several methods of achieving quadruple diversity are available and include combinations using 2 transmit frequencies and 2 spaced receive antennas, or 2 transmit frequencies and 2 scatter-angle receive antennas, or dual polarization of a single transmit frequency and spaced receive antennas.

Because conservation of the radio-frequency spectrum is of paramount importance, dual polarization of a single frequency with space diversity antennas was the method chosen for BT's transhorizon radio links to the offshore oil/gas production platforms. Two large parabolic antennas spaced approximately 100 wavelengths apart are used at each end of the radio link. Each antenna is capable of accepting both horizontal and vertical polarization of the incoming radio signals, but radiates energy in one polarization only. Fig. 12 illustrates the principle of space/polarization diversity: station A transmits vertical polarization at frequency f_1 from antenna 1 and horizontal polarization at frequency f_1 from antenna 2 (the polarization nomenclature used refers to the disposition of the electric field vector of the transmitted signal with respect to vertical and horizontal planes). At station B, each antenna receives the vertical polarized signal transmitted from antenna 1 and the horizontal polarized signal transmitted from antenna 2 at station A. Thus, reception of 4 diverse radio paths is achieved. De-correlation of received signals is greatest on converging paths; for example, the horizontal and vertical polarized signals received by antenna 2 at station B. The use of a circulator in the radio feed from the transmitter cabinet to the antenna enables a transmitted signal and a received signal of the same polarization (but different frequencies) to use a common waveguide or coaxial cable from the antenna to the equipment room. Fig. 13 illustrates the improvement in carrier-to-noise ratio that can accrue from the use of quadruple diversity. For example, at the 0·01%-of-the-time point, the improvement may amount to as much as 34 dB over a single path when rapid or Rayleigh type fading is present.

Pre-Detection Method for 4 Diverse Signal Paths

The 4 diverse and uncorrelated incoming microwave radio signals are each amplified by a low-noise uncooled parametric amplifier, before they are passed on to a frequency changer where the microwave signal is translated to an intermediate frequency (IF) of 70 MHz. The 4 radio signals which have traversed different paths to the receiver will, as a consequence, give rise to IF signals having different amplitudes and phase angles. These signals may, therefore, be represented by

$$A_1 \cos(\omega_1 t + \theta_1),$$
$$A_2 \cos(\omega_1 t + \theta_2),$$
$$A_3 \cos(\omega_1 t + \theta_3), \text{ and}$$
$$A_4 \cos(\omega_1 t + \theta_4),$$

where ω_1 represents the frequency modulated carrier centred at 70 MHz, and θ_1, θ_2, θ_3, and θ_4 are the 4 phase angles associated with the 4 diverse radio paths.

Fig. 14 illustrates the basis of the Marconi Company's pre-detection combiner, which represents a considerable advance in technology; it surmounts the problem of bringing

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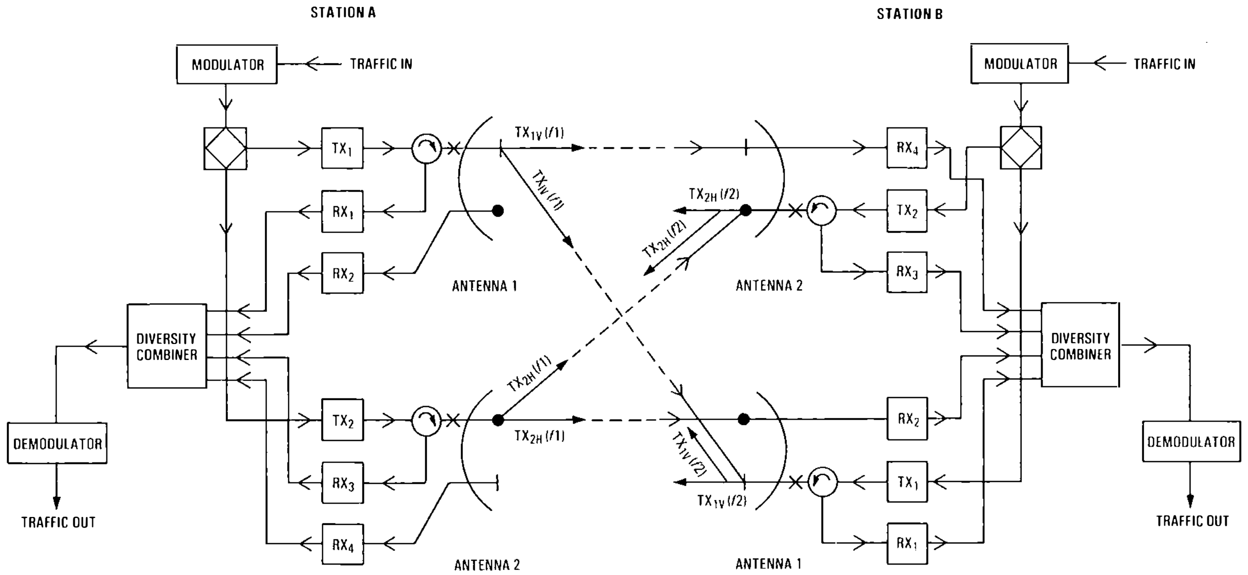


RX: Receive TX: Transmit

Note: Each antenna transmits either vertical (V) or horizontal (H) polarization, but receives both polarizations

FIG. 12—Space/polarization quadruple diversity

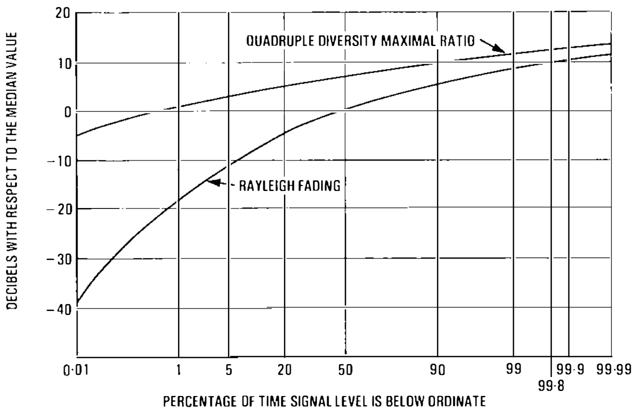


FIG. 13—Cumulative distribution of Rayleigh fading and quadruple diversity

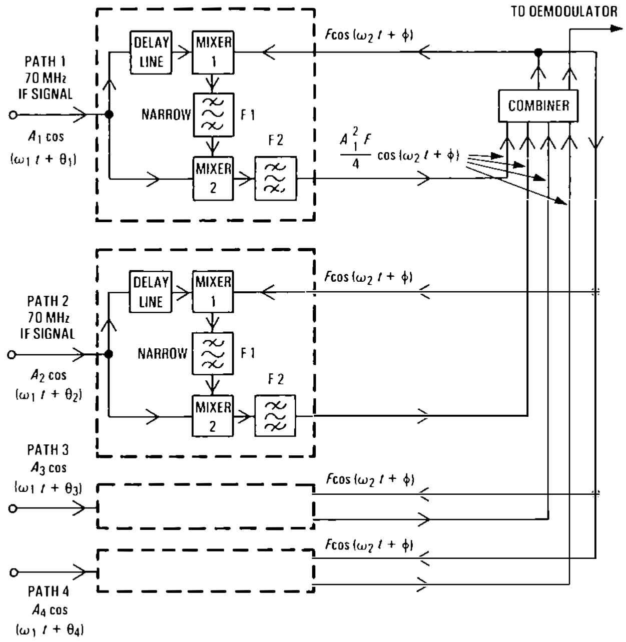


FIG. 14—Quadruple diversity pre-detection combiner

4 independent radio signal paths into phase alignment before the baseband traffic signals are extracted at the demodulator or discriminator. Essentially the combiner is a self-regenerative device containing a phase-correcting loop. Each of the 4 IF signals is first bifurcated before being passed to product mixers, A delay time is included in one of the 2 paths to ensure that the 70 MHz IF input signal arrives at the product mixer at the same time as the feedback signal from the passive combiner; this is represented by $F\cos(\omega_2 t + \phi)$, where ω_2 represents the frequency modulated (FM) carrier centred at 59·3 MHz and F is pre-determined by the combiner output requirement. With this arrangement, the modulation components centred on the 70 MHz IF signal and the feedback signal cancel each other, and the difference frequency $(\omega_1 - \omega_2)$ obtained from mixer 1 can then be routed through a narrow-band-pass filter (F1), which restricts the amount of noise applied to the second product mixer; as a consequence, the output noise from mixer 2 is determined only by the level of noise associated with the input signal.

Examination of path 1 in Fig. 14 gives the IF signal input as

$$A_1 \cos(\omega_1 t + \theta_1),$$

and the output from the mixer as

$$A_1 F \cos(\omega_1 t + \theta_1)\cos(\omega_2 t + \phi).$$

This expression may be written as

$$\frac{A_1 F}{2}[\cos\{(\omega_1 - \omega_2)t + (\theta_1 - \phi)\} + \cos\{(\omega_1 + \omega_2)t + (\theta_1 + \phi)\}].$$

The first term only is selected by the narrow-band-pass filter F1. At mixer 2, the above term is applied at one input and the IF signal,

$$A_1 \cos(\omega_1 t + \theta_1),$$

at the other input, and results in an output from this mixer of

$$\frac{A_1^2 F}{4}(\cos[\{\omega_1 - (\omega_1 - \omega_2)\}t + \{\theta_1 - (\theta_1 - \phi)\}] + \cos[\{\omega_1 + (\omega_1 - \omega_2)\}t + \{\theta_1 + (\theta_1 - \phi)\}]).$$

The difference frequency component is selected by filter F2, to give

$$\frac{A_1^2 F}{4}\cos(\omega_2 t + \phi),$$

which is the combiner output signal and represents the product of the feedback signal (containing the original information in a FM format and is common to each of the diversity paths) and the square of the IF input signal amplitude. The latter factor, A^2, is a necessary condition to achieve maximal radio combining and represents a method of weighting the carrier-to-noise ratio of each diversity path before summation in a passive combiner.

If each signal diversity path is equal in magnitude (say, A, for example) and the amplitude F of the feedback signal is equal to 4, then the total combined signal power-to-noise power ratio is

$$\frac{(4A^2)^2}{4N} = \frac{4A^4}{N},$$

where N is the noise component for a single path. The signal components of the 4 paths are in phase and add linearly, whilst the noise components are randomly distributed and, therefore, add on a power basis. Thus, since $\frac{A^4}{N}$ represents the carrier power-to-noise power ratio for a single radio path, the combiner gives a theoretical advantage of 6 dB. In practice, a figure of 5 dB is realised and this represents an extension of the FM threshold for a transhorizon radio receiver from -126 dBW for a single path to -131 dBW for a quadruple diversity receiver using a pre-detection combiner.

TRANSHORIZON RADIO TERMINAL EQUIPMENT

A block diagram of a transhorizon radio terminal is given in Fig. 15. Stand-by equipments, known as *redundant equipments*, are provided in both the transmit and receive paths to achieve high system reliability. The main items of equipment are outlined below.

Transmit and Receive Traffic Unit

For the transmit path, this unit combines the baseband or multichannel traffic signals with the sub-baseband signals, and for the receive path it segregates these signals into their respective output ports. The multichannel traffic signals are presented in the standard frequency-division multiplex (FDM) format from the line transmission equipment and are combined with the sub-baseband signals. These comprise a 5·7 kHz pilot signal for equipment path selection at the receiver, a speech engineering order wire (EOW) with selective call signalling tones, a supervisory system and control signals. In the receive traffic unit, out-of-band noise slot filters provide an arrangement to mute the traffic baseband when the received signal level approaches the threshold of the system and circuit noise is excessively high.

Baseband Amplifiers

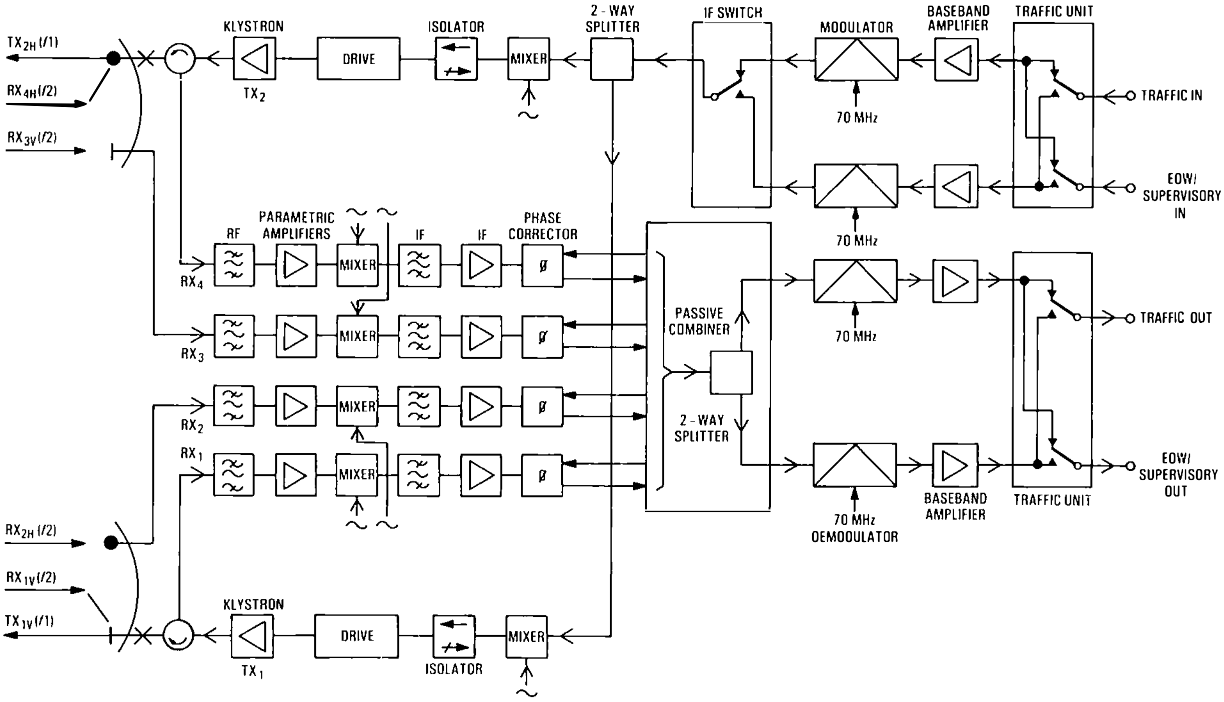
Baseband amplifiers are provided to increase the power level of the traffic and sub-baseband signals. Their design includes pre- and de-emphasis networks in the transmit and receive paths respectively, to provide compensation to the signal-to-noise ratios of the top channels of the FDM system. This compensation is necessary to offset the noise impairment to these channels by the transfer characteristic of the demodulator, which produces a triangular noise-spectrum amplitude response at the output.

Modulator

Each modulator has a 70 MHz oscillator, which is frequency modulated by the composite baseband/sub-baseband signals. The output from the modulator is bifurcated; each path connects with a frequency changer, an isolator, and a power amplifier which delivers radio-frequency energy via a coaxial cable or waveguide to the feed horn or antenna launch unit. Thus, because each transmitter is fed from the same signal source, the orthogonal electromagnetic radiation pattern from each of the 2 antennas are in phase and time alignment, and a coherent transmission is obtained.

Klystron Power Amplifier

The type of klystron power amplifier used is air cooled and



RX: Receive
TX: Transmit

V: Vertical polarization
H: Horizontal polarization

FIG. 15—Block diagram of transhorizon radio transmitter/receiver

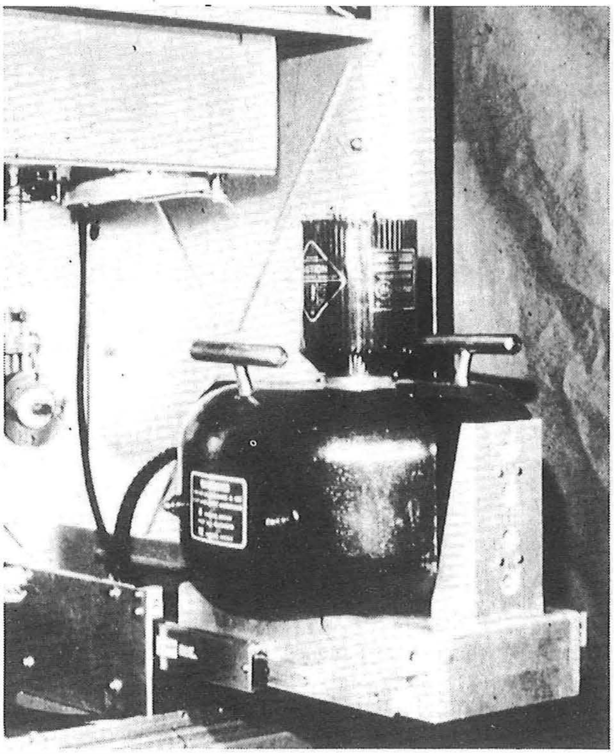


FIG. 16—Klystron valve

contains 4 separately tuneable cavities and a huge permanent magnet in the shape of a flattened sphere to focus the electron beam emitted by a heated cathode. It has a 3 dB bandwidth of about 13 MHz (although in earlier versions the bandwidth was restricted), a power gain of some 37 dB, and can deliver a radio-frequency power of 1 kW to the antenna launch unit. Special control and protection circuits are incorporated to guard against possible damage resulting from reverse power from the antenna or failure of the mains supply. Fig. 16 gives a view of a klystron valve extended from the transmitter cabinet for maintenance purposes.

Feed Horns or Launch Units

These were designed by the Marconi Company and are used to radiate the electromagnetic radio-frequency energy towards the large parabolic reflectors (see Fig. 4, Part 1). In outward appearance, they have a conical shape but internally they contain accurately machined corrugations to produce a circularly symmetrical electric-field pattern over the entire surface of the reflector. A field-strength taper of some 18 dB is used to reduce spill-over from the reflector sides and to secure the desired forward-pointing lobe structure. The feed horns are mounted on a separate tower at the focus of the parabolic reflector, but in order to reduce aperture blockage and achieve an improved sidelobe performance, a double offset design of antenna is used. The double offset design means that the feed horn is offset in both the horizontal and vertical planes with respect to the reflector, but is pointed towards the centre of the reflector. The feed horn incorporates an orthomode junction to cater for the horizontal and vertical polarized signals as well as a circular to rectangular waveguide transition. Fig. 17 shows a typical feed horn used on the shore station antennas.

Broadband Radio-Frequency Receive Filters

The broadband (35 MHz) radio-frequency receive filters select the wanted signal and help to reject unwanted ones (the main filtering being done at the IF stage of the receiver).

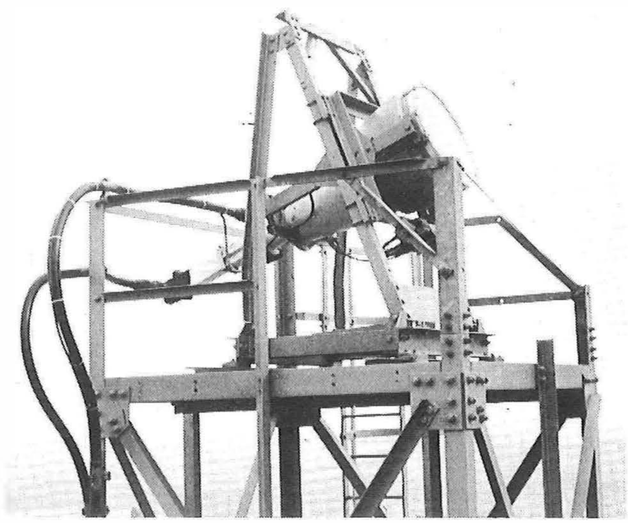


FIG. 17—Shore station feed horn

Uncooled Parametric Amplifiers

Each of the 4 separate diversity receive-signal paths includes a low-noise uncooled parametric amplifier, which enables a low-level receive-system threshold to be achieved. These special solid-state amplifiers raise the power level of the input signal by varying a circuit parameter which is usually the depletion-layer capacitance of a varactor diode. A gain of 18 dB over a 3 dB bandwidth of 19 MHz and a noise factor of 1·8 dB are typical parameters at an operating frequency of 2 GHz.

Receive Mixers

Each of the 4 diversity receive paths contains a mixer that translates the incoming microwave signal containing information to a 70 MHz intermediate frequency. All 4 mixers are supplied from a common source master oscillator, which has a reserve unit with automatic change-over facilities.

Intermediate-Frequency Filters

The IF filters provide the principal means of selecting the wanted signal from the unwanted signals. The IF filters have a 3 dB bandwidth of 3 MHz at the midband frequency of 70 MHz and are combined with IF amplifiers to supply the input signals to the pre-detection combiner. The IF filters are a critical feature of the design of the system and, in order to meet a bandwidth constriction of 3 MHz for a 132-channel capacity system, they must have symmetrical group-delay and loss/frequency responses so that intermodulation frequency products and noise impairment are reduced to acceptable levels.

Pre-detection Combiner

The output from the combiner is split 2 ways to connect with a demodulator and a baseband amplifier in both the active and the redundant equipment paths.

Demodulator

Two distinct types of demodulators are in use: one is an ordinary Round Travers type of frequency discriminator, and the other is a special threshold-extension demodulator; the latter is used on the longer transhorizon radio paths to obtain

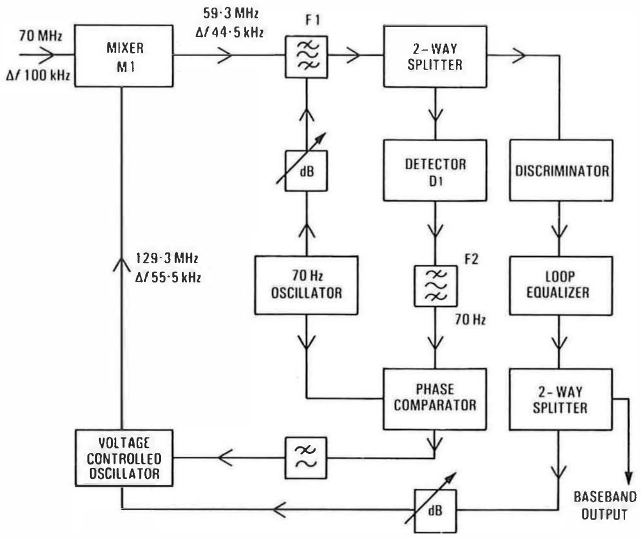


FIG. 18—Frequency modulation feedback threshold-extension demodulator

a 4–5 dB extension of the receiver threshold and thereby achieve an improved system availability. When used with a pre-detection combiner, this special demodulator enables signal levels as low as −136 dBW to be detected and to produce a usable output from the receiver.

Fig. 18 shows the principle of the threshold extension demodulator, which is of the frequency modulation feedback (FMFB) type. A fraction of the output signal from the demodulator is fed back to a voltage-controlled oscillator (VCO), which is also controlled from the output of a phase comparator. The output from the VCO is applied to one input of mixer M1 and the 70 MHz IF signal is applied to the other input. The output from mixer M1 contains the difference frequency with a reduced deviation. A secondary loop comprising a 70 Hz oscillator, an amplitude detector, and a phase comparator is used to keep the FM signal at the centre frequency of filter F1. This is achieved by modulating the filter centre frequency at a rate of 70 Hz and, if the FM signal at the filter input is at the centre frequency, a 140 Hz amplitude component is present at the output which is rejected by filter F2. If this FM signal is not at the centre frequency, then a 70 Hz component is detected by D1 and passed to the phase comparator. The DC output from the phase comparator is applied to the VCO and causes its frequency to be changed to the centre frequency of filter F1 whereupon the 70 Hz component at the output of this filter is reduced to zero. For a 3 MHz bandwidth at the IF frequency at 70 MHz, the bandwidth of the bandpass filter F1 is of the order of 900 kHz to achieve a carrier-to-noise improvement of 5 dB. Because the quadrature noise component present with the input signal is also reduced by the same amount by the action of the feedback loop, the signal-to-noise ratio above threshold is not degraded.

Equipment Installation

Fig. 19 shows a typical transhorizon radio transmitter/receiver equipment installation. The 2 klystron power amplifiers, with their special control and protection circuits, can be identified by their double-width cabinets. In between these cabinets is a drive cabinet containing the transmit traffic unit baseband amplifiers and modulators and 2 receive cabinets which together contain the 4 parametric amplifiers, receive mixers and IF filters the pre-detection combiner, the demodulators and receive traffic unit. Modular construction is used throughout.

Each transhorizon radio transmitter/receiver installation is located in a separate building close to the large parabolic reflectors in order to minimise antenna feeder lengths. Polyquad cable is used to connect the transmitters/receivers to a central building, where the equipments for line transmission and system control are installed.

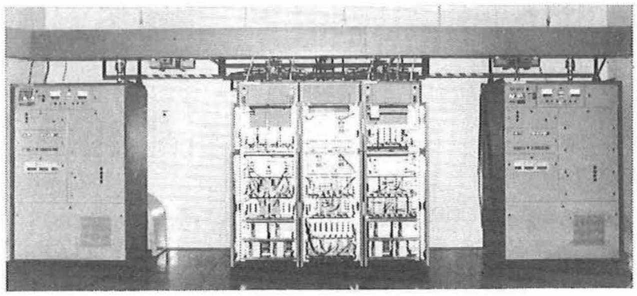


FIG. 19—Typical transhorizon radio equipment installation

BASIC NETWORK PHILOSOPHY

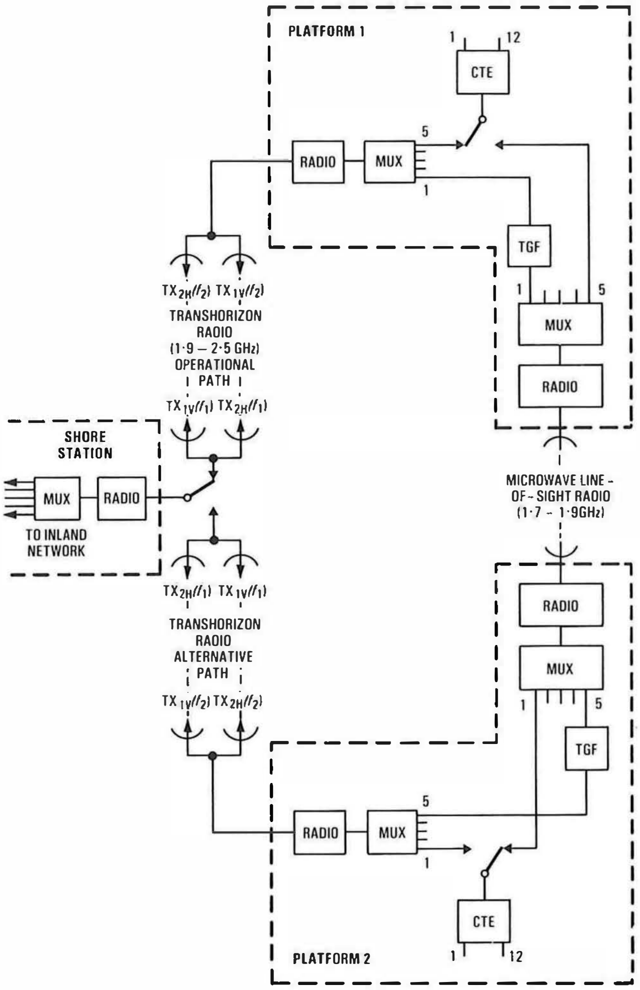
To conserve the radio-frequency spectrum and to obtain a high order of system reliability, a triangulated configuration of the transhorizon radio terminals was chosen; this meant that the shore terminal could transmit at any one time to either of 2 offshore transhorizon radio terminals which could then be interconnected by a microwave line-of-sight radio-relay link. The offshore transhorizon radio terminal that is operational and transmitting back to shore, relays the traffic to the other non-operational terminal over the line-of-sight radio link.

Fig. 20 illustrates the principle involved. In general, a separate pair of space-diversity antennas at the shore station are directed towards each of the 2 offshore platform terminals; either, or both, of these may be up to a maximum distance of about 400 km from the shore terminal. At the shore end, radio energy is radiated from one pair of antennas only at any given time depending on which of the 2 offshore platform terminals is in an operational mode.

Fig. 20 also illustrates the arrangement whereby vertical polarization is transmitted from one antenna and horizontal polarization is transmitted from the other antenna of each pair. The 2 radio frequencies required for each transhorizon radio system are spaced 213 MHz apart if the system operates in the 1·9–2·3 GHz band, and 95 MHz apart if it operates in the 2·5–2·65 GHz band. Because the 2 offshore platforms associated with a triangulated system use the same frequency to transmit information back to the shore terminal, it is imperative that only one offshore terminal should transmit at any given time. The system control logic is based upon multichannel voice frequency (MCVF) tones in the radio sub-baseband spectrum and is used to ensure that this very important system discipline is achieved. BT's transhorizon radio systems have a capacity of 72 or 132 channels.

Because of physical constraints on the design of the platforms, the diameter of the antenna used offshore is one half of that used onshore, and is usually of the mesh type with a centre-mounted feed or launch unit. Fig. 21 shows a typical antenna used offshore; it should be compared with the onshore billboard antenna shown in Fig. 4 in Part 1 of this article.

The interconnecting platform, or bridging microwave line-of-sight radio link is, on the other hand, limited to a distance of about 50 km by the constraints of antenna height and transmitter power. Bridging line-of-sight radio links generally have a capacity of 72 or 132 channels, use a transmitter power of 2 W, and operate in the 1·7–1·9 GHz band with a transmit/receive frequency spacing of 108 MHz. Simple dual diversity is employed by using 2 antennas vertically spaced to reduce the deep fades and loss of service availability which would other-



CTE: Channel translating equipment
MUX: Transmission multiplex equipment
TGF: Through group filter
TX: Transmit
H: Horizontal polarization
V: Vertical polarization

FIG. 20—Transhorizon radio alternative routeing principles

wise be encountered in the presence of strong destructive interference signals due to speculum-type reflections occurring at a point along the radio path. Calm sea or atmospheric layering caused by advection conditions can produce this phenomenon, and fades of up to 40 dB have been observed on some overwater line-of-sight radio paths. Unless there is an adequate margin in the design of the system, the received-signal level will fall below the receiver threshold (see Part 1), which occurs at a level of about −120 dBW, and intelligibility will be lost.

To avoid the problems of multiple contact switching of circuit connections on offshore transhorizon radio terminal platforms, and to facilitate system network planning, it was decided at the outset to offer BT customers a communication service based on packages of twelve 4 kHz channels (or 1 group) covering the frequency band 60–108 kHz. Fig. 20 shows the routeing arrangement for a customer: his group is transmitted as part of the traffic baseband, either directly to the offshore transhorizon radio terminal that is operational, or indirectly via a through-group filter on the operational platform and then across the bridging line-of-sight radio link to the other platform. Nominally 4 kHz channels (but limited by filters to the band 300 Hz–3·4 kHz) are assembled in the standard format for FDM as illustrated in Fig. 22, and include out-of-band signalling (3825 Hz using tone off-idle condition) to form the traffic baseband. Fig. 22 also shows the sub-baseband arrangement containing the following sections.

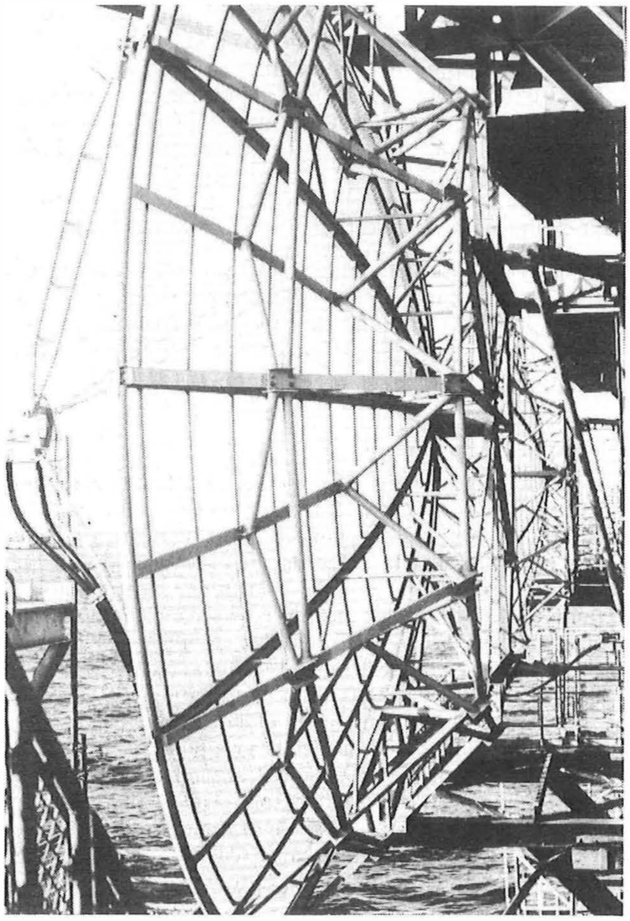


FIG. 21—Typical offshore antenna

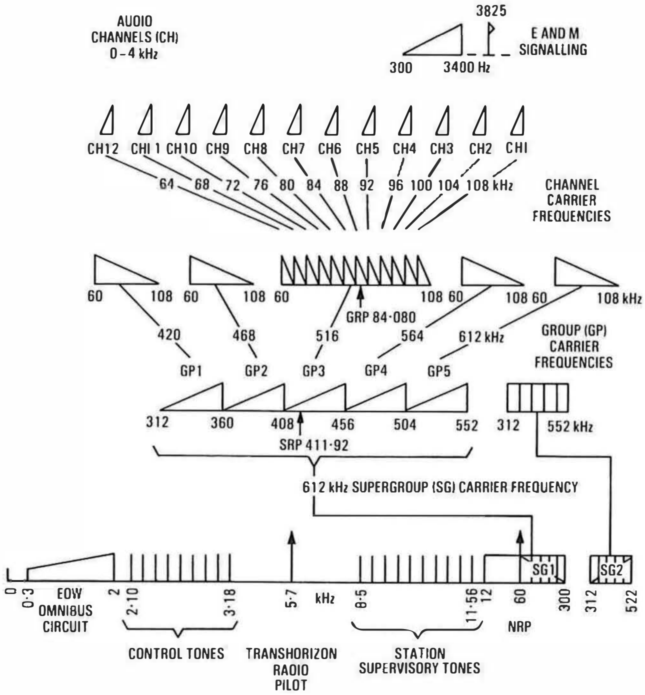


FIG. 22—Baseband and sub-baseband frequency arrangements

(*a*) 300 Hz–2kHz used for an EOW omnibus circuit with selective calling facilities for up to 23 stations.

(*b*) 2·0–3·4 kHz used for MCVF telegraph tones to provide alternative-routeing switching and control functions, including a station-equipment alarm-reset function.

(*c*) 8·0–11·8 kHz used for radio-station alarm-supervisory status reports. (Each triangulated radio system may contain up to a maximum of 10 stations associated with the status report function.)

(*d*) 5·7 kHz pilot tone used for control of the redundant-equipment path selection at the receive terminal.

It is arranged so that the total signal power in each of these 4 kHz sub-baseband sections does not exceed a nominal loading of −15 dBm0 and that the root-mean-square deviation of the radio-frequency carrier is kept within prescribed limits.

The Engineer's Circuit

For engineering purposes at the radio-link commissioning stage and, subsequently, for maintenance benefits, it is essential that all stations connected to a network (including platforms connected by line-of-sight microwave radio links to transhorizon radio terminal platforms) must be able to communicate with each other over a special omnibus circuit that is independent of any multiplex equipment. This EOW circuit is restricted to the band 300 Hz–2 kHz and has a selective-call facility which uses a permutation of 3 tones out of a source of 4 in-band tones. Each station is allocated a code corresponding to a particular grouping of 3 tones. The calling station selects the required station and presses the CALL button, which activates the tone sender, and the appropriate tones are sent as a repetition of 3 successive pulses over the sub-baseband circuit. At the selected receive station, these tones operate a *call alert* signal to indicate that attention is required.

System Control

Control of the alternative transhorizon radio path routeing between platforms in each system is vested with BT's shore terminal and may be effected on either an automatic or a manual basis. Two MCVF telegraph tones are transmitted from the shore terminal in the 2–3·4 kHz part of the sub-baseband and are used in a mark/space relationship to identify which of the 2 offshore platforms in the triangulated system is to be operational and have its transmitters energised. A single MCVF telegraph mark/space tone in the same section of the sub-baseband is transmitted back to the shore terminal, either directly or via the line-of-sight connecting link, from each of the offshore transhorizon terminals. These tones act as a revertive check to ensure that the selected radio path is maintained by the shore terminal's auto/manual control function.

If, for any reason, the established radio path from the operational platform fails, the loss of the revertive check MCVF tone at the shore station activates the automatic-change-over facility. The radio-frequency power output from each of the shore station's klystron transmitters is suppressed until coaxial switches have completed the connecting path to the other pair of antennas. When this switching is complete, the klystrons are re-energised and the appropriate mark/space code is transmitted to the previously non-operational platform; it can then take over the operational role and re-establish communication with the shore terminal. The time required for an automatic change-over is about 13 s.

Redundant-Receive-Equipment Path Control

As mentioned earlier, system availability is enhanced considerably by the use of redundant-equipment-path techniques. In the transhorizon radio systems, a 5·7 kHz pilot is included in the sub-baseband arrangement to control the switching to the redundant path at the receiver. A delay of 3–4 s is incorporated to prevent false switching to the redundant-equipment path under radio-signal fading conditions.

System Monitoring

A sequential-scan monitor receiver is used at the shore terminal for supervisory purposes. The monitoring system employed has a capacity of 10 stations and uses a single tone per station in the frequency range 8–11·8 kHz of the sub-baseband. Each transhorizon radio station is equipped with a supervisory transmitter that sends equipment status reports (in a 2 × 13 bit frequency-shift keying format) to the shore terminal supervisory receiver by modulating a tone carrier by ±85 Hz about its centre frequency. Up to 20 status or fault indications for each station may be accommodated. The monitor receiver at the shore station scans sequentially through each of the tone carriers, and if a change of state or alarm function has occurred at any of the stations, it is indicated by a change in the 2 × 13-bit format transmitted from that station; this activates a *station alarm* report on the monitor receiver. The status report for the station at which an alarm has occurred can be selected for interrogation on the monitor receiver by pressing the appropriate button; the station alarm/status indications are then displayed on a 4 × 5 lamp unit.

Power Supply Arrangements

Normally BT's transhorizon radio terminals are powered from the public mains supply, but special provision is made to ensure, that in the event of a failure of the mains supply, the radio stations can continue to be fully operational. This provision includes 2 diesel generators and a no-break power supply comprising a large capacity battery, a DC motor/generator mechanically coupled to a synchronous AC motor/generator, and sophisticated power switch gear. This switch gear ensures that the locally-generated AC supply derived from the no-break power equipment and the public or station diesel supply are in phase alignment before the supplies are connected in parallel prior to the disconnection of the no-break supply.

THE TRANSHORIZON RADIO NETWORK

The transhorizon radio links and how these are configured into separate systems to serve the offshore oil/gas industry are now described.

Reference to Fig. 23 shows how BT's 2 transhorizon radio stations, one at Mormond Hill near Aberdeen and one at Scousburgh in the Shetlands, are strategically sited to serve the offshore platforms. Planning for these stations commenced in 1973. Construction work started a year later in 1974 and within 13 months both sites were operational. Together, they included the construction of no less than six 18 m and six 12 m diameter billboard antennas, and required over 2300 m^3 of concrete at the Shetland site alone.

The complexity of the offshore networks is growing as more and more platforms are connected, via line-of-sight microwave links, to the established transhorizon radio systems. Fig. 24 shows the North East Shetland Basin communications network. It shows that some of the platforms that depend on line-of-sight radio links for their services have alternative line-of-sight routeing to each of the 2 transhorizon radio terminals and are thus able to circumvent the loss of service that could otherwise occur when the host transhorizon radio terminal platform is shut down for maintenance or operational reasons. These shut downs include periods of radio silence which may last up to 8 hours or so. Fig. 25 illustrates how the traffic is routed for a dependent platform (platform C) with alternative line-of-sight microwave radio links to each of the 2 transhorizon radio terminal stations of a triangulated system. Thus, platform C has 4 possible routeings back to shore and,

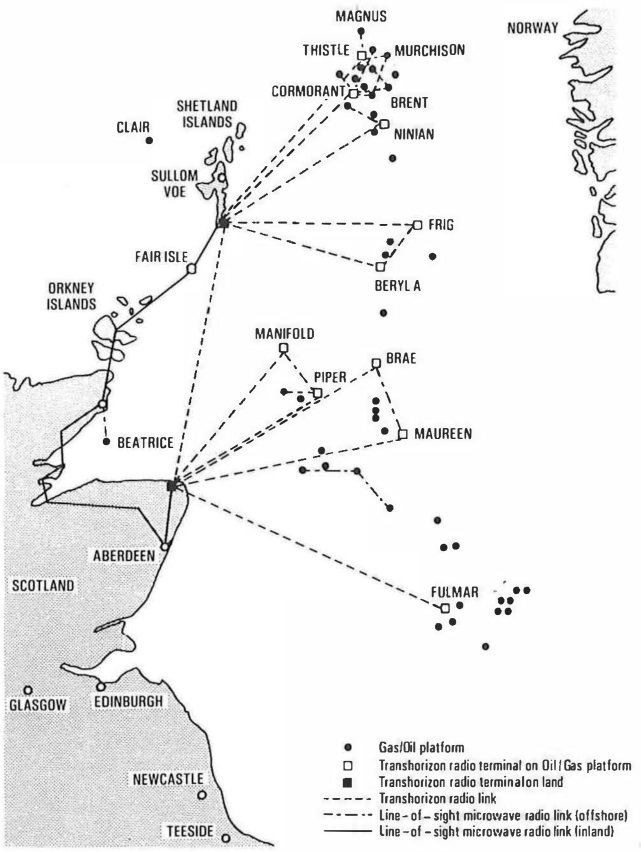


FIG. 23—UK North Sea communications network

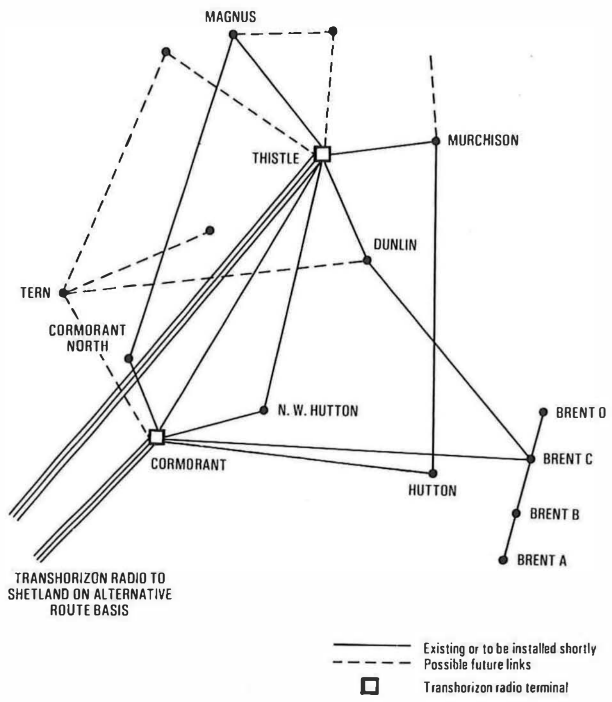


FIG. 24—North East Shetland Basin communications network

by the same token, it has a high service availability.

Some offshore line-of-sight radio links operate in the 1·7–1·9 GHz band and some small capacity links (up to 24 channels) in the 1·5 GHz band.

Transmission Constraints

Frequency-selective fading over a transhorizon radio path imposes a bandwidth limitation on the transmission and is generally reckoned to be reached when the correlation coefficient of the amplitude of the frequency at the edge of the band is reduced to one half the amplitude of the centre frequency. This is sometimes referred to as the *frequency correlation bandwidth*. Within this bandwidth, the transmitted frequencies undergo similar random phase and amplitude variations over the transmission path and experience a flat type of fading. Beyond this frequency correlation bandwidth, the selective fading that occurs manifests itself as intermodulation noise in the traffic baseband signal.

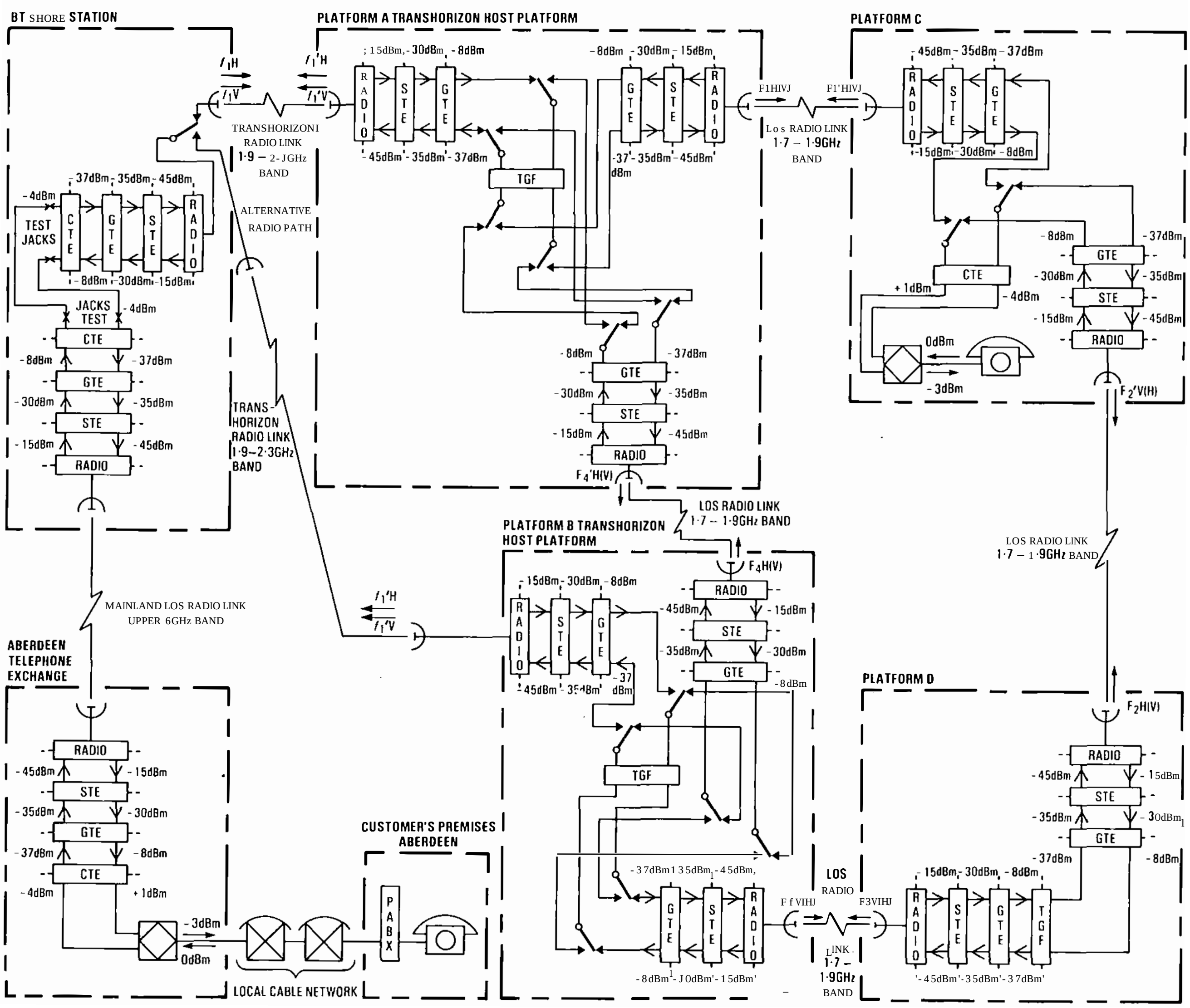
All BT's existing transhorizon radio links commenced service as 60/72-channel systems based on the use of supergroup 1, which occupies the baseband frequency range of 60–300 kHz. The option of including basic group A, which occupies the band 12–60 kHz, has not yet been taken up, but plans are in hand to include basic group A on the Mormond Hill to Scousburgh transhorizon link during 1982 when the transmission equipment is expected to be available. The capacity of this link was expanded from 60 channels to 120 channels in 1977, and a similar exercise was carried out on the Scousburgh to *Thistle/Cormorant* link in 1980. (See Fig. 23). After this modification, the bridging line-of-sight radio link was modified to give a 300-channel capacity. Laboratory and link tests carried out by the NSTF confirmed that provided the group-delay/frequency and loss/frequency curves for the IF filters are symmetrical, a 120/132-channel radio system using FDM/FM techniques can operate satisfactorily with excellent signal-to-noise ratios over the 3 MHz radio-frequency bandwidth initially allocated for 60/72-channel systems.

Qualitatively, the Marconi transhorizon radio systems have performed extremely well and have met the design targets (see Part 1). The median noise level recorded over 2 tandem connected transhorizon radio links totalling 430 km in length was −65 dBm0p. Transmission measurements carried out over a 265 km path length on a 72-channel system have produced noise power ratios (NPRs) of 52 dB in the top baseband channels under good signal conditions. This NPR of 52 dB is equivalent to a psophometrically-weighted signal-to-noise ratio of 77·6 dB or about 17×10^{-12} W. A comparison between the measured performance of a 265 km transhorizon radio link and the theoretical performance for the equivalent multiple-hop line-of-sight radio-relay link is given in Fig. 26. It shows that the target for transmission performance has been well exceeded.

In general, the transmission constraints that apply to the inland network because of the need to use frequency-selective filters also apply to BT's North Sea services. For example, the need to use group pilot filters means that channels 1/12 and 6/7 respectively are not suitable for high-speed (4800 bit/s) data links unless some special design of modem is used on the circuit. Out-of-band signalling at 3825 Hz is affected by the channel-12 filter at the 60 kHz end of the baseband and so this channel is usually used for telegraph MCVF bearer circuits. However, this out-of-band signalling circuit on channel 12 can be used with a relay-set to provide a 4 s HOLD/BUSY facility for inter-switchboard circuits between shore and offshore to prevent false release during short periods of radio fading.

At the inception of BT's transhorizon radio services, the design target was based on a data speed of 2400 bit/s and, in general, the North Sea circuits meet the transmission requirements of CCITT† Recommendation M1020 without the need of any group-delay equalisation. However, the insatiable appetite of modern sophisticated control and computer systems is pushing up the transmission requirement to 9600 bit/s per 4 kHz channel. Owing to the vagaries of trans-

† CCITT—International Telegraph and Telephone Consultative Committee



CTE: Channel translating equipment
GTE: Group translating equipment
LOS: Line-of-sight
STE: Supergroup translating equipment
PABX: Private automatic branch exchange
H: Horizontal polarization
V: Vertical polarization

Note: f_1 F_1, F_2 etc. and f_1' F'_1, F'_2 etc. refer respectively to frequency allocations in the low and high part of the band

FIG. 25—Alternative routeing arrangements for dependent platforms

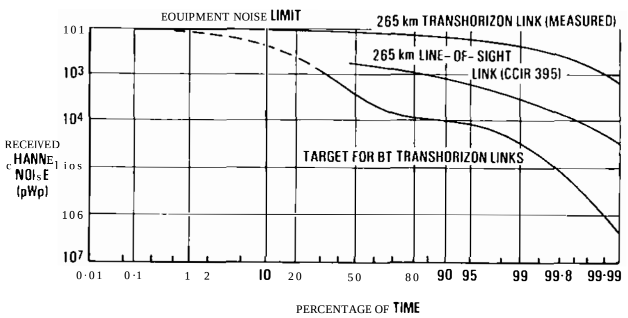


FIG. 26—Comparison of target and measured transmission performance for a 265 km transhorizon radio link

horizon radio paths with their random amplitude/phase characteristics, the sudden amplitude variations that occur produce a circuit impediment which requires the use of special adaptive-equalisation and error-detection techniques before satisfactory transmission at this speed can be maintained during periods of poor radio transmission. This problem is currently under investigation by the Marconi Company and the NSTF.

Most platforms have out-of-area exchange lines connected to the Aberdeen telephone exchange and are, therefore, able to dial national and international calls directly, and have access to some 425 million telephones in 100 countries. Telex services also are extended to the offshore platforms and likewise these also have access to national and international highways. Some platform owners prefer to have level-9 access via a land based PABX to the Aberdeen exchange, but as Fig. 27 illustrates, this can give rise to excessive line loss because of the need to traverse the local line network twice. It is interesting to note that the harmonics of the dial tone are satisfactorily transmitted over the 300 Hz–3·4 kHz FDM channels to the remote offshore platforms.

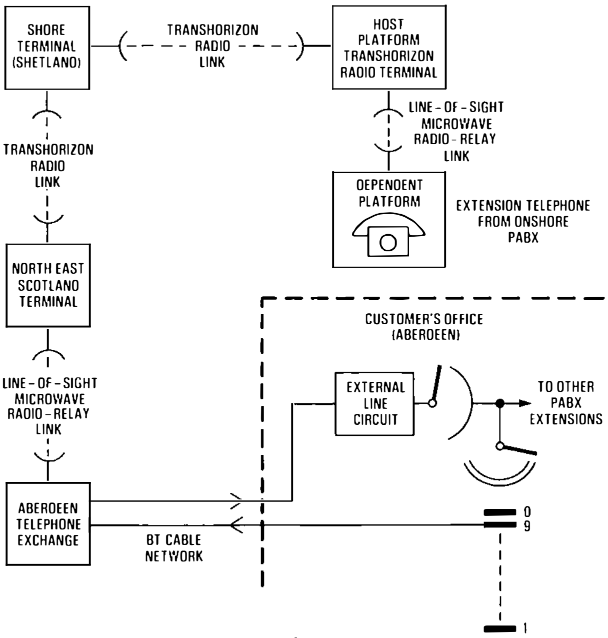


FIG. 27—Level-9 access routeing

Present and Planned Offshore Services

At present, BT has 5 offshore transhorizon radio systems: 3 are configured to the triangulated arrangement and serve the *Piper/Manifold*, *Beryl/Frigg*, and *Thistle/Cormorant* networks; and the 2 remaining systems are single offshore terminals serving the *Ninian* and *Fulmar* Platforms. (See Fig. 23).

There are also 13 platforms which rely upon microwave line-of-sight links to connect them with a transhorizon radio offshore terminal.

In late-1982, the sixth transhorizon radio system will be brought into operation when Marathon's *Brae* platform will be connected to BT's network. For economic reasons, signals to the *Brae* platform will be "squinted" from billboard reflectors facing the *Piper* platform, but will use separate feed horns. The angle of squint is about 3·2 degrees. A separate pair of billboard reflectors and associated feed horns will be used to transmit signals to Phillip's *Maureen* platform, which is scheduled to come on-stream next year and, together with the *Brae* platform, will form a new triangulated system.

The next 2 years will see the addition of 5 more platforms, which will be connected via line-of-sight links to existing transhorizon radio host terminals. Included in this number is the first "tethered" type of platform that will have the motions of roll, yaw, pitch and heave (usually associated with ships), but any movement will be constrained to within fairly close limits and the antenna pointing stability requirement of $\pm 0{\cdot}75°$ for line-of-sight radio links is expected to be met for 99·9% of the time. All told, there will be a total of 28 platforms connected to BT's transhorizon radio services by 1984.

In addition, a line-of-sight radio link direct from a BT radio station at Thrumster to a British National Oil Corporation platform in the Moray Firth has been provided.

The Future

Areas west of the Shetlands have received the attention of a number of oil companies and several potentially commercial oil fields are now known to exist. Further west, there are other fields where speculation is growing and it is conceivable that oil/gas developments will mature in the late-1980s.

The South Western Approaches and the English Channel areas may also prove to be commercial areas for oil/gas developments.

The Marconi Company has designed an automatic transmit and receive level control device which may be used to control the amount of power transmitted from a distant transhorizon radio terminal when anomolous or enhanced propagation conditions are detected at the receive terminal. By monitoring the total received signal power within a specified range, special attenuators may be brought into circuit to restrict the receiver input level and thereby avoid system overload and excessive intermodulation noise occurring. These automatic transmit/receive level control devices are intended to be fitted retrospectively to minimise mutual interference if it became necessary to install a large number of transhorizon radio links to serve the offshore oil/gas industry operating in UK waters.

European Satellites operating in the 14/11 GHz and 14/12 GHz frequency bands will be entering the communication scene by 1983/84 and no doubt these will complement the existing transhorizon radio services by

(*a*) providing a service to areas that may be difficult or uneconomic to serve by other means because of their large distances from shore,

(*b*) providing a service to the tethered, or moving, type of platform which may be very remote from land and in very deep water, and

(*c*) providing a range of digital services using high bit rates—such as video conferencing etc.

ACKNOWLEDGEMENTS

With the small numbers of staff employed in the NSTF, the job of transmission planning, procurement and successful system operation within the short timescale could not have been accomplished without the help of so many friends in BT Headquarters, Scottish Telecommunications Board and Aberdeen Telephone Area. The author wishes to acknowledge the support of serving and retired colleagues.

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[2] HILL, S. J. British Telecom Transhorizon Radio Services to Offshore Oil/Gas Production Platforms, Part 1—Service Requirements and Propagation Considerations. *Br. Telecommun. Eng.* Apr 1982, **1**, p. 42.

A Telephone Conference Repeater

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UDC 621.395.348.4: 621.395.664

Some time ago a simple idea for multi-way voice switching was described in this Journal[1]*. More recently, a workable telephone conference repeater based on that idea was produced. This article describes the concept and shows how the practical circuit functions.*

INTRODUCTION

Under normal circumstances a telephone instrument produces sufficient power to operate a similar instrument over the telephone network. For telephone conference service, however, a telephone is required to feed a number of other telephones. Without some form of amplification, this results in the reduction of received level because the power intended for a single instrument is shared between several instruments.

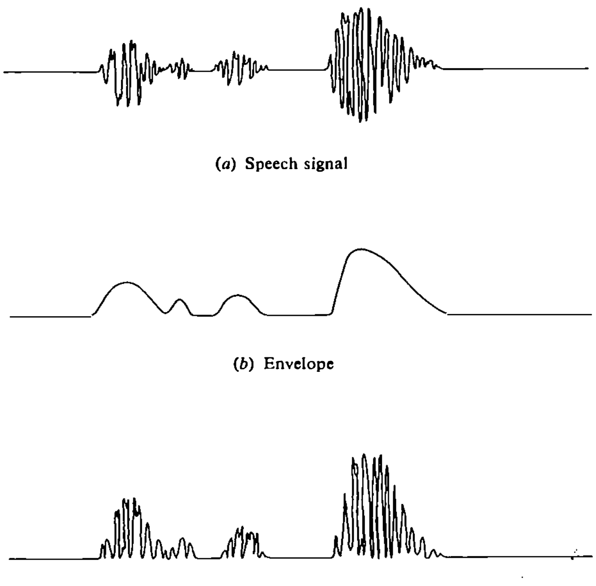
Unswitched amplification, as used in the Unit Amplifying No. 36A, can cause oscillation, but, because a conferee is predominantly either listening or talking, it is possible to switch the gain accordingly in order to avoid this risk. This switching is voice activated and is referred to as *voice switching*.

Usually, when voice-switched gain is used in telephone conference systems, each port has an individual 2-way voice switch[2] and the system may be described as *multiple 2-way voice switching*. However, when 2 conferees converse they do so over 2 independent stages of switching and any switching delay is thereby worsened.

In the past, a scheme had been devised which gave true multi-way voice-switching[1] although, at that time, the low-level performance was poor. Subsequently, advances in components made possible a workable circuit which was engineered into a practical form by the Midlands Telecommunications Region of British Telecom (BT), then the British Post Office, and later taken up by BT Headquarters. This is the circuit dealt with in this article.

Insertion loss and return loss are roughly the same as for 3-party bunched connections, though special cards have been produced giving slight gain in the direction incoming to the repeater. Although intended for interconnection of up to 8 PBX extensions and one exchange line, the device has found application for interconnecting exchange lines providing that their losses are not too great.

Known as *Combining Unit SA10198*, the repeater has been produced in limited numbers.



(*a*) Speech signal

(*b*) Envelope

(*c*) Unilateralised signal

FIG. 1—Unilateralisation of speech signals

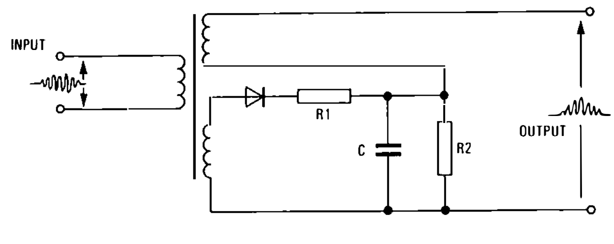


FIG. 2—Simple unilateraliser

BASIC CONCEPT

Unilateralisation of Speech

Speech signals are subjected to a process known as *unilateralisation* as illustrated in Fig. 1. Here, waveform (*a*) represents the original signal, waveform (*b*) is a voltage varying according to the signal envelope, and waveform (*c*) is the unilateralised signal which is the sum of waveforms (*a*) and (*b*). If reproduced acoustically, waveform (*c*) sounds the same as waveform (*a*) because the frequency components of waveform (*b*) are predominantly subsonic.

A simple form of unilateraliser is shown in Fig. 2. Essentially, it consists of an envelope detector and an adding arrangement. The charging time-constant (CR_1) should be small—say 5 ms, but the discharge time-constant (CR_2) should be long in comparison—say 100 ms.

Voice Switching

Unilateralised speech, which will pass through a diode if the polarity is correct, is used to facilitate switching the line of a talker to an amplifier input and the listeners' lines to the amplifier output. Fig. 3 shows a simple switching arrangement using a DC amplifier (A) with just under unity gain without inversion. Supposing the conferee on line 1 is talking, diode D1 will conduct as will diodes D′2 . . . D′n, and diodes D′1, D2 . . . Dn will be switched OFF; similarly for line 2 etc. The unilateraliser of Fig. 2 passes outgoing signals. Thus, as conferees talk, they are switched to the input of amplifier A

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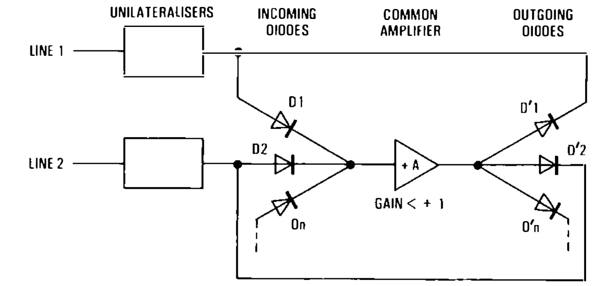
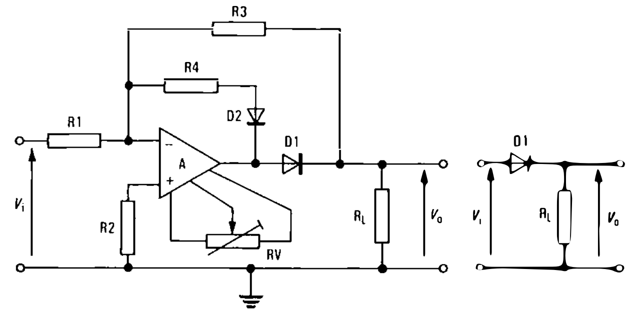


FIG. 3—Simple switching arrangement



(a) Precise diode circuit (b) Simple diode circuit

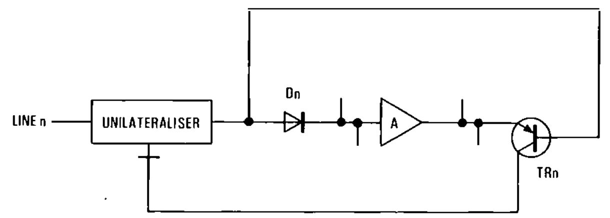
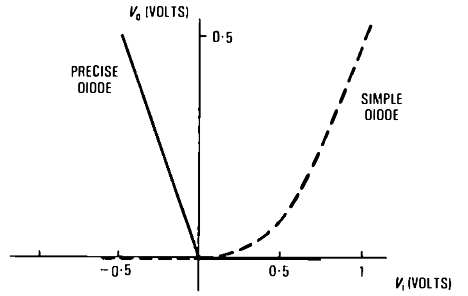


FIG. 4—Detection suppression



(c) Diode characteristics

FIG. 5—Comparison of simple and precise diodes

and the other lines are fed at almost the same level from the output of amplifier A.

Unfortunately, the envelope detector works equally well on outgoing signals, producing an envelope voltage which opposes the outgoing signal; mis-switching of the diodes can result unless detection of this signal is suppressed.

Suppressing Detection of Outgoing Signals

Detection of outgoing signals is prevented as shown in Fig. 4. Outgoing diodes, typically D′n of Fig. 3, are replaced by the emitter–base junction of transistors TRn as shown. For outgoing signals, TRn switches ON and the output at the collector is arranged to raise the detection threshold of the unilateraliser sufficiently to avoid detection of outgoing signals. Genuine signals of sufficiently high level which are incoming on this line can overcome the threshold, be detected and take over control of the common amplifier.

PRACTICAL CONSIDERATIONS

Precise Diode

The need for the circuits of Figs. 2, 3 and 4 to be able to operate down to low levels requires the use of diodes with near perfect transition from reverse to forward characteristic at the origin. Similarly, the transistor of Fig. 4 should be precise in giving zero output for zero input. Ordinary simple diodes and transistors are, however, very imprecise in low-level operation. To achieve the required performance, the circuit configuration, known as the *precise diode*, can be used. In this circuit the very high DC gain of an operational amplifier is used to compensate for the imperfect forward conduction characteristic of an ordinary diode.

Fig. 5(*a*) shows the circuit in which amplifier A has very high DC gain with inversion. The preset potentiometer RV enables a zero output voltage (v_o) to be obtained for a zero input voltage (v_i).

Then, $$v_o = -\frac{R_3}{R_1} v_i \text{ for } v_i \text{ negative,}$$

and, $$v_o \approx 0 \text{ for } v_i \text{ positive.}$$

Fig. 5(*b*) shows, for comparison, the load R_L fed via a simple diode (typically silicon), and Fig. 5(*c*) shows the corresponding relationships between v_o and v_i for the 2 circuits.

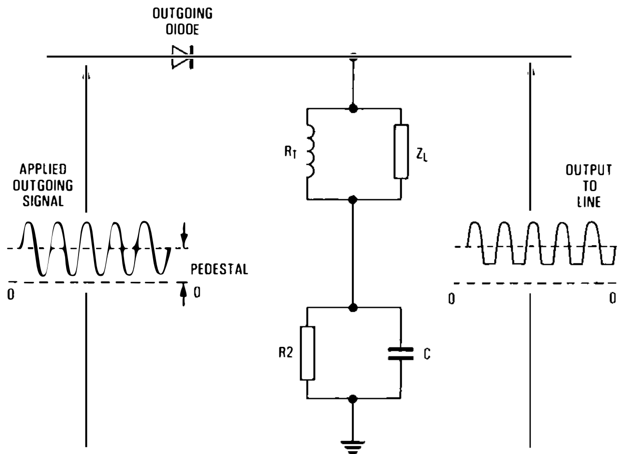


FIG. 6—Distortion due to load on outgoing diode

Important features of the precise diode are as follows:

(*a*) The forward characteristic appears in the fourth quadrant or, by reversing both diodes of Fig. 5(*a*), in the second quadrant.

(*b*) The forward characteristic is linear down to about 1 mV.

(*c*) The load on the source (v_i) is R1 which may be high instead of R_L which may be low.

Outgoing Distortion

For outgoing signals, the circuit of Fig. 2 loads the outgoing diode (the emitter–base junction of transistor TRn of Fig. 4) much as shown in Fig. 6; R_T being the resistance of the high-inductance transformer winding, Z_L the line impedance, and R2 and C the detector components as in Fig. 2. As the value of R_T is low, the DC component of the current in the outgoing diode is dependent largely on R2. However, the AC component is controlled by Z_L, C being large. When $|Z_L| > R2$ the circuit performs satisfactorily, but when Z_L is low, the AC component is high and it may be too high for the DC *pedestal* current upon which it is superposed. Under these conditions, the outgoing diode cuts off on the troughs of the signal, with the resultant distortion as shown in Fig. 6. One way of overcoming this problem is to increase the pedestal by over-unilateralising. This is done by adding gain to the detector circuit.

The effect of this type of distortion is worst at the ends of syllables because the voltage across the capacitor C is slow to follow the die-away of the pedestal voltage, and this causes undue reduction of pedestal current. Some precaution has therefore to be taken to buffer the outgoing signals from the large reservoir capacitor.

Referring to Fig. 3, the mis-switching of any one diode will cause the mis-switching of all the other diodes. Thus, the extreme case of a short circuit across one pair of line terminals must be taken into account in the design.

OTHER DESIGN CONSTRAINTS

Detector Gain

The introduction of a detection threshold for outgoing signals causes a competing incoming signal to have a disadvantage in activating the switching. Alternatively, an outgoing signal may be regarded as having an advantage in retaining control against competing incoming signals. It will be seen later that the detection threshold is directly related to the size of pedestal of the outgoing signal, which is itself proportional to detector gain. Thus, detector gain causes *switching hysteresis* in that the switching level of one signal against another is higher than the level to which the signal may be reduced before control is relinquished (the other signal being constant).

In practical applications, a certain amount of hysteresis is desirable and the optimum amount is determined subjectively.

Speed of Switching

For a conference repeater, fast switching is desirable. The time constants required for the pedestal to follow the speech envelope have been mentioned earlier and, together with hysteresis, they control the switching time. Part-wave switching occurs between signals of comparable magnitude and can initiate a fast total switching. However, a weak signal cannot take over after a strong signal has ended until the pedestal of the stronger signal has decayed sufficiently. In extreme cases, this delay may be intrusive, but it is a feature of the circuit configuration.

Dynamic Range

Use of the precise diode circuit enables low-level signals to switch. There remains, however, the problem of passing even lower levels—the lowest audible levels of signal—through the diodes without distortion. This can be achieved by maintaining a minimum very low-level bias through any precise diode that has been switched ON. Thus, a line having once gained control retains it even when the signal from that line falls to zero, unless another line has an incoming signal adequate to initiate switching and take over—the effect is called *retention*. The retention level decides the switching sensitivity of the circuit.

Loss Compromise

For simplicity, consider a 2-port version of the repeater, one port having an input signal and the other giving an output. Because of its basic circuit configuration and fast switching, this repeater must have a slight overall loss when the output is open circuit if oscillation is to be avoided. Now, referring to

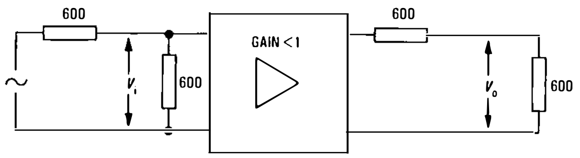


FIG. 7—Gain of fast-switched amplifier

Fig. 7, if the input impedance is 600 Ω and the output impedance is built out to 600 Ω then, when correctly terminated in 600 Ω, the loss would be just over 6 dB.

Making the input impedance 1200 Ω gives slight mismatch voltage gain from a 600 Ω source, and making the output impedance 300 Ω reduces slightly the loss at the output. Either impedance may, however, be presented to incoming signals and each then gives a return loss of about 9·5 dB. These impedance values were used as target figures at the time of this particular design.

For the special low-loss cards, the concession of return loss in favour of reduced insertion loss is more pronounced and a worthwhile improvement in insertion loss is achieved.

ACTUAL CIRCUIT

Main Parts

Fig. 8 shows how the concept has been realised in face of the foregoing practical considerations and other design constraints. Each line has a card with a circuit as shown. The values given are for normal line cards; the special low-loss cards, which give a slight incoming gain (gain to signals incoming to the repeater), have the same circuit configuration but different component values.

The main elements of the circuit are: the unilateraliser; an incoming diode; an outgoing diode; a means of talker identification in which a light-emitting diode (LED) shows when the card is switched to INCOMING; and a limiter which gives protection against line surges.

Incoming Diode–Outgoing Diode Loop

The incoming and outgoing diodes circuits are based on the precise diode configuration of Fig. 5(*a*). The amplifiers thus introduced dispense with the need for a common amplifier: there is, instead, a common point. Fig. 9 shows a simplified diagram of this arrangement.

The incoming diode circuit has a slight loss and the outgoing diode circuit has unity gain so the loop they form has just under unity DC and AC gain, and is stable. In the special low-loss cards, the incoming diode circuit is given gain and the outgoing diode circuit is given a slight loss, the loop again having an overall loss.

Outgoing Diode and Detector

In the outgoing diode circuit of Fig. 8, the precise diode (see Fig. 5(*a*)) has the transistor of Fig. 4 incorporated. The hysteresis line is the route via which the collector output causes the unilateraliser to raise the detection threshold when the line card is switched to the OUTGOING mode.

The detector (see Fig. 8) also is based on the precise diode circuit, but has reservoir capacitor C1 and buffer diode D8 incorporated.

Operation for Incoming Signals

Referring again to Fig. 8, speech signals from line are limited to about 4 V peak-to-peak by diodes D1–D5 and pass through transformer T2, which has ratios 1:1:1. The lower end of winding N2 has a low-resistance path to earth via resistors R17 and R18 and the upper end feeds the detector.

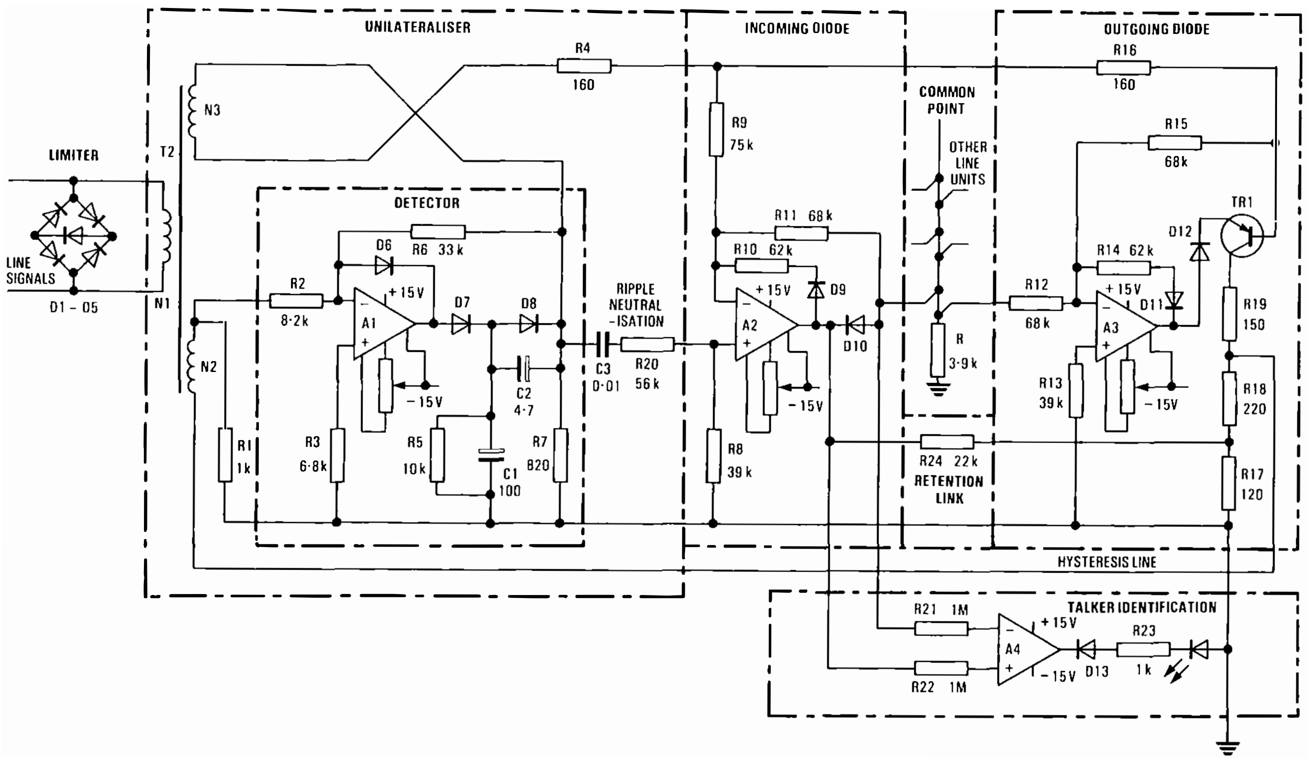
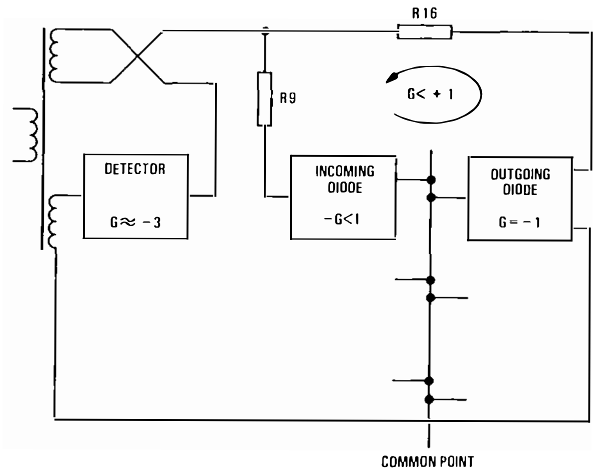


Fig. 8—Line card circuit



G: Gain

Fig. 9—Simplified diagram of switching circuit

The detector produces an output voltage of about 3 times the peaks of speech and to this is added the speech signal from winding N3.

The resulting positively unilateralised signal is fed via resistor R4 to the incoming diode which is thereby switched ON and inverts, diminishes and applies the signal to the common point. These negative-going signals on the common point feed the outgoing diodes of other line cards.

In the talker's line card, the net effect of the positive-going signal applied from resistor R4 to resistor R15 via resistor R16 and the diminished negative-going signal applied from the common point to resistor R12 is to cause amplifier A3 to give a negative output which cuts off the outgoing diode so that it does not shunt the line.

Operation for Outgoing Signals

From the talker's line card, negative-going signals appear on the common point and are applied to resistor R12, switching the outgoing diode ON. The positive-going output of the outgoing diode is applied via resistors R16 and R4 to winding N3; the DC envelope component is connected to earth via resistor R7 and the AC signal component is earthed via capacitors C2 and C1.

The net effect of the negative voltage applied to amplifier A2 via resistor R11 and the positive voltage applied from resistor R16 via resistor R9 (which is larger than resistor R11) is to cause A2 to give a positive output, and this switches the incoming diode OFF.

Positive-going outgoing signals appear at the collector of transistor TR1 and the proportion fed to the detector via the hysteresis line and winding N2 sets a threshold that is adequate to prevent detection of the outgoing signal. This also discourages detection of genuine competing incoming signals originating from the line, and switching hysteresis is produced.

Winding N3 is the main route of outgoing signals to line but a small contribution also comes via winding N2.

Impedance to Line

When a line card is switched to INCOMING, the main shunt on the line is resistors R1, R17 and R18 in series, and the input impedance is about 1200 Ω, the transformer shunt and series components having some effect.

Switched to OUTGOING, the feed to line is effectively via resistor R1 plus resistor R19, all shunted by resistor R16 plus resistor R4; the output impedance is about 300 Ω, the transformer parameters again having an effect. This is, of course, also the input impedance seen by extraneous incoming signals.

These impedance values do not apply to the special low-loss cards.

Ripple Neutralisation

Unilateralisation causes distortion. Particularly noticeable is the distortion suffered by a pure sine wave; the ripple in the pedestal resulting from the charging of the reservoir capacitor of the detector occurs every cycle and represents the introduction of overtones.

The small capacitor C3 and resistor R20 (see Fig. 8) feed these unwanted high frequencies to the non-inverting input of amplifier A2. In this way, the ripple is substantially subtracted from the main signal fed to the inverting input of A2 and the distortion at the common point is considerably reduced.

Retention Link

The need for retention—the quiescent control of the common point by the last talker—has been discussed earlier. Resistor R24 is the means by which retention is provided. It completes the A1–A2 loop via the hysteresis line to give positive feedback at low levels. When the incoming diode is quiescently conducting, the output of amplifier A2 stands at about −0·3 V because of the forward voltage drop across diode D10. The small negative voltage tapped off from resistor R24 by resistor R17 is fed via resistor R18 and the hysteresis line to the input of amplifier A1. This keeps the detector just conducting, which sustains the card switched to INCOMING.

The dummy load R on the common point helps to define the forward voltage drop across diode D10, particularly when few line cards are plugged in.

Talker Identification

This part of the circuit was introduced by Midlands Telecommunications Region and works as follows. When a card is in the SWITCHED-TO-INCOMING mode, diode D10 is conducting and its forward voltage drop is fed to the differential inputs of amplifier A4. A negative output from the amplifier causes the LED to glow. Diode D13 has to be included to prevent damage to the LED by reverse voltages when, in the SWITCHED-TO-OUTGOING mode, diode D10 is reverse biased.

In normal operation of a repeater, the LED of only one line card at a time will glow, indicating which line has control of the common point.

Number of Conference Lines

Fig. 8 shows that each line card loads the common point with 2 resistors, R11 and R12. The maximum number of cards that can be interconnected is determined by the number of such loads that the amplifier A2 can drive before the degree of overload becomes unacceptable. The Combining Unit SA10198 has 9 line cards, but several combining units can be connected together (at their earth lines and common points).

There is a risk that a noisy line will impose itself on the common point. Consequently, the upper limit on the number of lines that can be interconnected depends on the quality of the lines involved. However, the presence of voice switching ensures that the cumulative noise of all lines is avoided, a listener being subject only to noise of his own line and of that of the talker.

When combining units are interconnected, the 3·9 kΩ common point resistor R may be removed from each shelf to lessen the load on the common point.

PARAMETERS

The system performance figures given below are measured with respect to 600 Ω lines.

Insertion loss For normal line cards, the insertion loss of the repeater is 3 dB for the basic circuit shown in Fig. 8, but worsens to 4 dB when the line transformers are included in the circuit.

The insertion gain between the special low-loss cards including line transformers is about 1 dB.

When both types of card are used, the above loss and gain figures can be regarded as vested entirely in the card handling the signal incoming to the repeater.

Return loss For normal cards this is 9·5 dB.

Switching sensitivity This is better than −40 dBm.

Switching hysteresis Hysteresis is about 15 dB at moderate levels, but decreases at higher levels because of early detector overload. This figure is the difference between the lowest level to claim control and the highest level which permits release measured on one port when there is another signal on another port.

Switching time With a continuous tone at −20 dBm applied to one port of the repeater and a tone at −10 dBm pulsed 250 ms ON 250 ms OFF applied to another, switching is initiated by the higher level tone within 1 ms and completed within about 13 ms of tone commencement. Hangover of control beyond the end of a pulse is about 180 ms, restoration of transmission of the lower level tone being delayed during this time. This is an example of the difficulty experienced by a weaker signal taking over after a stronger signal, which was referred to earlier under Speed of Switching.

FURTHER DEVELOPMENTS

The original development of this circuit made use of germanium devices. However, a new circuit avoiding the use of germanium has been developed, and an improvement in the switching configuration[3] has enabled the introduction of gain with automatic level control to help bring speech from all lines to the same level. Return loss and switching sensitivity have also been improved.

In addition, the delay experienced by a weak signal breaking in after a strong signal is receiving attention.

APPLICATIONS

The circuit described was originally intended to replace that of the old PBX conference equipment, the Unit Amplifying No. 36A. In practice, however, the Combining Unit SA10198 is mostly installed as a free-standing facility on exchange lines, giving rein to user spontaneity in gathering correspondents together—some multi-national companies find this facility particularly useful. When installed in the free-standing mode, a single telephone is used together with a key-and-lamp unit to enable calls to be set up singly and then joined into the CONFERENCE mode.

The repeater can also be used at a PBX for telephone conference on a mixture of exchange lines, extensions and inter-PBX extensions.

References

1 JONES, R. A. A Prototype Conference Repeater Using a New Voice-Switching Technique. *Post Off. Electr. Eng. J.*, Jan. 1967, **59**, p. 246.

2 KUEBLER, W. P. A Multipoint Telephone Conference Bridge. IEEE Trans. on Communication Technology. Feb. 1968, **COM-16** No. 1, p. 168.

3 British Patent Specification No. 1 565 200.

A New Earth Station at Goonhilly Downs for a Satellite Service to Ships

Part 1–The Design of the Antenna and Radio Equipment

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UDC 621. 396. 676: 621. 396. 946

This article, which is in 2 parts, describes briefly how the INMARSAT ship's service functions and gives details of the equipment provided at the earth station at Goonhilly Downs to fulfil those functions. Part 1 describes the design of the antenna and radio equipment, and Part 2 (which will appear in a later issue of the Journal) will describe the access control and signalling equipment. The control and supervisory facilities are dealt with in Part 1 and Part 2 as appropriate.

INTRODUCTION

A recent article in the *Journal*[1] described the International Maritime Satellite Organisation (INMARSAT) system, which has been set up to provide highly-reliable world-wide communications between ships at sea and the major inhabited land masses. The UK is a member and the third largest shareholder of INMARSAT, and British Telecom International (BTI) has provided a coast earth station (CES), see Fig. 1, at its earth station at Goonhilly Downs to participate in the INMARSAT system.

† International Network Department, British Telecom International

FIG. 1—Goonhilly Downs coast earth station

THE INMARSAT SYSTEM

Services

The INMARSAT system offers automatic international telephone and Telex services as well as distress facilities. The UK CES enables ships to dial national and international calls directly over the public switched network in a similar manner to UK subscribers; distress messages, however, are recognised at the CES and routed directly by private wire to the Maritime Rescue and Co-ordination Centre (MRCC), which is operated by the Coastguard Service at Falmouth. In the shore-to-ship direction, direct dialling is possible for all but UK originated public telephone calls. Restrictions imposed by call charging facilities in the UK make it necessary for UK telephone calls to be made through an operator at any one of 6 international control centres located in London, Brighton, Leicester and Glasgow; the operator obtains a connection to the required ship automatically by dialling through the CES and plays no further part in the call except to record charging details. The MRCC has direct links to the CES and is able to dial any ship requiring assistance, without the intervention of an operator.

In addition to ordinary telephone and Telex calls, the UK CES provides facilities for

(*a*) telephony and Telex leased circuits,
(*b*) broadcast calls (that is, unidirectional calls from a single source to a number of recipients simultaneously),
(*c*) low-speed data (2·4 kbit/s), and
(*d*) short-form dialling for special services.

Future developments will include high-speed data (56 kbit/s).

The Communication Network

The completed INMARSAT network will comprise 3 pairs of satellites in geostationary orbit, one pair over each of the Atlantic, Indian and Pacific Oceans. One satellite of each pair will be used operationally, and the other kept in reserve in case of failure.

The coverage area of any one satellite is approximately a circle on the earth's surface, subtending an angle of 120° at the earth's centre; each satellite provides communication between any ship and any earth station in its coverage area. Within each area are a number of CESs which are authorised by INMARSAT, but owned and operated by the communication authorities wishing to offer a service to ships, and a network co-ordination station (NCS) that is operated by INMARSAT. The NCS supervises the operation of the system and controls the allocation of communication channels where necessary.

The UK CES operates in the Atlantic Ocean area, which it shares with stations already operating or under construction in the USA, Kuwait and Italy. A station in Norway is also operating in the Atlantic Ocean area, but it will be turned to operate in the Indian Ocean area, when the satellite serving that area becomes available later this year.

The satellites that are to be used over the Atlantic Ocean area are MARECS, supplied under contract to INMARSAT by the European Space Agency (ESA), and INTELSAT V with a maritime communication package, supplied by INTELSAT. The former satellite is already operational, and the latter is due to become operational later in 1982.

International agreements have allocated frequencies at C-band for CES operation and at L-band for ship earth stations (SESs). The frequencies used in the present INMARSAT system are given in Table 1. Frequency translation is provided in the satellite so that signals transmitted to the satellite at C-band are retransmitted to Earth at L-band, and those transmitted to the satellite at L-band are retransmitted at C-band. The CESs must operate at C-band for communication with ships and at L-band for communication with each other; the SESs, which communicate only with the CESs, only operate at L-band. Operation by the CESs at L-band is necessary for automatic frequency control (AFC) of the carriers transmitted in the system, for test purposes, to provide inter-CES order-wire facilities, and for reception of channel assignments from the NCS.

Telephony communication is on an analogue basis with a separate radio frequency (RF) carrier for each telephone channel, and narrow-band frequency modulation (NBFM) is used. Telex communication and signalling between the stations in the network are transmitted in digital form, multiplexed in time division, and modulated on a few carriers only by using binary phase-shift keying.

TABLE 1
Coast Earth Station Performance Requirements

Characteristic	C-band Requirements	L-band Requirements
Minimum Pass Band Transmit Receive	 6417·5–6425·0 MHz 4192·5–4200·0 MHz	 1636·5–1644·0 MHz 1535·0–1542·5 MHz
Antenna Figure of Merit (*G/T*)	32·0 dB/K	2·0 dB/K
Antenna Gain Transmit Receive	 54·0 dBi 50·5 dBi	 29·5 dBi 29·0 dBi
Polarisation Transmit Receive	 Right-hand circular Left-hand circular	 Right-hand circular Right-hand circular
Antenna Axial Ratio Transmit	 1·06	 1·3
Transmitter Linearity (level of inter-modulation products)	30 dB below each of 2 carriers having EIRP of 76 dBW (test level)	30 dB below each of 2 carriers having EIRP of 37 dBW (test level)
Transmitter Harmonics	60 dB below EIRP of carriers	Less than −23 dBW EIRP
Transmit Signal Level Stability	±0·7 dB with a probability of 0·95	–
Communication Signal Frequency Accuracy	Within ±230 Hz	–
Carrier EIRP (nominal)	66 dBW	36 dBW

EIRP: Effective isotropic radiated power
dBW: Decibels relative to 1 W
dBi: Decibels relative to an isotropic radiator

System Operation

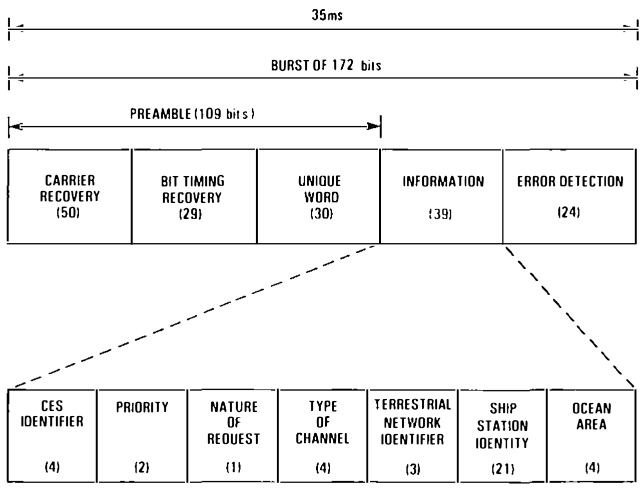
The full INMARSAT system provides for 299 RF carriers at frequency intervals of 25 kHz in each ocean area. Some 286 of these carriers are for telephone channels, the remainder being for *service request* and other digital transmission channels, order wires and AFC purposes. However, as a result of power limitations in the present satellites, only some 40 of the telephony carriers may be transmitted simultaneously, but it is estimated that this will provide adequate traffic capacity for the first few years of the service.

Digital transmissions from the CES and NCS are in the time-division multiplex (TDM) mode, while those from ships are in a controlled time-division multiple access (TDMA) mode for Telex traffic and in a random TDMA mode for the request channel.

One TDM channel, transmitted by the NCS, is designated the *common TDM channel* and, together with the request channel, is continuously monitored by all CESs in the area; each ship similarly monitors the common TDM channel except when it is engaged on a Telex call (in which case its TDM receiver is used for Telex reception).

Any ship wishing to make a call first signals its requirements on the request channel to one of the CESs. Although each CES continuously monitors the channel, only the station addressed in the message responds. The format of the *request* message is shown in Fig. 2. Access to the channel is on a random basis, but the short duration of the message makes it unlikely for 2 messages to occur at the same time. In the event of a clash, error detection using coding derived from a Bose-Chaudhuri-Hocquenhem (BCH) correction algorithm ensures that the earth stations detect the consequent errors and do not respond. The ships must then repeat the requests at intervals until a successful contact is achieved.

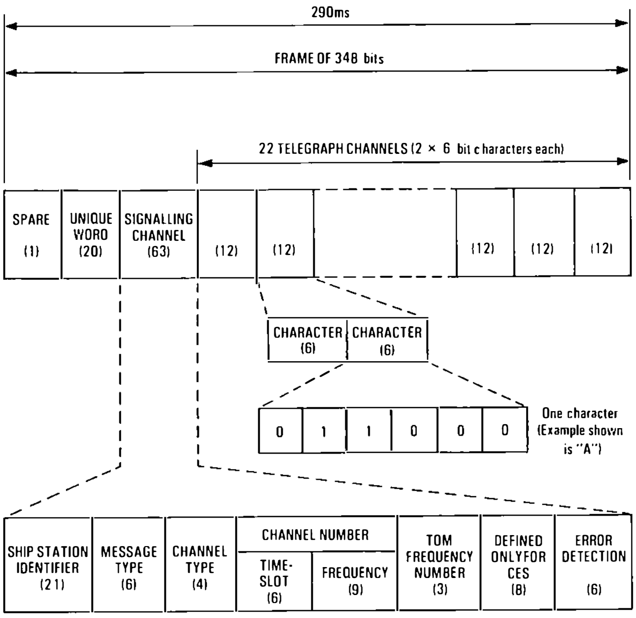
For a telephone call, the CES forwards the request via one of its own TDM carriers to the NCS, which allocates an operating channel and signals the channel number to both the ship and the CES in an *assignment* message on the common TDM channel. The format of a TDM channel is given in Fig. 3. Upon receiving the *assignment* message, the ship and the CES tune to the allocated channel; after a continuity check to confirm communication, the CES returns a *proceed-to-select* tone to the ship, and the caller then dials the required number. All signalling from then on is carried out in-band with the CES translating as necessary between the ship signalling and the inland signalling of the country



CES: coast earth station

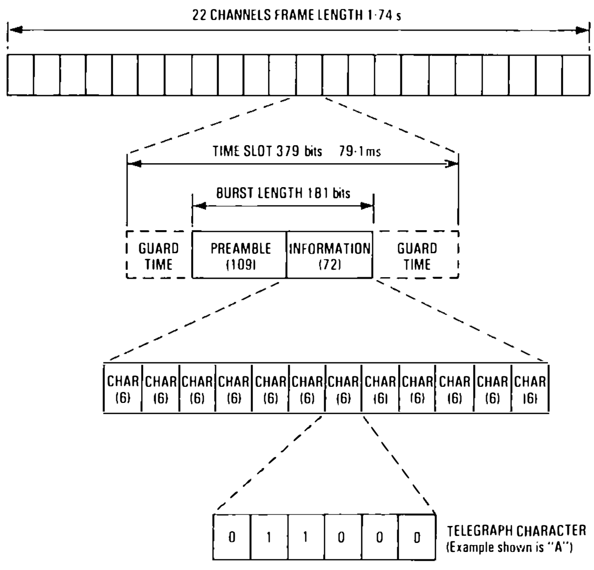
Notes: 1 The data rate is 4800 bit/s
2 The error detection coding is BCH 63,39
3 The figures in brackets indicate the number of bits allocated
4 The terrestrial network identifier is necessary only where there is a choice of common carrier

FIG. 2—Format of a *request* message



Notes: 1 The data transmission rate is 1200 bit/s; the Telex character rate is 151 character/s
2 In the telegraph channel, the first bit transmitted indicates the type of character field. When the first bit is 0, the subsequent 5-bit character field represents an international telegraph alphabet (ITA) No. 2 character; when the first bit is 1, the subsequent 5 bits represent line conditions for signalling
3 The figures in brackets indicate the number of bits allocated
4 The error detection coding is BCH 63, 57
5 The signalling channel is used in the CES's own TDM channel for *request-for-assignment* messages to the NCS. In the common TDM channel transmitted by the NCS it is used for the *channel assignment* message to the SES and the CES
6 The unique word is inverted every sixth frame

FIG. 3—Format of a time-division multiplex channel



CHAR: character

Notes: 1 The data transmission rate is 4800 bit/s; the Telex character rate is 151 character/s
2 In a telegraph channel, the first bit transmitted indicates the type of character field. When the first bit is 0, the subsequent 5-bit character field represents an international telegraph alphabet (ITA) No. 2 character. When the first bit is 1, the subsequent 5 bits represent line conditions for signalling
3 The preamble includes carrier recovery, bit timing recovery and the unique word, in a similar manner to the request message

FIG. 4—Format of a time-division multiple access channel

concerned. In the case of the UK, the CCITT† R2 system is used for inland signalling.

For Telex calls, the procedure is similar except that the CES itself allocates an unoccupied time-slot in its own TDM and TDMA carriers, and signals this to the NCS when forwarding the *request* message.

The CES transmits in the TDM format shown in Fig. 3. In order to multiplex channels destined for one earth station from a number of ships on a single carrier with maximum efficiency, operation in the SES-to-CES direction must be in a controlled TDMA mode; that is, each ship must turn its carrier on only for the duration of the time-slot allocated for it to send its digital signal burst. To ensure that each ship maintains time synchronism, the inverted unique word transmitted by the CES in its own TDM carrier is used as a reference. The TDMA channel format is shown in Fig. 4.

The procedure for calls in the shore-to-ship direction is similar to that in the ship-to-shore direction, with a channel being allocated by the NCS for telephony and by the CES for Telex. Advice of either type of call is sent to the ship from the CES via the NCS and the common TDM channel.

The UK Coast Earth Station

The UK CES comprises 4 main parts:

(*a*) A steerable antenna with equipment to enable it to track a satellite.

(*b*) Radio equipment to enable it to transmit and receive up to 39 carriers at frequencies in C-band (4 GHz/6 GHz) and up to 7 carriers in L-band (1·5 GHz/1·6 GHz).

(*c*) An access control and signalling equipment (ACSE), which accepts calls from ships and from the inland network, modulates and demodulates the necessary RF carriers, and carries out the necessary switching and signalling functions to enable the calls to pass through the INMARSAT system and be dealt with by a ship's terminal and the inland terminals. It also records all stages of the call to provide the raw data for billing and statistical purposes.

(*d*) A control and supervisory subsystem which provides automatic change-over to stand-by equipment in case of a fault and, like all the other antenna systems at Goonhilly Downs, enables the functioning of the CES to be monitored from the operations control area.

A block diagram of the CES is shown in Fig. 5.

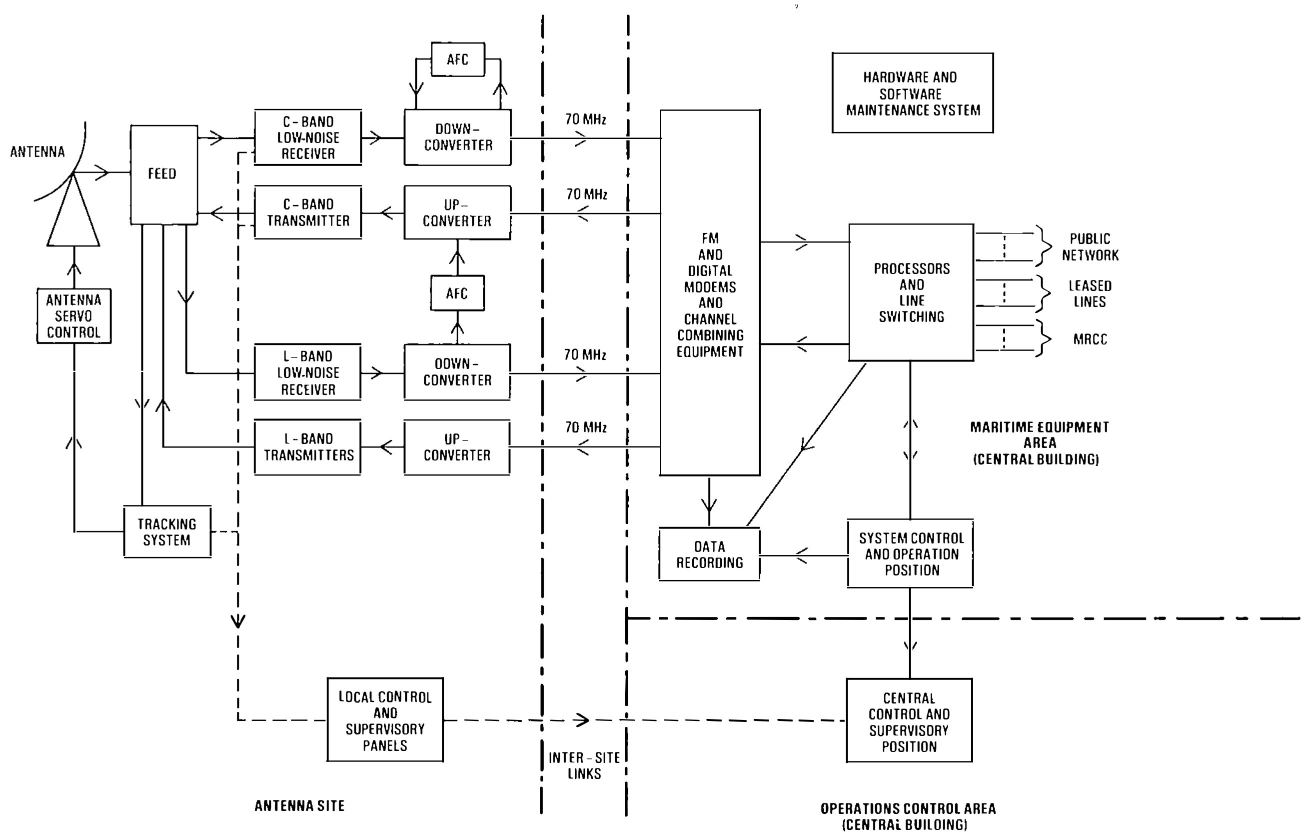
The antenna provided at Goonhilly Downs for the UK CES is considerably smaller in diameter than those previously provided for the INTELSAT service. This is because the parameters adopted by INMARSAT for reception at C-band by CESs require a signal-to-noise-density ratio (C/N_0) of 52 dBHz at the demodulator input, and a receiving system having a figure of merit (G/T) of 32 dB/K, which has been achieved at Goonhilly with an antenna of 14·2 m diameter. An antenna of that size also has sufficient gain to enable the carriers transmitted in C-band required by the CES at Goonhilly Downs to be provided by a 3 kW transmitter. The L-band antenna gain and G/T requirements for a CES are considerably less stringent than at C-band and are easily met with a 14·2 m antenna. It may be noted that each of the other antennas at Goonhilly Downs operating in the INTELSAT system normally provides several thousand telephony channels as well as a television channel. The INTELSAT system demands a C/N_0 of approximately 90 dBHz at the demodulator and a system G/T of 40·7 dB/K, which requires an antenna of some 32 m diameter.

ANTENNA STRUCTURE

General

The steerable antenna being provided for the CES at Goonhilly Downs has a parabolic main reflector with a hyperbolic

† CCITT—International Telegraph and Telephone Consultative Committee



FM: frequency modulation
AFC: automatic frequency control

FIG. 5—Block diagram of the coast earth station

subreflector and a corrugated horn feed arranged in a Cassegrain configuration. The antenna uses a rotating yoke to support the elevation axis above a high-level azimuth bearing as shown in Fig. 6; it is steerable ±135° of south in azimuth and 0–90° above the horizontal in elevation and has transmit gains of 56 dBi and 40 dBi at C-band and L-band, respectively. It can operate at wind speeds of up to 28 m/s and, when stowed at 90° elevation, will survive at wind speeds of up to 57 m/s.

Reflector and Subreflector

The main reflector is fabricated from 24 panels, which are formed from aluminium sheet rivetted to radial and circumferential aluminium reinforcing sections. The panels are independently adjustable to give a surface accuracy of within ±0·74 mm (RMS) and are supported by an aluminium space-frame backing structure comprising radial and circumferential trusses.

The subreflector is a fixed 1·5 m aluminium spinning mounted on a tetrapod support structure with elliptical legs to reduce aperture blockage. Access to the main reflector dish and feed can be gained at zenith by a hatch in the innermost of the 3 rows of panels.

Strong Ring, Elevation Wheel and Gear

The whole of the reflector structure is carried on a welded steel strong ring; bolted to this are the elevation wheel and the 2 self-aligning spherical roller bearings, which enable the antenna to be steered in elevation. The weight of the reflector structure is balanced around the elevation axis by counterweights located on the inside face of the elevation wheel. The elevation drive gear comprises a curved rack, 6·25 m in diameter and 0·15 m wide, attached to the outer face of the rotating elevation wheel, which meshes with 2 planetary pinions of the drive transmission system. A motor-operated steel pin engages with a bracket attached to the elevation wheel when the reflector is stowed at 90° elevation for survival in very-high wind conditions.

Antenna Pedestal Sub-Assembly

The pedestal sub-assembly consists of a truncated steel base cone supporting a box-section yoke, comprising a 1·25 m × 1·83 m steel girder base and 2 vertically-tapered welded steel arms, to which are fixed the elevation axis bearings. The base cone is bolted to the antenna foundation slab by 2 concentric rings of steel bolts cast in the concrete.

The interface between the base cone and the yoke consists of a 2·29 m pitch diameter crossed roller bearing, which enables the antenna to rotate in azimuth. A 2·54 m pitch diameter gear ring, 0·15 m in width, is attached to the outer (fixed) race of the bearing, which is bolted to the top of the cone tower. The base of the yoke houses the drive mechanisms and incorporates a circular mounting ring to interface with the inner race of the azimuth bearing. Pinions on the gearbox drive shafts engage with the azimuth gear ring to turn the antenna in azimuth. A cable wrap and waveguide rotary joint, which permit radio and electrical connections to pass between the fixed and rotating parts of the structure, are located inside the cone tower together with the azimuth position encoder.

Three main and 3 additional smaller working platforms are provided at different heights to allow access for maintenance to the bearings, drives and the elevated equipment room (EER) housing the low-noise amplifiers (LNAs) and the radio feed connections. Interconnecting stairways link the main platforms, with caged ladders providing an alternative exit from the main platforms in an emergency and also access to the smaller platforms.

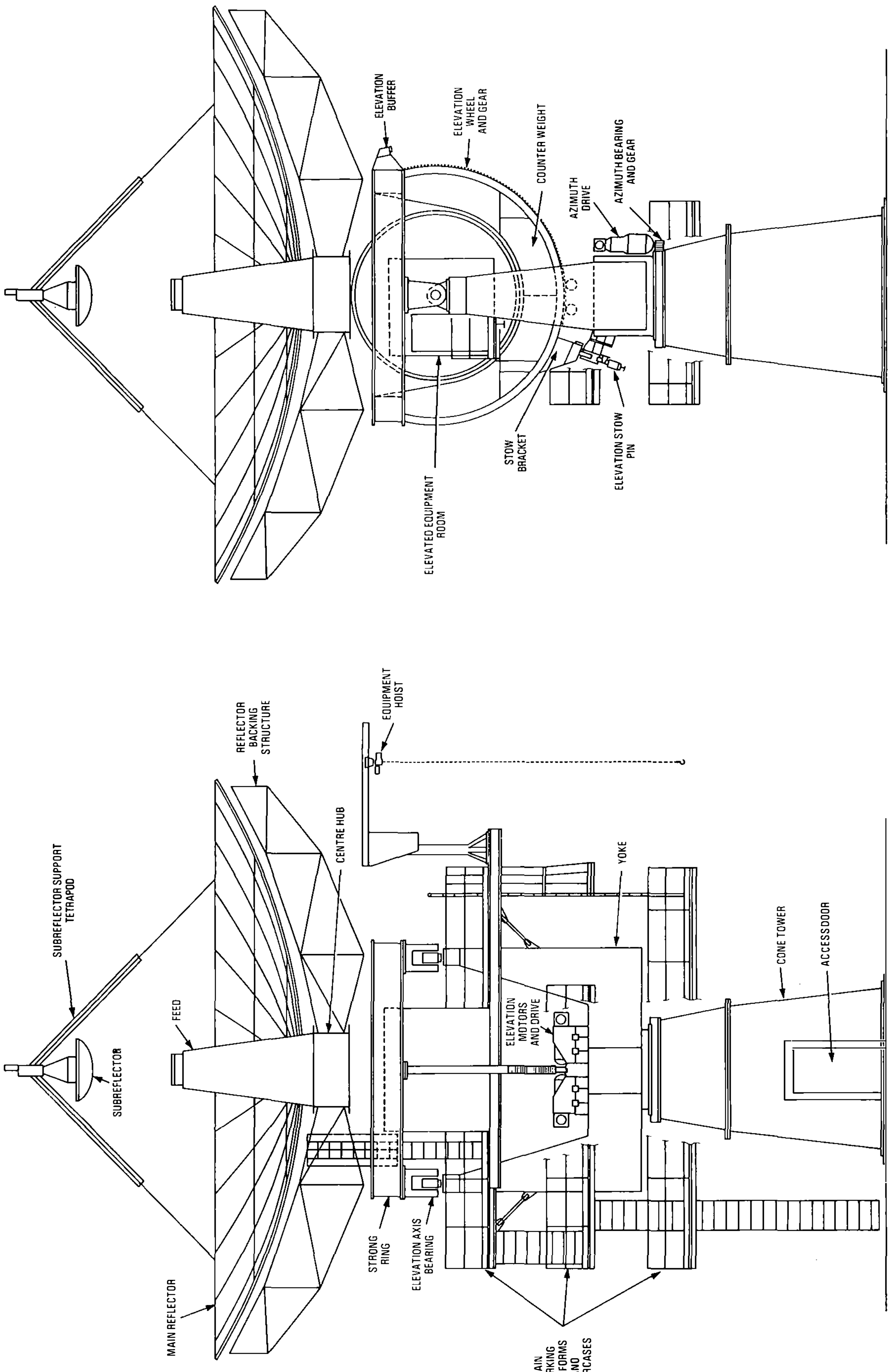


FIG. 6—Coast earth station antenna

Corrosion Protection

The aluminium subreflector, tetrapod, main reflector, and reflector backing structure are connected together with high-strength friction-grip joints using stainless-steel bolts, and left unpainted. The remainder of the structure is steel and is hot-dip galvanised except for the yoke base, elevation wheel and cone tower, which were either too large to be dipped or would have been distorted by the heat and have, therefore, been painted with a zinc-rich epoxy paint. After the steelwork has been galvanised or zinc painted, it is treated with an etch primer and 3 coats of micaceous iron-oxide paint in the factory, with a final coat on site. Stainless-steel shims are fitted between the aluminium and mild steel to prevent electrolytic corrosion.

FEED, TRACKING AND DRIVE CONTROL SYSTEM

General

The feed, tracking and drive control system used to track the maritime satellites is shown in Fig. 7 and includes components that allow the antenna to operate with the 2 satellites, MARECS and INTELSAT V, assigned to the Atlantic Ocean region; these satellites transmit left-hand circular polarised (LHCP) and right-hand circular polarised (RHCP) tracking beacons, respectively.

Feed

The antenna is fitted with a hub-mounted dual-polarisation C-band feed modified by providing L-band injectors into the corrugated horn at the appropriate cross-sections. The principles of operation of dual-polarisation feeds have been described in a previous article in this *Journal*[2]; the feed incorporated in the CES includes a C-band diplexer for demultiplexing the transmit and receive bands, with separate polarisers for each. Although the feed can transmit with either direction of polarisation at C-band, only the RHCP port is used in this application. However, in the receive band, one or both ports may be used depending on the polarisation of the satellite beacon. With the exception of the beacon, C-band signals received at the CES are always LHCP.

To accommodate the RHCP and LHCP tracking beacons, the CES includes a polarisation injection filter (PIF) between the 2 feed output ports and the LNAs. The PIF is a narrow-band filter that couples the INTELSAT V RHCP tracking beacon into the LHCP communications path; thus the need for separate LNAs for RHCP tracking is eliminated. When the system is not working to INTELSAT V, the PIF is removed.

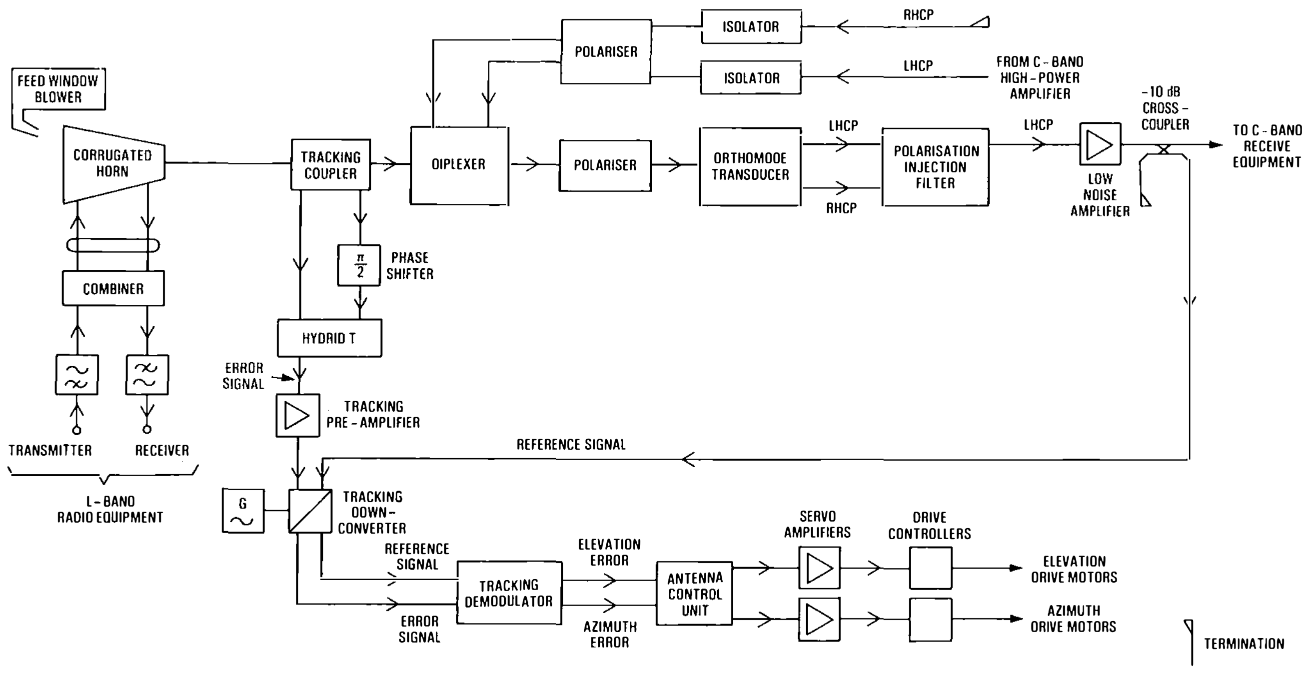
The feed is pressurised through the transmit waveguide, and an over-pressure alarm is provided to protect the mylar feed window. Warm air is blown across the window to prevent the accumulation of moisture and dust.

Tracking Demodulator

A TE_{21}-mode tracking coupler in the feed supplies a combined axis error signal which, together with the tracking beacon coupled from the communications path, is down-converted to 70 MHz by a dual-channel, double down-converter. The two 70 MHz signals are supplied as *error* and *reference* channels, respectively, to the tracking demodulator (see Fig. 8), which uses a phase-locked loop (PLL) to decode the error channel into separate elevation and azimuth error signals.

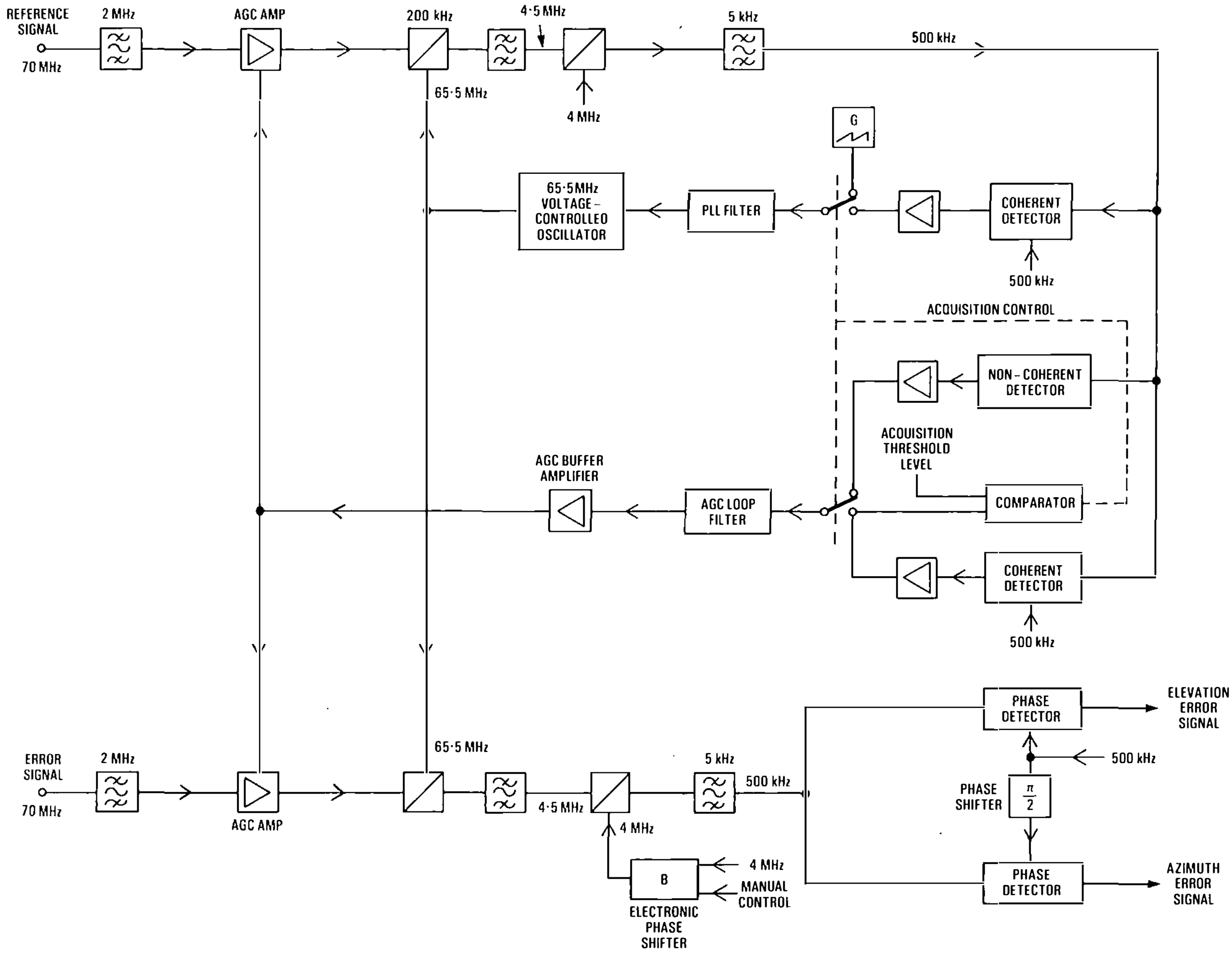
The tracking beacon (reference channel) is also used for automatic gain control (AGC); input variations, common to both channels, of up to 40 dB are reduced by the AGC loop to less than ± 1 dB so that the only significant changes in signal level in the error channel are those due to changes in pointing angles.

Acquisition of the beacon signal is established within the AGC loop from the output of a non-coherent detector. As the frequency of the output of a saw-tooth generator sweeps through the selected frequency band, the output of the non-coherent detector is a beat note of declining frequency superimposed on a DC signal; the former is audible on a loud-speaker as a manual tuning aid, and the latter is used to determine whether phase lock has been established. When phase lock is acquired, the PLL is completed and the AGC loop switches from a non-coherent to a coherent detector,



LHCP: left-hand circular polarisation
RHCP: right-hand circular polarisation

FIG. 7—Feed assembly and monopulse tracking system



AGC: automatic gain control
PLL: phase-locked loop

FIG. 8—Tracking demodulator

which has better frequency discrimination. Acquisition can be carried out automatically in the tracking receiver or manually under the control of an operator.

The PLL compensates for phase variations that are common to both channels; differential phase change can be eliminated by a front-panel control, which varies the control voltage to an electronic phase shifter. Noise bandwidth is manually selectable, with the sweep bandwidth and rate automatically determined by the bandwidth selection; the centre frequency of the sweep is set by a manual tuning adjustment. Facilities are also available for a manual frequency search.

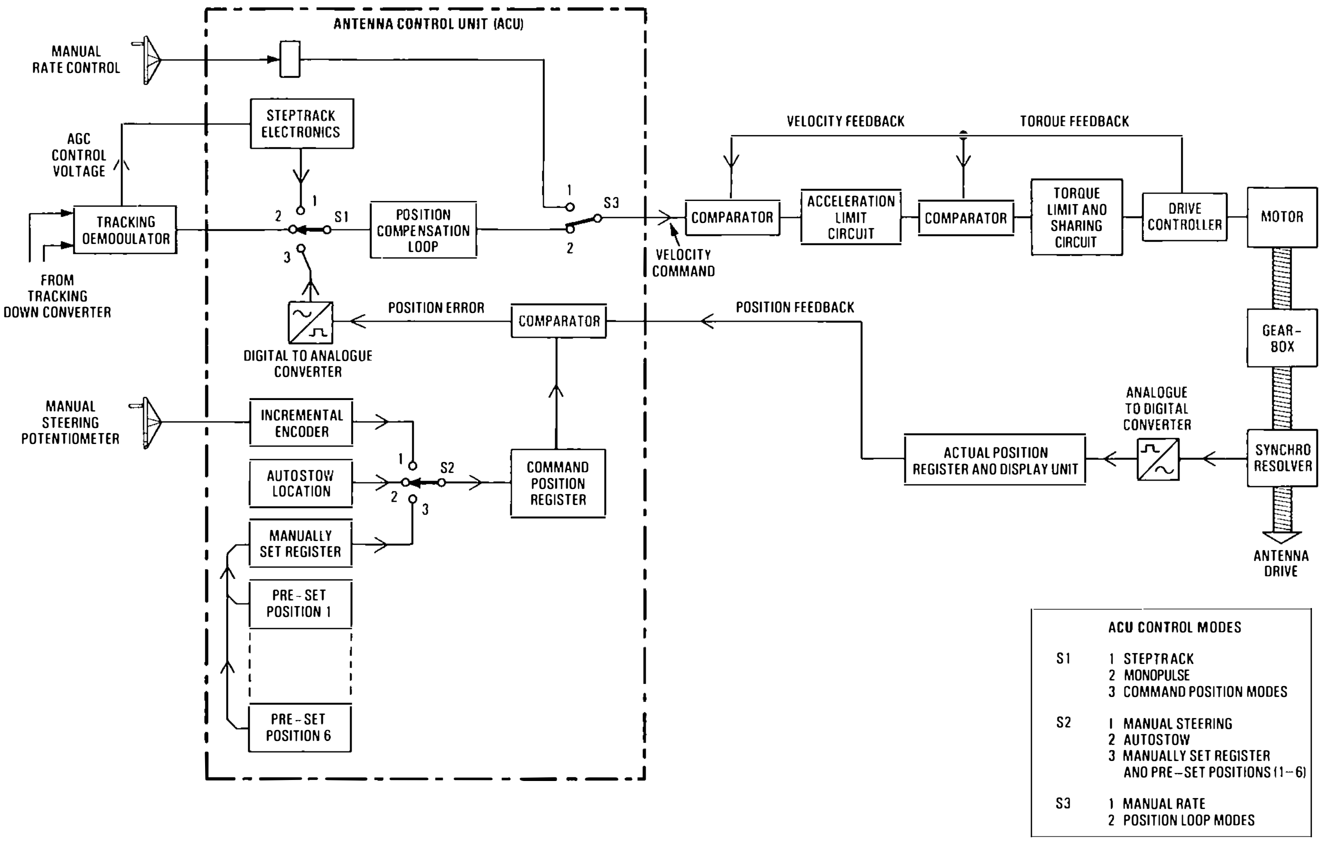
In addition to monopulse tracking, the antenna has a *step-track* mode. In this mode, the antenna is made to turn a small pre-determined distance in one direction, and the AGC feedback voltage from the demodulator is used to determine whether the signal received from the satellite has increased or decreased in power as a result of this movement. If the power has increased, the equipment deduces it has turned in the right direction and makes a further similar move. If, however, the signal decreases, the equipment deduces it has made an incorrect move and turns in the opposite direction. By acting in the azimuth and elevation planes in sequence, the antenna centres itself on the satellite.

The tracking demodulator allows various tracking alarm thresholds to be set and displayed, including tracking thresholds (level), error threshold (degrees) and the tracking acquisition level. If any of these thresholds is exceeded, an alarm output is generated by the demodulator.

Antenna Control Unit

The function of the antenna control unit (see Fig. 9) is to select the antenna steering and tracking mode that is required, to provide appropriate control signals to the servo amplifiers as velocity commands, to display the status of the antenna, and to select the step-track parameters. In addition to the 2 automatic tracking modes (monopulse and step-track), a number of steering modes are available. When the monopulse mode is selected, the errors from the tracking demodulator are fed via switch S1 to the position compensation loop, which incorporates a threshold detector to decide between alternative feedback loops. For small tracking errors, an integrator with capacitive feedback is used which gives a ramp output voltage to overcome stictional forces in the antenna drive machinery. Once the antenna starts to move, or for large tracking errors, negative feedback is selected to give an output voltage that is proportional to the positional error.

The various steering modes available all use the position compensation loop shown in Fig. 9 to generate velocity commands to the antenna drive system, except for the manual-rate mode when the velocity commands are derived from manually-controlled panel-mounted potentiometers. In the position compensation loop, a comparison is made between the contents of an actual position register and a command position register to determine the positional error that must be corrected by the antenna drive system. The contents of the former register are derived from synchro-resolvers attached to each antenna axis and are shown on a position display unit. The command position register can be loaded with the



Note: one axis only shown and single drive motor

FIG. 9—Simplified block diagram of the antenna control unit and the servo-drive unit

following:

(*a*) one of up to 6 stored satellite angular locations,

(*b*) the contents of a manually-set register,

(*c*) the elevation angle (+90°) selected by the auto-stow mode (for stowing the antenna in very high wind conditions), or

(*d*) the output of an incremental encoder driven by the manual steering potentiometer.

The Drive Control System

Each axis has a separate drive control system comprising a servo amplifier and 2 motor controllers. The servo amplifiers, housed in the drive control cabinet, incorporate 2 parallel feedback loops: the velocity loop and the torque loop. The velocity loop uses negative feedback of both current and voltage from a silicon-controlled rectifier (SCR) motor controller to limit the rate of acceleration and velocity. To eliminate backlash in the drive gears, a DC bias is added to the output of the velocity loop, and the resultant is divided equally between the 2 motor controllers. Errors in speed developed in the torque feedback loop are fed equally in amplitude, but opposite in sign, to each motor controller to eliminate differences in motor speed.

DRIVE TRANSMISSION SYSTEMS

Dual 7·5 kW DC drive motors are provided on each axis for both tracking and repositioning; they are capable of a pointing accuracy of 0·01° RMS at wind speeds of up to 28 m/s and a re-positioning velocity of 1·0°/s. The antenna can operate with a single drive motor, but with reduced tracking accuracy. The motors drive through individual differential units and gearboxes, and there are separate input shafts for either a handcrank or a small auxiliary AC motor, both of which drive through electrically-operated clutches. Backlash is reduced in the design of the gearboxes by using helical gears that have close manufacturing tolerance, and by the counter torque bias applied by the servo amplifiers.

RADIO FREQUENCY EQUIPMENT

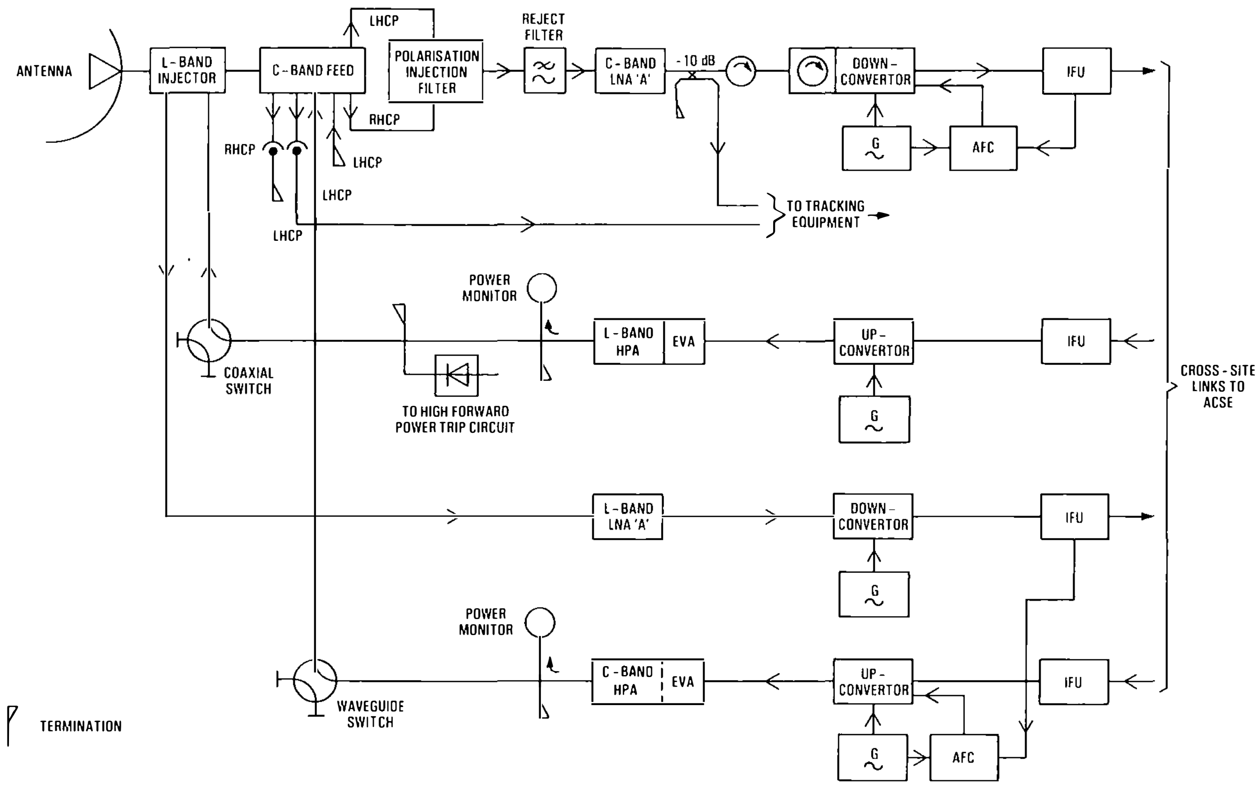
General

The RF equipment comprises duplicated C-band and L-band transmit and receive chains, an AFC system and associated switching and test equipment. A simplified block diagram of the RF equipment is shown in Fig. 10.

Automatic Frequency Control

The demodulators used in the INMARSAT system can tolerate only small frequency errors because the pre-detection filters have a limited noise bandwidth. To reduce the combined effect of satellite Doppler frequency shift and satellite frequency translation errors, which may total as much as 55 kHz, an AFC system is provided at the CES to pre-correct the frequency of its transmitted communications carriers and post-correct the frequency of its received carriers. At present, each CES is transmitting its own high-stability carrier for AFC purposes. In January 1983, however, the system will be changed so that one nominated CES in each of the northern, southern and equatorial regions of each ocean area will transmit 2 high-stability AFC carriers, one at C-band and the other at L-band. These carriers will be received by all the CESs in that region at L-band and C-band, respectively, after transmission through the satellite.

The C-to-L path at the CES uses a receiver having a PLL with a phase-sensitive detector in which the phase of the received pilot and that of a reference oscillator are compared and used to control the C-band up-converter. In this manner, the transmitted communications carriers are pre-corrected by



AFC: automatic frequency control EVA: electrically-variable attenuator HPA: high-power amplifier IFU: intermediate frequency unit
LHCP: left-hand circular polarisation LNA: low-noise amplifier RHCP: right-hand circular polarisation

Note: for simplicity, no redundant equipment or test equipment is shown

FIG. 10—Simplified block diagram of the radio-frequency equipment

the CES so that they are received by the SESs at a frequency within ±230 Hz relative to nominal. In the L-to-C path, the output of a phase-sensitive detector is used to adjust the frequency translation of the C-band down-converter so that the carriers are post-corrected to within ±600 Hz of their nominal frequency. The AFC module includes a memory which stores the received pilot offset from nominal frequency and, if the synchronisation of the pilot is lost, initiates a frequency search centred on the last known frequency of the received pilot. The memory of the standby AFC system is updated by the on-line system so that synchronisation is quickly re-established after a change-over from one system to the other.

Intermediate-Frequency Equipment

The individual carriers are combined (transmit path) or separated (receive path) in the ACSE, which interfaces with the RF equipment at a 70 MHz patch panel in the maritime equipment area. The ACSE is linked by coaxial cables to the antenna site where the signals are processed by single-channel-per-carrier (SCPC) intermediate-frequency (IF) modules, which incorporate cable equalisers, amplitude equalisers and level adjusters. In addition, the receive chains incorporate a splitter for extracting the pilot and the transmit chains include a combiner for pilot injection.

C-band Frequency Translators

The C-band transmit IF is double up-converted to the frequency range 6410–6425 MHz; the first mixer uses a 700 MHz signal from a voltage-controlled crystal oscillator controlled by the AFC phase comparator, and the second mixer uses a very-high frequency (VHF) crystal oscillator.

The C-band down-converter translates frequencies in the range 4180–4200 MHz to a band centered at 70 MHz and has a similar 2-stage construction to the up-converter; the oscillator control voltage is derived from the L-to-C pilot offset.

C-band Transmitters

High-power amplification is provided by duplicated 3 kW air-cooled klystron amplifiers (known as the *high-power amplifiers* (*HPAs*)), which have a 1 dB bandwidth of 45 MHz and are tunable over the necessary frequency range. The other elements of the amplifiers are very similar to those used elsewhere at Goonhilly Downs, and are described in a previous article in the *Journal*[3].

The high-voltage power supply used for the HPAs includes a purpose-designed ripple regulator to reduce the level of discrete components of phase noise resulting from spectral components of the supply voltage on the collector supply. The INMARSAT specification for transmitter phase noise is more stringent than the existing INTELSAT specification because of the effect of phase noise on the bit error rate at the low data speeds used on the phase-shift keying (PSK) modulated channels.

It is necessary to operate the transmitters at an output that is considerably less than their rated output in order to achieve adequate linearity for multicarrier operation.

C-band Low-Noise-Amplifiers

Two Peltier cooled low-noise parametric amplifiers are provided, each with a 1 dB bandwidth of 500 MHz and a noise temperature of 57 K when configured as a redundant sub-system with an input waveguide switch and a test coupler. The complete LNA assembly is mounted on a plate attached to an extension of the feed support frame in the EER. Coaxial cables and control cables connect the LNAs to the frequency translators and to the LNA control panel, respectively, in the equipment building.

L-band Super-High Frequency Equipment

The duplicated L-band HPAs have a 200 W output over the frequency range 1000–2000 MHz and incorporate a travelling wave tube operating in the depressed collector mode. Forced air cooling is provided for the HPAs and their associated power supply units, the output being discharged into the equipment room. To achieve adequate linearity, the HPAs are operated at much less than their rated output.

The 2 LNAs are solid-state devices with a minimum gain of 51 dB over the frequency band 1530–1545 MHz and a noise temperature of 226 K.

Both the HPAs and LNAs are rack mounted in the main equipment area and are connected to the feed by low-loss coaxial cables.

Test Equipment

Fixed test equipment, in the form of both purpose-built and proprietary test equipment, is provided for regular operational maintenance. Two test translators permit the stand-by equipment to complete in-station super-high frequency (6 GHz-to-1·5 GHz and 1·6 GHz-to-4 GHz) loops for testing of the overall system. The gain/frequency response of the stand-by LNAs alone can be displayed *in situ* by using a gain-bandwidth assembly, comprising a sweep generator and an X-Y display. Two test down-converters are provided to allow the traffic HPAs to be monitored by using a spectrum analyser. The test equipment also includes an off-air frequency standard and frequency counter for accurate adjustment of local oscillators, and RF power monitors for displaying the HPA output powers.

Redundancy

Redundant equipment is provided for each of the communications chains with automatic path switching on equipment failure and manual path selection for equipment maintenance. Automatic waveguide and coaxial switches are fitted at the input and output of the transmit and receive equipment chains respectively and between the IF equipment and the cross-site links. Similarly, all the tracking equipment between the outputs of the feed and the inputs to the drive control cabinet are duplicated; the tracking preamplifiers in a one-for-one configuration, and the remaining units in 2 parallel paths with the output of the selected path being forwarded to the drive control cabinet.

Control and Supervisory Equipment

Control and supervisory facilities for the antenna and the RF equipment are provided in 2 locations: the antenna equipment building (local) and the central building (remote). Indications of the failure of the traffic path and equipment are given in both locations and, in a similar manner, local and remote controls exist with control being delegated from the active control panels to the passive control panels.

Equipment alarms are provided at shelf, suite and equipment room levels and are integrated into the station alarm system. Each suite of racks has an associated RECEIVING ATTENTION key-and-lamp unit, which maintenance personnel use to clear the alarm indications whilst the fault is being dealt with.

Local control and status indications for the antenna system are provided by the antenna control units previously described, and switching between redundant equipment is controlled by a tracking redundancy unit for the tracking pre-amplifiers and by a redundancy switching unit for the remainder of the redundant tracking equipment. Remote facilities are provided by a remote control unit.

For the RF equipment traffic path and AFC sub-system, switching is controlled from 2 mimic panels, one associated with the C-to-L band equipment and the other with the L-to-C band equipment; the 2 panels are duplicated in both control locations. In addition, provision is made for local and remote monitoring and control of the output power level of each of the 4 HPAs.

Performance

Table 1 itemises the main parameters specified by INMARSAT that determine the performance of the system, and Table 2 and Table 3 show some of the major performance characteristics of the equipment. For the transmitting equipment, one of the most critical parameters of the system operating in a SCPC mode is the level of third-order intermodulation products which is related to the degree of transmitter back-off. The maximum level of intermodulation products permitted by INMARSAT is −30 dBc† relative to the level of the 2 test carriers of 76 dBW and 37 dBW for C- and L-band, respectively. The CES at Goonhilly Downs achieves levels of −38 dBc and −47 dBc, respectively.

The single most important parameter for the receive equipment is the *figure of merit* or *G/T*, which is quantified in Table 3. To meet the permissible C-band requirement of

† dBc—decibels relative to the carrier power level

TABLE 2
Transmit System Performance

Parameter	C-band (6·4 GHz)	L-band (1·64 GHz)
No. of AFC carriers*	1 at 66 dBW (max.)	1 at 37 dBW (max.)
No. of telephony carriers	35 at 66 dBW	4 at 37 dBW
No. of TDM carriers	3 at 63 dBW	2 at 37 dBW
Total EIRP	81·7 dBW	45·4 dBW
Antenna Transmit Gain	57·3 dBi	43·5 dBi
Transmit System Losses	2·7 dB	5·2 dB
Required Output Power	21·7 dBW	7·1 dBW
Max. transmitter power	34·8 dBW	23 dBW
Transmitter back-off	7·7 dB	15·9 dB
Transmit System Linearity	46 dB below each of 2 carriers having EIRP 75 dBW	54 dB below each of 2 carriers having EIRP 37 dBW
Transmitter Harmonics	<70 dBc	−93 dBW EIRP

*May not be required in future

TABLE 3
Receive System Performance

Parameter	C-band (4·2 GHz)	L-band (1·54 GHz)
Receive System Gain	54·3 dB	42·9 dB
Noise Temperature of LNAs	47 K	2570 K
Antenna Noise Temperature at 5° elevation	64 K	118 K
Figure of merit (G/T) at 5° elevation	33·8 dB/K	8·6 dB/K

Note: The performance figures shown are referred to the outputs of the feed

32·0 dB/K it is necessary to situate the LNAs close to the feed in the EER; whereas in the L-band, the required specification of 2·0 dB/K can be met with the LNAs in the main equipment area and by connecting them to the feed with 35 m of coaxial cable.

To be continued

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British Telecom Press Notices

NEW ANTENNAS FOR THE GOONHILLY AND MADLEY EARTH STATIONS

British Telecom International (BTI) has placed a contract for 2 new antennas for its earth station at Madley in Herefordshire and intends to place a further contract for a new antenna for its earth station at Goonhilly Downs in Cornwall.

The contract for the new antennas at Madley, the main reflectors of which will be 19 m in diameter, has been placed with the Toronto Iron Works in the United States at a total cost of £2·6M; the associated civil engineering works are to be carried out by the British company, International Design and Construction Ltd., at a cost of approximately £1·6M. It is intended to place the contract for the new antenna at Goonhilly, the main reflector of which will be 32 m in diameter, and the associated civil engineering work with Marconi Communication Systems Ltd. (MCSL); the cost is expected to be approximately £3M. In addition, it is intended to place contracts worth several million pounds with MCSL for telecommunications equipment for all 3 new terminals.

The new antennas at Madley will both work in the 14/11 GHz frequency bands. One will form part of a new earth-station terminal (Madley 4) working to the European Communication Satellite System, and the other part of a new terminal (Madley 5) working to an INTELSAT satellite over the Atlantic Ocean.

Madley 4 will be used initially, from about the end of 1983, to carry television programmes in the Eurovision network, but its primary purpose will be to provide (from about mid-1984) new telephony, Telex and data circuits to the more distant countries of Europe. Madley 5 will come into operation in mid-1984 and will be the eighth BTI terminal operating to the INTELSAT system. The new antenna for Goonhilly will form part of a new 6/4 GHz terminal (Goonhilly 6), which will also be used with the INTELSAT system from the end of 1984.

NEW ELECTRONIC TELEPRINTER WITH VISUAL TEXT DISPLAY

A new microprocessor-controlled electronic Telex terminal with a visual display screen and a conventional printer was introduced earlier this year by British Telecom (BT) for the public Telex network. The terminal, known as the *Cheetah*, offers customers many extra facilities, and its quiet operation and modern appearance makes it suitable for use in general offices, as well as in Telex rooms.

The Cheetah augments the new generation of electronic teleprinters with which BT is meeting the challenge of competition and the needs of customers. Other machines in the range are the Puma and the TP65.

Some of the facilities provided by the Cheetah are outlined below.

Off-line message preparation Outgoing messages are typed into an electronic store and presented to the operator on the visual display screen, while the reception of incoming messages or the transmission of outgoing messages through the teleprinter continues without the operator's work being interrupted; date and time are automatically added to each message when it is transmitted.

Editing and justifying Operators can insert, correct or delete parts of messages entered from the keyboard or from paper tape into store, and the operator is able to type freely, as the text is automatically adjusted by the machine at the end of lines; thus, split words are also avoided.

Automatic operation Stored messages can be transmitted at pre-set times without further action by the operator being required. If the distant machine is busy, the Cheetah makes a number of further attempts; the same message can also be sent to many destinations.

Short-code calling Up to 16 Telex numbers can be stored in the Cheetah's memory, and called automatically in response to a one-character code; the codes can also be used in automatic operation.

Keyboard calling The Cheetah has no dial: numbers are called by the operator pressing the figures on the keyboard or by selecting a short calling code.

Automatic pagination A message can be printed in A4- or A5-sized page lengths for ease of filing. Text presentation, on both the screen and the print-out, discriminates between received and transmitted characters.

Fault diagnosis The Cheetah's central microprocessor runs continuous fault-finding checks; if a fault occurs, the operator is prompted and can work through routine checks to identify the problem.

Control keys which enable users to select these facilities are sited above and to the right of the standard 4-bank typewriter keyboard.

The Cheetah can be supplied with a memory of 16 000 or 32 000 characters equivalent to 2250 or 4500 words. A back-up battery protects it against any temporary failure in the mains supply or disconnection. The Cheetah is available as a desk-top unit; it can also be supplied with a plinth, which is an optional extra. Customers wishing to retransmit messages on, or from, conventional teleprinters can obtain a punched-paper-tape attachment, which is also an optional extra.

The new teleprinter is being supplied initially in the London and the Midland Regions of BT; it will become available elsewhere in the UK during the rest of the year.

BT has started an instruction programme both for its staff and customers to highlight the simplicity and effectiveness of the Cheetah's advanced technology; this programme, which is video based, enables BT to demonstrate the advantages of the teleprinter's facilities and to help users get the most from their machines.

Removable Bodies for the 15 cwt Range of Vehicles

G. H. WAGG†

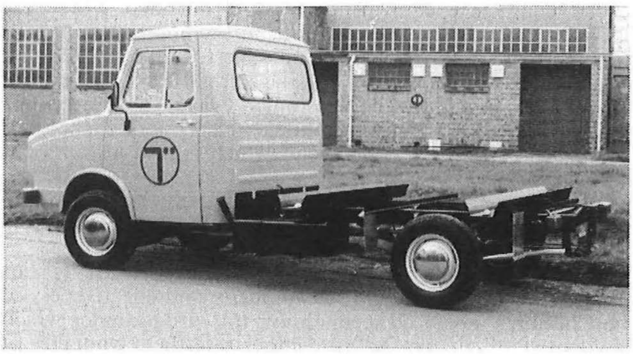
INTRODUCTION

A major portion of British Telecom's (BT's) fleet of 60 000 vehicles consists of the 15 cwt payload type, which are mainly used in the fields of installation and jointing. Vehicles supplied in the past have been mainly of the integral-panel type of van of Commer/Dodge manufacture. However, considerable problems in the utilisation and maintenance of these vehicles have been experienced. Approximately 17% of serviceable vehicles stand idle every day, and their use for alternative work is difficult, as they are generally job related and contain stores, tools and personal safety equipment. The bodywork of the panel vans is prone to rusting, and the motor transport workshops have to spend considerable time in costly rectification of bodywork. In addition, as with most BT vehicles, stores and equipment have to be transferred to other vehicles when the vans are serviced. This type of vehicle is not regarded as ideal for certain applications, since access to stores and equipment being carried in the rear is rather restricted. Numerous variations of the standard type of vehicle have been developed over the years to meet BT's special needs; therefore, scope for rationalisation was possible if greater flexibility of use for these vans could be introduced.

REMOVABLE BODY CONCEPT

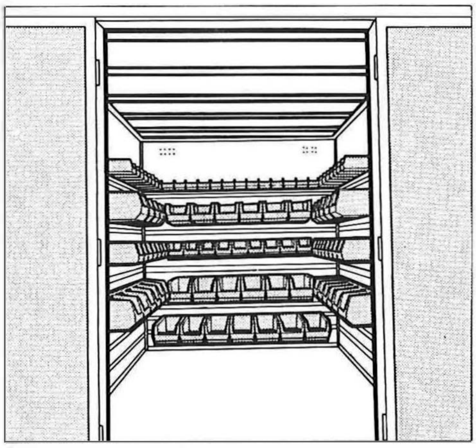
To assist in overcoming these problems, the Motor Transport Division of BT Headquarters developed a lightweight removable body that could be fitted to any currently available chassis cab. It was considered that the concept of a removable body would assist utilisation in a number of ways. It would allow the chassis cab to be used while the body and its equipment remained at the depot. The number of vehicles employed would be reduced and a great deal of the time spent in changing over vehicles for servicing would be eliminated. A purpose-built body with a universal fitting system for the interior bins and brackets would be of reasonable size to allow easy access and would provide scope for rationalisation and complete user flexibility. Also, the introduction of a chassis cab would reduce the requirement for maintenance, and having a body built of non-corrosive materials would drastically reduce expensive bodywork repairs.

† Energy, Transport and Accommodation Department, British Telecom Headquarters

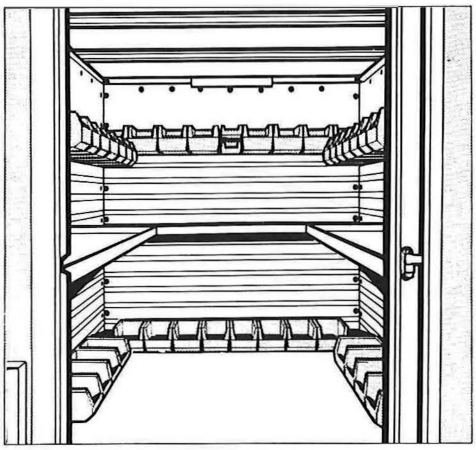


Typical 15 cwt chassis cab showing U-section cross members

The success of this project depended upon the production of a lightweight body which, at an acceptable cost, allowed a similar payload to the conventional vehicle to be carried and which stayed within the same gross maximum weight. The development of the body centred on the production of lightweight body panels having sufficient inbuilt strength to support the loading of the interior bins and brackets. Thus, a panel consisting of colour-impregnated glass-reinforced inner and outer plastic skins with a foam sandwich insert was developed in conjunction with body-panel suppliers. Rectangular uprights of aluminium were spaced vertically at 305 mm intervals in the sandwich to form the main load-bearing members for all the interior fitments. A plywood-foam sandwich floor was used to give a lightweight self-supporting structure without the numerous cross-loading members usually encountered. The same material as for the panel was used for the construction of the single centre door in the rear, and the 2 small locker doors on either side of it. A single-skin translucent roof and conventional aluminium extrusions for corner pillars and side members completed the structure. When finished, the body had interior measurements



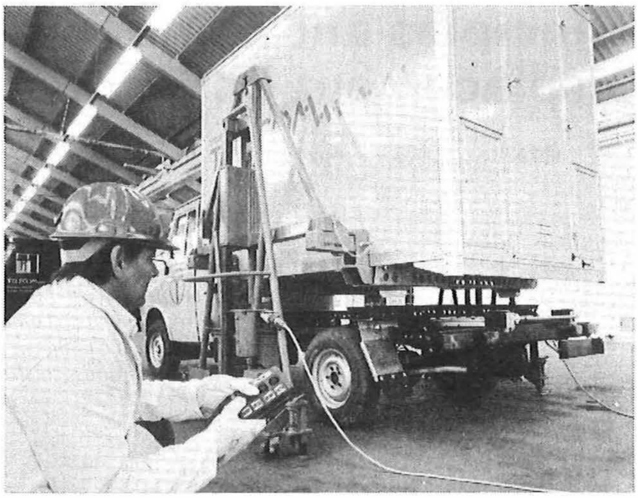
(a) Interior of body fitted out with bins only



(b) Interior of body fitted out with a mixture of bins and shelves

Interior fittings

Fork-lift truck method of body removal



Trolley method of body removal

of 2600 mm in length, 1830 mm in width, and in the centre a height of 1905 mm; with a weight of approximately 250 kg, the body weighed little more than the weight of the steel panels of the conventional panel van. In addition, by building the supports for the interior fittings into the wall panels, maximum utilisation of the available load space became possible; the nominal capacity of the body was enlarged to $9 \cdot 06$ m^3 as against $5 \cdot 66$ m^3 for the current panel van.

INTERIOR FITTINGS

In the interior, universal fitting was accomplished by the use of aluminium Z sections horizontally spaced at 110 mm intervals and riveted to the rectangular inserts in the panel, so that conventional shelf brackets or plastic bins could be slotted onto the Z sections.

Interior brackets were developed to enable various items of equipment to be carried, and a standard range of shelving was made available. Lashing rings were incorporated at floor level so that suitable hooks could be positioned to secure heavy items of equipment, and fence boards could be fitted to the floor to secure loose items. A roller was incorporated into the rear-side locker-door opening to make the loading of ladders easier, and the available area inside the off-side door could be easily converted into a gas locker by means of an easily assembled kit. It was felt that if this new type of vehicle proved successful, then a long-term objective would be to provide kits of this type for various equipment in order to enable a standard body to be easily converted to meet the requirements of a particular occupational group (heater kits are already available). Interior lighting consisting of two 12 V fluorescent lamps, with the electrical supply to the body being automatically connected, was installed; ventilation was also incorporated to prevent excessive heat building up through the translucent roof.

BODY REMOVAL

The demountable body systems that are available commercially have a cost and weight penalty that is unacceptable on this type of vehicle. With BT's system, the body is removed by external means. Two U-section cross members made of steel were fitted to the chassis with 2 mating members fitted to the body. The body members were fitted with nylon feet which acted as positioning guides to ensure clearance when the body was standing on the ground. The chassis members had guide slots and incorporated 4 twist locks which firmly clamped the body to the chassis. The removal of the body can be accomplished either by the use of a fork-lift truck or by a trolley-lifting attachment that has been specially developed for this application. The body cross member was designed as a pocket for the forks of the lift truck, and an adaptor was made to ensure the stability of the body on the forks. The trolley method uses 2 trolleys which have short stubs for insertion in the cross members; a trolley is positioned on either side and the body is electro-hydraulically lifted from a 12 V battery supply. Although BT has limited on-site use for bodies on their own, a sling was developed to enable a body to be carried and unloaded on site by a stores carrying vehicle.

Sling in use in conjunction with stores-carrying vehicle

FIELD EVALUATION

Considerable testing on the material used in the construction of the body, together with track testing, was carried out in order to determine the stability of the vehicle and to obtain clearance by the manufacturer for the method of fixing the body to the chassis. A trial to enable the removable-body concept to be evaluated has been arranged, and each Region will receive 25 vehicles, most of which will be based at one depot; a competitive contract has been placed for 250 of British Leyland's Sherpa chassis cabs, and the contract for the bodies has been spread between 4 body builders.

Principles and Performance of Insulation Displacement Connections

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UDC 621.315.683.004

The need for a high-speed high-density connection system to meet the needs of the rapidly expanding cable network and variety of subscribers' terminal equipment has highlighted the importance of the efficiency and reliability of the wire connector. To meet this growing requirement, British Telecom is introducing insulation displacement connection techniques. This article describes the general principles of the system and details some of the work carried out to test the reliability of the techniques.

INTRODUCTION

In the UK, the expansion of the British Telecom (BT) cable network, together with the rapid increase in the variety and capacity of subscribers' terminal equipment, has highlighted the importance of the efficiency and reliability of wire connectors.

The efficiency of any connection system can be assessed on its installation time, density of terminations, electrical performance and overall cost.

The emphasis on any one of these aspects depends on the specific application of the system. Within the BT network, increasing use is being made of the insulation displacement connection (IDC), or bifurcated tag, method by which high-speed high-density connections for the termination and jointing of wires can be made[1,2]. In the many diverse situations in which IDC technology is applicable, each use has its own particular restraint; in general, however, IDCs are quick and easy to use, occupy a minimum of space and yet maintain reliable electrical connection.

The design of these connectors is such that high-volume manufacturing techniques can be used, thereby enabling optimum manufacturing efficiency to be achieved.

This article describes the research carried out to establish the long-term integrity of the IDC methods and their suitability for use within the BT network. The article also includes comparative test results on a range of connection systems that use insulation displacement techniques.

PRINCIPLES OF INSULATION DISPLACEMENT CONNECTORS

Conventional Tags

Most tags consist of 2 cantilevered limbs between which is formed an accurately sized slot. Connection is made by forcing the wire into the slot, the slot size being narrower than the wire diameter (see Fig. 1). As the wire is inserted, the insulation is displaced along with any oxide films on the conductor, thus providing metallically clean contact surfaces.

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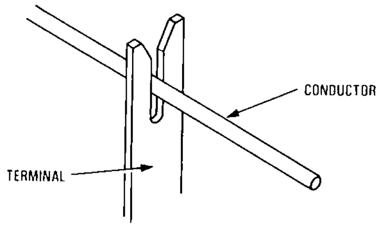


FIG. 1—Wire in position in tag slot

The insertion of the wire also forces the slot to open by separating the cantilevered limbs; this deformation of the tag provides the residual spring loading to maintain the contact pressure. The cantilever deformation can be simply represented by the relationship

$$x = \frac{Wl^3}{3EI},$$

where x is the displacement,
W is the load (in this case, the contact load),
l is the length of the cantilevered limb,
E is Young's modulus, and
I is the section modulus.

Although this relationship defines the general case, it does not include the other effects that occur under practical conditions. For example, this relationship does not take into consideration shear deflection of the tag legs, plastic deformation of the tag material, elastic and plastic deformation of both the wire and the terminal at the contact points, nor the deformation of the base of the tag. Also, stresses resulting from the specific shape of the tag are not considered in this simple analysis; such details affect the limits of elasticity. It has been suggested by H. K. Mueller[3] that the influence of these secondary conditions is related to the length/depth ratio of the tag leg. For cases where this ratio is less than 3, the total deflection of the loaded cantilever can be as much as $1\frac{1}{2}$ times that of the simple case. At the other end of the scale, with aspect ratios greater than 15, secondary effects can be considered negligible.

Again, considering the general case, the limit of elasticity can be found from simple bending theory using the relationship

$$M/I = f/y,$$

where M is the bending moment (contact length × length of tag to point of contact in the case of a bifurcated tag),
I is the section modulus,
f is the bending stress (maximum elastic condition occurs when $f = f_{yield}$), and
y is the distance from the neutral axis.

On the smaller devices, permanent deformation of the tag is not unusual, particularly where the slot must accommodate a large range of wire sizes. This limitation means that the tag is not re-usable on the full range of wire sizes. To increase the re-usable wire range of the device it is usual to increase the length of the legs of the tag. If the tag is operating totally within its elastic range, the contact loading is proportional to the displacement of the legs; consequently, as the wire size increases, the contact load also increases. It is essential, therefore, that the smallest wire in use receives sufficient contact loading, but that the largest wire does not permanently deform the tag.

With the wire positioned in the tag, the slot takes up the shape of a wedge. If another wire is inserted into the tag, it is unlikely that both wire contacts will receive adequate contact pressure. Consequently, this type of device cannot usually accommodate more than one wire.

Photoelastic Analysis of the Conventional Tag

A technique which has proved useful for evaluating this type of device is the technique of *photoelastic stress analysis*. Analysis by this technique requires a model of the device to be manufactured. The model is usually a scaled-up version and is reproduced in a plastic which has the property of *birefringence* (double refraction)[4]. When this model is loaded with wire and is exposed to polarised light, interference patterns are generated (see Fig. 2), which can be interpreted as stress magnitudes and directions. By using this technique, information on the maximum stress conditions for varying wire sizes can be established. For example, if a tag is to be re-usable and therefore not permanently deformed, the maximum stress anywhere on the tag must not exceed the yield stress. The point of maximum stress can be easily seen and the value calculated from analysis of the model.

Fig. 2 shows that the maximum stress occurs at the base of the slot where the fringe density is greatest. The contact pressure can be observed as a localised area of fringes at the wire position. The cantilevered portion of the tag members (which in theory are subjected to pure bending) displays numerous parallel fringes. These parallel lines confirm that this part of the tag is subjected to bending. A central dark line can also be observed on this portion of the tag; this line indicates zero stress and is the neutral axes of bending. At the base of the tag a complex stress system demonstrates the extent of the tag base deformation.

This method of analysis can, therefore, reveal elastic deformation at the contact points, stress raising effects of the tag shape, and the influence of the tag base. However, plastic deformation effects cannot be considered since the comparison between the model and the prototype are valid only when both materials maintain linear stress/strain characteristics.

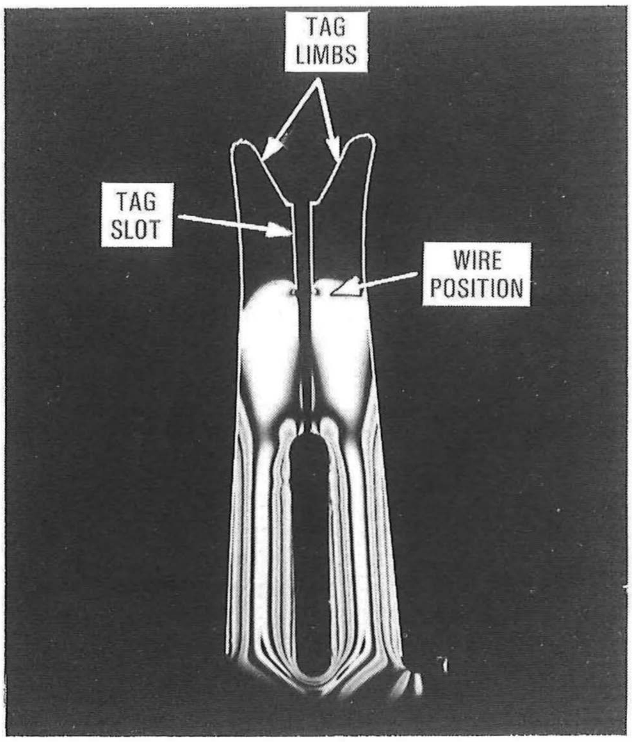


FIG. 2—Interference patterns in stressed photoelastic model

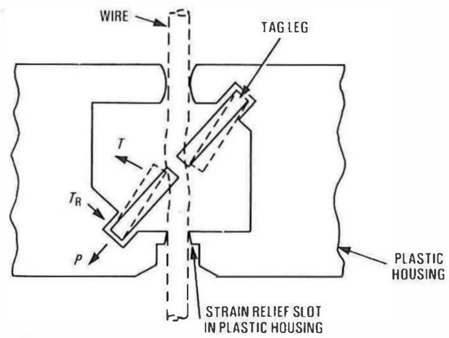
Torsional Displacing Tags

In contrast to the more conventional type of tag, there exist numerous more complex devices. One particular system now being introduced by BT uses a tag where the limbs deform by twisting. These are known as *torsional displacing tags*.

Fig. 3 shows that the 2 limbs of the tag are trapped within a plastic housing and that the wire approaches the tag at an angle of 45°. Thus a torque (T) is applied to the tag limb and the reaction (T_R) for this torque is provided by the tag butting against the plastic housing. With this arrangement, the tag presents a sharp edge to cut the insulation and contact the wire.

A specific feature of this design is that 2 wires can be terminated satisfactorily on the same tag. The 2 limbs of the tag are restrained at their ends, but the centre section of each leg is free to move. Thus, as the wire is inserted, it enters the slot at a point where the tag legs are fixed; this ensures reliable penetration of the insulation. The wire then passes down into the slot thus causing the tag legs to bow. As a result of this bowing, the maximum opening of the slot occurs at the wire position; consequently, when a second wire is inserted, the overall spring load available within the system is equalised between the 2 wires (see Fig. 4).

With this tag configuration, the wire is subjected to a greater proportion of shear loading than in the conventional case. The maximum loading condition can be optimised by



T: Direction of torsional displacement of tag
T_R: Reaction for torsional displacement (provided by plastic housing)
P: Direction of conventional displacement

FIG. 3—Plan view of torsional tag showing displacement caused by the insertion of a wire

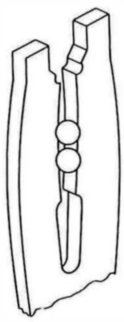


FIG. 4—Diagram of torsional displacing tag showing bowing effect when terminating 2 wires

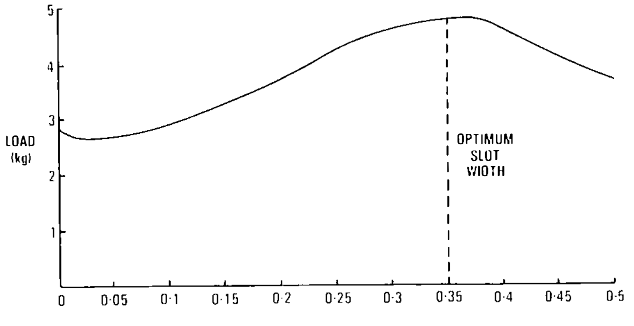


FIG. 5—Relationship between slot width and maximum obtainable load for a torsional displacing tag

varying the slot width. Experiments carried out by the British Telecom Research Laboratories (BTRL) have identified the relationship between slot width and maximum obtainable load (see Fig. 5). The optimum slot width of 0·35 mm coincides with that of the tag design in current use.

Analysis of this type of tag is a complex problem since there are a number of different mathematical models for the torsional deflection of rectangular sections. One method, by G. H. Ryder[5], results in the relationship

$$\theta = \frac{7Tl(b^2 + d^2)}{2Gb^3d^3},$$

where θ is the torsional displacement in radians,
T is the applied torque,
l is the length of rectangular shaft (or tag limb),
b is the breadth of limb cross-section,
d is the depth of limb cross-section, and
G is the torsional modulus of the tag material.

As with the conventional bifurcated tag, there are numerous additional effects that should be given consideration: plasticity, deflection of the tag base, and shear deflection of the tag will influence the practical case. In practice, however, the deformation of the tags will not be purely torsional. Depending on the fit within the housing and the amount of deflection of the housing, there will be an element of deflection of the leg acting as a conventional cantilever. In consideration of these secondary effects, the validity of the simple analysis is questionable. However, it is interesting to compare results for the 2 simplified models.

Fig. 6 shows that the 2 types of limb deformation provide different contact loadings. It is thought in practice that the major difference in the 2 principles occurs because the torsionally deformed tag presents an edge contact. The edge contact can provide very high contact pressure, this being dependent on the contact area. The actual contact area is established during the initial wire insertion and remains substantially constant over the service life of the connection.

A further advantage of this form of tag arises because the indentations at the point of conductor contact are not opposite each other and, therefore, any weakening effect on the conductor is minimised.

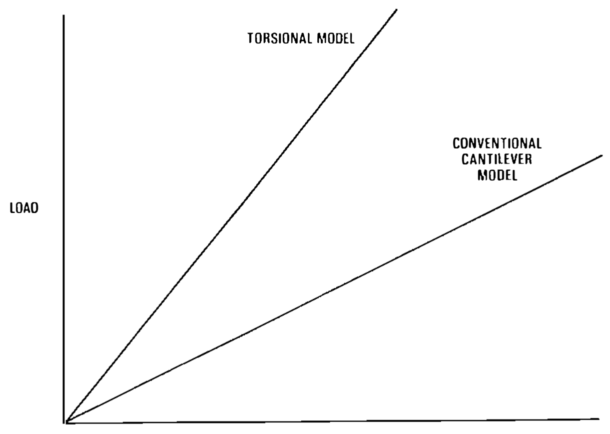


FIG. 6—Load/deflection characteristics of the 2 types of tag

TAG HOUSING DESIGN

It is usual with any connecting system for the plastic terminal housing to provide the insulation between the various circuits and also to serve as a mounting for the tag. With the development of the IDC, the housing is now required to perform a number of other functions:

(*a*) *Mechanical restraint of the tag* This can simply mean retaining the tag during wire insertion or, in the case of the torsional tags, providing the required reaction for the displacement.

(*b*) *Wire anchorage* This feature is normally required since the tag produces a notch in the wire which reduces its strength.

(*c*) *Wire insertion* It is not uncommon for the plastic housing to be used to provide a means of wire insertion. In such cases it is necessary only to insert the wire into the housing and by closing the housing the wires are forced into the tag slots.

A further requirement of the insulating housing occurs as a result of the greater connection density obtainable using IDC techniques; the reduced physical distance between the individual connections reduces the potential tracking distance between the circuits. It is necessary, therefore, to design the housing so that the tracking voltage is maximised by incorporating intricate moulding detail to produce long surface tracking distances between adjacent circuits. This consideration is of greater importance for external applications where damp or wet conditions often prevail.

The increased complexity of the housing mouldings and the greater mechanical contribution required of them has meant that sophisticated materials are needed for their manufacture; for example, polybutylene terephthalate.

TAG MANUFACTURE

Tag Material

There are numerous materials suitable for the fabrication of tags. The prime requirement is that the material used must provide suitable spring properties. Materials such as phosphor bronze, nickel silver and brass are commonly used; less common materials such as berilium copper and aluminium bronze are sometimes used. The contact properties of the materials are not of prime importance since it is usual to enhance this by plating.

Tag Plating

The object of plating the tag is to improve the electrical contact. The more common plating materials are gold, silver or tin. However, indium and lead/tin coatings are used for certain applications, particularly in conjunction with aluminium conductors. A further consideration is the roughness of the contact surface because, during the connection procedure, the wire must slide over the surfaces of the tag. Consequently, wear of the conductor occurs and this affects the residual deflection of the completed connection. For this reason, the stamped out surfaces of the tag, which by nature tend to be rough, can be improved considerably by the application of plating finishes. Although this problem is relevant when copper conductors are used, it is more severe in the case of aluminium conductors.

PROBLEMS ASSOCIATED WITH ALUMINIUM CONDUCTORS

The problems associated with making electrical contact to aluminium are very complex. Compared with copper, aluminium presents a very poor contact surface due to a rapidly forming high-resistance oxide film. This oxide film, together with aluminium's relatively poor mechanical properties and, particularly, with its ability to cold flow under low applied stress, makes the contact pressure sensitive[6]. It is difficult to effect a satisfactory electrical contact to an aluminium surface by using the IDC techniques. Wire insertion must ensure successful penetration of the aluminium oxide without excessive weakening of the conductor, and the tag limbs must deform sufficiently to provide the spring range necessary to accommodate the long-term creep and stress relaxation of the conductor.

Many connector systems resolve the problem of connecting to aluminium by using indium plated contact surfaces. Indium has a very low yield strength (approximately 35 times lower than aluminium); consequently, on termination, the indium readily deforms into the surface of the aluminium conductor, establishing a large intimate contact area. Because the indium is very soft, the contact is effective at much lower contact pressures. In this way, the use of indium enables the contact to withstand the mechanical fretting actions that occur in practice.

Recent experiments have demonstrated that lead-tin-indium alloys can also provide enhanced connection performance. Alloys with as little as 5–10% indium content do not reduce the reliability of the connection, but do reduce considerably the cost of the plating required on the tags. Although this work is at a preliminary stage, it is hoped to prove with further testing the reliability of the connection and, eventually, to establish the required production process for the tags. It is proposed to apply the technique firstly to terminations at building entry points where the cable may be of aluminium.

EFFECT OF CONDUCTOR INSULATION ON THE CONNECTION

By definition, the IDC system is designed to displace the conductor insulation to establish contact, in contrast to the crimp connector system which pierces the insulation. The limitation of the latter occurs because the wire and insulation are compressed within a closed volume. When the quantity of insulation on the wires at the point of connection equals the volume available within the connector, the closing of the connector is restricted. This blocking can occur before a satisfactory electrical contact has been established. In contrast, the insulation displacement type of connection is more tolerant of insulation hardness and thickness because the insulation is cut and displaced within an ample volume, thus avoiding the blocking problem. The insulation penetration is also more reliable since the tag limbs are more resilient than the insulation piercing tangs of the crimp connector.

There is obviously a practical limit to the thickness and hardness of insulation that can be penetrated but the normal polyethylene and polyvinyl chloride (PVC) insulation presents little problem. Minor problems have been encountered when using the new family of irradiated PVC insulated conductors. This wire is currently used for jumpering, the tough irradiated insulation being necessary to minimise scuffing and insulation damage during the jumpering activity. The ideal insulation characteristics, therefore, conflict with the terminating requirements and a test to control the hardness of the insulation is to be introduced into the wire specification. It is proposed to use a dynamic cut-through test to control this parameter.

Many of the existing tags, including the device currently being introduced for internal wiring, include design features that enhance the insulation cutting process by increasing the severity of the slot entry. The design of this detail requires careful control since a slot entry of extreme severity will displace the conductor material as well as the insulation thereby reducing the displacement of the tag limbs.

APPLICATIONS FOR IDC CONNECTORS

Discussion so far has considered the general principles of the IDC. This technique can be incorporated into a multitude of different systems to suit various applications; each application may require a different shape and size of tag. The applications fall into 2 main categories:

(*a*) terminals (wire to equipment), and
(*b*) connectors (wire to wire).

Terminals

The requirements for a bifurcated tag terminal are generally quite different from those for a connector. The most common requirement is that the terminal is re-usable and able to cope with the whole range of wire sizes in general use. To achieve this feature it is essential that the limbs of the terminal do not permanently deform when the wire is inserted. If this occurs, the amount of elastic deformation available is reduced and consequently, on subsequent retermination, the contact loading is reduced. This makes the connection vulnerable to the incursion of reactive gases and shortens its usable life.

The re-usability of the terminal is also dependent on the effects of wear on the contact surfaces, particularly where the performance of the system is dependent on the surface plating. As already discussed, the use of indium plated contact surfaces, perhaps, presents the worst case. Here, the soft indium is gradually removed leaving less and less for subsequent connections.

The termination system currently being used by BT requires a specific wire insertion tool. It is unfortunate that other systems that are available require different insertion tools. It is not practical to provide a range of tools for installation staff and it is hoped to standardise with a particular tool for particular applications.

There are many other facilities that can be associated with a terminating system, such facilities as test access and over-voltage protection are common.

Connectors

The use of bifurcated tags in connectors presents a much less complex problem than with terminations since the reconnection requirement does not normally apply. It is usual for the connector having once been used to be discarded on any future modification of the cabling. Since permanent deformation of the tag does not present a problem the tag size can be reduced significantly. This makes it possible to use such devices within the normal external joint closures as an alternative to the crimp connector (CWI 1A, or Bell connector, see Fig. 7) in current use.

The connectors are usually housed in a plastic case which can be filled with a protective grease to minimise the ingress of moisture; the housing also provides the means of wire insertion. To make a wire connection, the wires are inserted through holes in the housing which align the wires with the slot (or slots). The housing, which is in 2 parts, is then forced together by using a suitable tool, forcing the wires into the contact. It is not uncommon for multiple slots to be provided within the connector element, the slot nearest the point at which the wire emerges from the housing providing a strain relief effect. This strain relief can be provided as an alternative to that provided by the plastic housing, or in addition to it.

A variety of connector pliers are available, ranging from simple modified pliers to tools with bandoleer feed connectors. The principle of the connector has significantly reduced the force necessary to make the connection and has reduced operator fatigue and has enabled a greater variety of tools to be used. The correct tool design is vital to obtain maximum

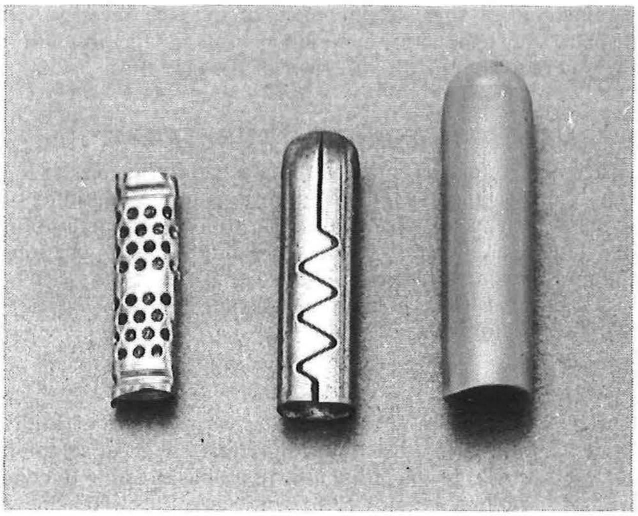


FIG. 7—CWI 1A crimp connector

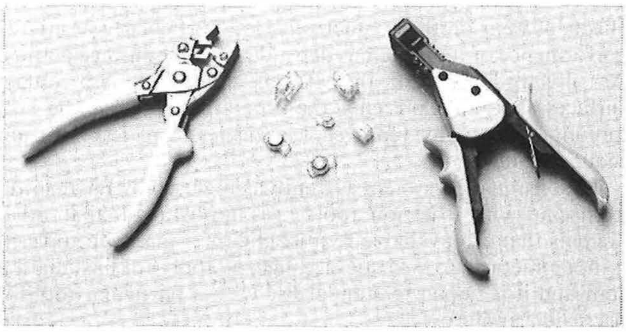


FIG. 8—Various bifurcated tag connectors and associated pliers

effectiveness from the connector, and any initial economies on tooling will effect the long-term success of the connection system.

Connectors of this type are available from various manufacturers and can be supplied in several forms (see Fig. 8) to suit different applications; for example, a butt splice (2-or 3-wire connection) and a bridge splice (tee connection to existing through wire).

These connectors are being evaluated by BTRL and have already demonstrated superior electrical performance over the existing crimp connector, particularly in conjunction with aluminium conductors.

Another application of these connectors where particular advantages can be demonstrated is with the current 0·6 mm diameter copper cable (in use in the local network and junction pulse-code modulation circuits) with which a satisfactory connection using the CWA 1A connectors requires the pre-stripping of the conductor because of the thickness of the insulation.

TESTING CONNECTION PERFORMANCE

The original evaluation of these various devices was based on test procedures established for other terminating and jointing techniques such as wire-wrap and crimp connections. In general, these tests seemed adequate, but it was essential to formalise an agreed performance specification between the various operational groups within BT. Therefore, a draft specification has been published and this has been agreed collectively by all the relevant parties. Although testing is incomplete, it would seem from the results already obtained that this technology is able to provide the required performance.

For the purpose of this article, the results given concentrate on the connection resistance as the prime performance criterion, although mechanical test results are also discussed.

Connection Resistance Results

The performance of the various systems included in this article are based on resistance measurements taken during various accelerated ageing exposures. These results are shown in the form of histograms (see Figs. 9–12). Each histogram is produced from results taken at one measuring interval. Each histogram was produced by using measurements on 40 connections. For convenience, the devices are measured as 2 in series. Analysis of the results indicate 2 aspects of connection performance:

(*a*) initial resistance, and

(*b*) long-term stability of the connection over the simulated life.

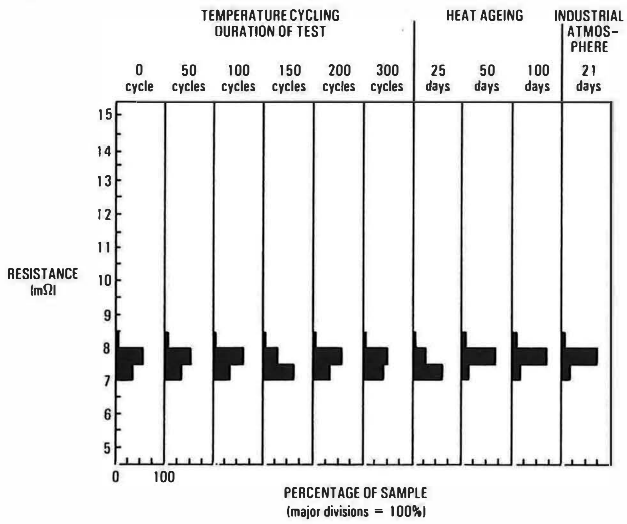


FIG. 9—Resistance change for a slotted tag connector used on copper wire

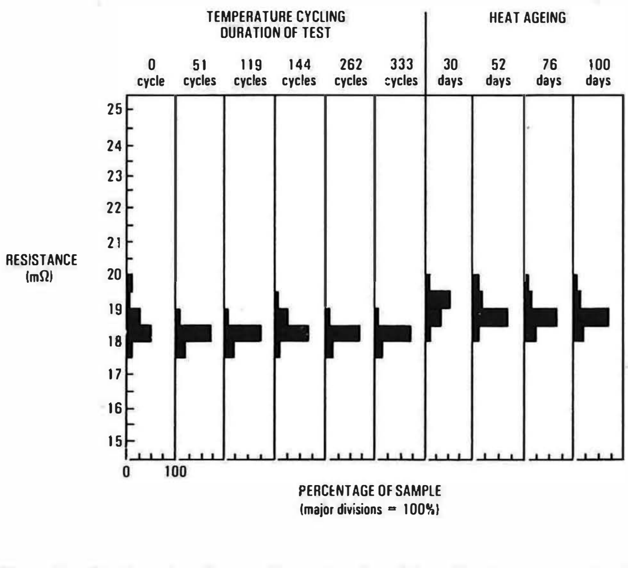


FIG. 10—Resistance change for a torsional tag (2 wires connected)

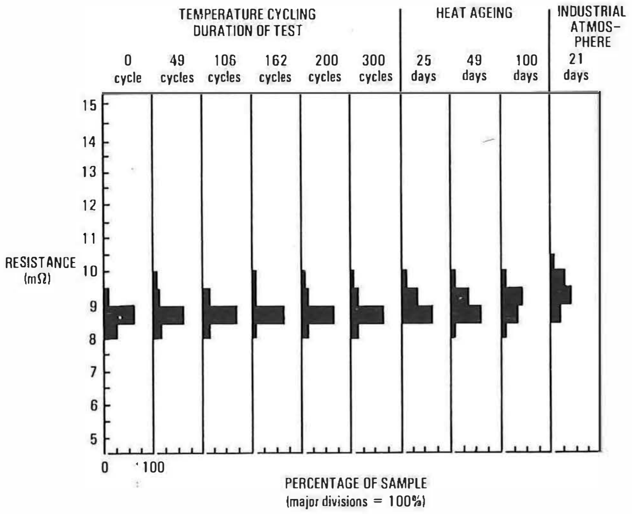


FIG. 11—Resistance change for a slotted tag connector on aluminium conductor

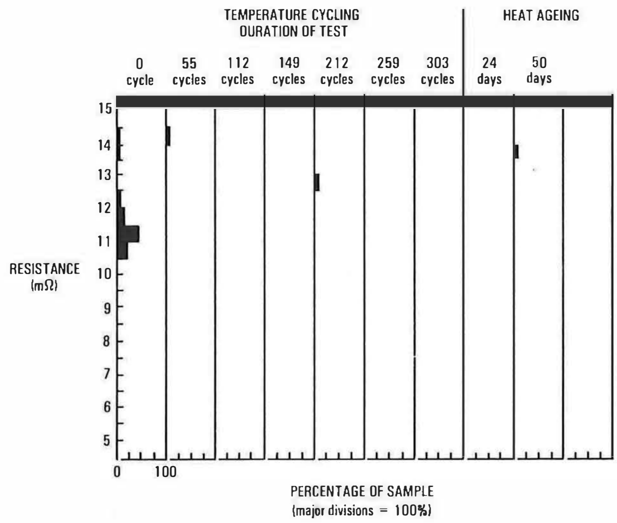


FIG. 12—Resistance change for a CWI 1A crimp connector on aluminium wire

To conform to the present specification, the initial resistance must not exceed 2·5 mΩ per connection and must not increase with age by more than 2·5 mΩ per connection. It should be noted that the results shown include the bulk, or pole resistance of the connection, hence the total resistance will be higher than that due to the termination. However, the comparison of resistance stability is still valid.

Mechanical Test Results

At present, information is limited to tensile testing of a variety of different systems. The performance specification states that the connection should withstand a force of 75% of the breaking load of an unconnected wire, without disturbing the connection. The experiments carried out by BTRL have, as yet, only established the ultimate tensile load of the connection; this is expressed as a percentage of the ultimate wire tensile load. It should also be noted that the devices have been tested with the strain relief features still effective, and obviously such features contribute to the overall tensile performance.

Results obtained for the system currently being used has resulted in ultimate failure in excess of 95% of the wire strength. Similar results have been obtained for a variety of other connectors and terminals. Although it has proved difficult to achieve similar results with the smaller copper conductors and the aluminium conductors, results in excess of 85% of the wire strength are usual. It is therefore considered practical that the requirements of the present specification (that is, 75% of wire strength) can be achieved.

USE OF INSULATION DISPLACEMENT SYSTEMS

The number of connections currently being made by using insulation displacement techniques is increasing rapidly. Apart from small field evaluations, the major application of these techniques occurs on internal work where a new family of connection boxes and subsystem main distribution frames have been developed. This new system[2], known as the *Rapide connection system*, is now used within customer's premises and has demonstrated the potential improvements in efficiency that IDC methods can provide. The new techniques have, so far, been implemented with few problems and, currently, the number of connections achieved by such methods is estimated as being in excess of 200 million.

The new interconnection system is based on 2 units: the terminating module (Fig. 13), and the connector (Fig. 14). The terminating modules can be supplied in a variety of forms with test facilities and high-voltage protection. A number of low-profile modules, in particular, the Strip Connection No. 238A (3-way) and the Strip Connection No. 239A (4-way), have been developed from the basic module. Fig. 15 shows the range of modules together with the wire terminating tool—the Inserter Wire No. 2A.

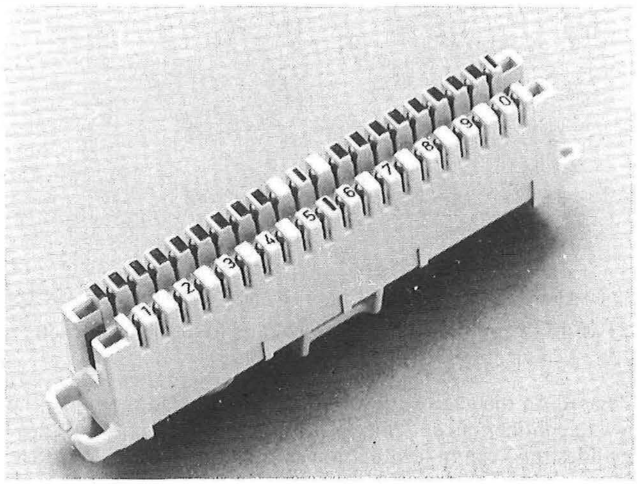


FIG. 13—Terminating module (Strip Connection No. 237A)

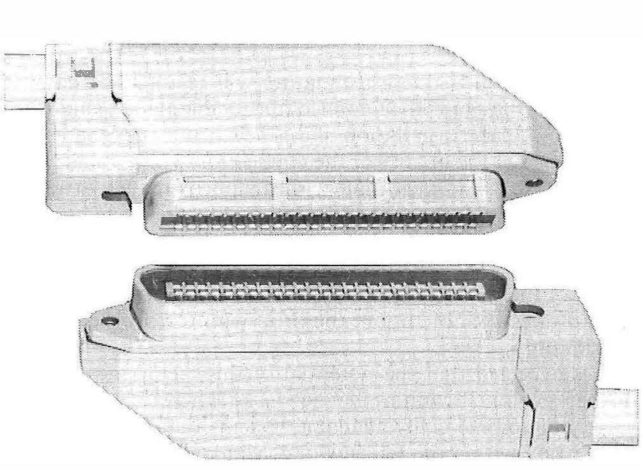


FIG 14—Connector No. 226 system.

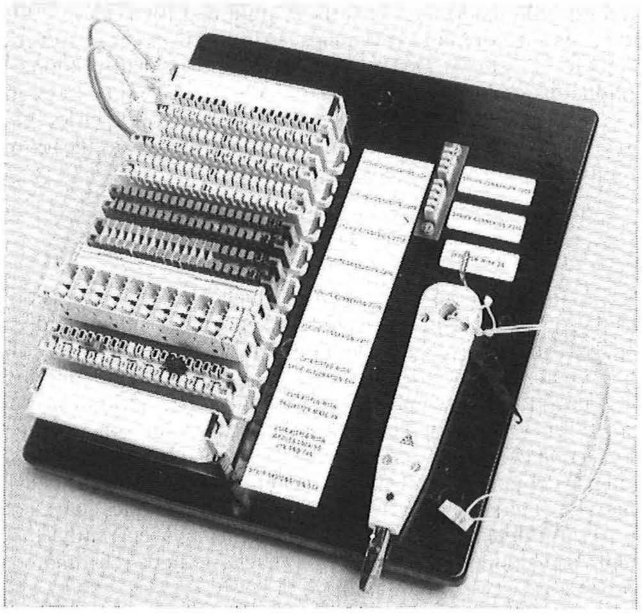
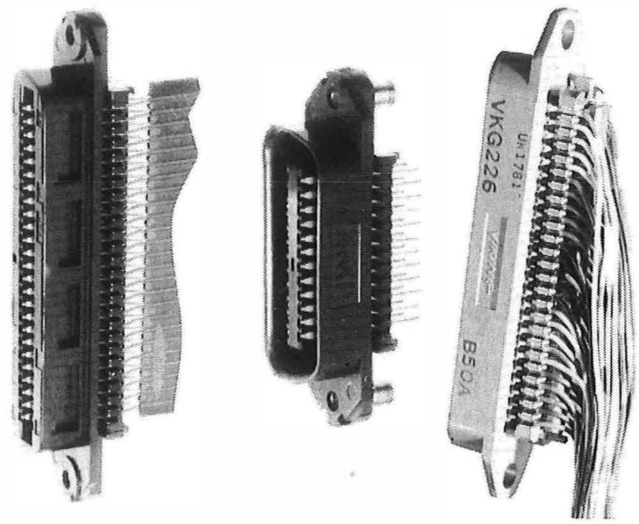
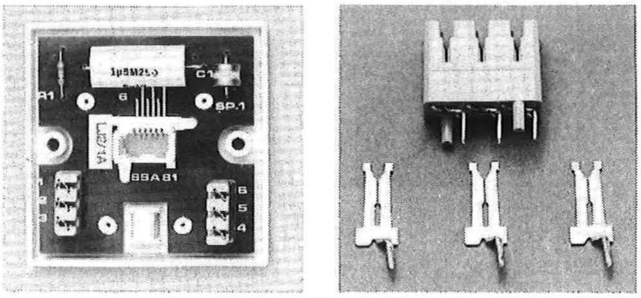


FIG. 15—Range of connecting modules for the IDC system



(a) Ribbon cables (b) Conventional cables

FIG. 17—Application of IDC connectors to cables



(a) Line Jack Unit No. 2A (b) Strip Connection No. 238A

FIG. 16—Application of IDC techniques to telephone sockets

Based on the success of these new connection methods, the new telephone socket (Line Jack Unit No. 2A, Fig. 16(a)) now includes this type of termination (Strip Connection No. 238A, Fig. 16(b)).

The connector, coded Connector No. 226, can also be supplied to accommodate a variety of applications; for example, ribbon cables (Fig. 17(a)) and conventional cables (Fig. 17(b)).

The adoption of these techniques will result in a massive increase in the number of connections being made using IDC principles. As the installation of this new product expands, the significance of the quality of the connection will become more apparent. It is hoped that within approximately 4 years 60–70% of all telephone instruments will be connected via the new plug and socket, and consequently via an IDC termination.

Use of the slotted-tag technique is also being applied in the form of a connector to join the drop wire for overhead local distribution.

It is expected that the potential of this technology can be further exploited within the network. There exists a wide variety of commercially available systems that could have an application within the BT network. Many already include the features required to suit BT applications, and others have the potential for development.

CONCLUSION

The efficiency of the IDC system has been monitored with respect to the 4 parameters outlined at the beginning of this article. The performance of the system against these parameters is discussed below.

(a) *Time to make a termination* The time taken to make a termination can be considered as a prime indication of the termination efficiency. There is little doubt that the simple insertion of a wire into a slot without the necessity for pre-stripping the insulation provides significant advantages over the existing techniques such as soldering, wire wrapping and screw connection. It has been predicted that the use of IDC techniques will give a significant reduction in the time taken to make a termination. This is based on actual times taken, and is supported by time-and-motion studies.

(b) *Density of termination* The connection density obtainable by using IDC technology is greater than that of the traditional techniques. Comparing the relative termination density of the new internal IDC system and the previous wire-wrap and solder tag unit (Jacks Test (JT) 37) by considering the area consumed on the termination face shows that a 22% increase in capacity is available with the new system. However, the terminating face of the IDC unit also includes the test-access facility. If the test-access facility of the JT 37 is included in the calculation, the overall increase in capacity on the working face rises to 145%. It is therefore concluded that significant increases in termination density can be achieved by using the new methods.

(c) *Electrical contact performance* This parameter perhaps presents the greatest area for concern since it is this aspect that affects the long-term integrity of the telecommunications network. It also determines the future maintenance liability of the system—a consideration that is becoming of increasing concern and expense. There is no doubt that the contact area and number of contact points is reduced when using IDCs. For example, wire wrapping can provide up to 24 areas of contact per terminal, while the slotted-tag principle usually provides only 2. Extensive evaluation and increasing practical field experience have not revealed a reduction in connection reliability. It is apparent that the connection design is crucial for good electrical performance and that manufacturing quality must be maintained and controlled. The results included with this article demonstrate that consistent stable connections are readily achieved by using the principles of insulation displacement and, in certain applications, improved connection performance has resulted. It is in the light of these findings that increasing confidence in this technology is being established within BTRL.

(*d*) *Cost of the System* As with any new technology, initial cost disadvantages have to be overcome. Sources of supply must be established, which inevitably presents tooling expense and limited competitive procurement. Operational problems are inevitable as installation staff acquire the new techniques and skills required for the new systems. However, these problems will ease as more sources of supply are established and field experience increases. Then, the full economic advantages of this technology, provided by more efficient manufacture and installation, will be achieved.

It is apparent that conventional conductor and cabling methods will remain as a prime component within the BT network. It is therefore essential that the development of wiring methods continues to improve efficiency and reliability, thus enabling the system to be competitive. Within this objective, the use of insulation displacement connection methods has a vital part to play.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work done on this subject and the assistance given by his colleagues in BTRL.

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British Telecom Press Notices

MICROFICHE DIRECTORIES TO GO ON SALE

Bulky telephone directories could become a thing of the past, for British Telecom (BT) has started to produce them in microfiche.

The first stage in transferring the country's 86 alphabetical paper directories, which weigh more than 51 kg and which take up more than 2 m of shelf space, and the Telex directories onto microfiche is now taking place. Microfiche directories will be built up gradually over 18 months; the first orders are now being taken. However, paper directories will still be available.

About 500 postcard-sized sheets of tough, clear plastic—the fiche—each holding 98 pages of a directory will eventually be available and will take up just 76 mm of shelf space. The entire alphabetical microfiche set will fit into three A4-sized binders.

Standard microfiche directories will be published at the same time as paper directories and will have the same geographical coverage and frequency; like the paper directories, they will be brought up-to-date every 18 months.

The London E–K, L–R and S–Z directories (with A–D following in April), plus the directories for Leeds, Durham and Wearside, Tyneside, West Midlands (South), Shrewsbury, Hereford and Mid-Wales, and Manchester (North East), are the first to become available.

The new microfiche directories, providing miniaturised pages that need to be read on a viewing machine, are primarily aimed at businesses already using microfiche for other purposes; but other businesses holding large numbers of directories may find it economic to buy viewers and change to microfiche.

While the London S–Z directory can be contained on 8 pieces of microfiche, the average number of pieces per directory is 6. As well as the valuable savings in space, microfiche is cheaper to produce than the paper pages of the old directories. For example, an extra paper directory costs £2·50, including postage, but an extra microfiche directory costs just £1·15, including postage and value-added tax. The directories are also more durable and, because the images of the pages are photographically reproduced without the use of printing ink, they are much cleaner to use.

While the first directories to become available will be straight copies of the paper directory pages, BT subsequently intends to produce, via computer processes, directories for which a paper equivalent does not exist. These special directories, based on market research, are expected to cover business needs in the larger cities. They are likely to be more expensive than the standard microfiche directories.

INTELSAT VI SATELLITES

The International Telecommunications Satellite Organisation (INTELSAT), in which British Telecom (BT) has as take of 11·3%, has placed an order for 5 new INTELSAT VI satellites costing over £350 M. The satellites will be made by the Hughes Aircraft Company for delivery starting in 1986, and the Space and Communications Division of British Aerospace Dynamics Group will be a major subcontractor in the project.

The new INTELSAT satellites will be 3 times more powerful than present-day versions; they will be able to carry up to 33 000 telephone calls at once, as well as several television pictures. They will benefit telephone customers in Britain wishing to make calls to America, Australasia, Africa, India, and Asia, and help BT to satisfy the growth of 20%, which shows no sign of slackening, in international telephone calls. Moreover, by using modern digital techniques the new satellites will make a valuable contribution to the extension of information technology, and provide additional capacity for BT's digital-based business services of the future; that is, high-speed text, data and facsimile, and audio and video teleconferencing.

The INTELSAT VI contract makes provision for further satellites to be ordered later, including more powerful "stretched" versions for delivery towards the end of the decade. These are expected to meet the needs of INTELSAT well into the 1990s.

INTELSAT VI will be the sixth in the series which started in 1965 with *Early Bird*, the world's first commercial space relay station in geostationary orbit. Satellites in this orbit, 35 780 km above the equator, travel at the same speed as that of the earth rotating on its axis; therefore, they appear from the ground to be in a fixed position in the sky.

INTELSAT's system of global satellites, which is by far the world's largest, consists at present of 12 fourth-generation satellites (INTELSAT IV and IVA) and 3 INTELSAT V satellites now taking over from the earlier version. Each generation of satellites needs to be replaced every 5 years or so to cope with growth.

At present, INTELSAT's total capacity is about 25 000 two-way telephony circuits. Britain's share is some 6000 circuits and its use of these is growing at the rate of 21% a year.

The Scottish Telecommunications Museum

A. NESS, C.ENG., M.I.E.E.†

UDC 069: 621.39

This article is about the telecommunications museum which has been established in Edinburgh. It outlines the range of subject matter covered by the museum's exhibits, and gives descriptions and background information on some of the more interesting and unusual items in the collections.

INTRODUCTION

The Scottish Telecommunications Museum is located in the old telephone-exchange building at Morningside in Edinburgh. Storage of potential museum items from all over Scotland started here in 1976 and, since then, the collection has grown to thousands of items dating from 1878 to the present time. These items include manual and automatic telephone exchanges, customer apparatus, overhead and underground line plant, transmission and telegraph equipment, power equipment, tools and testers. As with most museums, there is a display section and a storage section. There is also an archive section comprising documents, books, maps, diagrams photographs and films. Most of the exhibits are in good condition and many of these have been restored to working order.

The museum is not normally open to the public, but access may be made after a specific request. On special occasions, exhibitions are arranged to which members of the general public or invited guests are admitted.

THE BUILDING

The old telephone-exchange building at Morningside is of historic interest in itself. It was built in 1924 to house a Siemens No. 16 satellite exchange as part of the initial conversion of Edinburgh from manual to automatic in 1926. An article on the new automatic system for Edinburgh was published in the *Journal* at that time[1], and it includes a photograph of the Morningside apparatus room as it was when originally brought into service. The Siemens No. 16 exchange was in continuous service until 1974, when it was replaced by a crossbar TXK3 exchange in a new building. Today, the former apparatus room is the main display area of the museum amounting to some 220 m^2. About half of this contains the large fixed exhibits, and the remainder is laid out on a semi-permanent basis. Storage areas with access for research are on the ground floor, and further storage is in the basement. The total storage area is 300 m^2, including a garage which houses 2 restored Morris Minor vans. One of the vans is finished in the green livery of Post Office Telephones and the other, which is in the later yellow livery of the Scottish Telecommunications Board, was the last Morris Minor to be taken out of service in Scotland.

TELEPHONE EXCHANGES

Whole exchanges, or representative parts of them, have been reconstructed in the display area to give a semblance of the layout and an impression of the atmosphere that was present when they existed in service. At present, 16 different exchanges, 5 manual and 11 automatic, are on display. Some of these are in working order and own-exchange calls can be made. Further restoration is necessary on the other exchanges and it is intended to have them all working and interconnected with an appropriate network of junction circuits. When this is achieved it will represent a cross-section of the public switched network that gave telephone service in the UK during a period of more than 50 years.

Manual Exchanges

One of the most notable exhibits in the museum is a switchboard position from Portree on the Isle of Skye[2], which was the last manual telephone exchange in the UK. The historic transfer to automatic working took place in October 1976, thereby ending an era when both manual and automatic exchanges co-existed in the network; this period began with the introduction of the first automatic exchange at Epsom in 1912. Portree was a Central Battery Signalling (CBS) No. 2 system and position No. 5, which has been restored, is now combined with a similar switchboard from the island of Scaranish to make a 2-position CBS No. 2 exchange.

Other manual exchanges represent the magneto system and the central battery (CB) system. There are 2 magneto exchanges. One is a single-position floor-pattern switchboard and the other is an unusual table-top model, which served the island of Fair Isle until 1975. The CB exchange is a 3-position switchboard, of which 2 positions are from Helensburgh, and one from Ardrossan. These date from 1912, but were later converted for auto-manual working when their respective exchanges were transferred to automatic operation. Since acquired by the museum, they have been reconverted to their former appearance. The manual exchange area is shown in Fig. 1.

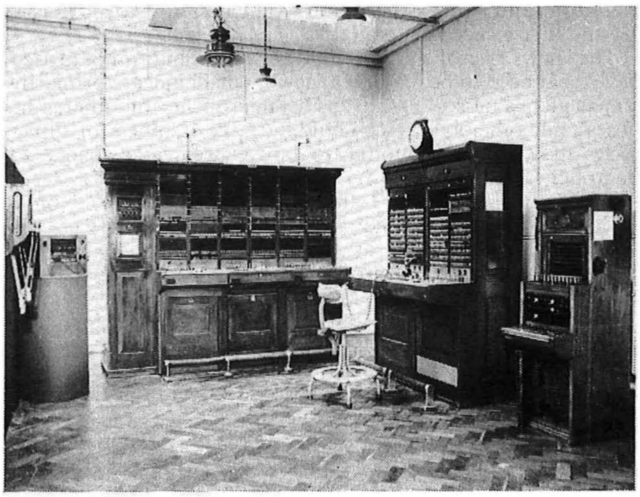

FIG. 1—Manual exchanges

† British Telecom Scotland Headquarters

Auto-Manual Exchanges

The auto-manual exchange is a 3-position, sleeve-control switchboard, which was recovered from Rose Street auto-manual centre (AMC) in Edinburgh. A suite of relay-set racks, free-line signalling equipment, and other apparatus from the AMC, is located opposite the switchboard (see Fig. 2).

Automatic Exchanges

The main automatic-exchange display comprises 3 suites of standard Post Office Strowger racks, together with a main distribution frame (MDF), a test desk, a power-plant switchboard, and a ringer panel. Ancillary features, such as a travelling ladder, a plenum ventilation plant and a master-clock system, are also installed (see Figs. 3 and 4). Various types of equipment and switching systems are mounted on the Strowger racks. Half of one rack displays the Siemens No. 16 system using selectors and other items recovered from the very same room where they have now become exhibits. Another rack portrays the director system, in the form of a working demonstration set, complete with subscribers' meters.

The first automatic exchange in Scotland was at Paisley. It was manufactured and installed for the Post Office by the Automatic Telephone Manufacturing Company in 1916. One selector mechanism from that exchange still survives, so this is of special interest. Similarly unique is a uniselector and a 2-motion selector from Dundee, which had the second automatic exchange in Scotland, opened in 1924. This was the Peel Connor system from the Northern Electric Company in USA, and was installed for the Post Office by the General Electric Company.

Scotland has always had a very large number of unit automatic exchanges (UAXs) serving the rural and remote parts of the country. It is appropriate, therefore, that the museum has 5 different examples of UAXs (UAX Nos. 5, 7,

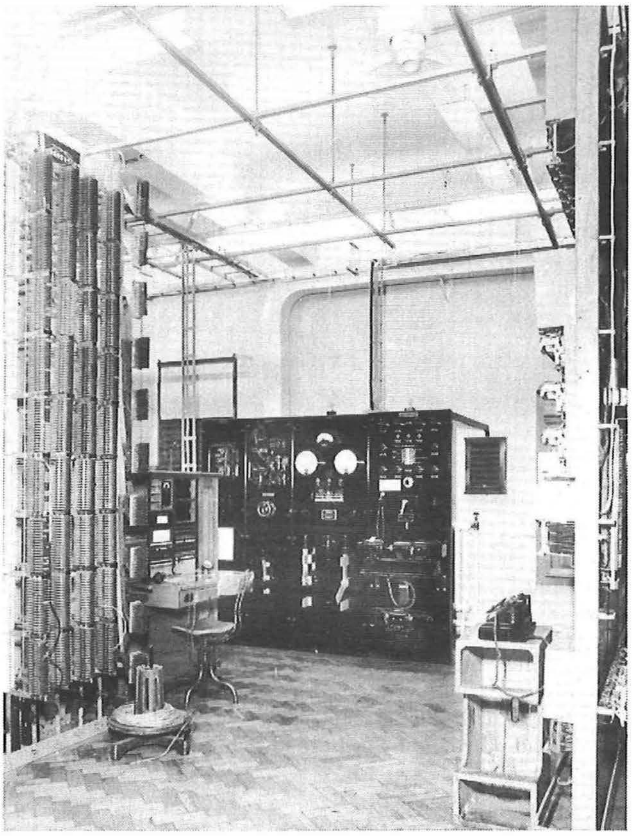

FIG. 3—Main automatic exchange

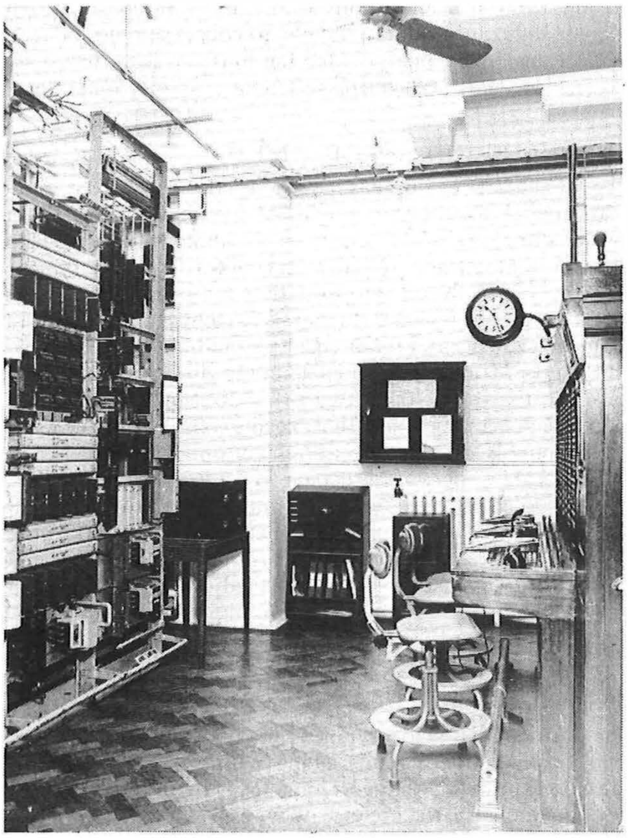

FIG. 2—Auto-manual exchange

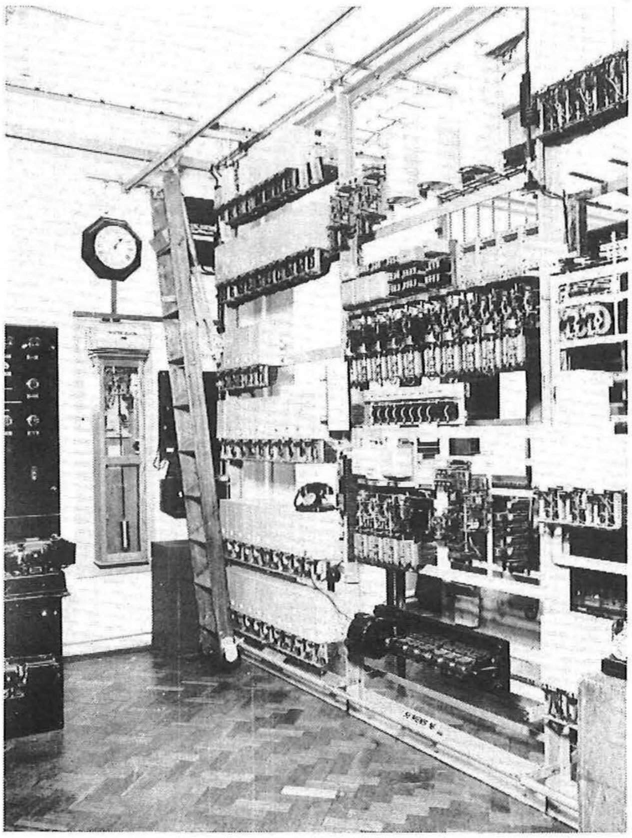

FIG. 4—Automatic exchange equipment

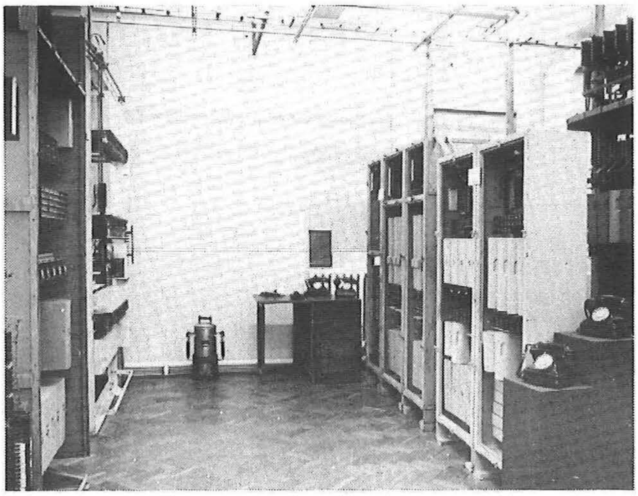

FIG. 5—UAX No. 5 and UAX No. 12

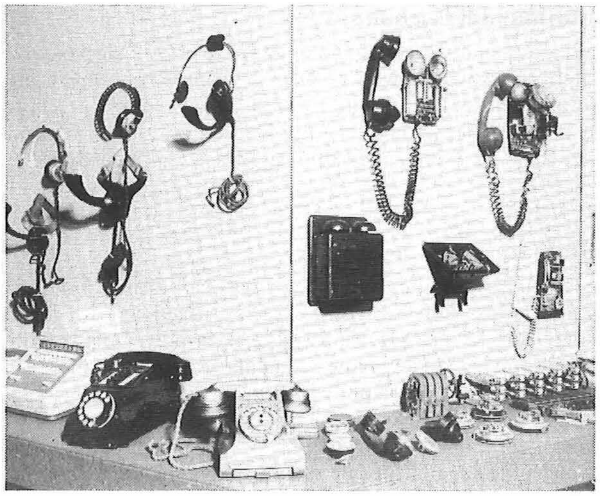

FIG. 7—Telephones and components

12, 13 and 14) to represent this important part of the telephone network. The UAX No. 5 and UAX No. 12 are in full working order, and the others are being restored. Even smaller than the UAXs, there are on display a country satellite exchange, a remote line connector unit, and a non-standard 10-line semi-electronic switching unit which served the small Hebridean island of Muck. Some of the UAX display can be seen in Fig. 5.

CUSTOMER APPARATUS

The museum's collection of customer apparatus ranges from the turn of the century to the present time. Earliest items are National Telephone Company telephone instruments of various designs, some of which are shown in Fig. 6. An interesting item is a magneto bell bearing the inscription "Glasgow Corporation Telephones", a tangible reminder of the time when that city had a municipal public telephone system. Telephones, bell-sets and other apparatus are represented, from the Telephone No. 1 to the Telephone No. 776 (known as the *Compact*), including both the Jubilee (1977) versions of the latter (there was an English model and a Scottish model).

FIG. 6—Customer apparatus and call offices

A factor that makes customer apparatus important in the history of telephone service in the UK is that a relatively few basic designs of telephone were in continuous use for very long periods. For example, the candlestick-type (Telephone Nos. 2 and 150) served for over 40 years, and later the 300-type also served for over 40 years. The 700-type introduced in 1956 is still in general use after 25 years. Standardisation to that extent is unlikely to continue and already the design of customer apparatus is entering the fashion market, with the British Telecom (BT) special range and the influx of non-BT models arising from the relaxation of the BT monopoly. It will become difficult, if not impossible, to collect samples of every item of customer apparatus for the museum in future years. Fig. 7 shows part of the display of apparatus and components.

UNDERGROUND LINE PLANT

The design of cables has changed considerably over the years and it is fortunate that many samples have been acquired which show the development of technology in this field. Paper-insulated lead-covered cables contrast with the present-day use of polyethylene for insulation and sheathing. Jointing methods have also changed from the time when the skills of a plumber were a basic requirement. Examples of many cables and joints are on display and held in the storage section of the museum, together with many of the tools and special equipment used in connection with cable and jointing operations. A future trend is indicated by sections of optical fibre cable.

The local line network is depicted by a fixed display where a footway joint box has been built into a simulated pavement. Viewing panels in the pavement expose underground ducts running from the joint box to a distribution cabinet and to a pillar. Lead-covered cables are installed in the joint box, and the roadworks scene is completed by a jointer's tent and other items nearby (see Fig. 8).

OVERHEAD LINE PLANT

The once familiar sight of poles carrying a route of overhead trunk or junction circuits along country roads has long since disappeared, although remnants of these can sometimes be seen. Similarly, the use of bare wires fixed to insulators has been discontinued for new work on local distribution, although open wire spurs are still in use on some existing lines.

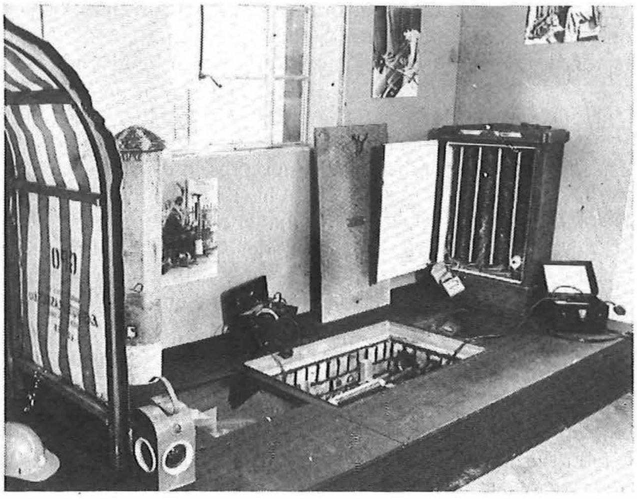

FIG. 8—Underground works

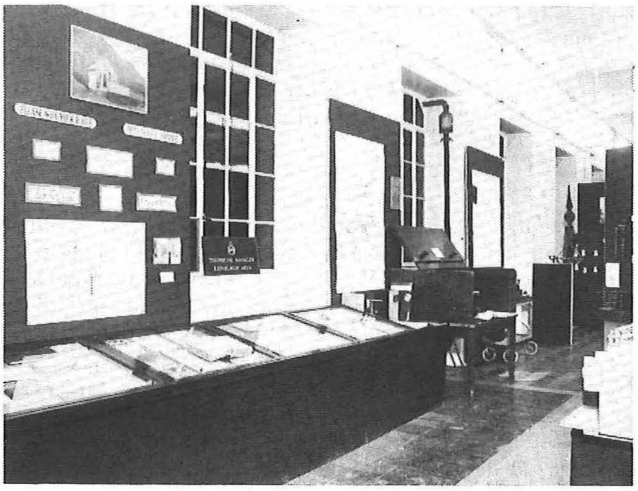

FIG. 10—Archive display

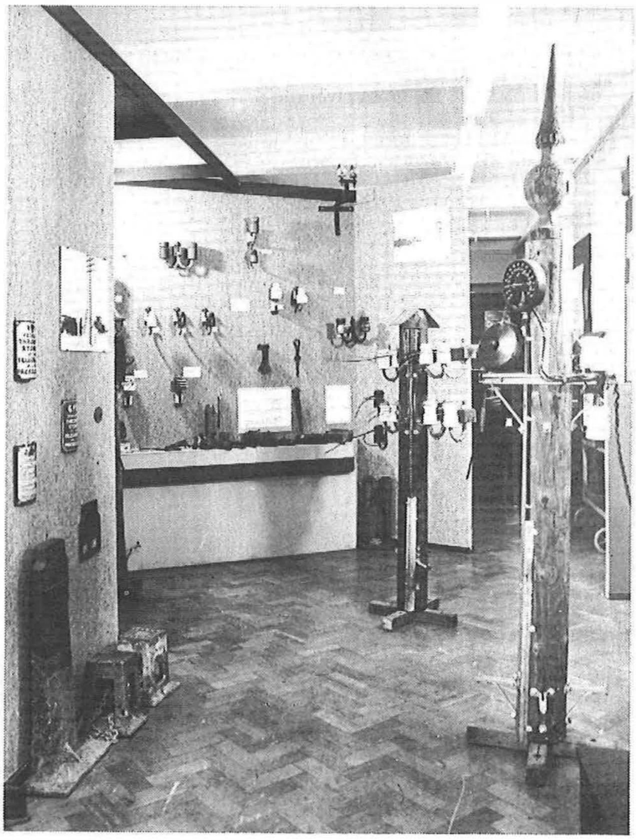

FIG. 9—Overhead line plant

Overhead line construction required many different types of insulators, spindles, brackets and other fittings. Fig. 9 shows some of these and top sections of distribution poles which have been built to show construction methods used at different periods. A cast-iron roof-top pole standard is in the process of being restored, as is a galvanised-sheet-steel pole.

TOOLS AND TESTERS

A feature of telecommunications engineering has always been the need for special tools and testers. The tool collection covers external works practices, with items such as tension gauges and joint makers for overhead wire. There are many special pliers, spanners, gauges and bending tools used for the adjustment of electromechanical selector mechanisms and relays. Different makes of equipment each required their own sets of special adjusting tools.

Testers range from a simple probe lamp for detecting the presence of DC voltage, to large trolley-mounted units, which carry out a complete routine check of operational equipment functions. Early items include galvanometers and Wheatstone bridges. Portable voltmeters and ammeters used by linemen over the years are displayed, as are a range of lineman's portable telephones.

ARCHIVES

As mentioned previously, the archives include documents, books, diagrams, maps, photographs and films; there are also some special gramophone records and tape recordings. A selection of archive material is on display (see Fig. 10), but the great bulk of it is in storage. There are, of course, Technical Instructions, Engineering Instructions, Educational Pamphlets, specifications and circuit diagrams. As well as their importance for historical research and study, these are invaluable in connection with the identification, cataloging, repair and restoration of the museum exhibits themselves. A complete edition of the *Rate Book* and *Vocabulary of Post Office Stores* dated 1933 is well used for this purpose.

Among the unusual items is a National Telephone Company tenancy register book giving details of rented sites and properties. Entries include those for a number of sites for call-offices in 1908, where the rental was 10 shillings per annum, plus 10% of the takings of the coinbox. Also of special interest is an illustrated booklet commemorating the opening of the new central telephone exchange in Aberdeen in 1909. Although greatly extended since then, that building is still in use today as a telephone exchange.

POWER PLANT, TRANSMISSION SYSTEMS, TELEGRAPHS

The collections of power, transmission and telegraph equipment are, at present, the least well developed in the museum. Although some items are on display, a great deal of work has yet to be done on restoration.

Power

Power panels include those for various 50 V DC plants of the mains rectifier type, such as the Nos. 201, 207, 208 and 210. A Power Plant No. 220, which used motor-generator sets, is part of the main automatic exchange exhibit (see Fig. 3). In storage, there are 2 standby diesel engines, one of them associated with a Magnicon alternator: an unusual machine incorporating a cross-field generator, which came from an early coaxial-cable repeater station.

Transmission

Equipment from repeater stations includes amplifiers, filters and other items that show the advance of technology from the thermionic valve to the integrated microcircuit. A particularly fine exhibit is a Sullivan precision tester, incorporating a mirror galvanometer, used for accurate fault location on trunk cables; this can be seen in Fig. 10.

Telegraphs

Notable in the telegraph-equipment collection are early Wheatstone machines operating on the Morse code. These include perforators, transmitters, receivers and printers, which were used on the fast-speed automatic system. Devised to overcome the inherently slow rate of transmission by hand keying, this system uses perforated paper tapes as the basis for mechanisation. Punch-coded tapes were produced at various stages in the handling of each telegraph message and, although cumbersome by today's standards, they were technically ingenious. Some extent of this can be seen in the Creed printer, which translates coded information from the perforated receiver tape and prints alphanumeric characters on a gummed paper tape for assembly onto a telegram form.

Of more recent origin, Teleprinters No. 7 and No. 11, along with their paper tape perforators and transmitters, which operate on the 5-bit Murray code, are being repaired and restored so that working demonstrations can be given.

CONCLUSION

There are now a number of BT museums in different parts of the UK, and reports on 2 of these have been published in the *Journal*[3,4]. The value of regional collections has been acknowledged, but BT is unable to devote more than minimal resources to museum activities. Progress is therefore slow and success is due, in no small measure, to the enthusiasm of the people at all levels who are involved.

The Scottish Telecommunications Museum is no exception to this and a great deal of work remains to be done. Continuing research, cataloguing and restoration of the present stock will take many years and the acquisition of new items will extend this work indefinitely. A stage has now been reached, however, where a substantial portion of our telecommunications history is on display in Edinburgh, in a location which is less than 2·5 km from the house where Alexander Graham Bell was born 135 years ago.

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Book Review

Foundations for Microstrip Circuit Design. T. C. Edwards. John Wiley & Sons Ltd. xiv + 265 pp. 135 ills. £12·75.

Microstrip and its various derivatives are becoming increasingly important in the design of microwave and millimetre-wave circuits, since they offer circuit integration at low-cost. This book presents an extremely good introduction to the subject, one that enables undergraduates or graduates to reach the stage where they could begin to design their own circuits. The basic theory is well covered, and all relevant formulae are quoted or derived without recourse to complex mathematics. The author has directed his book at the practising design engineer, and to this end the many design algorithms are welcome.

Most books on this subject begin with transmission line theory, and this book is no exception. Chapter 2 briefly surveys, and discusses the merits of, various microwave integrated circuit techniques such as microstrip, slotline, finline and imageline. Monolithic microwave integrated circuits are only briefly mentioned, but in view of their future significance more attention is warranted.

The fundamental aspects of microstrip analysis are covered in Chapters 3 and 4 in an excellent section on microstrip impedance, and, as with all the chapters, the text is supported by many up-to-date references.

The latter half of the book translates the theory into practical designs by first considering the characterisation of microstrip discontinuities such as series gaps, short circuits, bends, junctions and impedance transformations. A design for a microstrip coupler is worked through, as an example; however, broadband multi-section couplers are omitted. Appendix A suddenly appears at the end of chapter 6 and, although it is relevant to this chapter, it would be more appropriate if it were placed with Appendix B at the end of the book.

Chapter 7 is mainly devoted to measurement techniques and, as waveguide is still the principal transmission medium at frequencies above 10 GHz and as a microstrip to waveguide transition is essential, a short section is addressed to this topic. The final chapter reviews some practical component designs involving couplers, filters and amplifiers. It is not surprising that most of the chapter is devoted to filter design as it is in this field that the author is currently working—at the Royal Military College of Science, Shrivenham.

This book is based on material which the author gathered while he was lecturing on a design-oriented microwave course and pursuing research into microstrip technology; however, there is sufficient practical data in it to make the book an essential tool for the practising microwave engineer. The text is well presented and easy to read; the excellent diagrams compensate for a lack of photographs. Although a book for the specialist, it is likely to appeal to lecturers, graduates and design engineers.

B. C. Barnes

The Principles of Scramblers and Descramblers Designed for Data Transmission Systems

I. B. RIDOUT, B.SC., C.ENG., M.I.E.E., and I. B. HARVIE†

UDC 621.394.4: 681.327.8

Applications of scramblers and descramblers in the data transmission environment are outlined and a simple mathematical explanation of their operation is given. The use of adverse-state detectors, combined with scramblers, is presented. A large-scale integrated circuit scrambler/descrambler, designed for data transmission systems, is also described.

INTRODUCTION

Data transmission modems invariably incorporate facilities for scrambling the data to be transmitted. This is not, as might be expected, for security purposes, but to assist in the correct operation of the modem. The reasons for using scrambling in data transmission systems are

(*a*) to spread the energy of the signal spectrum evenly across the frequency band, irrespective of the data sequence being transmitted,

(*b*) to ensure that there are ample transitions in the received signal from which the modem can recover timing signals, and

(*c*) to make the transmitted data sufficiently random for an automatic or adaptive equalizer in the modem receiver to function correctly.

This article describes how self-synchronizing scramblers and descramblers operate, using simple mathematical notation. The operation of a scrambler/descrambler, including its adverse-state detector (ASD), is given, using as an example the scrambler specified in CCITT* Recommendation V36. The article concludes by describing a large-scale integrated circuit (LSI) designed and fabricated at the British Telecom (BT) Research Laboratories. The LSI chip can be used to perform the following functions:

(*a*) scrambling,
(*b*) descrambling,
(*c*) pseudo-random pattern generation, and
(*d*) error detection.

SCRAMBLER/DESCRAMBLER PRINCIPLES

The block diagram of a simple scrambler is shown in Fig. 1, from which the following mathematical relationship can be derived:

$$D_s = D_i \oplus D_s z^{-u} \oplus D_s z^{-v},$$

where D_i is the input sequence,
D_s is the scrambled sequence,
z^{-1} is the unit delay,
u and v are the tap numbers, and
$\oplus$ represents modulo-2 addition.

Since modulo-2 addition and subtraction are identical,

$$D_s(1 \oplus z^{-u} \oplus z^{-v}) = D_i.$$

Hence $$D_s = \frac{D_i}{1 \oplus z^{-u} \oplus z^{-v}} = \frac{D_i}{D_G}, \quad \ldots\ldots (1)$$

where $D_G = 1 \oplus z^{-u} \oplus z^{-v}$, and is known as the *generator polynomial*.

The scrambler is very similar in form to a pseudo-random sequence generator; the feedback tap positions, corresponding to the orders of the terms in z, are chosen to generate a maximum length pseudo-random scrambled sequence (D_s) when a continuous binary 0 or 1 input sequence (D_i) is applied. The example uses a 2-tap polynomial, but this principle is valid for maximum length generator polynomials requiring any number of taps.

A descrambler performs the inverse mathematical process, in that it multiplies the received signal by the generator polynomial. Fig. 2 shows the principle of operation for a descrambler using a 2-tap polynomial, from which it can be seen that

$$D_o = D_s \oplus D_s z^{-u} \oplus D_s z^{-v}.$$

Hence $$D_o = D_s \times D_G, \quad \ldots\ldots (2)$$

where D_o is the output sequence.

From equation (1), substitution of $D_s = D_i/D_G$ (that is, no message errors occurring during the course of transmission) in equation (2) produces the result $D_o = D_i$.

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* CCITT—International Telegraph and Telephone Consultative Committee

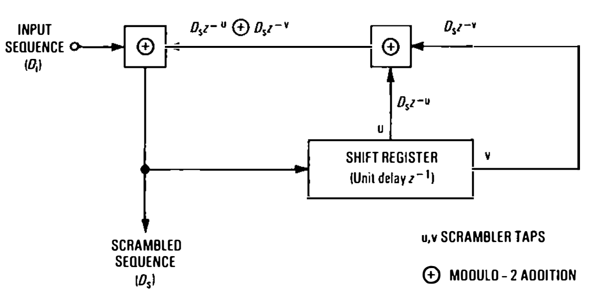

FIG. 1—Scrambler configuration

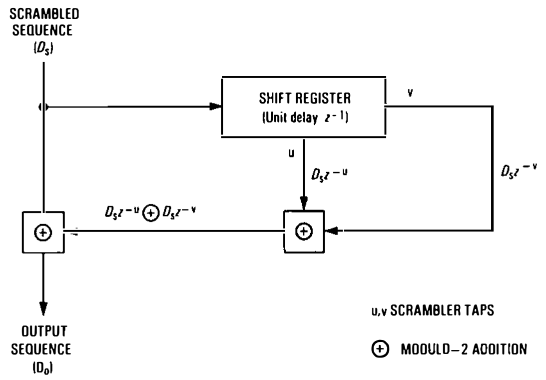

FIG. 2—Descrambler configuration

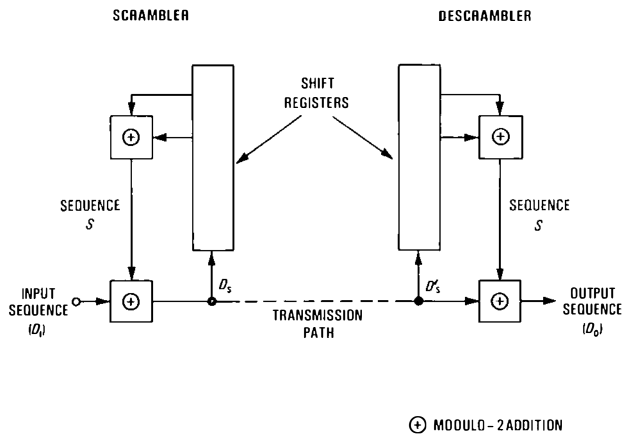

FIG. 3—Scrambler/descrambler configuration

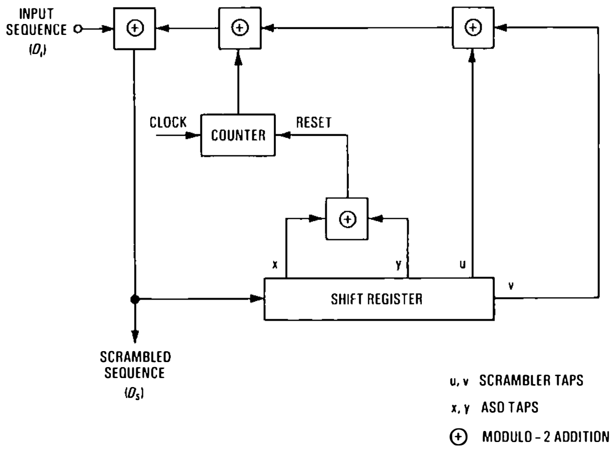

FIG. 4—Block diagram of a scrambler with ASD

Looking at a complete transmission system (Fig. 3), and assuming no message errors during transmission, the scrambler/descrambler combination can be regarded as 2 exclusive-OR gates in tandem, with their second inputs joined together and fed with a common logic sequence (S). The output sequence (D_o) is identical with the input (D_i) if the same sequence (S) is applied to the 2 exclusive-OR gates. The self-synchronizing descrambler ensures that, after a number of intervals equal to the length of the shift register to clear the initial conditions, and assuming no transmission errors, the scrambled sequences (D_s) and (D'_s) are the same; they pass along the 2 shift registers and the identical logic associated with each generates the same sequence (S).

It can be seen that a single error in the received sequence (D'_s) leads to 3 errors in the output sequence (D_o), the additional errors occurring as the error in D'_s reaches each of the feedback taps. Generator polynomials requiring a larger number of taps worsen this error-extension effect and, for this reason, are not normally used in data transmission applications.

ADVERSE-STATE DETECTORS

Under certain conditions, a self-synchronizing scrambler can become transparent to continuous conditions or short repeating patterns applied at the input, or it may merely generate other short repeating patterns[1,2]. When this occurs, there is strong autocorrelation in the transmitted data sequence, and the line signal has a frequency spectrum containing unacceptably high discrete components. The probability of this occurring is usually very low, and it becomes lower as the order of the generator polynomial is increased. Nevertheless, to guard against this possibility, an ASD is often incorporated in scrambler/descrambler circuits.

The principle used is to monitor the signal passing along the scrambler shift register with a circuit capable of recognising the more damaging repeating patterns that are considered most likely to occur. For example, an exclusive-OR gate connected between outputs from the shift register 8 stages apart gives a continuous 1 output if the signal passing along the shift register is continuous 0, continuous 1, reversals, or any repeating pattern of length 4 or 8 elements. A counter, driven from a clock, is reset by non-adverse states, but if the monitor gives an adverse-state indication for enough successive clock intervals to fill the counter, the adverse pattern is broken by inverting one element in the feedback path of the scrambler. This inversion is usually sufficient to step the scrambler out of its transparent or locked-out condition, and a new properly scrambled output sequence begins. An identical ASD circuit is incorporated in the descrambler; since, in the absence of transmission errors, the signals passing along the scrambler and descrambler shift registers are identical, the descrambler ASD circuit re-inverts the same element on reception and no processing error results.

The ASD for the scrambler used in the CCITT Recommendation V36 is connected to taps 1 and 9, and the complete block diagram is shown in Fig. 4.

APPLICATION OF SCRAMBLERS FOR DATA

The use of scramblers in synchronous data transmission systems has been well known for several years. The technique is used to spread the transmitted signal energy evenly across the frequency band of the channel to be used. This is particularly important for modems using the frequency-division multiplex (FDM) network[3]. Unless special precautions are taken, repetitive data patterns could cause large-energy, single-frequency signal components to occur, which could overload the FDM translating equipment and repeaters, causing unacceptable interference with other channels. Such repetitive patterns are also incompatible with the correct operation of data modems using adaptive equalization, since these require the data sequence to be substantially free from autocorrelation within the span of the equalizer delay line.

Furthermore, at the receiving end of the transmission link, a relatively jitter-free timing signal is needed to regenerate the signal or to drive an adaptive equalizer. As clock recovery circuits usually rely on the presence of transitions in the received signal, it is necessary to guarantee that the data does not contain too many consecutive zeros or ones.

The self-synchronizing scrambler/descrambler technique meets these requirements, with only a very small probability of failure. Provided that the parameters are well chosen, ample transitions and a substantially uniform signal spectrum are obtained irrespective of the source data sequence. Fig. 5

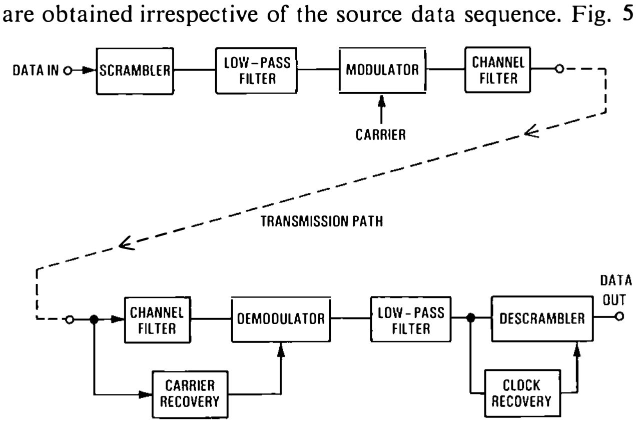

FIG. 5—Block diagram of a typical data transmission modem

is a block diagram showing the basic units of a modem incorporating a scrambler/descrambler pair.

There are several recommendations for scramblers contained in CCITT V series Recommendations for use in modems for data transmission, some with and some without ASDs. A typical example is contained in Recommendation V36 for use in modems operating over group-band links.

THE OPERATION OF A CCITT V36 SCRAMBLER/DESCRAMBLER

A scrambler/descrambler pair, conforming to CCITT recommendation V36, is used in the BT Modem 36. The modem is capable of transmitting data at rates between 48 kbit/s and 72 kbit/s over a group-band circuit in the FDM network.

Fig. 6 shows the block diagram of a recommended V36 scrambler/descrambler with ASD. The scrambler is conventional, with a shift register length of 20 stages, and feedback taps on stages 3 and 20. These taps yield a pseudorandom pattern length of 1 048 575 bit with a constant logic input; consequently, quite a simple ASD is required because of the low probability of occurrence of sustained adverse states. The ASD is designed to detect repeating patterns of length 2 (reversals), 4 and 8, as well as a constant logic condition on the shift register. Only one exclusive-OR gate, connected to the outputs of the first and ninth shift-register stages, is required to achieve this; its output drives the ASD counter logic, which counts to 32 and is designed to start at a count of 1 instead of from zero.

Gated clock pulses are used to trigger a monostable circuit (to introduce a delay) which, in turn, resets the ASD counter. In the event of an adverse state occurring, the first one is neglected because of the delay; thereafter, a counter counts until consecutive adverse states cease to be detected. If the adverse state persists, the fortieth element after the start of the occurrence of the adverse states at the output of the scrambler is inverted; this arises because the counter counts to 31 on the first cycle, with a further delay of 9 elements for the condition to reach tap 9. Subsequently, for the case where the adverse state still persists, every thirty-second bit is then inverted, hence removing the adverse-state condition from the transmitted data. Usually, the first inversion is sufficient to restore the scrambler to normal working. It is very unlikely that the input sequence will be such that the adverse state continues after the first inversion.

An identical ASD circuit is incorporated in the descrambler and, in the absence of transmission errors, the signals passing along the scrambler and descrambler shift registers are identical. Thus, the descrambler ASD circuit re-inverts the fortieth bit after the start of an adverse state and also re-inverts every thirty-second bit if the adverse state persists, resulting in no processing errors.

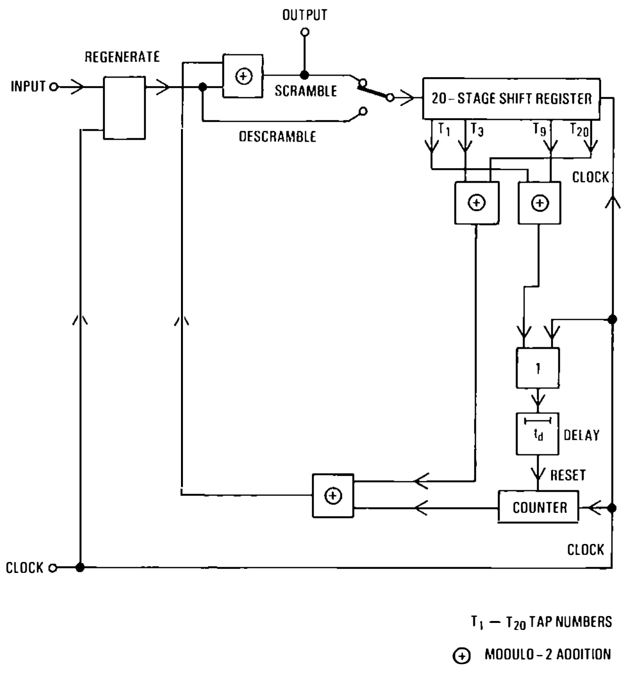

FIG. 6—Block diagram of CCITT V36 scrambler/descrambler

LSI IMPLEMENTATION OF A GENERAL-PURPOSE MULTI-FUNCTION SCRAMBLER/DESCRAMBLER CIRCUIT

A duplex data transmission link, incorporating a scrambler and descrambler at each end, requires about 16 integrated-circuit packages in each modem if built in standard medium-scale integration technology. A single LSI circuit to replace these, dedicated for use with one speed of transmission, or conforming to only one CCITT recommendation, would not be an economically viable proposition in the numbers currently envisaged for specific data modems. However, one LSI device, covering a wide variety of speeds and switchable between several systems, was believed to be viable. At the BT Research Laboratories, a multi-function scrambler/descrambler integrated circuit was designed and produced. The technology used is high-voltage n-channel silicon-gate metal-oxide semiconductor, which is compatible with transistor-transistor logic and complementary metal-oxide semiconductor circuits.

Basically, the circuit includes a scrambler section, a descrambler section, and a common-control matrix (Fig. 7). The scrambler and descrambler can be driven from independent timing signals, but the generator polynomial, which

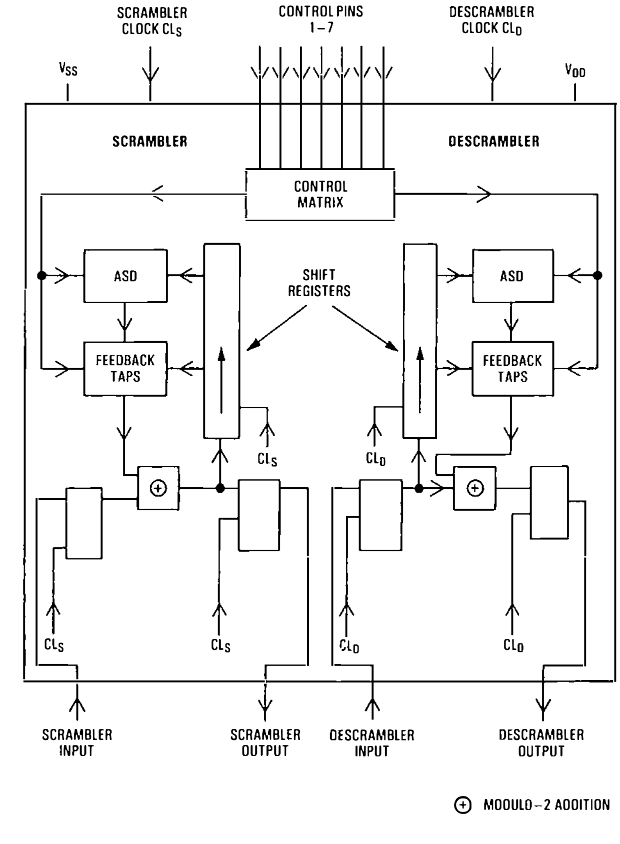

FIG. 7—Block diagram of the multi-function scrambler/descrambler integrated circuit

is selected by 5 inputs to the control matrix, is the same for each. Similarly, the choice of ASD circuit, selected by 2 further control-matrix inputs, is common to the scrambler and descrambler. Specific scrambler/descrambler functions were incorporated for use with modems complying with CCITT Recommendations V27, V29, V35 and V36, some of which include an ASD. The shift registers have 23 stages, and any of the maximum-length-sequence generator polynomials up to degree 23, requiring only 2 taps, can be selected.

Facilities Provided by Scrambler Section

The scrambler section can be used as a conventional scrambler or as a pseudo-random pattern generator.

Scrambler

A scrambler, with or without an ASD, can be selected by using any of the 2 feedback taps combinations available.

Pseudo-Random Pattern Generator

When used as a pattern generator, all maximum length pseudo-random sequences, requiring 2 feedback taps up to length $2^{23} - 1$, can be generated by applying a constant logic condition to the scrambler input.

Facilities Provided by Descrambler Section

Simultaneously, by using an independent timing signal, the descrambler section can be used as a conventional descrambler or error detector.

Descrambler

Descrambling can be performed by using the same feedback taps and ASD circuit (if used) as selected in the scrambler section of the remote unit.

Error Detector

If a scrambler is used as a pattern generator, a descrambler. set to the same pattern length, can be used to detect errors; this is achieved by connecting the signal to be checked to the descrambler input terminal and monitoring the output terminal for the appropriate constant logic condition. If the output changes to the other logic condition, an error has occurred on the input sequence. For a single transmission error, 3 inverted elements appear at the descrambler output. At high error rates, cancellation may occur and reduce the error multiplication factor slightly, but for most practical purposes this effect can be neglected.

General Features

Although each ASD circuit would normally be used with its related scrambler/descrambler configuration (for example, V27, V35 or V36), any ASD can be associated with any of the available scrambler configurations if desired.

It is possible for pseudo-random pattern generators, using the feedback-shift register principle, to lock up with all stages set to zero. This can occur when first switched on for example, and special action is required to initiate the normal pattern generation. When the integrated circuit is being operated as a pattern generator, one of the ASD circuits can be used for this purpose.

Without the ASDs in circuit, the scrambler and descrambler sections operate correctly at data rates up to at least 2·5 Mbit/s, with some operating as high as 4 Mbit/s. The maximum rate with the ASDs operating was found to be at least 1 Mbit/s. The supply voltage required is +12 V, and the typical power dissipation is in the order of 350 mW.

These integrated circuits are currently being used to provide the necessary scrambling and descrambling functions for a new group-band modem (Modem 36) and its baseband extender (Modem 35).

CONCLUSIONS

The reasons for using scramblers in conjunction with data transmission modems have been presented and a simple mathematical analysis of their operation has been given. In most circumstances, it is advantageous to incorporate an ASD with the scrambler/descrambler circuitry to prevent the occurrence of specific unwanted sequences. The additional circuitry required has been shown to be easily implemented.

An LSI scrambler/descrambler chip has been designed and fabricated at BT Research Laboratories. It is capable of being used over a wide range of data transmission rates and can be externally programmed to generate 32 different sequences, which can be used with or without one of the ASDs that are provided.

ACKNOWLEDGEMENTS

The authors wish to thank P. N. Ridout for his contributions, and other colleagues for their work in designing, producing and testing the LSI scrambler circuit.

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[2] WESTCOTT, R. J. Patent Specification 1281390. Testing Digital Data Transmission Systems. July 1972.

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The XVth Plenary Assembly of the International Radio Consultative Committee

INTRODUCTION

The XVth Plenary Assembly of the International Radio Consultative Committee (CCIR), one of the 4 permanent organs of the International Telecommunication Union (ITU), was held in the Geneva International Conference Centre from 15–26 February 1982. Some 393 delegates, representing 77 countries, and representatives of 16 international organisations and 10 recognised private operating agencies attended. As the name indicates, the CCIR is responsible for carrying out studies and issuing Recommendations on technical and operating questions specifically related to radiocommunications.

The Assembly was chaired by Mr. E. J. Wilkinson (Australia). Messrs. A. Badalov (USSR), W. Bellchambers (UK), G. Huffcutt (USA) and E. Kamdem-Kanga (Cameroon) were elected as Vice-Chairmen.

CCIR STUDIES

At the final meetings of the 13 CCIR Study Groups, held in the latter part of 1981, the technical documents which were submitted for consideration by the Plenary Assembly were prepared. An important part of the work of the Assembly, which meets every 3–4 years, was the examination and approval of these documents. Among the most important results of the CCIR studies during the study period between the XIVth and XVth Plenary Assemblies were the following:

(*a*) the first Recommendation on a world-wide uniform standard concerning the coding parameters for digital-television studio equipment,

(*b*) a consolidated Report on teletext systems (systems intended to transmit textual or graphical information by means of the television broadcasting networks) used throughout the world,

(*c*) Recommendations concerning a digital selective calling system for maritime communications, as well as automated radiotelephone systems for maritime communications,

(*d*) a series of Reports concerning maritime satellite services (including emergency position indicating radio beacons by using satellites),

(*e*) numerous texts on the utilisation of satellites for broadcasting and other communication purposes,

(*f*) a major publication on satellite broadcasting systems,

(*g*) a report on low-capacity earth stations and associated satellite systems of special importance to the developing countries, and

(*h*) detailed studies on questions concerning frequency sharing throughout the radio-frequency spectrum.

Additionally, handbooks on spectrum management and monitoring using computer techniques and on the fixed-satellite services are nearing completion.

Approval of these results will facilitate and improve the operation of various radio services throughout the world to a great extent and will have an important influence on the design and manufacture of the corresponding radio-communication equipment.

ASSEMBLY COMMITTEES

Among the 3 major committees that were formed to carry out the work of the Assembly was a special Technical Co-operation Committee, chaired by Mr. H. Balduino (Brazil). This committee deliberated on the assistance given by the CCIR to developing countries, so that they can make the best use of the technical information included in the CCIR documents, and on how the active co-operation in CCIR work by the administrations of those countries can be fostered.

The Organisational Committee of the Assembly, chaired by Mr. N. Morishima (Japan), reviewed the methods of the work of the CCIR and introduced some important improvements in this work. In particular, it set forth precise organisational principles of the preparatory work to the forthcoming administrative radio conferences in which the CCIR is now heavily involved. Some of the most important of these conferences are

(*a*) the VHF FM Sound Broadcasting Planning Conference for Europe, the Middle East and Africa (first session, Geneva, August 1982);

(*b*) the Conference for Mobile Telecommunications (Geneva, February–March 1983);

(*c*) the Satellite Broadcasting Conference for the Region of the Americas (Geneva, June–July 1983); and

(*d*) the HF Broadcasting Planning Conference (first session, Geneva, January–February 1984).

Both these and later conferences require a considerable amount of technical preparatory work. Even a relatively distant conference, such as the World Administrative Radio Conference for the Utilisation of Geostationary Orbit, the first session of which is at present planned for July–August 1985, and the second session in September–October 1987, is already being prepared, and many CCIR experts from all over the world are engaged in this work.

The Assembly re-elected Mr. R. C. Kirby (USA) as Director of the CCIR for the next study period, 1982–1986.

BACKGROUND

The ITU is the specialised agency of the United Nations that is concerned with problems involving telecommunications. It was founded in 1865 and has 157 member countries. Its headquarters in Geneva comprise 4 permanent organs: the General Secretariat, the International Frequency Registration Board (IFRB), the CCIR, and the International Telegraph and Telephone Consultative Committee (CCITT).

The CCIR was set up in 1927 at the Washington International Conference for Radiotelegraphy. It is the organ of the ITU which studies technical and operating questions relating to radiocommunications and issues recommendations on them.

All members of the ITU can participate in this work, while certain private companies operating telecommunications services, scientific or industrial organisations and international organisations can take part with the agreement of their respective administration.

The CCIR holds a Plenary Assembly every 3–4 years. The Plenary Assembly draws up a list of technical problems concerning radiocommunications (*Questions*), the study of which would lead to improvements in international radiocommunications. The Questions are then entrusted to a number of Study Groups, which are composed of experts from the member administrations of the ITU. The Study Groups draft *Recommendations* that are submitted to the succeeding Plenary Assembly. If the Assembly adopts these Recommendations they are published in the printed texts of the CCIR, which are then disseminated by the ITU.

The CCIR Recommendations have an important influence on radiocommunication scientists and technicians, administrations and operating companies, manufacturers and designers of equipment throughout the world.

The Microfiche System of Directory Information Storage and Retrieval

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UDC 778.14: 621.395 (058.7)

Continued growth in the number of telephone customers in the UK has resulted in the gradual increase in size of the paper telephone directories. This has caused particular problems in British Telecom's directory enquiry bureaux, where the shelf space available to store the paper directories at each operator position is at a premium. This article describes the microfiche system of directory information storage and retrieval that has been introduced to overcome these problems.

INTRODUCTION

The amount of space taken up by the UK's 86 paper telephone directories has been steadily increasing as a result of the growth in the number of telephone customers. In British Telecom's (BT's) directory enquiry (DQ) bureaux, the shelf space available at each operator position for the storage of telephone directories has already been filled. Consequently, an alternative method for the storage and retrieval of information for DQ working has had to be found. Ultimately, a computerised information system will be introduced, but, as an interim measure, a microfiche system of directory information storage and retrieval was introduced in February 1981.

Microfiche readers are used extensively throughout BT and the British Post Office. The microfiche system of information storage and retrieval is particularly convenient since the storage space necessary for the microfiche is considerably less than that required for paper records. The type of reader used varies according to the particular application, but all readers are commercially available models. The reader developed specifically for use in the DQ bureaux, however, was the first reader designed by BT to meet a particular requirement; there was no commercial reader available that was capable of performing to the rigorous specification required for DQ work.

HISTORY

During 1972, studies concerning the working of the DQ bureaux and the projected growth of the service were carried out by the Operator Services Division of BT Headquarters. These studies led to the consideration of alternative information storage and retrieval systems for use in the DQ bureaux. A computerised information storage and retrieval (CIR) system was thought to be the most desirable and, after projected costings for the introduction of the system were completed, development of a CIR system was started. However, the projected time-scale for the development was so long that an interim system was considered necessary, and the use of a microfiche system as a storage and retrieval system was investigated.

Simulated feasibility trials of the microfiche system were carried out in July 1973. Commercial microfiche readers were used for these trials, which proved that such a system of information storage and retrieval was feasible. Modified commercial microfiche readers were purchased and used in trials carried out at Nottingham, Walsall and Bloomsbury between September 1974 and March 1975. During these trials, the study groups maintained close co-operation with the local Regional Medical Officers and the Applied Psychiatry Unit of the Medical Research Council. Operator's comments and requirements were noted, as were the recommendations made by the Medical Research Council.

† Exchange Systems Department, British Telecom Headquarters

Study of the reports on the trials and the project costings led to the decision to develop a microfiche reader specifically for the DQ bureaux. Some of the technical reasons for this decision were

(*a*) poor carriage performance during the trial,
(*b*) unacceptably high temperature at the rear of the reader,
(*c*) optical performance was below the standard required for DQ working, and
(*d*) overall size of the reader was too large.

The costings for the introduction and upkeep of the system showed that the minimum target rate of return on investment would be met.

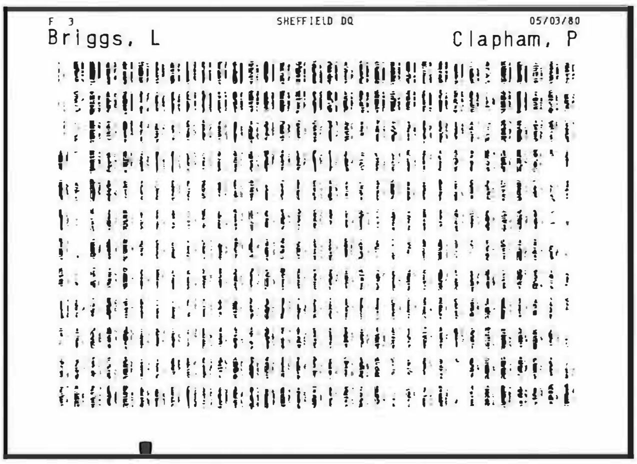
THE MICROFICHE SYSTEM

The directory information is recorded photographically in the form of a microfiche, each telephone area directory being made up of a number of microfiche stored in a binder. The required information is retrieved by the DQ operator by inserting the appropriate microfiche into a microfiche reader and viewing the required information on the screen. In the DQ bureaux, the shelf space allocated for the paper directories for the UK (approximately 2 m) now becomes more than adequate because the space required for the equivalent microfiche version of the directories is a little over 1 m. This saving means that each operator now has easy access to the complete UK directory information at the operator position, thus giving an improved service to the public.

THE MICROFICHE

Master microfiche are manufactured by first encoding the directory information on magnetic tape. The magnetic tape is processed by a COMp 80 computer, which regenerates the directory information in frame form on a cathode ray tube, and the displayed characters are photographed frame-by-frame until a complete microfiche is filled with information photographically reduced in the ratio 1 : 42. Each microfiche has 12 rows, each containing 33 columns or frames of information. An index is contained in the A column and the remaining frames used for directory information equivalent to approximately 70 pages of a paper directory. Individual frames have a letter reference for the column and a number reference for the row (see Figs. 1 and 2).

Secondary copies produced from the master microfiche are made on diazo film for use in the DQ bureaux. Diazo film has the advantage of being less expensive than silver-based emulsion film, while giving high definition and having good handling characteristics. The disadvantages of diazo film are that excessive exposure to ultraviolet light or infra-red light, together with temperatures above 40°C, cause damage to the film emulsion.



Note: Frame A1 is in the top left-hand corner

FIG. 1—Typical microfiche used by the DQ bureaux


J12
Ericksone.J,GoldCrest,Sladela Haverfordwest(0437) 3580
EricksonI,41 HopGdns,CarewPk Carew(06467) 362
EricsonS,529 HywelRd Haverfordwest(0437) 67421
EriksenB,17 Brynymor Cres (See Below)
N.B Swansea(0792) 57533 will change to Swansea
(0792) 472533
EriksenE,2 Heathfield,Mt.Pleasant Swansea(0792) 474473
ERNIE JONES,Travel-
15 AngelSt Neath(0639) 56858
Res,Pentreharne Fm,Rhos Pontardawe(0792) 863713
Ernies Taxis,Erwin,Mwtshwr La Cardigan(0239) 613579
ErnstingD,FHA,113 CharlesSt MilfordHvn(06462) 2409
Ervine A.J,
48 LeyshonRd,GwaunCaeGurwen AmmanVly(0269) 824004
Ervine W,12 Gwr-yr-Afon,Glanamman AmmanVly(0269) 824328
Erw Colliery Co.Ltd,
GrenigRd,Glanamman AmmanVly(0269) 824663
ErwinT.R.J,3 SingletonSt Swansea(0792) 49061
ErwinL.E,105 MerlinCres,Townhill Swansea(0792) 43356
ErwinT.J,
20 Rhyd-y-DefaidDr,DerwenFawr Swansea(0792) 205091
EsaiasG,33 ElmwoodRd,Baglan BritonFerry(0639) 814620
EsaiasG,
4 Twyn-y-Gored,Pwll-y-Glan Port Talbot(0639) 894446
EsaiasJ.M,65 The Greenway,Llandarcy Skewen(0792) 812421
EsauA.D,3 Bryngias Aberporth(0239) 810002
EsauA.M,New Bungalow,Sarnau Llangranog(023978) 614
EsauSister Dilys,Almyra,Sarnau Llangranog(023978) 380
EsauE.T,Dolawel New Bungalow,
Llanfihangel-ar-Arth Pencader(055934) 413
EsauJ,Plasparke Inn,Pentrecwrt Llandyssul(055932) 2330
EsauJ.B,The Poplars Newcastle Emlyn XD
EsauJ.O,5 Rhos Y Dre Cardigan(0239) 612167
EsauP.& R,PorthSq Newcastle Emlyn(0239) 710803
EsauR.J,Overdale,Brynhafod Cardigan(0239) 612725
EsauS.L,Pensarnau,Sarnau Llangranog(023978) 283
Escombe Gwyn & Co Ltd,Travel Agts & Shipbroks,
Exchange Bldgs Swansea(0792) 42971
Escombe Gwyn Tours,
Exchange Bldgs,Adelaide St Swansea(0792) 42971
EscotF,156 CwmRd,Hafod Swansea(0792) 468352
EscottB.M,4 Westbourne Gro,Sketty Swansea(0792) 205341
EscottE.V,56 Gwylfa Rd,Townhill Swansea(0792) 56149
EsgairowenFarm,Rhydcymerau,Llandeilo Talley(05583) 593
Esmile Ernie,43 Furzey Pk Haverfordwest(0437) 5613
EsmondA.M,
10 Tregennis Hl,Pembroke Dk Pembroke(0646) 686911
EsmondC,82 Cherry Gro,Sketty Swansea(0792) 204382
EsmondD.I,Fmr,Thornbush,Slebech Rhos(Dyfed)(043786) 267
EsmondD.T,15 Deer Pk,Stackpole Lamphey(0646) 672179
EsmondD.T,20 Waterloo,Pembroke Dk Pembroke(0646) 684338
EsmondM,7 Clare Wlk,Buttermilk Est Pembroke(0646) 684755
EsmondM,17 DelTan,Talcoppa Swansea(0792) 795909
EsmondP,
47 GuildfordRd,Llangwm Johnston(Dyfed)(0437) 890540
EsmondeJ,3 Pen-y-Banc Seven Sisters(0639) 700907
EsmondeN,41 ChurchRd Seven Sisters(0639) 700492
EsmondeR,29 Tegfan,Llansamlet Swansea(0792) 792172
EsneyB,3 Arthur St Llanelli XD
EsneyJ.F,26 Marble Hall Rd Llanelli(05542) 4847
EsneyP,57 Hilltop,Swiss Valley Pk Llanelli(05542) 58884
EsnoufL.M,1 Nant Hir GlynNeath(0639) 721390
Esplanade Hotel Tenby(0834) 2760
Do. Tenby(0834) 2391
EspositoDes,2 NurseryRd,Glyncorrwg Cymmer(0639) 851425

FIG. 2—Typical frame (J12) as seen on the microfiche reader

READER DQ NO. 1A

The reader, known as the *Reader DQ No. 1A* (see Fig. 3), has been designed primarily for use in BT's DQ bureaux. The design parameters for the reader were dictated by the working environment of the normal DQ bureaux, the needs of the operators, and the type of film to be used for the microfiche. The development of the reader was carried out by the Development and Technical Support Division of BT Headquarters in conjunction with CIL Ltd., and Shrewsbury Electronic Engineers Ltd.; in addition close co-operation was maintained with the Human Factors Advisory Service[1] and the Quality Assurance (QA) Division of BT Headquarters.

The reader is designed to have a working life of at least 5 years with minimal maintenance during this period. The reader's design conforms to the requirements of safety as stated in the Offices, Shops and Railway Premises Act, 1963; the Health and Safety at Work Act, 1975; and the recommendations for the safety of office machinery contained in British Standards Institution publications BS3861, Parts 1, 2 and 3, and BS4644. Limitations on the size of the readers imposed by space available at DQ positions prevented the reader from having its own built-in power source. The reader is powered by a separate Power Unit No. 150A, which may be mounted discreetly at the DQ positions. Although the reader has been designed for use in the DQ bureaux, it is suited to other applications, such as street-plan index files, stores lists etc.

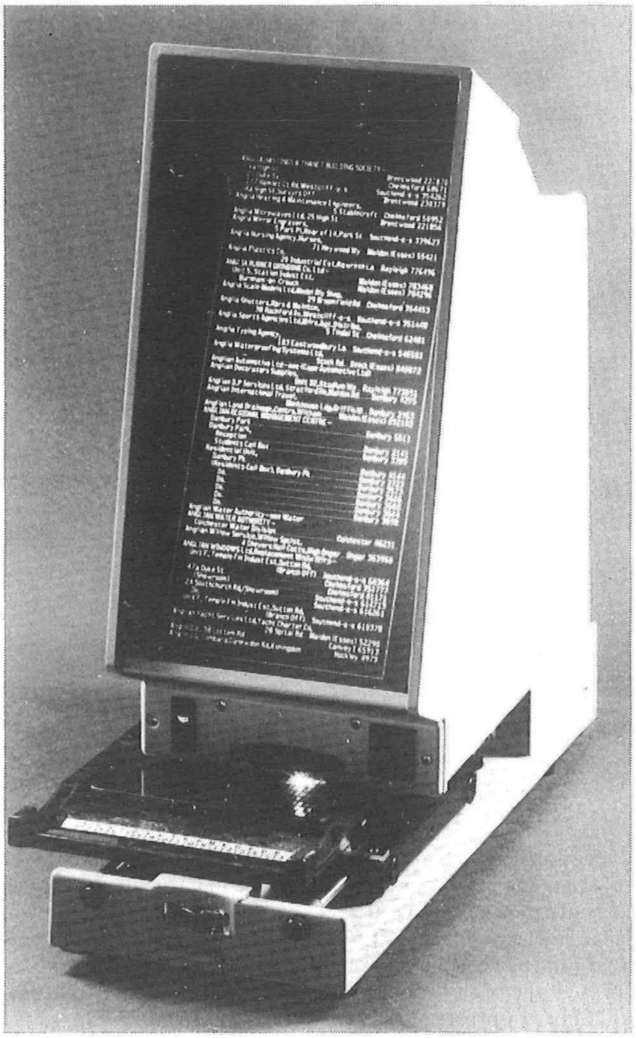


FIG. 3—Reader DQ No. 1A

In order to maintain a high quality of performance[2], while keeping the cost of the reader low, extensive use has been made of plastic components in its construction. The base moulding is manufactured from polyphenylene oxide (modified), glass filled 15%. This material was selected because of the ease with which it can be moulded, for its dimensional stability, ability to withstand high temperature and robustness in use. The cover is manufactured from glass-filled structured polycarbonate foam. This material was selected because of its suitability for moulding, dimensional stability, rigidity, light weight and ability to withstand shock loading. All plastics used in the microfiche reader are self-extinguishing grades.

Optical System

The optical system is housed in the base and cover mouldings of the reader. The light source is a tungsten halogen lamp, forced-air cooled, having an expected life of 2000 hours. In order to achieve continuity of operation, a stand-by lamp has been incorporated in the reader for use should lamp failure occur. A concave dichroic mirror, which reflects light forwards, is sited behind the lamp. The light passes through

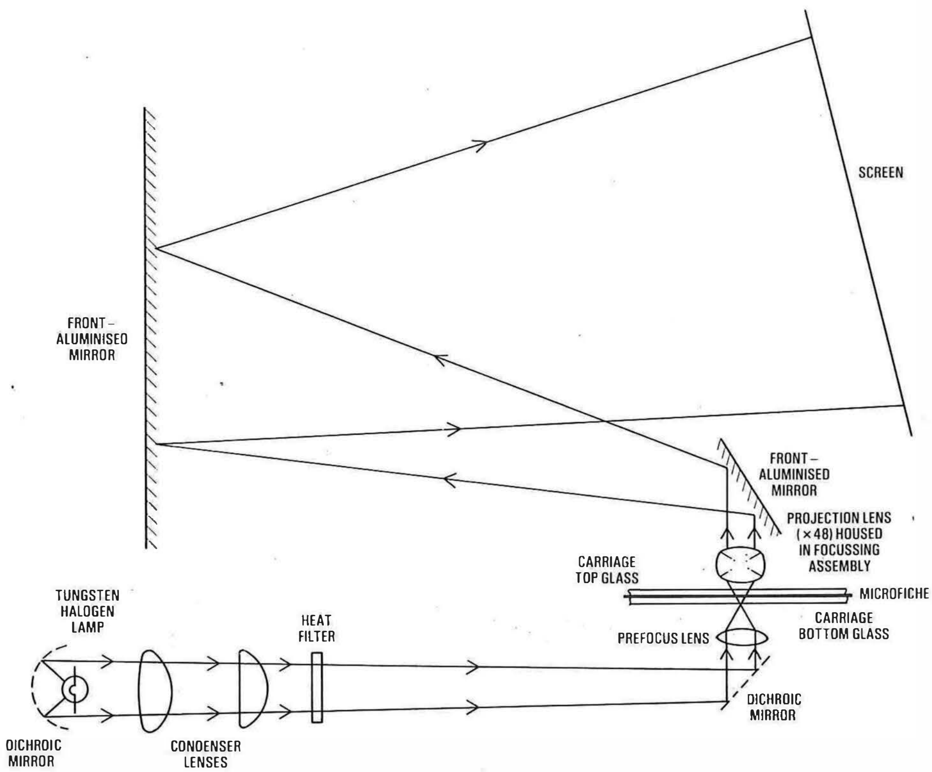


FIG. 4—Optical arrangement of the microfiche reader

condenser lenses and a heat filter to a target dichroic mirror set at an angle of 45°, which reflects the light through a convex lens situated below the fiche and in line with the projection lens. Hence, the frame of information on the fiche is illuminated and projected into the projection lens. The light passes through the projection lens and reaches the screen via 2 front-aluminised mirrors. The arrangement is shown in Fig. 4.

The dichroic mirrors filter out the infra-red component of the generated light. The ultraviolet light present in the generated light is reduced to an insignificant level by the condenser lenses, heat filter, the convex lens, and the carriage glass. The temperature of the microfiche is kept low by the use of a long light path from the lamp to the fiche, the use of a heat filter, and the lamp cooling system.

Light losses are minimised by using front-aluminised mirrors after the projection lens, and a screen having high resolution and high light-transmitting characteristics. Focussing is carried out at the front of the reader by rotating the FOCUSSING knob. Focus is maintained at the screen by the floating action of the projection lens mount which follows the contour of the top glass of the carriage assembly as it passes the projection lens, thus keeping the object distance constant within 0·05 mm. The projection lens has a resolution† in excess of 300 line pair*/mm, giving a screen resolution of at least 5·8 line pair/mm. The high screen resolution is necessary to ensure that operator eye strain is kept to negligible proportions.

The ambient light level in a DQ bureaux varies with the location within the room and the operator may adjust the screen luminance by using a HIGH-LOW switch located at the front of the reader. When in the HIGH position, the screen luminance is 260 cd/m^2 (minimum) at the centre. In the LOW position, the screen luminance is 130 cd/m^2 (minimum) at the centre. In exceptionally high ambient light conditions, an extension hood can be fitted to the reader to aid the operator.

† Resolution is the spacial frequency (that is, the number of identical line pairs that can be contained within an overall width of 1 mm) of the smallest pattern of the British Standard Microform Reader Resolution Test Film in which the lines within the pattern can be identified on the reader screen.

* Line pair is a spacial unit within the test pattern consisting of one line in such a pattern together with one space separating it from the next adjacent line within the pattern, the line and the space being of equal widths.

The Carriage Assembly

The carriage assembly consists of a carriage which holds the microfiche, and a carriage mounting which provides the means of transport for the carriage. The carriage mounting is a welded subassembly, housing 4 bush bearings, a cross slide, and fixings for 2 lifting cams. Precision ground rods pass through the bush bearings supporting the carriage assembly and allow it to move along the rods. The carriage is secured to the cross slide which provides lateral movement for the carriage. The carriage consists of a moulded plastic frame

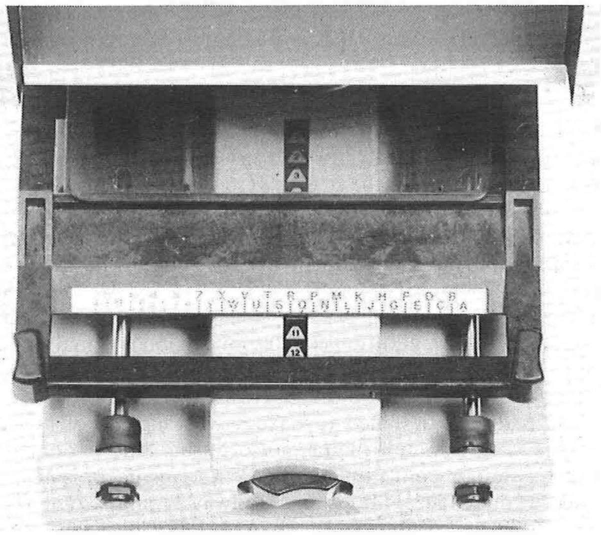


FIG. 5—Carriage assembly showing index label

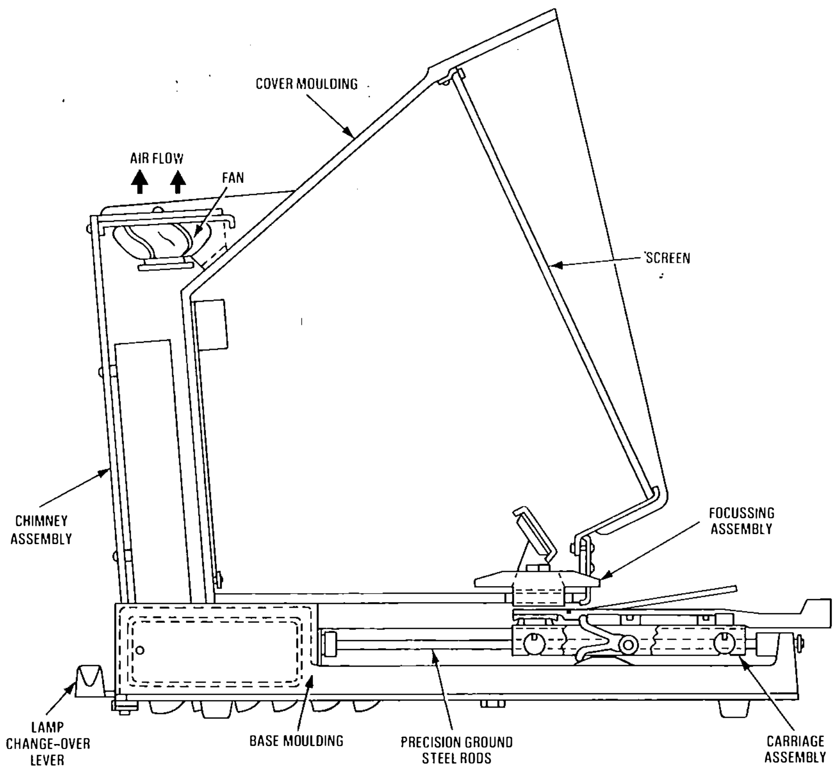


FIG. 6—Cross-section of Reader DQ No. 1A showing carriage assembly

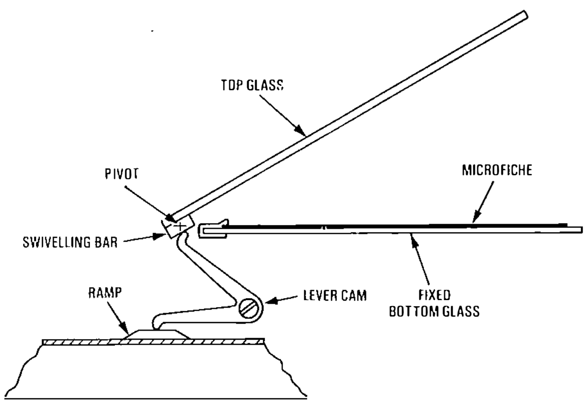


FIG. 7—Operation of the lifting cam

housing a fixed bottom glass, a moveable top glass mounted on a swivelling bar, and an index label. To locate the required frame on the microfiche the index label on the carriage is aligned with a number on the index label fixed to the base (see Fig. 5). When the carriage assembly is drawn to the front stop, the lifting cams ride up ramps on the base and act on the swivelling bar to open and support the moveable top glass; this allows the operator to insert or remove a microfiche. If a load is applied to the top glass when it is in the open position, the lifting cams flex allowing the top glass to close without causing any damage. The carriage assembly is shown in Figs. 6 and 7.

The bearings and lifting cams are moulded from an acetal homo-polymer plastic. This material has the properties of low wear, low creep and good moulding characteristics, and requires no lubrication when used for the bearings. The carriage moulding is manufactured from the same material as the base of the reader.

The carriage assembly design has had to meet the requirements of reliability, low maintenance, and ease of operation whilst being relatively insensitive to vibration caused by table shock. The carriage assembly has completed over 1 million operations on life test and has shown minimal wear.

POWER UNIT No. 150A

The power unit, known as the *Power Unit No. 150A*, supplies 12·6 V AC at 130 VA to the reader's lamp and 24 V AC at 10 VA to the reader's extraction fan. The power units may be free standing when mounted inside a DQ position or secured via mounting brackets (integral with the power unit case), when mounted externally.

The power unit supplies power to the Reader DQ No. 1A via a low-tension socket fitted at the DQ position. The regulation of the Transformer No. 563A-1 used in the Power Unit No. 150A is between 5% and 7%, which prevents the lamp from being over run due to mains fluctuation. In normal use, the Reader DQ No. 1A is often subjected to long periods of continuous operation as DQ bureaux operate on a shift basis. The core temperature of the transformer is kept relatively low (37·5°C) in order to keep the temperature of the outer case within acceptable limits for office safety.

It is essential not to over run the lamp to prolong its life. The designed voltage across the lamp is always less than the 12 V nominal operating voltage. This is ensured by:

(*a*) Using a standard low-tension socket assembly with a pre-cut length of cable attached for connection to Power Unit No. 150A. This, together with the internal wiring of the lamp circuit inside the Reader DQ No. 1A, acts as a dropping resistor and gives a nominal 11·7 V across the lamp.

(*b*) Maintaining the correct working temperature for the lamp.

TEST TECHNIQUES

The urgency of the project, and a very short time-scale of 3 months for acceptance testing of the reader, prevented a full-scale trial being carried out prior to implementation of the microfiche system in DQ bureaux. In order to evaluate the reader design, 2 preproduction models were submitted by the manufacturer. A test programme was drawn up taking account of the mode of working and the numbers of calls per annum expected in a busy DQ bureaux.

The testing of the 2 readers was carried out in an identical manner with the exception of lamp voltage. One reader had a lamp voltage of 12 V and the other a lamp voltage of 12·6 V. This difference enabled the lamp performance to be observed under normal voltage conditions and when over run by 5%, whilst being subjected to expected carriage shock. Pneumatic test jigs were developed by the test section at BT's QA Division, Studd Street, London, to provide carriage movement and count carriage cycles. Screen luminance and resolution, lamp life and surface temperature of the readers were also monitored during the life test. The readers were run without the screens, top glass or carriage transport being cleaned.

On completion of 1 million operations (this figure approximates to 9 months of reader use), the readers were examined for wear. Carriage bearings and transport rods showed minimal wear, but scratches were present on the top glass and wear was present on the focus assembly that had been in contact with the top glass. Detailed examination of the focus assemblies and top glasses showed that the scratches were caused by minute particles of grit and glass embedded in the focus assembly surfaces in contact with the top glass. The scratching of the top glass could have been minimised by routine cleaning of the top glass and focus assembly. Despite dirt on the screen and scratched top plates, the display was easily read. Carriage movement along the rods was found to be more difficult as the life test progressed. This was found to be caused by dirt on the rods; again, this could have been minimised with routine dusting of the rods. The carriage movement, despite being more difficult, was found to be acceptable. The reader working with a lamp-voltage of 12 V had one change of lamp after 1650 hours whilst the reader using a lamp voltage of 12·6 V had 2 lamp changes during the same period of time. The lifting cams were found to have weakened during the life test, but the design was not changed because of production problems, and the relative low cost of changing the cams on a 6-monthly basis.

Other tests on major components carried out prior to production included impact loading tests on plastic components, such as the cover base moulding and carriage mouldings, and optical examination of the projection lens using the optical transfer function technique.

Despite the rigorous tests carried out on the reader, problems were experienced during the initial period following the implementation of the system. Some of these problems were, however, attributable to the inexperience of installation and maintenance staff, who had no previous microfiche reader experience to draw upon.

IMPLEMENTATION PROGRAMME

The implementation programme for the microfiche system of directory information storage and retrieval was arranged to run in parallel with that of the manufacturing time of 18 months for the reader, power unit, microfiche and spare parts.

During this period, some 5000 DQ operator positions were modified to accept the reader and the power unit (see Fig. 8), and a computer was installed at the Barbican Computer Centre, London for the manufacture of the master microfiche. In order to supply each DQ position with directory information it was necessary to create over 5000 secondary microfiche from each master. This reproduction was carried out by BT's Reprographics Services at Old Street, London, who ensured that the microfiche were available on time. This called for close production control and for new techniques to be evolved, a task made more difficult by the fact that conventional paper directories had to be produced at the same time.

FIG. 8—Typical office-type DQ bureaux

To keep the directory information at the DQ bureaux up to date, approximately one million microfiche are produced each month.

Staff training also had to be carried out, and the first 500 readers and associated power units off the production line were used for this purpose. In all, 30 000 operators had received training in the new system by the implementation date.

CONCLUSIONS

The success of the system has to be judged bearing in mind the following consideration. The system was completely new to BT and staff agreements had to be negotiated, as well as personnel trained to operate and maintain the equipment. After one year of service, the initial problems have been overcome, with BT's Birmingham Factory handling the major maintenance problems and local maintenance staff handling the minor ones. In all, there are 6500 readers and power units in use in BT's DQ bureaux and back-up systems.

Most operators now prefer the microfiche system of directory information storage and retrieval to the old paper directory system. The time taken to provide the customer with the required information has been maintained and will be reduced in the future.

The cost of operating the DQ service has been reduced as a result of the increase in efficiency available with the new system and the low cost of producing microfiche compared with paper directories.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in BT Headquarters, in particular Mr. J. McAllister and Mr. P. M. J. O'Dell, for their assistance with this project.

References

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2 BRITISH STANDARDS INSTITUTION. Specification for Microform readers. 1976. BS 4191.

Telecom Technology Showcase

An interesting new exhibition centre—called the *Telecom Technology Showcase*—in which the development of telecommunications from its earliest days to the present electronic era is shown, has been set up by British Telecom London. The centre, housed on 2 floors of an annexe to Baynard House in Queen Victoria Street in the City of London and close to the Mermaid Theatre, was officially opened on 30 April, this year, by the founder of the theatre—Lord Miles of Blackfriars; it will work in neighbourly co-operation with the Mermaid's Molecule Club. The Molecule Club is a travelling theatre company who present dramas based on science and engineering subjects to school children.

The purpose of Showcase is to demonstrate to the public the important role played by telecommunications in today's world. To illustrate its importance, many of the most recent developments in information and communications technology are on display. Many examples of British Telecom's vast range of services and equipment are on show so that people can see the many fascinating things that are happening in telecommunications; for example, digital switching, optical-fibre transmission, Prestel, telephones that can "think", and word processors. Previews are also given of future developments which are constantly being updated to keep pace with the needs of a rapidly changing society.

Showcase also traces the evolution of telecommunications from its very beginnings with the work of men, such as Cooke, Wheatstone, Bell, Edison, and Marconi, whose inventions have led to the communications revolution that is still going on today. It describes the development of the telecommunications business, how the Post Office took over from private enterprise, how public service was created, how Post Office Telecommunications became British Telecom and how the service has been expanded and improved by using modern technology.

To illustrate these developments, Showcase features many exhibits of historical interest. Many items of early equipment are on display, such as telegraph apparatus, telephones and switchboards, many of which are in working order and displayed in their historical context. There are several models and diagrams which demonstrate the working of a telephone, the operation of a Strowger automatic exchange, the inside of a manhole, the telecommunications plant and other services beneath the streets and pavements, and many other topics. Set pieces show an early telegraph office, the trenches in the First World War, and a village Post Office exchange.

The deck level of Showcase is devoted to a general survey of the development of telecommunications and includes the following displays.

Lord Miles and Mr. Peter Benton, Deputy Chairman of British Telecom, viewing the display of an early switchboard

(*a*) *An early switchboard*

(*b*) *The invention* The electricians. Philosophical toys. The transport revolution. Electric telegraphs. The 5-needle telegraph.

(*c*) *Early telegraphs* Railway telegraphs and the beginnings of a public service.

(*d*) *Cables* Running out the wire overhead and under the sea. Transatlantic cables.

(*e*) *Personalities* Some of the people who have contributed to telecommunications technology.

(*f*) *Telephones and Companies* The invention. Bell and Edison. The rivalries between the companies. The Electrophone.

(*g*) *The Telephone Service* The Post Office takes over. Operators. Poles and holes. Subscribers. Development.

(*h*) *First World War* Post Office engineers at the Front.

(*i*) *Early Radio* Wireless communication. Rugby. For those in peril on the sea.

(*j*) *The 1930s* Automatic exchanges. Telegrams. New services. A new image.

(*k*) *Second World War* Keeping the lines working on the Home Front.

(*l*) *From General Post Office to British Telecom* Subscriber trunk dialling. Dial the world. Telex. Information technology. Telecom update.

(*m*) *The Digital Revolution* System X. The digital revolution at home and in the office. Optical fibres. High definition Prestel. Facsimile. Slow-scan television. Telecom Gold. The digital future.

Also on the deck level there is an information desk where information on specific exhibits can be obtained. There are also books, leaflets, and souvenirs available.

On the lower level, specific topics are dealt with in greater detail for the visitor who requires more technical information; the following displays are included.

(*a*) *Public Telephones* Call offices. Kiosks. Coin-collecting boxes.

(*b*) *Telephones* How the telephone works. Receivers, transmitters and dials. Historical display of telephones.

(*c*) *Telephone exchanges* Early switchboards. PBXs. Village Post Office exchange. Auto-manual exchanges. Automatic exchanges. Strowger. Register translators. Call charging. Relays. Modern exchanges.

(*d*) *The network* The network beneath our feet. Local network. Cables. Transmission. Manholes. External plant. The main network.

(*e*) *Telegraphs* The first electric telegraphs. Historical display of telegraphs. The telegraph service. News services. Telex.

(*f*) *Emergency and Maritime Radio* 999 service. SOS. Ship-to-shore.

(*g*) *Radio Communication* Early attempts at radio communication. Preece and Marconi. Electromagnetic waves. The coherer. Valves. International links. Microwave. Satellites.

In adjacent accommodation there is a study centre housing a large array of books, manuals and magazines which cover all aspects of telecommunications; this can be visited by appointment, and facilities for photocopying are available.

The opening times for Showcase are Monday–Thursday, 10.00 hours to 16.30 hours. Showcase is closed on Bank Holidays. Admission is free. Details of group visits and other special facilities can be obtained from the Administrator, Telecom Technology Showcase, Baynard House, 135 Queen Victoria Street, London EC4V 4AT; Telephone 01-248 7444.

The editors wish to acknowledge the help given by the staff of the Telecom Technology Showcase in preparing this review.

Institution of British Telecommunications Engineers

(formerly Institution of Post Office Electrical Engineers)

General Secretary: Mr. R. E. Farr, BTHQ/TE/SES5.3, Room 458, 207 Old Street, London EC1V 9PS; Telephone 01-739 3464, Extn. 7223.
(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the October 1981 issue of *The Post Office Electrical Engineers' Journal*.)

AMENDMENTS TO THE RULES OF THE INSTITUTION

A number of changes to the Rules proposed by Council were submitted to Corporate Members in a letter dated 1 February 1982, in accordance with Rule 33. A total of 105 objections was received to the proposed change to Rule 33 itself, and a ballot has been organised. Only 2 objections were received to the remaining proposals for changes to the Rules, and a number of members suggested minor editorial improvements which have been taken into account. These Rules as amended are listed below and became effective on 1 July 1982.

Further related changes to the Rules of a non-contentious nature, notably to the Rules concerning the Associate Section, have been agreed by Council and have been certified by the Chairman of Council as not affecting the intended operation of the Rules in accordance with Rule 33. These amended Rules also became effective on 1 July 1982 and are included below, marked thus *.

Rules 4–15 Replace by the following:
"*Corporate Members*

"4. Corporate Members shall comprise Members and Affiliated Members who shall be in the employ of the British Telecommunications Corporation, such of its Subsidiaries as Council may allow, or the Post Office, except as permitted under Rule 10(a), and Honorary Members.

"5. *Members*

5.1 All British Telecommunications Corporation or Post Office staff below the Senior Salary Structure in the grades listed below shall be eligible to be Members:

(a) Executive Engineer
Motor Transport Officer Class III
Assistant Regional Motor Transport Officer
Commander, Chief Officer, 2nd Officer, Chief Engineer and 2nd Engineer (Cable Ships)
Technical Costs Officer
Senior and Leading Draughtsman/woman
Senior and Leading Illustrator

(b) Assistant Executive Engineer
Inspector
Technical Assistant
Draughtsman/woman
Illustrator
Cable Ship Officers not included in (a) above
Assistant Factory Foreman/woman
Assistant Technical Costs Officer

5.2 Senior Salary Structure staff of the British Telecommunications Corporation or the Post Office who were promoted from the grades listed in 5.1 or are directly involved with engineering work shall be eligible to be Members.

"6. *Affiliated Members*

6.1 All other British Telecommunications Corporation and Post Office staff in grades at the same level as those covered by Rule 5, who are not eligible to be Members under Rules 5 or 10 but who are associated with the engineering work carried out by Members, shall be eligible to be Affiliated Members.

6.2 Employees of such British Telecommunications Corporation Subsidiaries as are agreed by Council who are directly involved in engineering work, of similar status to the grades listed in Rule 5 and not eligible to be Members under Rule 10, may apply to become Affiliated Members.

6.3 Affiliated Members who have written and read a paper before the Institution and which paper has been accepted by Council for printing may be invited by Council to take full Membership of the Institution.

"7. *Honorary Members*. Council may elect a limited number of Honorary Members from among persons whose services to the Institution have been of an exceptional character.

"*Non-Corporate Members*

"8. Non-Corporate Members shall comprise Corresponding Members.

"9. *Corresponding Members*

The admission of Corresponding Members shall be controlled by Council in accordance with the principles laid down in this Rule. Application for Corresponding Membership may be made by the following:

(a) Former Corporate Members of the Institution who have left the employ of the British Telecommunications Corporation, its Subsidiaries or the Post Office and are engaged on responsible work connected with communications engineering.

(b) Engineers engaged on work of a responsible character either in connection with an overseas postal or telecommunications service or telecommunications under the control of a British Government Department.

The power to grant or terminate Corresponding Membership may be exercised by the Chairman on behalf of Council.

"10. *Retention of Membership*

(a) Corporate Members who retire from the British Telecommunications Corporation or the Post Office, who transfer to or retire from a Subsidiary of the British Telecommunications Corporation, or who are transferred to non-engineering posts in these organisations, may retain their existing class of membership.

(b) Corporate or Non-Corporate Members who enjoyed a class of membership different from that proposed under these Rules may, if they so desire, retain their existing class of membership.

"11. Notwithstanding eligibility for membership as stated or implied in these Rules, the membership of any particular individual shall be at the discretion of the Council.

"12.* In subsequent Rules, unless the context indicates otherwise, 'member' or 'membership' connotes any class of Corporate Member.

"13. *Subscriptions*

(a) The annual subscription for Corporate Members of the Institution shall be as determined by Council and published in the Journal. Honorary Members shall not be required to pay a subscription. Members or Affiliated Members who retire from the employ of the British Telecommunications Corporation, its Subsidiaries or the Post Office and who wish to retain their membership may commute their annual subscriptions for life by payment of a sum equal to two annual subscriptions rounded to the nearest multiple of 50p.

(b) Any proposal to increase the subscriptions of Corporate Members shall be submitted by Council to Local-Centre Committees for endorsement before it can be implemented. In the event of endorsement not being given by one or more Local-Centre Committees, the proposal shall be submitted to the membership as for a change of Rules and Rule 33 shall apply.

(c) Exceptionally, Council may waive the requirement for an annual subscription for Corporate Membership where the membership of a particular individual is deemed to be in the interest of the Institution.

(d) The annual subscription for Non-Corporate Members of the Institution shall also be published in the Journal and shall be calculated as 20% of the subscription for a Corporate Member, rounded up to the next multiple of 20p, plus the cost of the annual postal subscription to the Journal.

"14.* Every Corporate and Non-Corporate Member of the Institution shall be considered as belonging thereto and, unless exempted under Rule 13, liable to pay the annual subscription until he or she has signified to the Honorary Local Secretary (the Secretary in the case of Corresponding Members) the wish to resign. Before any person who has previously resigned from the Institution is permitted to resume membership, he or she shall pay any subscription in arrears at the time of resignation.

"15.* Any Corporate or Non-Corporate Member whose subscription is in arrears shall be notified of the fact by the Honorary Local Secretary (the Secretary in the case of Corresponding Members). Any Corporate or Non-Corporate Member whose subscription remains in arrears three months after such notification shall not be entitled to vote, to receive the Institution's Journal and Printed Papers or to make use of the facilities afforded by the Institution's Library."

Rule 18 Amend to read:

".......... Sixteen members of Council shall be nominated and elected by the members by and from each of the following groups:

Group 1. Members employed in the British Telecommunications or Post Office Headquarters Departments and London Regions holding posts in Bands 1 to 8 of the Senior Salary Structures.

Group 2. Members employed in the British Telecommunications or Post Office provincial Regions holding posts in Bands 1 to 8.

Group 3. Members employed in the British Telecommunications or Post Office Headquarters Departments (London) holding posts in Bands 9 and 10.

Group 4. Members employed in the British Telecommunications or Post Office London Regions holding posts in Bands 9 and 10.

Group 5. Members employed in the British Telecommunications or Post Office provincial Regions or Headquarters Departments (provinces) holding posts in Bands 9 and 10.

Group 6. Members employed in the British Telecommunications or Post Office Headquarters Departments (London) listed in Rule 5(a) with the exception of those in Group 14 below.

Group 7. Members employed in the British Telecommunications or Post Office London Regions listed in Rule 5(a) with the exception of those in Group 14 below.

Group 8. Members employed in the British Telecommunications or Post Office provincial Regions or Headquarters Departments (provinces) listed in Rule 5(a) with the exception of those in Group 15 below.

Group 9. Members employed in the British Telecommunications or Post Office Headquarters Departments (London) listed in Rule 5(b) with the exception of those in Group 14 below.

Group 10. Members employed in the British Telecommunications or Post Office London Regions listed in Rule 5(b) with the exception of those in Groups 12 and 14 below.

Group 11. Members employed in the British Telecommunications or Post Office provincial Regions or Headquarters Departments (provinces) listed in Rule 5(b) with the exception of those in Groups 13 and 15 below.

Group 12. Members employed as Inspectors in the British Telecommunications or Post Office London Regions.

Group 13. Members employed as Inspectors in the British Telecommunications or Post Office provincial Regions.

Group 14. Members employed as Draughtsmen/women or Illustrators and above, but below the Senior Salary Structure, in British Telecommunications or Post Office Headquarters Departments (London) and London Regions.

Group 15. Members employed as Draughtsmen/women or Illustrators and above, but below the Senior Salary Structure, in British Telecommunications or Post Office provincial Regions and Headquarters Departments (provinces).

Group 16. All Affiliated Members.

"Although not specifically stated, the foregoing Groups shall be taken as embracing members who are in the employ of a British Telecommunications Corporation Subsidiary, of the same class of membership and status and in a similar organisational and geographical location.

"Council shall have the right to nominate one additional member of Council to represent members employed by the Post Office when these members are not otherwise represented on Council.

"The Honorary Treasurer shall be nominated and elected from members employed in the London Headquarters Departments of British Telecommunications or the Post Office but members frequently away from London shall not be eligible. All members shall be entitled to vote in the election of the Honorary Treasurer. Members of Council and the Honorary Treasurer shall be elected by ballot."

Rule 20(a) Insert "British Telecommunications and" in front of "Post Office".

Rule 22 Add new penultimate sub-paragraph:

"The Committee shall have the right to nominate one additional Committee member to represent members employed by the Post Office where these members are not otherwise represented on the Committee."

Rule 24 Add new sub-paragraph at the end of the section headed "Centres other than Martlesham Heath", to read as in Rule 22 above.

New Rules 34X and 34Y (These are temporary numbers.) These rules are to be inserted between Rules 34 and 35 and are to read as follows:

"34X. The results of ballots held under Rules 33 and 34, and all alterations to the Rules whether or not they are consequential upon a ballot, shall normaliy be published in the Journal except that from time to time when Council decides that such action is necessary, the complete Rules or extracts thereof shall be published on the basis of one copy per member. This action shall constitute the sole notification of such matters to the membership.

"34Y. As far as the Rules in the section headed 'THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)' are concerned, the references to Corporate Member, Corporate Membership and member in Rules 33 and 34 shall be taken as referring only to Members of the FITCE Group of the Institution. It shall be the exclusive right of Members of the FITCE Group to formulate, add to, alter or cancel Rules in the FITCE section, except that Council shall be asked to certify that the intended operation of the remaining Rules of the Institution is not affected."

Rules 54–58 Replace by the following:

"54.* The objects of the Associate Section of the Institution are

(a) to further technical education by the reading of papers and the discussion of topics relating to telecommunications or postal engineering and allied subjects, and by visits to appropriate places of interest, and

(b) to facilitate the exchange of information and ideas on such matters among its members.

"55.* The Associate Section shall be organised in Local Associate Section Centres which may be established at such places as are determined locally. Each Local Associate Section Centre shall hold meetings in furtherance of the objects of the Associate Section and shall be managed by a Local Associate Section Centre Committee responsible for ensuring that the Rules of that Centre, as agreed by its members, are observed.

"56.* A number of Local Associate Section Centres may jointly organise and elect representatives to a Committee to co-ordinate their activities on a British Telecommunications Regional or other appropriate geographical basis. An elected National Executive Committee shall co-ordinate the activities of the Associate Section nationally and shall hold an annual meeting at which Regional Committees are represented. This National Executive Committee shall also constitute the liaison point with the Council of the Institution on all matters of national concern to the Institution and the Associate Section. Local Associate Section Centres may remain independent of the Regional/National Committee if they so wish.

"57.* The Associate Section National Executive and Regional Committees shall each have their own set of Rules agreed by the participants and shall be empowered to require a subscription to be paid by participating Local Associate Section Centres on a per-member basis. The amount of such subscriptions shall be determined by the Committee concerned and Local Associate Section Centre subscriptions shall be determined by the Local Associate Section Centre Committee concerned.

"58.* All Associate Section Rules shall be based upon a set of guiding principles approved by the Council of the Institution. The Rules must include the requirement to keep audited financial accounts and measures to ensure, in the event of a Local Centre or Committee of the Associate Section being disbanded, specific action with regard to the disposal or safekeeping of remaining funds. The Council of the Institution reserves the right to require specific action to be taken with regard to such Rules and their observance where matters considered to be detrimental to the interests of the members concerned, the Associate Section or the Institution are brought to its notice.

"59.* Area and Regional Liaison Officers, whose activities shall be conducted under the guidance of the President of the Associate Section, shall be jointly nominated by the Chairman of the appropriate Institution Local Centre and British Telecommunications Corporation or Post Office local management, from among the Corporate Members of the Institution, to liaise between Local Associate Section Centres or Associate Section Regional Committees and parallel Institution Local Centres and British Telecommunications/Post Office local management on matters of mutual concern.

"60.* Membership of the Associate Section shall be restricted to staff employed on Engineering, Drawing Office, Factories, Motor Transport and Radio Operator duties of the British Telecommunications Corporation and the Post Office, in grades below those eligible for Corporate Membership of the Institution. Local Associate Section Centres shall be entitled to enrol any other British Telecommunications or Post Office non-technical staff who are not entitled to be Corporate Members of the Institution as Affiliated Members if they so wish.

"61.* Members of the Associate Section shall be entitled to use the services of the Institution Central Library and to purchase at reduced rate, for personal use only, copies of Printed Papers published by the Institution.

"62.* An affiliation fee to cover administrative costs shall be paid to the Secretary of the Institution not later than 1 July each year. For those Local Centres which subscribe to the Associate Section National Committee, this Committee shall pay on behalf of all such Centres an annual bulk fee and for independent Local Associate Section Centres, the annual fee shall be on a per-member basis. The amounts of such fees shall be as determined by the Council of the Institution, published in the Journal and notified to the Committee/Centres by the Secretary of the Institution."

SUBSCRIPTIONS TO THE INSTITUTION

In accordance with the foregoing Rule changes, the following subscriptions apply from 1 July 1982:

Corporate Members	£3.96 per annum
Non-Corporate (Corresponding) Members	£6.00 ,, ,,
Commuted Subscription for retiring Corporate Members	£8.00 (once and for all payment)
Affiliation Fees (Associate Section):	
National Executive Committee	£50.00 per annum
Independent Centres	2p per member per annum

MEDAL AWARD—75TH ANNIVERSARY AUDIO-VISUAL PRESENTATION

A special 75th Anniversary Silver Medal has been awarded to Mr. J. M. Avis for his outstanding contribution to the Anniversary Audio-Visual Presentation. This Presentation, which covers technical developments in telecommunications engineering over the last 25 years, has already been seen by some Institution and Associate Section Centres and is available for presentation to British Telecommunications/Post Office and outside audiences.

MAGAZINE CIRCULATION

My letter of April 1982 announcing to members the cessation of the magazine circulation service at the end of August 1982 quoted budgeted figures for the cost of magazine purchase and distribution for 1981/82 (£12 000 gross, £10 000 net after magazine sales). The actual figures have proved to be very much higher at £15 500 gross, £14 000 net after sales.

R. E. Farr
Secretary

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(formerly The Institution of Post Office Electrical Engineers)

SUITABLY QUALIFIED CORPORATE MEMBERS

of

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

may apply for

MEMBERSHIP

of

THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)

FITCE is an organization with similar objects to IBTE and draws its members from the public telecommunications administrations of Belgium, Denmark, Eire, France, Italy, Luxembourg, the Netherlands, the UK and West Germany. Greece and Spain are negotiating affiliation. FITCE publishes a quarterly Journal from its Brussels headquarters, sponsors multi-national study groups (Commissions) to enquire into and report on problems of general interest, and each year organizes a General Assembly/Congress in one of the member countries at which members are invited to present papers.

Full membership of FITCE in the UK is available only through IBTE. Members and Affiliated Members of IBTE who hold a University science degree or who are Chartered Engineers may join through the FITCE Group of IBTE. The annual subscription for 1982/83 has been fixed at £5·00; this covers local administration expenses as well as the per-capita contribution to FITCE funds, and thus ensures that no charge proper to FITCE affairs will fall upon the general membership of IBTE. Membership forms are available from your Local-Centre Secretary (see p. 304 of the October 1981 issue of this Journal) or direct from the General Secretary.

THIS IS YOUR OPPORTUNITY TO PLAY AN ACTIVE PART IN CO-OPERATION WITH TELECOMMUNICATIONS ENGINEERS FROM OTHER EUROPEAN COUNTRIES

British Telecom Press Notices

BRITISH TELECOM SETS ANOTHER NEW OPTICAL-FIBRE RECORD

British Telecom's (BT's) fibre research team, in co-operation with UK industry, has set another new world record in optical-fibre transmission. A 650 Mbit/s digital signal—equivalent to nearly 8000 simultaneous telephone calls—has been sent along a 31·5 km length of continuous fibre laid in duct.

The fibre was incorporated in a trial cable installed between BT's Research Laboratories at Martlesham Heath and its new System X exchange in Woodbridge, Suffolk. The transmission is the longest to be achieved in the world without intermediate regeneration in monomode optical fibre made up into cable and installed in an operational duct. The pulse rate of 650 Mbit/s is the highest achieved under similar circumstances, and is 4 times greater than that currently used for the transmission of long-distance telephone calls.

The trial system was set up jointly by BT, GEC Optical Fibres, and Telephone Cables Ltd. (TCL), and its success brings much closer the goal of achieving reliable transmission systems that operate at up to 30 km without intermediate repeaters. It operates at a wavelength of 1300 nm, and the monomode transmission which is used is much more efficient than the existing multimode technique.

In multimode, the central light-carrying part of the fibre is comparatively large, and allows the light to travel in up to 250 different ray paths. This means that each light pulse spreads as it travels along the fibre; eventually it reaches the point where successive pulses start to overlap and make pulse regeneration necessary.

Monomode transmission uses fibre with a light-carrying core that is so small that it supports only one ray path, or mode. This greatly reduces pulse spread, and allows the pulses to travel much further. The fibre itself was made by BT's Research Laboratories and GEC using glass of such high purity that a slab 20 km thick would transmit as much light as an ordinary window glass. It was made up into cable by TCL using a *loose-tube* structure, and this avoids microbends in the fibre (small bends that scatter light, and thus increase loss).

In the loose-tube structure, each fibre is enclosed loosely in a plastic tube 2·8 mm in diameter. As a result, the loss of the cabled fibre differs little from its original figure.

The cable was installed—with one exception—in 1 km sections; these were jointed by research-laboratory engineers using specially developed fusion-splicing equipment. One 2 km-long section was installed to demonstrate the ease with which the cable could, because of its light weight, be handled. The 30 km length was achieved by linking up 4 fibres end-to-end over the 7·5 km route. Jointing was carried out in a test vehicle and in a tent mounted above a manhole.

As a further experiment, BT's fibre research team connected the 31·5 km of ducted, cabled fibre to a similar length of fibre in an experimental cable wound on a drum in the Martlesham laboratories. This cable was jointed at 2 km intervals to simulate likely future operational conditions.

The team successfully transmitted 1300 nm wavelength pulses at 140 Mbit/s over the combined 63 km of fibre, again without intermediate regeneration.

LAYING OF A NEW £100M TRANSATLANTIC TELEPHONE CABLE BEGINS

The first section of a new £100M transatlantic telephone cable was brought ashore in Cornwall earlier this year by the combined efforts of British Telecom International's (BTI's) cable ship, *Monarch*, and a beach working party. The cable can carry up to 4200 telephone calls simultaneously, and it will boost Britain's transatlantic cable capacity by more than 50% when it comes into service next year. This new link, called *TAT 7*, is 6100 km long, and can handle computer data and Telex messages as well as telephone calls between Europe and the USA and Canada.

About £30M of its cost is being spent in Britain with Standard Telephones and Cables, which is making about 5000 km of cable. The cost of TAT 7 is being divided equally between North America and Europe with BTI contributing more than a fifth of the £100M total. On the European side, Britain is partnered by 17 other participants, and her share, 22% of the total, is the largest. Seven North American organisations are taking part, including the American Telephone and Telegraph Company, which has the largest single share in the system, some 40% of the total.

The UK end, about 4 km long, was floated ashore from *CS Monarch* at Porthcurno, Land's End. It was jointed to a land section running 3·2 km inland to Land's End repeater station. Cable across the remainder of the European continental shelf section—stretching out more than 333 km—will be put down later this year; it will be laid in a trench in the seabed to protect it against damage from trawling. The deep ocean crossing, spanning 5556 km, will be laid in 4 sections from November to March 1983.

TAT 7 is the ninth in a series of telephone cables to be laid between North America and Europe. This series began in 1956 with the laying of TAT 1, the historic UK–USA link which became the world's first transoceanic telephone cable. TAT 1 began the great leap forward in global communication which was made possible by long-distance cables and satellites.

The new submarine system is needed across the Atlantic to cater for the massive growth in calls, which is still continuing, between the 2 continents, and, in particular, between the USA and Britain, the world's busiest transoceanic telephone cable route. At present more than 30 million telephone calls are made each year between the UK and the USA, about half of which go by cable. The new cable will also help to maintain the balanced division of transatlantic telephone circuits between cable and satellite. At present, cables provide some 7000 telephone circuits between Europe and North America.

On the heavily loaded telecommunications links between Europe and North America the economics of submarine cables compare favourably with those of satellites. Sharing the telephone load between the 2 technologies also improves the security and reliability of transatlantic communications. It ensures that a reasonable number of alternative paths are available in the event of a system breaking down.

TAT 7 will therefore enable BTI to continue providing more transatlantic telephone, Telex and other facilities at steadily reducing rates of charge in real terms.

NEW EXCHANGE FOR OVERSEAS TELEX CALLS

A new £8 M computer-controlled Telex exchange was handed over to British Telecom International (BTI) earlier this year by Plessey Controls Ltd. This all-electronic exchange, installed and commissioned on schedule in Keybridge House, London, transmits messages between Britain's 90 000 Telex customers and more than a million Telex users in 170 other countries.

With its computer control, this new addition to BTI's network of international Telex exchanges provides a faster service and new facilities for Britain's Telex users. In particular, it is capable of storing Telex messages which cannot be transmitted on demand and of automatically retransmitting them later; thus it enables customers to overcome congestion in overseas networks and inter-continental time differences.

The new Telex exchange is providing 11 000 extra connections to Europe and beyond, in order to keep pace with the rapid growth of international Telex calls; eventually it could be expanded to 27 000 lines.

Calls are set up in only a fraction of the time taken by electromechanical gateway exchanges; and if at the first try the call does not connect, the exchange automatically makes further attempts without the caller having to re-dial the number. In addition, the exchange offers a store-and-forward facility; this allows the exchange to be instructed to store a particular message for transmission later, when international lines are less busy.

Multi-address is available; this means that the exchange automatically sends the same message to more than one customer. The message is held in store in the exchange until the sender has transmitted the Telex numbers of all the destinations. After the caller has finished, the exchange calls these numbers automatically and transmits the message to each in turn.

The control computer is programmed to send out automatically service messages giving notice, for example, that circuits to a particular country are temporarily unavailable. The exchange computer maintains a continuous record of information on all calls it handles, for accounting and traffic analysis. At regular intervals it produces call figures and other statistics, and continuously checks its operations to provide immediate indication of fault detection.

Associated with the exchange in Keybridge House is a new centre for checking all lines into and out of the exchange. The centre enables engineers to keep a 24-hour watch on the circuits. A transmission link developing a fault is pinpointed by an automatic indicator light; engineers are then able to connect test equipment to find the trouble. Faults can be spotted and dealt with immediately, and this minimises interruptions to the services.

Last year, in spite of the recession, the volume of Telex calls to and from Europe increased by 2%, and inter-continental calls rose by 13%. Over 99% were automatic calls, set up directly by users without the help of an international Telex operator.

This is the second computer-controlled Telex gateway exchange to be installed in Britain. The first—a smaller, less powerful version of the new exchange—was brought into service in 1978. The opening of this new unit means that British Telecom is able to phase out an old electromechanical (Strowger) Telex gateway exchange in London.

Book Reviews

Reliability and Maintainability, David J. Smith. Macmillan Press Ltd. viii + 243 pp. Hardback: £15·00; Paperback: £8·95.

The author of this book sets out to inculcate thinking about reliability and maintainability (R & M) in all aspects of the development of products and systems—from specification and design through production, to operation and maintenance. In contrast to his 2 previous books—*Reliability Engineering* (1972) and *Maintainability Engineering* (1973, with Alex H. Babb)—reliability and maintainability are treated here as being complementary to each other in all 4 parts of the book.

In part 1, *Understanding Terms, Parameters and Costs*, the author confidently believes that, while quality cannot be justified for its own sake, properly engineered R & M will produce a favourable return in terms of reduced down-time and increased revenue-earning ability. He suggests that a company balance sheet of quality costs should be drawn up to convince top management of the value of R & M. (Here he probably underestimates the difficulty of identifying all the relevant costs in a large organisation without re-orienting the accounting system).

In part 2, *Achieving R & M Objectives*, the approach is essentially practical, the broad principles on the enhancement of R & M being interspersed with detailed hints. The need to design products and systems with production, diagnostic testing and maintenance methods in mind is argued. Failure modes, effects and criticality analysis and fault-tree analysis techniques are broadly described, though not to working detail. In this chapter, and in those on quality assurance, automatic test equipment and computer-aided prediction, references to publications giving more detailed information would have been useful.

In part 3, *Making Measurements and Predictions*, the essential equations and distributions of reliability are developed, and examples of their application given; redundancy is well covered. The point is made that predicting reliability is not an exact science, but that nevertheless it is a valuable tool for comparing designs and allocating and optimising module reliability.

Part 4, *Essential Management Topics*, gives further practical advice to product managers on planning and running development projects, on ensuring meaningful R & M clauses in contracts and on advising on legislation for product liability. The final chapter touches on the reliability of software, not quantitatively, but to give hints on how to organise programming for the better control of quality.

Overall, the book should appeal to product managers and engineers involved in product development rather than to the advanced specialist in R & M.

J. S. Gore

Electronic Devices and Components. J. Seymour. Pitman Books Ltd. vii + 504 pp. 311 ills. £9·95.

The text of this book, based on lectures given to students at Thames Polytechnic, London, was written to provide a complete course in electronic devices and components for undergraduates of electrical and electronic engineering and applied physics. As such, the book is written at a level that enables those who read it, at any stage of their career, to get a flavour for the modes of operation of particular electronic devices and their critical parameters.

After introductory chapters on charge flow in materials and across metal-semiconductor and p n junctions, subsequent chapters cover the theory and operation of bipolar transistors, optoelectronic devices, field-effect transistors and charge-transfer devices, and integrated circuits. Additional chapters deal with the mainly non-semiconductor topics of vacuum and gas-filled tubes, microwave devices and dielectric and magnetic materials and components. As this is a textbook aimed primarily at undergraduates, it also contains sets of questions at the end of every chapter.

The subject matter of the book is well written and presented. The combination of sufficient mathematics and readability enables the reader to gain a good grasp of the salient features of operation of the electronic devices covered. In all, it is a useful addition to the bookshelf for those with an interest in, but little background of, electronic devices and components.

D. H. Newman

1982 International Symposium on Subscriber Loops and Services

Bell Canada will host the 1982 International Symposium on Subscriber Loops and Services (ISSLS 82) at the Toronto Hilton Harbour Castle Convention Centre, Toronto, from 20–24 September 1982. The event is expected to draw some 800 delegates from 20 countries for 5 days of technical sessions and a varied programme of tours and social events.

The symposium, which returns to Canada for the first time since it was held in Ottawa in 1974, will be concerned with technical advances in local telecommunications networks.

Technology has now matured to the point where the key issues of papers chosen for ISSLS 82 are the new services made possible by this new technology and the strategies for economically introducing services and systems.

The response to the call for papers for ISSLS 82 was unprecedented, both in quality and quantity. Nearly 200 papers were submitted, of which 49 have been chosen for presentation. The papers will continue to emphasise the theme of technical advances in the subscriber loop or access line. They will also highlight new services and the requirements for customer access that are becoming realities as the technology matures. In addition, sessions will be devoted to the important topics of operational support and subscriber-loop management.

Technical visits will include Ontario Hydro's nuclear facility at Pickering, and its research centre in Toronto; and Northern Telecom's plant in nearby Brampton where it manufactures digital switching multiples.

Social attractions will include the reception at the Harbour Castle on September 20, and the general chairman's reception —*A Taste of Toronto*—at the famed St. Lawrence Market in Toronto on September 21. Optional activities include a visit to Niagara Falls.

The technical chairman of ISSLS 82 is Richard E. Mosher, Division Manager—Management and Technical Advisory Services of American Telephone and Telegraph (AT & T) International.

Copies of the advance programme may be obtained from:

A. G. Hare (Chairman ISSLS Council)
British Telecom Headquarters
SESD/SES6
Room 538
207 Old Street
London EC1V 9PS

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

Contributions to *British Telecommunications Engineering* are always welcome. In particular, the Board of Editors would like to reaffirm its desire to continue to receive contributions from Regions and Areas, and from those Headquarters departments that are traditionally modest about their work.

Anyone who feels that he or she could contribute an article (short or long) of technical, managerial or general interest to engineers in British Telecom and the Post Office is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and to try to arrange for help with the preparation of an article, if needed.

GUIDANCE FOR AUTHORS

Some guiding notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal's* editors, printers and illustrators, and help ensure that authors' wishes are easily interpreted. Any author preparing an article is invited to write to the Managing Editor, at the address given below, to obtain a copy.

All contributions to the *Journal* must be typed, *with double spacing between lines*, on one side only of each sheet of paper.

As a guide, there are about 750 words to a page, allowing for illustrations, and the average length of an article is about 6 pages, although shorter articles are welcome. Contributions should preferably be illustrated by photographs, diagrams or sketches. Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that is 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. Good colour prints and slides can be accepted for black-and-white reproduction. Negatives are not required.

It is important that approval for publication is given at organisational level 5 (that is, at General Manager/Regional Controller/BTHQ Head of Division level), and authors should seek approval, through supervising officers if appropriate, before submitting manuscripts.

Contributions should be sent to the Managing Editor, *British Telecommunications Engineering*, IDP 3.9, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

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Copies of the April 1974 issue covering sector switching centres and the October 1973 special issue on the 60 MHz transmission system are still available.

Copies of the October 1981 special issue, which marked the 75th anniversary of the Institution of Post Office Electrical Engineers (IPOEE), are still available. A summary of the contents of the issue and an order form are printed opposite.

Back numbers can be purchased, price £1·30 each (including postage and packaging), for all issues from April 1974 to date, with the exception of April and October 1975 and April and October 1976.

Orders, by post only, should be addressed to *British Telecommunications Engineering Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG. Cheques and postal orders payable to "*BTE Journal*", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post. A self-addressed label accompanying the order is helpful.

OCTOBER 1981 SPECIAL ISSUE

The October 1981 special issue contains articles on the following topics:

- THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS
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- THE INLAND NETWORK
- INTERNATIONAL SERVICES
- SWITCHING AND SIGNALLING
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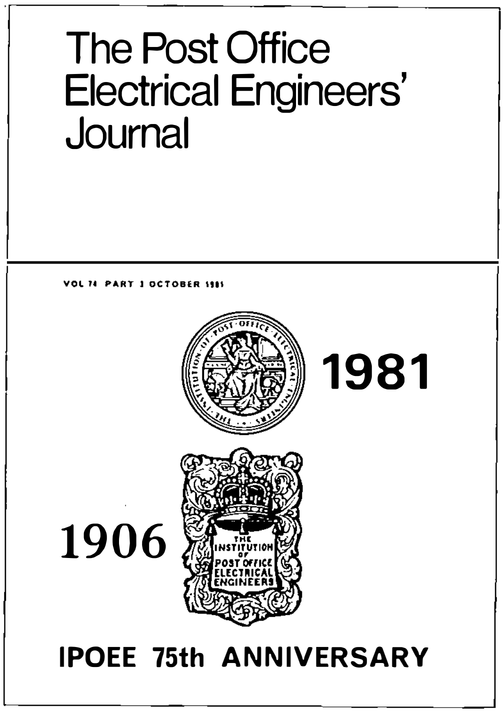
- RESEARCH
- THE FUTURE



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Further details can be obtained from the conference department of the organising body.

ICCC '82, PO Box 23, Northwood Hills, Middlesex HA6 1TT. Telephone: 09274 27511. Telex: 25198

Sixth International Conference on Computer Communications (ICCC '82)
(host—British Telecom)
7–10 September 1982
Barbican Centre, London

FORUM 83 Secretariat, International Telecommunications Union, CH-1211 Genève 20, Switzerland.
Telephone: 441–22–995190

Fourth World Telecommunications Forum, Part 2, Technical Symposium
29 October–1 November 1983
New Exhibition and Conference Centre, Geneva
Papers: Summaries by 1 November 1982

Institution of Electrical Engineers, Savoy Place, London WC2R 0BL. Telephone: 01–240 1871

Switching and Signalling in Telecommunications Networks
5–11 September 1982
Vacation School at the University of Essex

Stored-Program Control of Telephone Switching Systems
13–17 September 1982
Vacation school at the University of Essex

1982 International Symposium on Subscriber Loops and Services (ISSLS 82)
20–24 September 1982
The Toronto Hilton Harbour Castle Convention Centre, Toronto, Canada
(A note about the ISSLS 82 appears on page 128 of this issue of the *Journal*.)

Third International Conference on Electrical Safety in Hazardous Environments
1–3 December 1982
Institution of Electrical Engineers

Second International Network Planning Symposium (Networks '83)
21–25 March 1983
University of Sussex

Fifth International Conference on Software Engineering for Telecommunications Switching Systems
4–8 July 1983
Lund, Southern Sweden
Papers: Synopses by 20 September 1982

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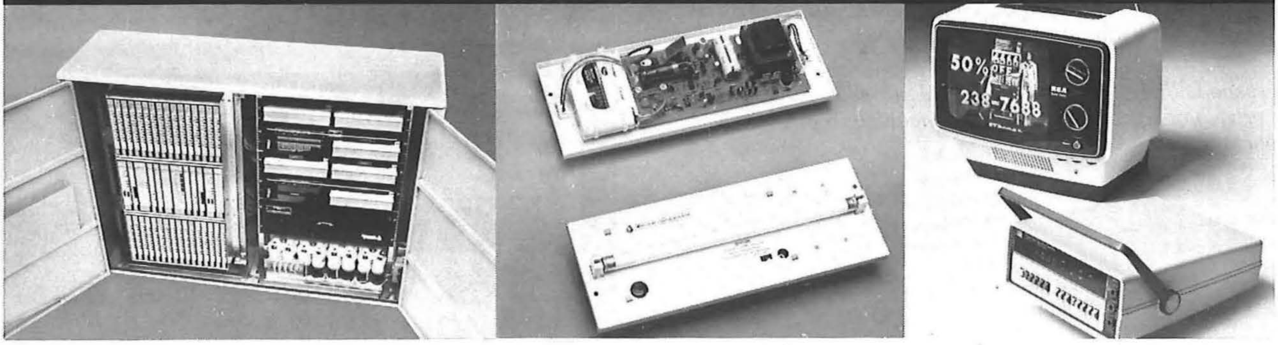

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