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EDITORIAL

To the end user, the integrity of the data transmitted over a telecommunication network is of paramount importance. With the increase in use of computer-based communications, the transmission of sensitive data is becoming more and more common and poses an ever increasing problem of security against unauthorised interception and possible sabotage. The use of data encryption can greatly allay these fears and ensure secure transmission of the data. An article on p. 257 of this issue of the *Journal* describes British Telecom's LEKTOR encryption system which makes use of public key encryption techniques to provide secure data transmission. The increase in use of digital data services, however, poses problems for the transmission engineer as there is a greater risk that the data stream might simulate the 2·048 Mbit/s basic frame alignment sequence. In order to increase the robustness of the frame alignment structure and improve the error detection capability, the CCITT has recently adopted the use of a cyclic redundancy check procedure within the basic frame structure. An article on p. 218 describes this new procedure and shows how it is used to overcome the earlier deficiencies.

The next issue of the *Journal* will be a special issue describing the various component parts of CCITT Signalling System No. 7 and how it is being implemented in the British Telecom network.

Introduction of a Cyclic Redundancy Check Procedure into the 2048 kbit/s Basic Frame Structure

R. W. McLINTOCK, B.SC., C.ENG., M.I.E.E., and N. HARRISON, B.SC., C.ENG., M.I.E.E.†

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This article discusses the inherent deficiencies in the 2048 kbit/s basic frame structure and shows how they are overcome by use of the recently standardised cyclic redundancy check procedure. Attention is given to the theoretical error detecting capability of these procedures together with an insight of the underlying mathematical theory.

INTRODUCTION

The basic frame structure at 2048 kbit/s has been defined in CCITT Recommendations for many years. It was first defined for use in 30-channel PCM multiplex equipment[1] and shortly afterwards in digital exchanges. In recent times, it has been more widely used, appearing in recommendations for data multiplex equipment, drop and insert equipment, transcoders, transmultiplexers, video-conferencing codecs, and cross-connect equipment.

By the end of 1984, as part of a recommendation restructuring exercise, the CCITT had produced a new Recommendation, G.704[2], which defines the basic frame structures at the 1544, 2048, 6312 and 8448 kbit/s hierarchical levels when synchronous multiplexing is employed. The objective of this exercise was to provide a single source for this information to which individual equipment recommendations could then simply cross-refer.

This article concentrates on the 2048 kbit/s basic frame structure. It begins by describing the original 2048 kbit/s basic frame structure and some of its inherent deficiencies. The recently standardised cyclic redundancy check (CRC) procedure is then examined, and it is explained how this procedure overcomes these deficiencies. Attention is then turned to the theoretical error-detecting capability of the CRC procedure and an Appendix to the article provides an insight into the mathematical theory of CRC procedures.

ORIGINAL 2048 kbit/s BASIC FRAME STRUCTURE

The original basic frame structure at 2048 kbit/s comprises frames of 256 consecutive bits occurring at a frame repetition rate of 8000 Hz. The first eight bits in the frame (numbered 1 to 8) are reserved for specific purposes, whereas all the other bits in the frame (that is, bits 9 to 256) represent the payload area. The bit allocation and more detailed structure of the payload area, which may or may not be octet structured‡, does not form part of the definition of the basic frame structure. However, bits 1 to 8 are more fully defined, and their use changes in alternate frames (see Figure 1).

Figure 1
Original basic frame structure at 2048 kbit/s

ALTERNATE FRAMES	BIT NUMBER IN FRAME								
	1	2	3	4	5	6	7	8	9 - 256
FRAME CONTAINING THE *FRAME ALIGNMENT* SIGNAL	S_i	0	0	1	1	0	1	1	PAYLOAD
	Note 1	*FRAME ALIGNMENT* SIGNAL							
FRAME NOT CONTAINING THE *FRAME ALIGNMENT* SIGNAL	S_i	1	A	S_n	S_n	S_n	S_n	S_n	
	Note 1	Note 2	Note 3	Note 4					

Note 1: S_i —Bits reserved for international use*.
Note 2: This bit is fixed at '1' to assist in avoiding simulations of the *frame alignment* signal.
Note 3: A —Remote alarm indication; set to '0' in undisturbed operation, set to '1' in an alarm condition.
Note 4: S_n —Spare bits reserved for national use*.

* If these spare bits are not being used in a designated international application, they are set to '1' when crossing international borders.

ORIGINAL FRAME ALIGNMENT STRATEGY

The original frame alignment strategy is based on the following criteria:

Loss: Frame alignment will be assumed to have been lost when three consecutive incorrect frame alignment signals have been received.

Recovery: Frame alignment will be assumed to have been recovered when the following sequence is detected:

- for the first time, the presence of the correct *frame alignment* signal;
- the absence of the *frame alignment* signal in the following frame, detected by verifying that bit 2 of the basic frame is a '1';
- for the second time, the presence of the correct *frame alignment* signal in the next frame.

† Network Systems Engineering (Transmission), British Telecom UK Communications

‡ *Note*: In octet structured signals, bits 1 to 8 are conventionally known as *time-slot 0*.

SHORTCOMINGS OF THE ORIGINAL FRAME STRUCTURE AND ALIGNMENT STRATEGY

Two shortcomings were identified with the original frame structure and alignment strategy:

(*a*) There is a slight risk of incorrect frame alignment being established and persisting if there happens to be a simulation of the frame-alignment sequence present during the time that realignment is being sought. Although believed to be very small, the risk of this occurring (either fortuitously or as a result of malicious intent) was difficult to quantify. In those applications where the payload conveys encoded speech signals, the coding rules had been defined so that the risk of persistent simulation is negligible. However, with the advent of digital data services and the provision of access to PCM multiplex equipment at 64 kbit/s, no longer could it be safely assumed that the risk of incorrect alignment would be negligible.

(*b*) In order to detect the presence of errors occurring during transmission, it was normal practice to count errors in the frame alignment signal. However, because the frame alignment signal represents only a relatively small proportion of the total signal (approximately 1·5%), detection of low persistent error ratios necessarily takes a long time to achieve any reasonable degree of confidence (see Table 1).

TABLE 1

Improved Error Ratio Detection Times at 2048 kbit/s When Using CRC

Error Ratio (pe)	Typical Detection Times (s)	
	Monitoring the *frame alignment* signal	Using CRC (*Note* 2)
10^{-3}	10·0	0·046
10^{-4}	50·0	0·216
10^{-5}	200·0	1·97
10^{-6}	1 430·0)	19·5
10^{-7}	14 300·0)*Note* 1	200·0
10^{-8}	143 000·0)	2000·0

Note 1: Assumes all seven bits of the *frame alignment* signal are monitored.
Note 2: Based on similar probability requirements as those calculated for monitoring the *frame alignment* signal.

CRC PROCEDURE

History

The initial proposals for introducing a CRC procedure into the 2048 kbit/s basic frame were made by British Telecom in a contribution to CEPT in 1983. At about the same time, a similar CRC procedure was under consideration in the US and in the CCITT for introduction into the 1544 kbit/s basic frame structure (used in North America and Japan).

Although agreement was quickly reached in CEPT to adopt the concept of a CRC procedure, it took a number of meetings to define precisely the modifications to the basic frame structure. The finally agreed CEPT solution was subsequently agreed within the CCITT and incorporated into CCITT Recommendation G.704.

In early 1987, a further Recommendation, G.706[3], was adopted by the CCITT (using the accelerated approval procedure). This recommendation defines how the CRC procedure should be used to increase the robustness of the frame-alignment strategy and enhance the error-performance monitoring capability.

It should be noted that CRC procedures have been widely used for many years in other applications for error detection purposes. For example, CCITT Recommendation X.25 includes a very powerful 16 bit frame check sequence (an alternative name for CRC), as does Common-Channel Signalling System No. 7. Computer disc formats also commonly include a 16 bit CRC.

Description of CRC Procedure as Applied to the 2048 kbit/s Basic Frame

Figure 2 shows how, over a 16-frame multiframe, bit 1 in the basic frame is used to carry two 4 bit CRC words, the associated 6 bit *multiframe alignment* signal (001011) and two spare bits.

Figure 2
Basic frame structure at 2048 kbit/s including CRC multiframe structure

ONE MULTIFRAME	SUB-MULTIFRAME NUMBER	FRAME NUMBER	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	9 – 256
			BIT NUMBER IN FRAME								
	I	0	C_1	0	0	1	1	0	1	1	PAYLOAD AREA
	I	1	0	1	A	S_n	S_n	S_n	S_n	S_n	
	I	2	C_2	0	0	1	1	0	1	1	
	I	3	0	1	A	S_n	S_n	S_n	S_n	S_n	
	I	4	C_3	0	0	1	1	0	1	1	
	I	5	1	1	A	S_n	S_n	S_n	S_n	S_n	
	I	6	C_4	0	0	1	1	0	1	1	
	I	7	0	1	A	S_n	S_n	S_n	S_n	S_n	
	II	8	C_1	0	0	1	1	0	1	1	
	II	9	1	1	A	S_n	S_n	S_n	S_n	S_n	
	II	10	C_2	0	0	1	1	0	1	1	
	II	11	1	1	A	S_n	S_n	S_n	S_n	S_n	
	II	12	C_3	0	0	1	1	0	1	1	
	II	13	S_i	1	A	S_n	S_n	S_n	S_n	S_n	
	II	14	C_4	0	0	1	1	0	1	1	
	II	15	S_i	1	A	S_n	S_n	S_n	S_n	S_n	

KEY: C_1, C_2, C_3, C_4, - CYCLIC REDUNDANCY CHECK (CRC) BITS Note 1
S_i - SPARE BITS FOR INTERNATIONAL USE Note 2
A - REMOTE ALARM INDICATION BIT
S_n - SPARE BITS RESERVED FOR NATIONAL USE

Note 1: All the bits in a particular sub-multiframe are used to compute the values of C_1, C_2, C_3 and C_4 transmitted in the next sub-multiframe. However, during this calculation, the positions of C_1, C_2, C_3 and C_4 in the particular sub-multiframe being encoded are initially set to '0'.
Note 2: An application being discussed, and almost certain to be incorporated into the 1988 revision of CCITT Recommendation G.704, is the use of S_i bits to provide a means for indicating to the remote end that an errored sub-multiframe has been detected.

The *multiframe alignment* signal is required in order to introduce a structure into the bit-1 position for identification of the location of each CRC word and the spare bits. It should be noted that, although time-slot 16 in 2048 kbit/s octet-structured signals sometimes contains a 16-frame multiframe structure (that is, when used for channel-associated signalling), its presence could not be relied upon for this application.

Each 4 bit CRC word is associated with a check block comprising 2048 bits (that is, 8 frames and having a duration of 1 ms), and referred to as a *sub-multiframe.* All bits within the entire sub-multiframe are included in a check block, although the positions used to carry the CRC words are initially fixed at binary state '0' during the CRC encoding procedure.

Each check block is operated upon by a process which is comparable to mathematical division under modulo-2 arithmetic. In this process, the check block can be represented as a polynomial of a dummy variable, x say, which, in the 2048 kbit/s case, is first pre-multiplied by x^4 and then divided by the generator polynomial $x^4 + x + 1$. The remainder from this process must be less than degree 4 (that is, no more than 4 bits) and forms the CRC word associated with that check block. The CRC word calculated for sub-multiframe N, is then transmitted in sub-multiframe $N+1$.

This encoding algorithm is explained in more detail in the Appendix.

One of the major advantages of CRC error detection techniques is their simplicity of hardware (or software) realisation. Figure 3 gives a simplified diagram of how a 4 bit shift register can be used to implement the CRC encoding algorithm.

At the receiving end, exactly the same mathematical procedure is implemented. If any transmission errors have occurred, there is a very high probability, although not certainty, that this will be evident in a disparity between the sent and re-calculated (that is, at the receiver) CRC words.

It should be noted that the CRC procedure is only able to detect the fact that at least one error has occurred over the period of the check block; that is, 1 ms. It is not able to provide any information on the number of errors or their distribution within the check block.

CRC Procedures Adopted at Other Bit Rates

Table 2 shows the different CRC procedures which have been agreed (or are in the process of agreement) by the CCITT for the basic frame structures defined in Recommendation G.704.

PERFORMANCE OF CRC PROCEDURE FOR DETECTING ERRORS

A detailed theoretical analysis of the performance of the CRC procedure is given in the Appendix. In summary, it will detect errors within a check block as follows:

(*a*) all single errors;

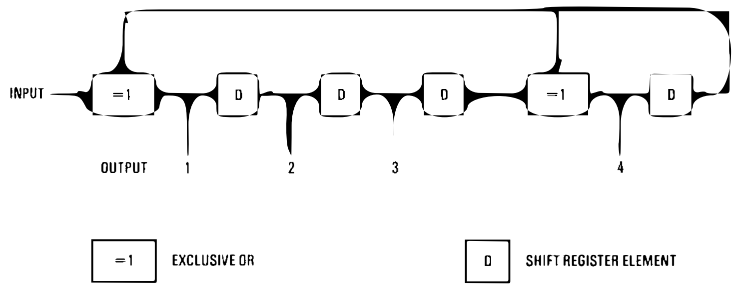
(*b*) all error bursts (see the Appendix for a definition of an error burst) where the number of bits covered by the burst, inclusive of the first and last errors, is less than five bits;

(*c*) approximately 87% of all error bursts where the number of bits covered by the burst, inclusive of the first and last errors, is exactly five bits; and

(*d*) approximately 94% of all error bursts where the number of bits covered by the burst, inclusive of the first and last errors, is more than five bits.

The performance described above is obtained from using only four check bits out of 2048 bits. The CRC procedure therefore represents a powerful and efficient error detection capability. Furthermore, Table 1 shows the improvement in the theoretical detection periods obtainable for the CRC procedure when compared to a typical error detection strategy which uses the *frame alignment* signal. The detection periods given in this table are based on similar statistical confidence requirements for each method when subject to a given persistent random bit error ratio based on Poisson statistics. However, it has to be noted that neither method is good at estimating error ratios when the error distribution is not Poisson; that is, when it is bursty. Under bursty conditions, the CRC procedure can only estimate the performance in terms of the percentage of error free inter-

Figure 3
Generation of CRC bits



Logical operation:

(*i*) The outputs (1 to 4) of the shift-register stages are initially reset to '0'.

(*ii*) The sub-multiframe is fed serially into the circuit at the input.

(*iii*) When the last bit of the sub-multiframe has been fed into the shift register, the CRC bits C_1 to C_4 are available at the outputs 1 to 4 respectively.

(*iv*) Bits C_1 to C_4 are then transmitted in the next sub-multiframe.

TABLE 2

CRC Procedures Defined (or in the process of being defined) by the CCITT for Recommendation G.706

Bit Rate (kbit/s)	Check Block Size (bits)	Generator Polynomial
1544	4632	$x^6 + x + 1$
2048	2048	$x^4 + x + 1$
6312	3156	$x^5 + x^4 + x^2 + 1$
8448	1056	$x^6 + x + 1$ (*Note* 1)

Note 1: The frame structure and CRC procedure at 8448 kbit/s have not been fully defined by CCITT in Recommendations G.704 and G.706, respectively, at the time of writting this article. However, the drafts for these Recommendations are almost complete, and it is expected that they will appear in the Blue Book series of Recommendations which will be published at the end of the 1984–88 study period.

vals (at 2048 kbit/s), with a minimum time resolution of 1 ms.

USE OF CRC PROCEDURE TO DETECT A STATE OF INCORRECT FRAME ALIGNMENT

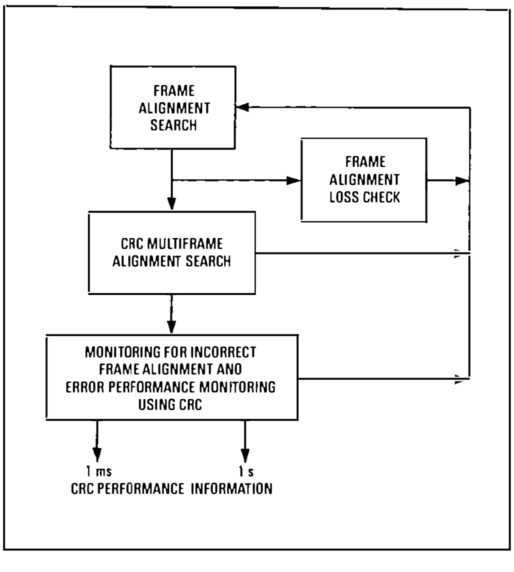
The CRC procedure can also be used to indicate a state of incorrect frame alignment at the receiving end, and thereby instigate a new search for frame alignment.

If incorrect frame alignment has occurred at the receiving end, it is most unlikely that there will also be a simulation of the *multiframe alignment* signal. However, even if incorrect multiframe alignment was established, it is almost inconceivable that the CRC words could also be simulated to a sufficient degree to sustain incorrect alignment.

For this final check of a state of incorrect frame alignment, a 1 s check period is defined, with the criterion that a count of greater than or equal to 915 errored check blocks (out of 1000) constitutes a state of incorrect frame alignment. This criterion ensures that the state of incorrect frame alignment can be differentiated from the state of correct frame alignment in the presence of a sustained random error ratio of 10^{-3} within the 1 s checking period. Furthermore, in the case of correct frame alignment with a random error ratio of 10^{-3}, the procedure has also been designed to be more robust than the basic frame alignment loss strategy (referred to earlier) in terms of unnecessary loss of frame alignment due to the effects of the errors.

Figure 4 illustrates the procedure to be followed in passing from the frame alignment search to error monitoring using CRC at 2048 kbit/s. The detailed information relating to this procedure is given in CCITT Recommendation G.706.

Figure 4
Procedure to be followed in passing from frame alignment search to error monitoring using CRC at 2048 kbit/s



Note: The details for all of the above processes are given in CCITT Recommendation G.706 (see reference 3).

IMPLEMENTATION IN EQUIPMENT

Recognising that there is a tremendous amount of equipment already installed in networks, it was quickly determined within the CCITT that the new procedure would need to be defined in such a way as to allow it to be introduced on a gradual basis; an evolutionary approach rather than a revolutionary one.

CCITT Recommendation G.704 specifically requires that new equipment incorporating the CRC procedure should be designed to be capable of interworking with existing equipment which does not incorporate the CRC procedure. The operating mode is to be manually selectable; for example using straps. For such interworking, bit 1 of the frame should be fixed at the ONE state in both directions of transmission.

Up until the completion of CCITT Recommendation G.706, there had been some reluctance by Administrations and manufacturers to implement the CRC procedure within equipment designs. This was because a customised chip realisation was envisaged. They did not want to commit themselves to a costly design before the international standard had been completed.

Now that the international standard has been published, it is to be expected that the CRC procedure will be incorporated in all new designs of equipment which use the 2048 kbit/s basic frame structure.

ERROR PERFORMANCE MONITORING IN THE NETWORK USING CRC

A future article will report the outcome of current studies aimed at identifying how the CRC procedure can best be used as a tool in the context of overall surveillance.

CONCLUSION

The new CRC procedure, defined in CCITT Recommendations G.704 and G.706 and for use in 2048 kbit/s basic frames, has been described. The performance of the procedure has also been discussed, together with the shortcomings that it is intended to overcome.

Practical implementations of the CRC procedure are only just beginning, and inevitably it will take time to percolate through into the network in significant quantity.

However, for the future, the procedure will provide increased robustness of the frame alignment strategy and the potential of an enhanced error monitoring capability.

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Biographies

Robert McLintock was awarded a first-class honours degree in Electronic and Electrical Engineering by Manchester University in 1972. He joined the then Post Office Telecommunications Development Department as an Executive Engineer and worked, initially, on the development of 24-channel and, subsequently, on 30-channel PCM transmission systems. In 1978, he became Head of Group responsible for digital network transmission standards. These duties included regular participation in some of the international standardisation committees of the CCITT and CEPT and he chaired a CEPT working team concerned with the standardisation of speech coding techniques and multiplexing issues. Since 1986, he has been Head of Section responsible for the system engineering aspects of transmission test equipment, television and various network management systems.

Neil Harrison was awarded a first-class honours degree in Electrical and Electronic Engineering by Preston Polytechnic in 1981. He then joined BT as an Executive Engineer working in the digital transmission performance standards group. Since designing the CRC procedure for the 2048 kbit/s basic frame structure in 1983, he has been involved in a wide range of issues related to error performance work. He attends the CCITT and CEPT international standards forums and, within the latter, he is the Special Rapporteur for error performance issues.

APPENDIX

THEORETICAL ANALYSIS OF HOW CRC PROCEDURES DETECT ERRORS

INTRODUCTION

The scope of this Appendix is limited by space considerations. Therefore, the reader wishing to acquire a more in-depth and rigorous knowledge of CRC techniques is referred to reference 4.

CRC procedures are based on the underlying mathematical properties of true cyclic code structures. However, whereas true cyclic codes have very specific structures regarding the number of codewords permissible for a certain error correction/detection capability, CRC techniques are purely designed to detect errors in an arbitrary number of bits. The CRC generator polynomial (which possesses certain properties outside the scope of this article), chosen from the associated true cyclic code, determines the percentage error burst detection capability within those arbitrary number of bits.

A pre-requisite for the understanding of what follows is only a knowledge of addition and multiplication under modulo-2 algebra and familiarity of binary representation in polynomial form.

Modulo-2 Algebra

Addition:

The rules are:

$$0 \oplus 0 = 0$$
$$0 \oplus 1 = 1$$
$$1 \oplus 0 = 1$$
$$1 \oplus 1 = 0$$

From the group theory on which the above is based, it should also be noted that $1 = -1$.

For example,

$$\begin{array}{r} 1011011 \\ \oplus\ 1011101 \\ \hline 0000110 \end{array}$$

Multiplication:

This has the simple rules:

$$0 \times 0 = 0$$
$$0 \times 1 = 0$$
$$1 \times 0 = 0$$
$$1 \times 1 = 1$$

Polynomial Representation of Binary Digits

Using the above example, let

$$\begin{array}{rl} 1011011 = & x^6 + 0 + x^4 + x^3 + 0 + x + 1 \\ \text{and } 1011101 = & x^6 + 0 + x^4 + x^3 + x^2 + 0 + 1 \\ \hline \text{Modulo-2 addition } & 0 + 0 + 0 + 0 + x^2 + x + 0 \\ \text{or, in binary } & 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 1 \quad 0 \end{array}$$

Therefore, x is a dummy variable, the degree of which indicates the appropriate bit location.

MATHEMATICAL REPRESENTATION OF THE CRC ENCODING PROCEDURE

The aim of a CRC procedure is to encode a message of k bits into an n bit codeword by appending $n-k$ check bits. Any errors which subsequently occur in the n bit codeword are detected (with a high probability) by violations of the $n-k$ check bits. A cyclic code is defined in terms of a generator polynomial, $G(x)$, of degree $n-k$. Any polynomial of degree less than n is a code polynomial if, and only if, it is divisible by $G(x)$.

Code polynomials can be formed simply by multiplying any polynomial of degree less than k by $G(x)$. However, this approach does not allow easy identification of the k message bits and the $n-k$ check bits. A clearer, though identical, encoding method is as follows:

To encode a message polynomial $D(x)$, of degree less than k, the polynomial $x^{n-k}D(x)$ is divided by $G(x)$ and the remainder, $R(x)$, is added to $x^{n-k}D(x)$ to produce the final code polynomial.

That is,

$$\frac{x^{n-k}D(x)}{G(x)} = Q(x) + \frac{R(x)}{G(x)}$$

$Q(x)$ is a polynomial which has the same degree as $D(x)$, and represents the quotient part of the division. The remainder, $R(x)$, must, of necessity, be of degree $n-k-1$ or less.

The above can be rewritten as

$$x^{n-k}D(x) + R(x) = Q(x)G(x) = F(x).$$

Note 1: From modulo-2 algebra, $R(x) = -R(x)$.
Note 2: Since a code polynomial is any polynomial of degree less than k multiplied by $G(x)$, then $Q(x)G(x)$

must be a code polynomial; this is shown as $F(x)$. Hence, $x^{n-k}D(x) + R(x)$ must also be $F(x)$. Since $x^{n-k}D(x)$ leaves $n-k$ zero-order coefficients in the overall polynomial, the latter $n-k$ lower-order terms represent the check bits given by $R(x)$.

PRINCIPLES OF ERROR DETECTION

Polynomial Representation of Errors

An encoded message corrupted by transmission errors can be represented by

$$H(x) = F(x) + E(x)$$

where $F(x)$ is the correct transmitted codeword, $H(x)$ is the corrupted received codeword and $E(x)$ is the error polynomial which has non-zero terms only in the errored positions of $F(x)$.

For example,

if $F(x)$ was:	$x^5 + x^3 + x^2 + 1$	$= 101101$
and $E(x)$ was:	$x^4 + x^2$	$= 010100$
then		
$H(x)$ would be:	$x^5 + x^4 + x^3 + 1$	$= 111001$

Note: Addition is modulo-2 and, therefore, adding two terms of the same degree yields zero. Thus, in the above example, $x^2 + x^2 = 0$.

If the received message $H(x)$ is not divisible by $G(x)$, then at least one error must have occurred. However, if $H(x)$ is divisible by $G(x)$, then all that can be said is that either no errors have occurred, or, an undetectable error pattern has occurred. In a practical situation, if $H(x)$ is divisible by $G(x)$, the assumption is that $H(x)$ is a valid message. The objective, therefore, is to choose a generator polynomial which minimises the risk of undetectable error patterns.

Since $F(x)$ was constructed to be divisible by $G(x)$, then $H(x)$ is divisible by $G(x)$ if, and only if, $E(x)$ is also divisible by $G(x)$. In other words, $E(x)$ must also be a valid codeword if errors are to be missed.

Examination of the following theorems illustrates how cyclic codes detect various error patterns.

Detection of Single Errors

Theorem 1: A cyclic code generated by any polynomial, $G(x)$, having more than one term detects all single errors.

Proof: For errors to remain undetected it has previously been shown that $E(x)$ must be divisible by $G(x)$. A single error which affects the ith bit of $F(x)$ may be represented by $E(x) = x^i$ (counting from the right). If $G(x)$ contains more than one term (for example, $1+x$, $1+x^2$, .. etc), then $G(x)$ cannot divide $E(x)$ (or, equivalently, $H(x) = F(x) + E(x)$) without a remainder ocurring.

For example, if $G(x) = 1 + x^f$ and $E(x) = x^i$, where $i \geq f$, then

$$\begin{array}{r|l}
 & x^{i-f} + x^{i-2f} + \dots\dots + x^{i-mf} \\
\hline
x^f + 1 & x^i \\
 & x^i + x^{i-f} \\
 & \overline{\quad x^{i-f}} \\
 & \quad x^{i-f} + x^{i-2f} \\
 & \quad \overline{\quad x^{i-2f}} \\
 & \quad\quad \vdots \\
 & \quad\quad x^{i-(m-1)f} + x^{i-mf} \\
 & \quad\quad \overline{\quad\quad x^{i-mf}}
\end{array}$$

The division process terminates when the remainder is of less degree than $G(x)$. That is, the lowest integer value of m which satisfies $i-mf < f$.

Note: Since the remainder is always of the form x^{i-mf}, then even if $i-mf = 0$, $x^{i-mf} = x^0 = 1$; that is, there must always be a remainder.

The simplest form of $G(x)$ with more than one term is $G(x) = 1 + x$.

Theorem 2: Every polynomial divisible by $1+x$ and leaving no remainder must have an even number of terms.

Proof: If the above is true, then any polynomial, $P(x)$, having an even number of terms must satisfy:

$$\begin{aligned} P(x) &= x^k + x^{k-1} + x^{k-2} + \dots\dots x^2 + x + x^0 \\ &= (1+x)Q(x) \end{aligned}$$

with k odd.
Now,

$$Q(x) = \frac{x^k + x^{k-1} + x^{k-2} + \dots\dots x^2 + x + 1}{x + 1}$$

must have no remainder.
This division is only satisfied if

$$\begin{array}{r|l}
 & x^{k-1} + \quad x^{k-3} + \dots\dots + x^2 + \quad 1 \\
\hline
x+1 & x^k + x^{k-1} + x^{k-2} + \dots\dots + x^3 + x^2 + x + 1 \\
 & x^k + x^{k-1} \\
 & \overline{\qquad\qquad x^{k-2} + \dots\dots + x^3 + x^2 + x + 1} \\
 & \qquad\qquad x^{k-2} + x^{k-3} \\
 & \qquad\qquad \vdots \\
 & \qquad\qquad\qquad x^3 + x^2 + x + 1 \\
 & \qquad\qquad\qquad x^3 + x^2 \\
 & \qquad\qquad\qquad \overline{\qquad\quad x + 1} \\
 & \qquad\qquad\qquad\qquad x + 1 \\
 & \qquad\qquad\qquad\qquad \overline{0 \quad 0}
\end{array}$$

Since $Q(x) = x^{k-1} + x^{k-3} + \dots\dots x^2 + x^0$ ($x^0 = 1$), then the general term of $Q(x)$ is $x^{k-(2n-1)}$ where $n = 1, 2, \dots\dots (k+1)/2$.

Clearly, for n to yield an integer solution in the last term, k must be odd. Therefore, since $P(x)$ was given as degree k, $P(x)$ must contain an even number of terms. It immediately follows that if $P(x)$ represents the error polynomial $E(x)$, then all odd numbers of errors will be detected. In effect, the validity of an overall parity check bit procedure has been proved.

Note: Any generator polynomial, $G(x)$, which contains the factor x^r+1 ($r > 1$) also contains the factor $1+x$ and will therefore detect any odd number of errors.

For example,

$$x^r+1 = (x+1)(x^{r-1} + x^{r-2} + \dots\dots x + 1).$$

Double and Triple Error Detection

Before discussing the theorems for $G(x)$ being able to detect double or triple errors, it is necessary to define the exponent of $G(x)$.

A polynomial $G(x)$ is said to belong to an exponent, e, if e is the smallest positive integer which permits $G(x)$ to divide into $x^e + 1$ leaving no remainder.

Theorem 3: A code generated from $G(x)$ detects all single and double errors providing the length of the codewords, n, is not greater than the exponent, e, to which $G(x)$ belongs.

Proof: Detection of double errors requires that $G(x)$ will not divide without remainder $E(x) = x^k + x^j$, for any $k, j < n$.

Assuming that $k > j$, then factorising $E(x)$ gives $E(x) = x^j (x^{k-j} + 1)$. Now, for $G(x)$ to be of any use it must contain more than one term, and from Theorem 1, $G(x)$ will not divide without remainder into x^j. It is therefore sufficient to determine that $G(x)$ does not divide without remainder into $x^{k-j} + 1$.

However, since it has already been stated previously that the smallest degree polynomial of this form that $G(x)$ divides without remainder is $x^e + 1$, and, since $k-j < n \leq e$, then $G(x)$ cannot divide $x^{k-j} + 1$ without remainder. Also, from Theorem 1, all single errors will be detected.

Theorem 4: A code generated from polynomial $G(x) = G_1(x)(x + 1)$ will detect all single, double and triple errors provided the length of the code, n, is no greater than the exponent, e, to which $G_1(x)$ belongs.

Proof: Single and triple errors (and, indeed, any odd number of errors) are detected by the presence of the factor $1+x$ in $G(x)$ (see Theorem 2). Double errors are detected since we have determined that $G_1(x)$ belongs to exponent e, and $e \geq n$ (see Theorem 3).

Burst Error Detection

Theorems 1 to 4 are general to cyclic codes having a defined structured relationship between the exponent e of $G(x)$, and the lengths of the coded and uncoded messages (n and k respectively). However, in the case of a CRC procedure, n is generally larger than e, and therefore only Theorems 1 and 2 apply in full.

Before the theorems related to burst error detection are examined, exactly what is meant by an error burst must be defined:

'An error burst of length b, is defined as any pattern of errors for which the number of symbols between the first and last errored symbols, inclusive of these, is b.'

For example, if $E(x) = x^7 + x^4 + x^3$ in any message (of length obviously ≥ 8), then $b = 5$. This can be visually represented as:

x^n	x^{n-1}	....	x^8	x^7	x^6	x^5	x^4	x^3	x^2	x^1	x^0
0	0	....	0	1	0	0	1	1	0	0	0

$b = 5$ (spanning x^7 to x^3)

Theorem 5: Any cyclic code generated from $G(x)$ of degree $n-k$ will detect any error burst of length $b = n-k$ or less.

Proof: Any error burst can be factored into the form $E(x) = x^j E_1(x)$ where $E_1(x)$ has length b, and therefore degree $b-1$.

The error burst will be detected provided $G(x)$ does not divide without remainder $E_1(x)$ —Theorem 1 shows that $G(x)$ cannot divide without remainder the factor x^j. However, $E_1(x)$ has degree $b-1$ and since it has been stated that $b \leq n-k$, then $G(x)$ cannot divide without remainder $E_1(x)$ since $G(x)$ is of higher degree.

A high percentage of longer error bursts will also be detected as shown in Theorem 6.

Theorem 6: The fraction of error bursts of length $b > n-k$ that are undetected is:

$2^{-(n-k)}$ if $b > n-k+1$, and
$2^{-(n-k-1)}$ if $b = n-k+1$.

Proof: The error pattern is $E(x) = x^j E_1(x)$ and $E_1(x)$ has degree $b-1$. Since $E_1(x)$ has the polynomial terms x^{b-1} and x^0 fixed at '1' (that is, errors), then there are 2^{b-2} possible patterns for the binary symbols between these two extreme errors. Thus, $E_1(x)$ can take the form of 2^{b-2} different polynomials.

For the error pattern to be undetected, $G(x)$ must divide without remainder $E_1(x)$.

That is:

$$\frac{E_1(x)}{G(x)} = Q(x) \text{ or, equivalently,}$$

$$E_1(x) = G(x)Q(x).$$

Now, since $G(x)$ has degree $n-k$ and $E_1(x)$ has degree $b-1$, then $Q(x)$ must have degree $(b-1)-(n-k)$.

If $b-1 = n-k$, then $Q(x)$ has degree zero, that is, $Q(x) = 1$. This means that there is only one error pattern, $E_1(x)$, which will be undetected —that being when $E_1(x) = G(x)$. Hence, of all the possible patterns of $E_1(x)$ (that is, $2^{b-2} = 2^{n-k-1}$) the fraction undetected must be

$$\frac{1}{2^{n-k-1}} = 2^{-(n-k-1)}.$$

If $b-1 > n-k$, then $Q(x)$ has degree $(b-1)-(n-k)$ giving rise to $2^{(b-2)-(n-k)}$ possible patterns for $Q(x)$. There are, therefore, $2^{(b-2)-(n-k)}$ possible patterns for $Q(x)$ which give rise to undetected error patterns out of a total of 2^{b-2} possible patterns for $E_1(x)$. Thus, the fraction of error patterns satisfying $b-1 > n-k$ which go undetected is:

$$\frac{2^{(b-2)-(n-k)}}{2^{b-2}} = 2^{-(n-k)}.$$

CONCLUSION

For $G(x) = x^4 + x + 1$, which is the generator polynomial used for CRC at 2048 kbit/s, these theorems show that:

(*a*) All single errors will be detected—Theorem 1.

Note: $G(x) = x^4 + x + 1$ is an irreducible polynomial (that is, similar to a prime number when dealing with real positive integers), and therefore does not have any factors. Since it does not have the factor, $1+x$, Theorem 2 does not apply.

(*b*) All error bursts of length less than 5 will be detected — Theorem 5.

(*c*) There will be 87·5% (that is, $(1 - 2^{-3})\times 100$) of error bursts of length exactly 5 detected — Theorem 6.

(*d*) There will be 93·75% (that is, $(1 - 2^{-4})\times 100$) of error bursts of length greater than 5 detected — Theorem 6.

Optical Character Recognition System in Letter Mechanisation

R. W. POWELL†

UDC 656.851 : 681.187

In 1978, the British Post Office (BPO) decided to evaluate the use of an optical character recognition system to control a letter coding/sorting machine. After investigating alternative systems, a contract was placed for the development and manufacture of a prototype system to meet BPO requirements. In November 1982, the prototype was installed at a London sorting office, where it was subjected to extensive testing. Some problems have been identified, but overall the system performs well. This article outlines the requirements of the system and give a brief description of the prototype. The article is based on a paper presented at the International Postal Engineering Conference, May 1986.*

INTRODUCTION

In the late-1970s, many overseas postal administrations were successfully using letter mechanisation equipment that incorporated optical character recognition (OCR) techniques. However, many of the systems available were only able to read the bottom address line and recognise an all-numeric postcode or zip code. The British Post Office (BPO) requirement for an automatic address reader was much more demanding and it was important to obtain a suitable prototype system in order to evaluate the performance with British mail.

BRITISH MAIL

British letter mail tends to be very varied in terms of the colour and size of mail pieces and the position and layout of addresses. Both areas are potentially a problem to the automatic reading of addresses by OCR.

Address Variations

The British postcode, introduced as a major aid to mechanising the letter sorting process, has unfortunately three disadvantages when it comes to reading addresses automatically:

(*a*) An alpha/numeric postcode is used rather than the more commonly used all-numeric code.

(*b*) The postcode is divided into two parts: an outward part containing the routing and primary inward sorting information for the destination mechanised letter office (MLO), followed by an inward part representing the final delivery information. The inward part is of a fixed three-character alphanumeric format (numeric, alpha, alpha), but the outward part can be any one of seven different formats (see Figure 1). This means that a complete postcode can consist of 5, 6 or 7 characters, which complicates the task of detecting the presence of a postcode by its format.

FORMAT		EXAMPLE		APPROX NUMBER OF POSTCODE DISTRICTS TAKING THIS FORMAT
AN	NAA	M2	5BQ	70
ANN	NAA	M34	3AB	250
AAN	NAA	DN5	7XY	950
AANN	NAA	DN16	9AA	1350
ANA	NAA	W1A	4WW	10
AANA	NAA	EC1A	1HQ	60
AAA	NAA	NPT	6JD	2

where A = Alphabetical Character
N = Numerical Character

Figure 1—Examples of postcode format variations

(*c*) Only about 60% of the total letter mail contains a postcode, although the figure is higher for business mail. Although the BPO issues guidelines on laying out addresses, the recommendations are not enforced and in practice there are many address format variations in terms of the type of information contained in an address and its relative position within the address.

The first weight step in the letter post tariff is 60 g and this means that mail up to 7 mm thick falls within the machineable mail category. This is generally thicker than the mail normally processed by OCR-controlled mail handling systems.

REQUIREMENTS FOR THE PROTOTYPE SYSTEM

After a detailed study, the following major points were considered to be special requirements essential for a prototype OCR coder/sorter (OCRCS) suitable for processing British mail:

(*a*) Since many of the addresses would not contain postcodes, the OCRCS should be able to read and recognise other address infor-

† British Post Office Research Centre

* POWELL, R. W. The introduction of an optical character recognition controlled mechanization system into the British Post Office. Postal Engineering, *Proc. I. Mech. E.*, **1986–5**, p. 1.

mation such as posttown, country names, counties and localities as well as postcodes.

(*b*) The lack of redundancy in the postcode could result in missorting, if individual postcode characters were incorrectly recognised. To limit this problem, the OCRCS should be able to correlate the postcode with other information contained in the address, such as the posttown.

(*c*) The large variations in address format make it necessary for the OCRCS to be able to read and recognise information contained anywhere in the bottom three address lines in order to be sure of finding all of the significant data.

(*d*) The mail transport system should be capable of accepting mail items of up to 7 mm thickness.

(*e*) A phosphorescent codemarking system is used by the BPO throughout its letter mechanisation operation and the OCRCS would need to incorporate a printer capable of producing compatible codemarks.

(*f*) It was intended that codemarked mail from an OCRCS would be merged with codemarked mail from conventional coding desks at the main stages of sorting. This would mean that the sorting plans on the OCRCS presorter would need to be compatible with those of other presorters in an MLO; that is, have the ability to divert mail items into the appropriate selection bin according to a particular combination of outward and inward codemarks.

ACQUISITION OF A PROTOTYPE OCRCS

The Options

There were three possible options for obtaining a prototype system for evaluation:

(*a*) Develop the prototype OCR postcode reader already produced by the British Telecom Research Laboratories who at that time were working on postal engineering projects.

(*b*) Use existing resources within the BPO Research and Development Department to develop a suitable system.

(*c*) Make a study of proprietary systems, identify the most suitable for UK use and place a development/manufacturing contract with the manufacturer to produce a prototype system to a BPO specification of requirements.

The Decision

It was decided that, although the British Telecom designed prototype had a good per-character recognition performance, it was only a single-line postcode reader, and to develop it to meet all the current BPO requirements would take too long and cost too much.

An in-house development programme was also rejected on the same basis.

The remaining option was the development of a UK prototype from an existing proprietary system. A detailed specification of requirements and 10 000 item packs of test mail were produced by the BPO Research and Development Department. A study was made of a number of alternative OCR systems and in January 1981 a development/manufacturing contract was placed with a West German firm for a prototype OCRCS. The prototype was to be based on the system that was being used in a number of German sorting offices, but suitably modified to meet BPO requirements. The prototype would also incorporate a commercial ink jet printer that had been modified by the BPO to operate with phosphorescent ink, and a BPO-designed sorting translator to control the routing of mail items in the presorter.

Installation of Prototype

The prototype system successfully completed acceptance tests with test mail at the manufacturer's site during September 1982 and was installed in the Mount Pleasant sorting office in London later that year. During 1983 and 1984, the OCR system was subjected to intensive engineering and operational testing using live mail items.

BRIEF DESCRIPTION OF PROTOTYPE OCR CODER/SORTER

The prototype system consists of a modified address reader and incorporates a BPO-developed ink jet printer† and sorting translator. A photograph of the transport system is shown in Figure 2 and a block diagram of the total system in Figure 3.

The function of the OCR system is to read the addresses on mail items automatically, print a phosphorescent code on the item derived from the address, and presort the coded items into one of eight stacking bins.

Feeder

In the address reader, the items are put by hand into the feeder stack. The feeder incorporates a vacuumless high-friction destacker that automatically singles the items at a high belt speed of 3 m/s and at a constant gap. The items pass through a 'settle-down' section and the dimensions of each item are checked in a format separator unit, at which point items that are mechanically unsuitable, that is, too high, too long, too short, too stiff or too thick, are rejected.

Scanner

Suitable items pass into the scanner unit which scans an area 238 mm long by 60 mm high (see Figure 4) on the face of each mail item. The scanner module uses a high-powered light source to illuminate a narrow strip,

† EVANS, D., and SPICER, C. J. Advances in High-Speed Phosphor Printing. *Br. Telecommun. Eng.*, Oct. 1987, **6**, p. 186.

Figure 2—Optical character recognition coder/sorter system

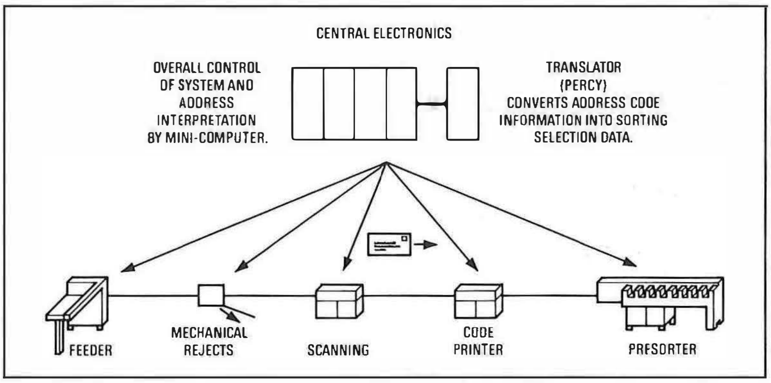
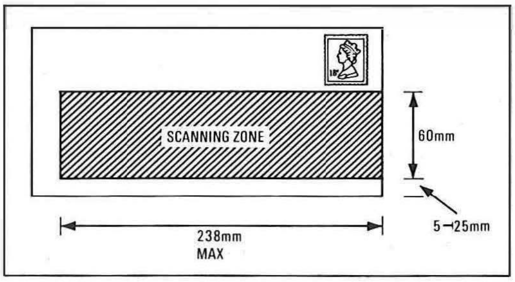


Figure 3—Layout of the OCR letter coder/sorter system

Note: The mail transport system runs at 3·0 m/s giving a throughput of up to 30 000 items per hour

Figure 4
Scanning zone of the OCR letter coder/sorter



60 mm high, on the surface of a mail item through a viewing slit and a lens system to focus images onto a vertical array of 512 photodiodes. As a mail item moves horizontally across the viewing slit at 3 m/s, a binary image of the complete scanned area is built up at a resolution of 120 μm × 120 μm. This data is transferred to the central electronics unit for subsequent pre-processing, character recognition and address interpretation.

Central Electronics

All of the preprocessing of the scanner image data is carried out by four high-speed bit-slice microprocessor modules and specialised electronic hardware.

Line Finding

The first stage of processing the image data received from the scanner unit is to identify and localise lines, select a block of lines as being the likely address block, remove specks of dirt and underlinings and select relevant lines from the chosen address block for further processing.

As the data is received from the scanner, a vertical histogram of the black/white information is produced and used to determine the co-ordinates of line-like structures. Localised lines are then formed into geographical groups or blocks, and isolated specks of black and underlinings are eliminated. Where there is more than one block, a priori knowledge is used to select the block of lines most likely to be the true address block. The data in the relevant lines in the selected address block (usually the bottom three lines) is forwarded to the next pre-processing stage, segmentation.

Segmentation

Each address line forwarded from the line finding module has to be divided up into individual characters. This process is called *segmentation*.

The sum of the black image elements in each of the vertical columns making up a line is calculated to produce a horizontal histogram. The majority of typed characters conform to a standard typewriter pitch; for example, 10 characters per inch. Comb functions for 10, 12 and 14 characters per inch are compared with the histogram of an address line to determine how well the peaks and troughs fit. If an acceptable fit can be achieved, the complete line is segmented into individual characters according to the selected pitch. In cases where none of the combs gives an acceptable fit, as with proportionally-spaced characters, segmentation is achieved by detecting vertical paths of white between areas of black. The lines of segmented characters are forwarded to the next pre-processing stage, normalisation.

Normalisation

The OCR system accepts characters of heights within the range of 1·9 mm to 7·7 mm. To simplify the character recognition process, each segmented character is normalised on to a grid of 16 × 16 image elements. The characters are centralised on to a grid according to their centre of gravity and dimensionally normalised isotropically to a scale determined by the greatest extremity of the character in the vertical or horizontal direction.

Classification

The final pre-processing stage is *classification* and this is where a recognition decision for each character is made. A decision must be made as to which group an unknown character belongs, that is, upper- or lower-case alphabetic, machine printed or handwritten numeric, and the class within the group; for example, A, B, C etc.

The BPO's prototype OCR has four classifier channels dealing with:

(*a*) upper-case alphabetic characters,
(*b*) lower-case alphabetic characters,
(*c*) machine-printed numerals, and
(*d*) handwritten numerals.

Note: A classifier for recognising handwritten numerals, although useful when dealing with an all-numeric zip code, has no practical use for British mail, but was supplied as part of the standard system.

Each unknown character from the address lines being processed is offered simultaneously to all four classifiers. Each classifier then provides an answer in the form of:

(*a*) the first, second and third choice decision as to what the unknown character is likely to be;
(*b*) a confidence level value indicating the degree of certainty of the first choice decision; and
(*c*) a value representing the degree of certainty that a particular classifier channel was the correct channel.

An arbitrator compares the results from the four classifiers, selects the most suitable channel and forwards the relevant three-character choice and confidence values to the next processing stage—word interpretation. An example is shown in Figure 5.

Statistical classifiers are used for the character recognition process. The classifiers are pretrained with quantities of known characters and the results are used to select sets of elements from the 16 × 16 raster images received from the normalisation module that are critical for a particular character class (A, B, C etc.) in order to distinguish it mathematically from other classes. These critical points are given weightings and the coefficients and constants are permanently stored in the classifier memory. When the raster image for an unknown character is presented to a classifier, the required elements for each class are extracted as black/white, 1 or 0 values and used in a polynomial expression, involving linear and quadratic terms, to calculate a direct measurement of the probability of the unknown character being a member of a particular class. By comparing the values for all classes in a classifier, the three best scores and hence the three most likely characters can be determined.

CLASSIFIER CHANNELS — FIRST, SECOND AND THIRD CHOICE CHARACTERS

		TYPE-WRITTEN CAP					TYPE-WRITTEN SMALL					TYPE-WRITTEN NUMBER					HAND BLOCKNUMBER				
	EK	RAD	1	2	3	ZTYP	RAD	1	2	3	ZTYP	RAD	1	2	3	ZTYP	RAD	1	2	3	ZTYP
P	P	43	P	O	U	34	40	p	g	r	29	155	2	0	8	-3	86	0	5	2	3
O	O	72	O	O	C	7	73	o	c	b	18	1	0	6	5	40	27	0	6	3	-1
S	S	28	S	B	K	41	88	s	a	\	26	115	5	3	8	10	147	3	5	9	-13
T	T	59	T	F	U	57	188	m	r	f	6	115	7	1	0	21	205	7	0	5	-19
T	T	75	T	I	U	55	190	r	m	l	8	129	1	7	0	18	210	5	0	7	-16
O	O	77	O	C	G	11	66	o	c	m	24	38	0	:	6	33	62	0	5	2	-4
W	W	51	W	T	O	45	50	w	z	p	33	196	2	9	4	-5	179	8	1	2	-10
N	N	24	N	P	K	87	241	p	m	w	-14	215	1	0	8	-5	255	7	0	5	-4

ZTYP = Measure of confidence of classifier choice (+127 = maximum confidence)

RAD = Measure of confidence of 1st character choice (0 = maximum confidence)

Final decision

Original scanner image

Figure 5
Examples of classifier decisions

Word Interpretation

The words on each line (consisting of the now recognised characters) are transferred to a central computer (PDP 11/70) whose first task is to examine the structure and position of each word in a line and attempt to identify the word type: for example, postcode, or posttown. Unwanted information such as an inward line (for example, 25 High Street) identified by an all-numeric character string at the start of a line is rejected at this point. The object of the word interpretation process is to speed up the next processing stage, address interpretation, by identifying possible significant words in an address.

Address Interpretation

The computer then compares the unknown words (in order of significance) with entries in an operational directory stored in the computer memory. The directory consists of a large look-up table containing all postcodes, posttowns, important localities, county names, foreign countries and special words.

Where the word interpretation process has identified a postcode-like character string, access to the directory is by the outward postcode. If a character-by-character match between a directory entry and the unknown word occurs, an attempt is made to match the posttown name associated with the particular directory entry with one of the other words in the address being interpreted. If a match occurs, full correlation will have taken place and the address interpretation process completed.

If no significant words have been identified by the word interpretation process, each address word is used in turn to access the directory in an attempt to achieve a character-by-character match with an entry in the directory. This process continues until a final address interpretation decision can be made with a high enough level of confidence. Generally this means that two separate words from an address must match up with entries in the directory and correlate with one another; that is, outward postcode to correlate with a posttown; posttown to correlate with an outward postcode or county; or locality to correlate with an outward postcode or county. No correlation is required for a foreign country.

On completion of the address interpretation process, one of a number of decisions will have been made for a particular mail item:

(*a*) address could not be satisfactorily interpreted: route item to presorter reject stack uncodemarked, or

(*b*) destination address identified as being a foreign country: route item to appropriate presorter stack uncodemarked, or

(*c*) postcode satisfactorily identified: fully codemark item and route it to the appropriate presorter stack, or

(*d*) only posttown or locality satisfactorily identified: code item with outward only codemark and route to appropriate presorter stack.

The codemark information is forwarded to the high speed ink jet printer, and the phosphorescent marks are sprayed on to the mail item as it passes through the printing station. The same information is sent to the BPO-designed sorting translator which converts it into a routing code, according to the sorting plan being used, to send the item onto the appropriate presorter selection stack.

ASSESSMENT OF THE OCR SYSTEM

Mechanically, the machine operates reliably, quietly and with few mail jams. Typical figures are:

Mean Time Between Failures		6·39 hours
Noise Level	70 dBA	(measured at operator's ear)
Jam Rate	less than 1 jam per 8000 items	

The vacuumless destacker in the feeder module gives a good performance over the required mail size range and the stacking action of the flat-bed presorter produces stable stacks of mail. Operating the machine is relatively straightforward and the various control panels give adequate information on the current status of the system. Loading the machine with mail and clearing the presorter stacks are both simple operations requiring little effort.

Performance

Throughput

The number of mail items processed by the system per hour is dependent on:

(*a*) the speed of the transport belts,

(*b*) the gap between mail items,

(*c*) the length of mail items, and

(*d*) the amount of processing time required to interpret addresses.

The speed of the transport belt is constant at a nominal 3 m/s and the gap between mail items is fixed at an optimum value, so the variables affecting throughput are mail length and address interpretation time. If a mail item has a particularly awkward address or if it has been put into the machine upside-down, more than the average time is needed for the address interpretation process to attempt to reach a satisfactory decision. If a number of such items follow in sequence, the destacking rate and hence throughput is automatically reduced. The tests at Mount Pleasant have shown that, for normal meter type business mail, an average throughput of 28 000 items per hour can be expected.

Recognition Rate

The recognition performance is affected by various factors, but, before commenting on these, it is important to define what is meant by the term *recognition rate*:

$$\text{recognition rate} = \frac{\text{the total number of items successfully read}}{\text{the total number of items processed}}$$

where 'successfully read' means an address interpretation decision other than reject; that is, full postcode decision, outward postcode decision, posttown decision, locality decision, or foreign country decision.

The main factors governing successful address recognition are:

(*a*) *Quality of the characters in the address* This is in terms of contrast, completeness, size, gap between adjacent characters and to some extent style; for example, character font. The colours of characters and background are not critical providing the contrast between character and background remains good. The colour red, however, is seen as black by the reading system, so that items with a red background cannot be processed satisfactorily.

(*b*) *Use of punctuation* In general, punctuation can cause more problems than it solves. The use of fullstops and other punctuation between the characters in a postcode (this happens frequently with London postcodes) breaks the postcode format rules and results in it not being recognised as a postcode by the machine. This particular problem has now, to a large extent, been overcome as a result of changes to the word interpretation software by the BPO Research Department.

(*c*) *Address position* If an address is unusually high or low on a mail item, it is possible that important information will not be seen by the address reader. If there is other information on a mail item (for example, a return address), its position and format relative to the delivery address are important. For items with address windows, the complete address must be visible through the window. This is often a problem when the contents of a window envelope are able to move about.

(*d*) *Address format* The address format is not particularly critical providing that all relevant information is available in the bottom three lines of an address. If a postcode is positioned too remotely from the rest of the address block (a fairly common practice with computerised addresses) it may be ignored by the address preprocessing procedures.

Extraneous information written immediately underneath an address such as 'Private', 'For the attention of' etc. would be taken as the bottom line of the address. The system normally processes the bottom three lines of an address, and important information on the third address line from the bottom ('Posttown' in the following example) could be lost because of the additional bottom line containing the extraneous information.

Smith & Co. Precision Engineering Ltd
18 Brook Street
Posttown
County
Postcode
For the attention of the Accounts Dept

(*e*) *Operational directory* The completeness of the look-up directory containing posttowns, counties, postcodes etc. significantly affects the quality of the address interpretation decision. If legitimate information contained in an address cannot be matched with information in the look-up directory, the item may be rejected or an inferior decision made.

(*f*) *Window envelopes* In general, window envelopes do not present a problem to address reading providing the contrast between characters and background is good and the complete address is visible in the window area. Some types of transparent window material, when badly creased, produce unwanted glare, and this can cause parts of an address to be unreadable. The prototype OCR is fitted with a window detector and, as long as this device is kept dust free, it performs well and is an aid to the subsequent processing of the information read from such mail items.

The variation in mail quality means that the recognition rate can also vary considerably. For high-quality mail, such as that produced by the BPO Electronic Post laser printing system, recognition rates in excess of 95% can be expected, whereas the recognition rate can be below 40% for low quality mail such as the incoming foreign mail at Mount Pleasant sorting office, which contains large amounts of mail items with poor quality print, unorthodox formats and a proliferation of extraneous information in addresses.

For average UK meter mail with a 15% handwritten address content, a recognition rate of 65–70% can be expected.

A typical distribution for 100 items of meter-type mail is given in Figure 6.

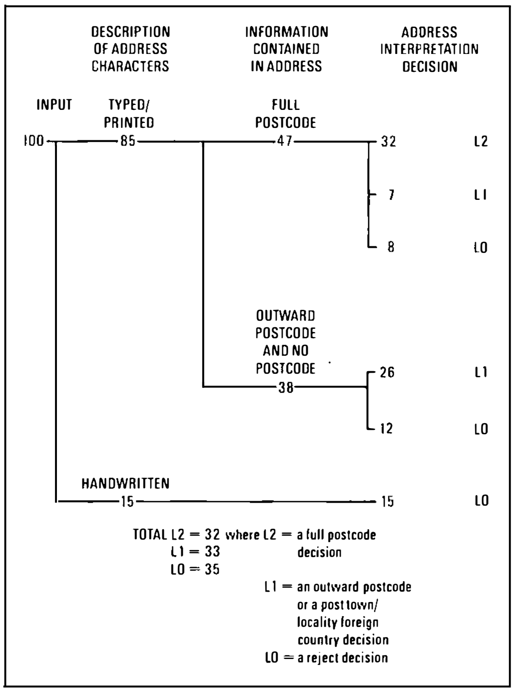


Figure 6
Typical distribution of meter mail

For some of the mail items with fully-postcoded addresses, the result of the address interpretation process results in an outward only decision being given; for example, outward postcode or posttown/locality. The outward part of a postcode can often be correlated with other information contained in the address to improve by confirmation or correction the quality of the final decision. The inward part of the postcode, however, cannot be correlated in this way and the interpretation decision can only be based on the confidence with which the characters in the inward postcode have been read. If an inward postcode is not read with sufficient confidence, an outward only decision is given rather than totally reject the item. The confidence level threshold for all parts of a postcode can be adjusted but there is a trade-off between positive decisions and errors.

Maintenance

The OCR system is currently being operated for more than 16 hours per day, 6 days per week and, apart from regular cleaning of the transport system and ink jet printer and periodic replacement of the feeder clutch/brake unit, the system is reliable and requires little maintenance.

FURTHER DEVELOPMENT

The overall performance of the prototype system is satisfactory, but there are two main areas requiring some improvement.

- *Character Recognition* Certain character classes are not recognised as well as others and, although errors in reading individual characters can be corrected during the address interpretation process, an improvement in this area could reduce the number of reject decisions.

Unfortunately, improving the per character recognition performance is not easy. The technique is to retrain an existing classifier with many samples of the problem character to produce a modified classifier. This is a labour intensive operation involving experienced personnel. The retraining exercise affects every class in the classifier and improving the recognition performance for one character can have a detrimental effect on the recognition performance for the other characters; this results in a reduction in the overall performance of the system. This is an area currently being investigated by the BPO Research Department.

- *Treatment of Inward Postcodes* The decision as to the acceptability of an inward postcode is, as mentioned previously, entirely dependent upon the quality of the recognition result for each of the three characters, since there is currently no method of correlating the inward postcode with other address information. This means that many mail items with fully-postcoded addresses are only outward codemarked by the OCR system, which is unsatisfactory operationally. An improvement in the per character recognition performance as discussed above would reduce the problem, but the BPO Research Department is also investigating possible ways of achieving some measure of correlation between inward postcodes and inward information contained in addresses.

CONCLUSION

At the time of preparing this paper, the engineering and operational evaluations of the prototype OCR system have been completed and the system was being fully used operationally to process nearly three million items per week.

The tests have shown that the prototype OCR system is able to process satisfactorily the majority of typewritten/machine-printed mail falling within the size limits for machineable mail. Operating the system is straightforward, and mechanically the machine is fast, quiet, reliable and not prone to mail jams.

As expected, the recognition performance is very dependent upon the quality of addresses in terms of the standard of printing, address format/position and the amount and accuracy of information contained in an address.

The recognition performance is not as good as that of manually operated coding desks and the latter can also process handwritten mail. However, the high throughput of the OCR system means that it can provide a cost-effective role as a high-speed coding/preculling machine for business mail in some of the larger MLOs with sufficient volumes of suitable mail. In this role, rejects from the OCR system would be processed by standard coding desks.

The BPO is currently installing OCR coder/sorters, based on the prototype design, at a further 17 of the larger MLOs.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to the Director of Engineering for permission to publish this paper, and to the engineering and operational personnel who have contributed to the OCR project over the years.

This paper was first published in the conference proceedings *Postal Engineering*, and is reproduced by permission of the Council of the Institution of Mechanical Engineers.

Biography

Roger Powell is Head of the OCR Development Group of the Engineering Department of Postal Headquarters. He joined the Post Office in 1959 as an apprentice at Luton in the Bedford Telephone Area, and later, as a technician, was associated with early letter mechanisation experiments at the Luton Head Post Office. He continued on postal engineering work both as a technician and as an Executive Engineer B, initially in the Luton area and then at Cambridge where he was directly involved with the commissioning and subsequent maintenance of the letter mechanisation office. In 1974, he transferred to Postal Headquarters, London, as an Executive Engineer A, specialising initially in maintenance policy formulation and then, in 1980, he transferred to his current duties.

RASE—System for Recording and Scanning Alarms in the Digital Transmission Network

A. W. JONES†

UDC 621.394.4 : 81.327.8 : 654.924

This article describes RASE, a computer-based scanner which detects digital transmission alarms which may occur in a number of digital multiplex equipments. RASE was designed and installed by Messrs. A. W. Jones, D. Jones, and N. F. Walker in Manchester Irwell Repeater Station and was a finalist entry in the 1987 New Ideas Competition run by British Telecom.

INTRODUCTION

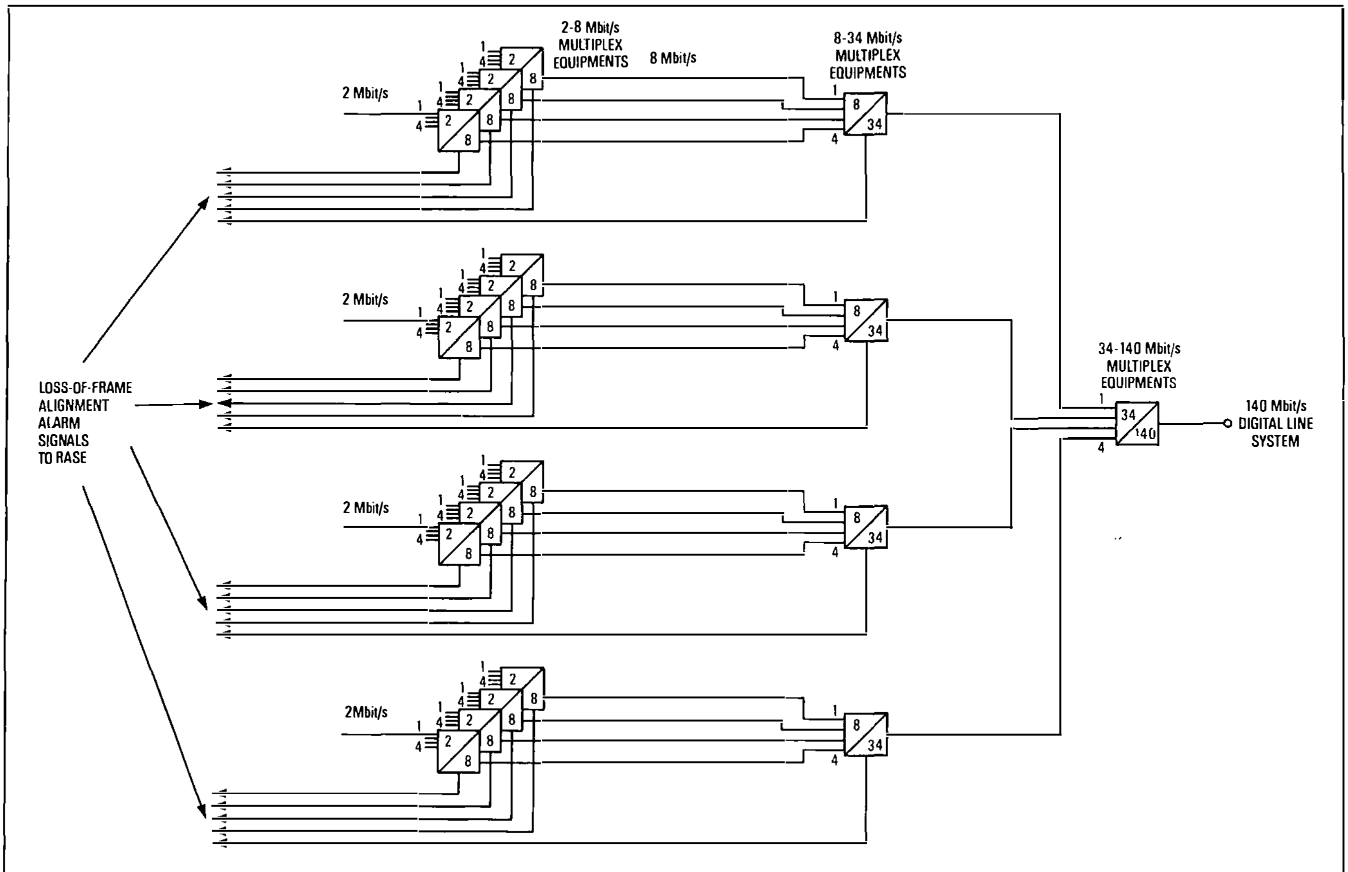
The transmission of digital signals over cable (coaxial or optical) at 140 Mbit/s requires the multiplexing of basic 2 Mbit/s signals through three stages. The digital bit rates are 2·048, 8·448, 34·368 and 139·264 Mbit/s, but are more generally known as 2, 8, 34, and 140 Mbit/s. Figure 1 shows the interconnection of the various digital multiplex equipments (often referred to as *muldexes*) used to assemble the 140 Mbit/s signal.

Each stage of multiplexing has alarm facilities designed to indicate loss of frame alignment, alarm indication signal (AIS), and loss of input signals at lower and higher bit rates.

† Trunk Network Operations, North West Region, British Telecom UK Communications

Early experience showed that, although transmission errors and failures were adequately detected by the multiplex equipment, the attention of maintenance staff could only be drawn to them if the failure persisted long enough to allow inspection of the alarm indicators. Location of an individual multiplex equipment that was exhibiting alarms could take some time, and often the alarm cleared before localisation was possible. As the number of installed multiplex equipments in a station increases, the task of locating transient alarms from a particular equipment becomes more difficult. RASE (recording and alarm scanning equipment) was conceived as an attempt to overcome the problems of detecting and recording alarms from multiplex equipment.

Figure 1
Interconnection of multiplex equipment for 140 Mbit/s line system



OBJECTIVES OF THE PROJECT

The main objective of RASE was to record and display alarms exhibited by any digital multiplex equipment within a repeater station. The surveillance system would have to be fast enough in operation to detect transient alarms on any multiplex equipment, with a high probability of detecting any alarm of any duration. Because of the intermittent nature of many alarms, a recording system that detailed the time such events occurred would enable closer monitoring of the link to be initiated. Thus, RASE was designed to meet the following objectives:

- to detect alarms in the receive direction of transmission at 8, 34, or 140 Mbit/s multiplex points,
- to record the date and time of alarm detection and clear,
- to display alarm data visually at a central location,
- to provide an historic record of alarm events and issue a summary at predetermined times or on demand, and
- to allow for the installation of additional multiplex equipments and to provide a means of identifying links from a central point as new equipment is brought into service.

CHOICE OF MONITORING CONDITION

Choosing which of the available alarm conditions to monitor was an important decision upon which meeting the objectives of the project depended. The three alarms presented by multiplex equipment in the receive direction of transmission are:

(*a*) AIS,
(*b*) loss of frame alignment, and
(*c*) loss of demultiplex input signal.

The loss-of-demultiplex-input alarm occurs at the multiplex equipment when the signal from the previous higher stage of demultiplexing is lost. This alarm is present only when the signal has failed completely within the station. The demultiplex input alarm does not occur when signals from a higher-order multiplex equipment are replaced by an AIS under higher-order failure conditions. The AIS alarm is displayed by the multiplex equipment when the previous higher-order of multiplex equipment or line system has failed. Under AIS conditions the multiplex equipment has no frame-alignment information. The AIS signal is the all '1's signal; that is, no '0's are present within the signal pattern. Loss-of-frame-alignment alarm is announced by the multiplex equipment after three attempts to regain alignment have been attempted†. In the absence of frame-alignment information, the multiplex equipment assumes a search mode and shifts alignment, to seek a recognisable pattern of frame-alignment word inserted at the distant-end multiplexer. The times taken for a particular multiplex equipment to regain alignment are shortest for highest-order systems. A typical recovery time for a 2–8 Mbit/s system is 560 μs, at 8–34 Mbit/s the recovery time is 250 μs.

Given the constraints of the alarm signals available and remembering that the chief objective of the project was to detect transient alarms among a large number of multiplex equipments, the loss of demultiplex input signal was rejected as a monitoring condition because it would only indicate the failure of a signal within the station itself.

The AIS alarm would indicate the failure of a higher-order system, but would not necessarily indicate the failure of an individual link alone, unless that link had caused the injection of AIS somewhere along its route.

The most sensitive indicator of performance of the individual link was the loss-of-frame-alignment alarm. The frame-alignment pattern can be considered as being analogous to pilot tones in FDM systems. The multiplex equipment indicates loss of alignment under AIS conditions, and the loss-of-frame-alignment detection process is sensitive enough to detect transmission degradation and worsening error performance.

Hence, loss of frame alignment was chosen as the alarm condition for monitoring by RASE. Sufficient network information could be gathered by monitoring only the 2–8 and 8–34 Mbit/s multiplex equipments, correlation to higher- or lower-order links being achieved by using a records system.

RASE EQUIPMENT

RASE consists of a BBC model B computer, a VDU, a printer, and an interface cabinet (Figure 2). The interface cabinet is of 62-type construction and comprises a number of shelves each housing an address decoder and input cards.

The BBC computer has a user port addressable by the machine and a 1 MHz bus also addressable and comprising an 8-wire data bus. Under control of the software, the 1 MHz bus address wires are enabled to access one page of memory (256 byte) giving a possible 2048 single-bit addresses. The principle of the scanning process is to address a bank of eight alarm conditions from the multiplex equipments, read those conditions into the computer and continue with the next eight until all 2048 inputs have been scanned.

The VDU allows information regarding the multiplex alarm and the time and date of its occurrence to be displayed, along with the main menu for the programme. Additional VDU displays are provided away from the RASE equipment in the Network Management Centre and in the repeater station. The

†BYLANSKI, P., and INGRAM, D. W. E. Digital Transmission Systems. IEE Telecommunication Series 4, p. 85. Peter Perigrinus (1976).

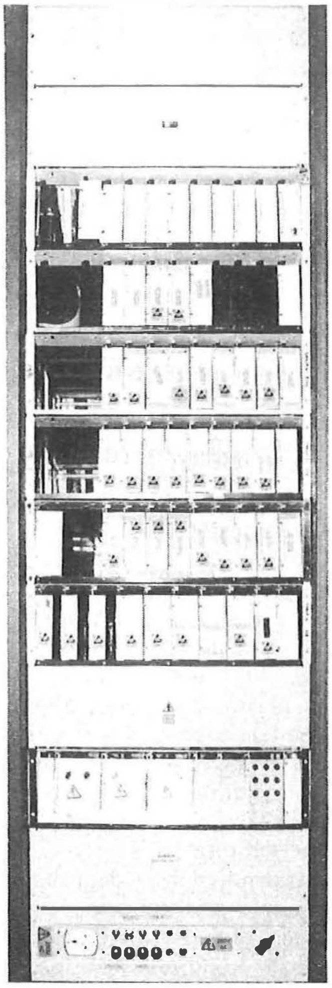


Figure 2—RASE cabinet

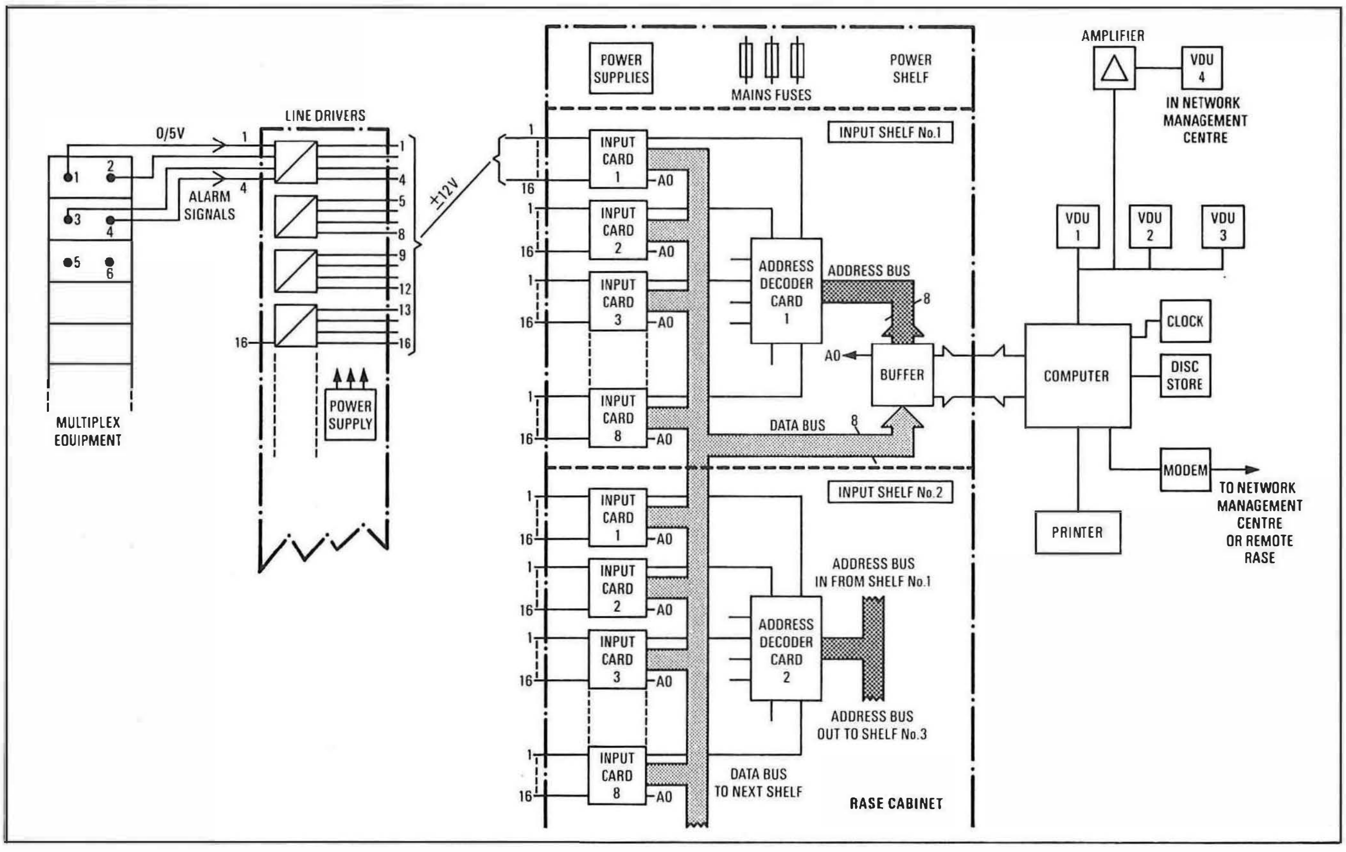
printer is under operator control unless automatic summary time calls for the print out of stored alarm conditions. A real-time clock module connected to the user port of the computer is used for system time keeping.

OPERATION

A block diagram of RASE is shown in Figure 3. The frame-alignment alarm condition appears as a 0 V TTL logic state at the multiplex equipment. Each multiplex equipment has this alarm voltage wired via a 20-way ribbon cable to a wiring flexibility block. Ribbon cables from other suites of multiplex equipments are concentrated here and wired to the adjacent line-driver shelves. The line drivers are 4-input RS232 devices whose function is to convert the 0/5 V TTL multiplex alarm voltage to a ±12 V state suitable for transmission over some 50 m of internal cabling to the central monitoring equipment. Line drivers were found to be necessary after experiments showed that considerable propagation distortion was introduced to alarm signal pulses during transmission over the internal cabling. Corresponding RS232 receivers are installed in the RASE interface cabinet which convert the ±12 V back to TTL voltages. Line drivers additionally provide a barrier, protecting equipment at either end of the station cabling from damage or spurious operation due to induced noise voltages.

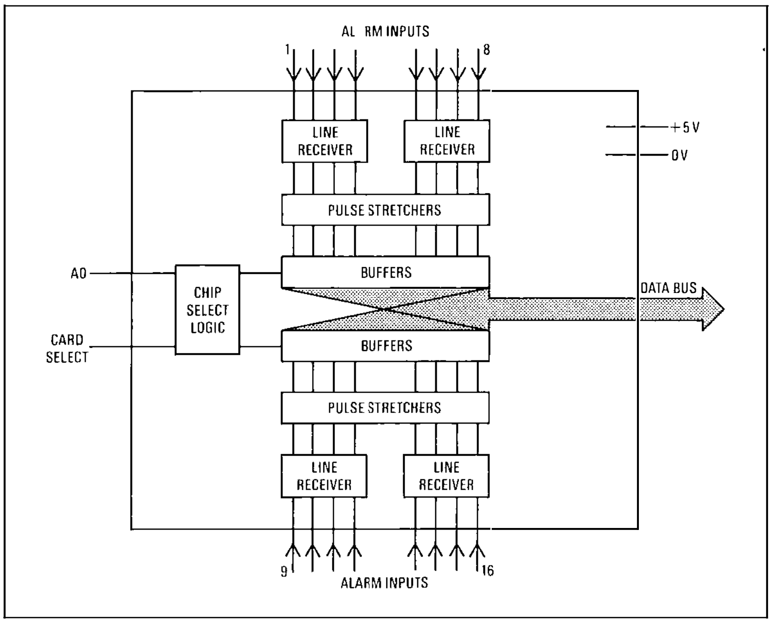
The RASE interface cabinet provides the means by which the computer receives

Figure 3
Block diagram of RASE



changes in alarm conditions from the multiplex equipment. The cabinet houses up to eight shelves. Each shelf contains eight input cards and one address decoder card. The computer addresses eight alarm inputs at a time and reads their alarm voltage states on to the data bus as one byte. The addressing system is arranged so that the address decoder on each shelf decodes the address for that shelf, and then a card on the shelf followed by a choice between two banks of eight alarm inputs per card. In this way, all input alarms are read in turn in banks of eight on to the data bus for analysis by the computer software. Figure 4 shows a diagram of the input card. The A0 address wire and card-select wire are presented to the chip-select logic (74LS00), which performs the logic necessary to enable, in turn, each input card buffer (74LS240) to allow alarm data through to the data bus.

Figure 4
Input card details



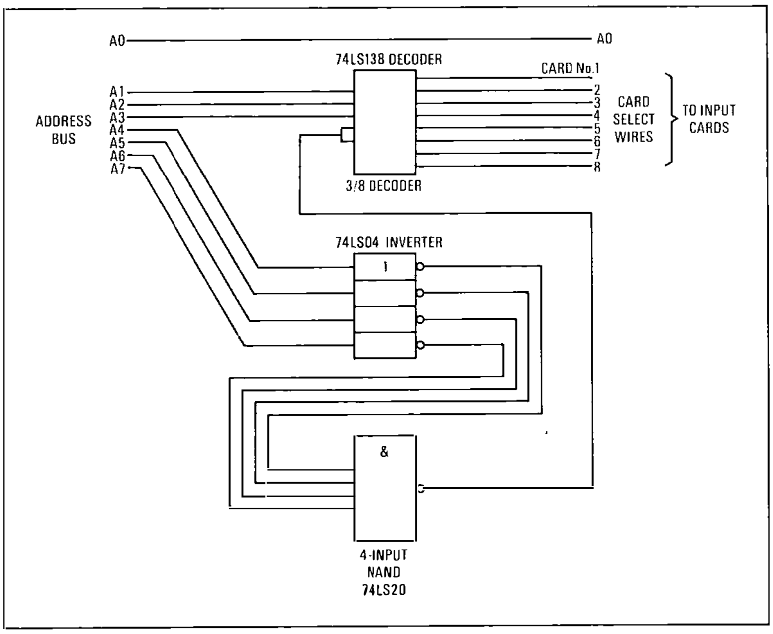


Figure 5—Address decoder card (one per shelf)

A diagram of the address decoder card is shown in Figure 5. The address decoder card is responsible for the correct addressing of each card on each shelf. The eight address wires from the 1 MHz bus are split into two groups of four. The A0 wire is used in input bank choice selection at the input card and is not used in the decoder card. Address wires A1–A3 are decoded by the 74LS138 3/8 decoder to provide the card-select wires which enable the buffer chips on the input cards. Address wires A4–A7 allow logic states relating to a particular shelf to be set up. Each shelf has a unique code which can be set by using the inverter chip 74LS04. The inputs to the following 4-input NAND gate 74LS20 must be logic 1 to output $\overline{\text{ENABLE}}$ to the 3/8 decoder. In this way, the addressing system follows a shelf–card–input bank form to allow the input card to read data to the data bus.

The other card in the cabinet is the buffer card which performs the function of ensuring sufficient drive currents for the address and data buses. There is also a clean-up circuit on the buffer card which corrects timing problems associated with the 1 MHz bus.

SOFTWARE

The software was written for the BBC computer in 6502 machine code. The program is menu driven, and provides 'housekeeping' tasks in addition to the basic multiplex scan routine. The scan option of the program initiates a scan of all connected multiplex equipments and, upon detection of a change in alarm state, performs the following tasks:

(*a*) displays the multiplex designation on screen,

(*b*) prints the multiplex designation on the printer if the printer is selected,

(*c*) displays the alarm status (FAULT or CLEAR) and date/time of the fault on screen, and

(*d*) files fault information to memory.

The other choices on the menu are:

(*a*) *ALLOCATE INPUTS* This option allows the names of digital blocks to be inserted on to a disc file; for example, an input name for an 8 Mbit/s link between Manchester and Preston might be allocated as PR 8001 at Manchester.

(*b*) *CHECK ALARM STATES* This option initiates a scan of all inputs and prints out any detected as being faulty. The option is useful to check on alarms that have been active for some time and are not currently displayed on screen.

(*c*) *PRINT FAULT SUMMARY* A summary of faults may be printed at the request of the operator. Additionally, there is an automatic print-out of faults every 8 hours, or if the memory is full.

(*d*) *LIST INPUTS* This menu option prints a list of all or some of the input numbers allocated and their block names.

(*e*) *DISPLAY ALARM STATES* As an aid to maintenance of the system, this menu option gives an on-screen matrix display of all inputs, indicating an alarm by showing a '*' and a clear state by a '–'.

(*f*) *SCAN* This is the main alarm detection routine.

(*g*) *SET CLOCK* This allows the operator to set the system date/time.

THE MAIN SCAN SOFTWARE

A flow chart for the main software controlling the scan routine is shown in Figure 6. The BBC 1 MHz bus is addressed at page FC00 labelled as FRED. Upon initialisation, the alarm states of all inputs are copied to STORE 1. The scan continues with addressing/reading of each bank of eight inputs, each data byte being compared with that in STORE 1. If there has been any change of state, either from CLEAR to ALARM or vice versa, the relevant bit in the HIT STORE is set, as is a flag, named HIT FLAG, indicating that a change has occurred. When all bytes have been checked, the status of HIT FLAG is examined. If the HIT FLAG is set, then the HIT STORE is checked to determine which bits are set. STORE 1 is examined for FAULT or CLEAR information and the bit position as defined in the HIT STORE is used to decode the relevant input, as shown in Figure 7. The allocated input information relating to block names is stored in the CODE store as 3 bytes per input. The first byte is a number associated with the input block name; the second byte gives the bit rate of the input (that is, 8 or 34 Mbit/s); and the third byte gives the circuit number (that is, 01, 09 etc.). An arithmetical operation is performed on the first byte of the CODE store to compute the position of the name of the block held in the NAME store. The NAME store holds as 8 bytes the ASCII characters for the station code name. Thus, information as to the particular block exhibiting a fault can be decoded. This form of decoding was chosen because it is economical in use of memory. Information relating to a block—for example, PR 8001—is held as PR in the NAME store, 80 in the second byte of the CODE store and 01 as the third byte in the CODE store. Early versions of the software held that information as an ASCII string which wasted a lot of memory.

The rest of the software is concerned with running the clock and controlling the peripherals. An audible alarm is given when a fault is detected, and is silenced by pressing the keyboard space bar.

MODIFICATIONS

It was noticed in practice that some transient faults at 34 Mbit/s were missed by the scanner. The transient persistence time was very short, typically much less than 1 ms. As the number of inputs from multiplex equipments connected to RASE increases so does the time taken to complete the scan. If the scan time became large compared with the transient persistence time, some alarms would be missed. With the BBC clock running at 2 MHz, 300 inputs are scanned in 500 μs. The scan time rises linearly reaching 1300 μs with 800 inputs.

The scan time, S, in microseconds, is given by

$$S = 1{\cdot}28I + 125,$$

where I = number of inputs.

At low transmission error rates, the probability of random frame-alignment-word corruptions is small. Short frame-alignment alarm persistence times indicate low error rates. The objectives of RASE were to detect such transient alarms as possible indicators of a worsening condition, and initiate early corrective action. The solution adopted, after

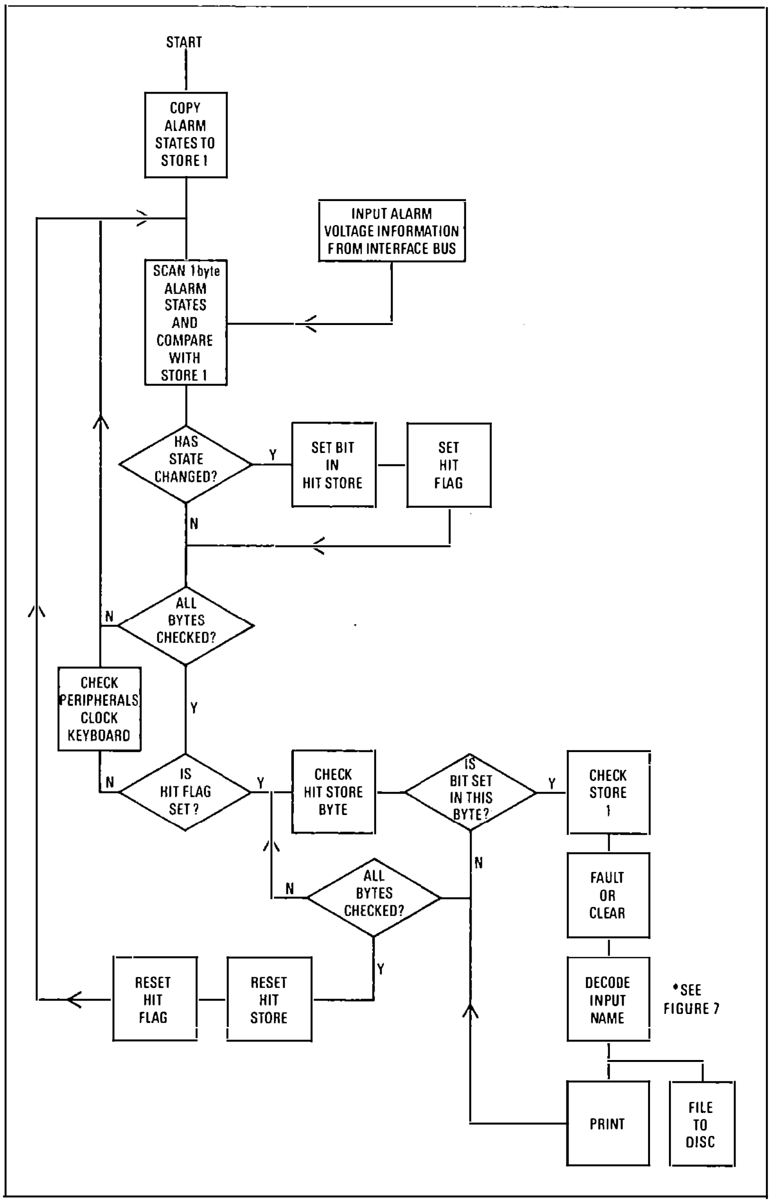
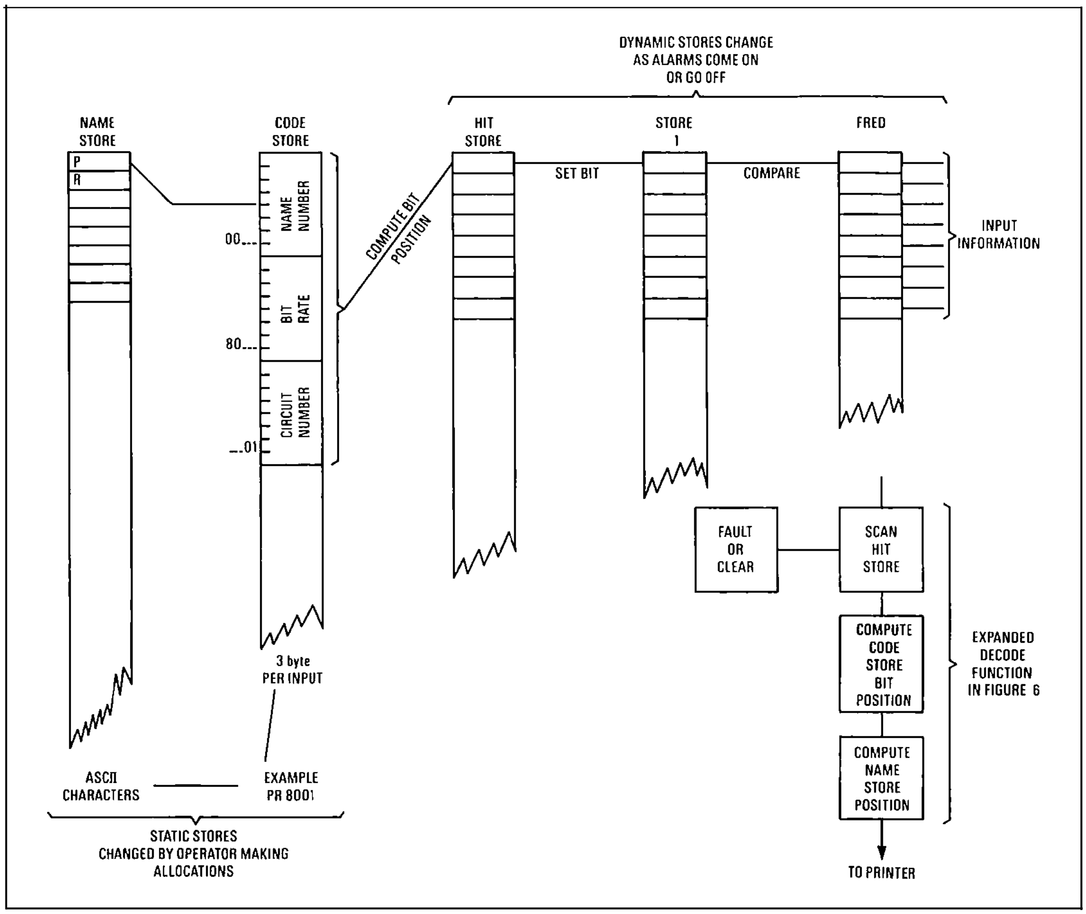


Figure 6
Flow chart of RASE scan-routine software

Figure 7
Decode process and store allocations



trials, was to stretch the alarm pulses to a length that made their detection during one scan certain. This was achieved by incorporating a pulse stretcher circuit in the input card. A new type of input buffer circuit became available in CMOS construction which had high input impedance allowing this to form the basis for a pulse stretcher circuit with a capacitor and resistor. Alarm persistence time was increased by the pulse stretcher circuit to some 7 ms which ensured detection during scan times for the maximum number of installed alarm inputs.

DEVELOPMENTS

By incorporating a modem, it was found that RASE could be installed at remote sites and its fault information reported over a telephone line to a central point. This has formed the basis for a system of multiplex equipment scanners which are being installed nationally to report to central locations.

CONCLUSIONS

RASE has proved to be an invaluable aid to maintenance of the digital network as it provides transmission maintenance control staff and network management centre staff with real-time information concerning traffic faults. RASE has made possible the early detection of faults and allows corrective action to be taken before transmission performance is degraded to a point where the circuits are unusable. The system has been working reliably since late-1984 and is being expanded in Manchester. Locating RASE centrally has reduced considerably the time taken to detect faults and frees maintenance staff for other work.

ACKNOWLEDGEMENTS

The author and codevelopers of RASE acknowledge the assistance of managers and staff at Manchester Irwell Repeater Station and wish to thank them for their many helpful suggestions made during the course of the RASE project.

Biography

Alan Jones joined BT as an apprentice in 1963. After training, he worked on all aspects of transmission maintenance duties as a Technical Officer eventually joining Trunk Network Operations on digital transmission maintenance in Manchester. He is currently working in the Transmission Operations and Network Surveillance (TONS) centre in Manchester.

An Introduction to the Digital Specific Equipment Assignment System and the Computerisation of Frame Management in the Digital Trunk Network

G. DUNN, B.A., M.A.†

UDC 621.395.34 : 681.32

Frame management in the digital trunk network is concerned mainly with the assignment and control of the equipment and tie-circuits that have ports on digital distribution frames. The digital specific equipment assignment (DSEA) system has been introduced to computerise the trunk network frame management function. This article introduces DSEA by describing the background to computerisation, the major features of the system, the strategy for implementation and future development.

INTRODUCTION

In June 1986, British Telecom introduced a computerised frame management system as an aid in the utilisation of resources in the higher-order digital trunk transmission network. This system is known as the *digital specific equipment assignment* (DSEA) system.

The main objective in digital trunk network utilisation is to ensure that demands for trunk network services are promptly met while making the most efficient use of network resources.

Resources in the digital trunk transmission network can be divided into two main categories: line plant and terminal plant. Line plant is utilised to make inter-station connections, and terminal plant to make intra-station connections.

With the introduction of DSEA, two computer systems are now in use for managing the utilisation of the digital trunk network (Figure 1). The main network utilisation system (MANUS) is used in the selection of line plant resources for inter-station connections, and the DSEA system is used in the selection of terminal equipment and tie-circuits for intra-station connections. Because most intra-station connections are made on distribution frames, systems like DSEA which are used to manage these connections are known as *frame management* systems.

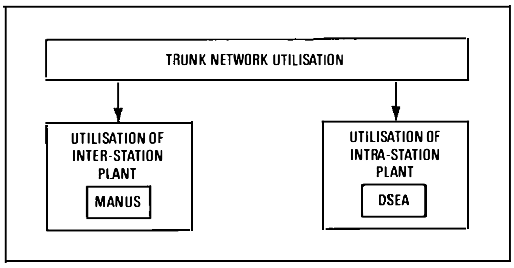


Figure 1
Role of MANUS and DSEA in digital trunk network utilisation

STRUCTURE OF CIRCUIT PROVISION IN THE DIGITAL TRUNK NETWORK

Circuit provision in trunk network operations has a three-tier structure which includes the Network Operations Centre, Regional circuit provision controls (CPCs) and repeater station and switching unit circuit provision field units. This structure and the major functions involved are illustrated in Figure 2.

Network Operations Centre

Engineers at the Network Operations Centre are responsible for the efficient use of network resources, and for the issue of digital circuit orders.

Before the introduction of DSEA, digital trunk network utilisation involved the specific assignment of line plant, but only the bulk-terms assignment of equipment and tie-circuits. The specific assignment of equipment and tie-circuits was carried out by using manual-record-based systems in repeater stations (in the case of transmission equipment and tie-circuits), and Regional offices (in the case of switching equipment).

Typically, a requirement for a higher-order digital bearer would be received and the details processed in MANUS. MANUS would be used to select the optimal line

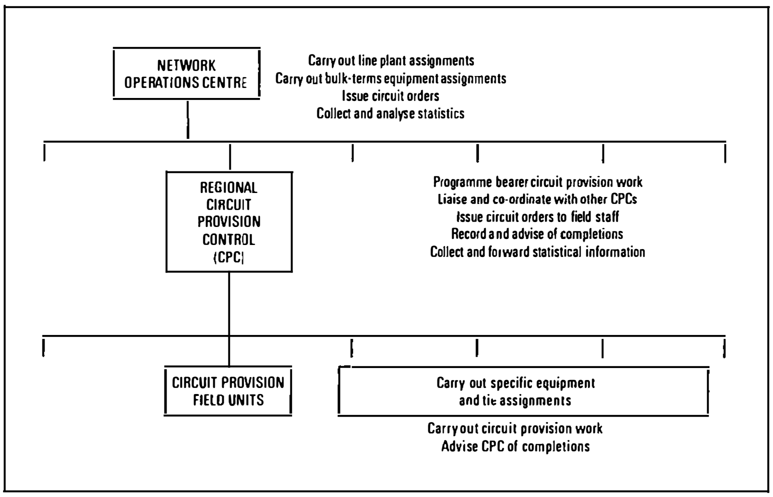


Figure 2
Trunk network circuit provision

† Network Operations Centre, British Telecom UK Communications

routing between the terminal nodes and to specify the type of equipment and the inter-station tie-circuits to be used at installations en-route. This information would then be used to produce the circuit order, which is the authority for the circuit provision work to be carried out. The assignment of line routings would be specific, in the sense that real items of plant would be identified, but the assignment of equipment and tie-circuits would not be specific because only the equipment type and tie-circuit type would be identified. The quantities used would be deducted from the inventory bulk totals for each of the installations concerned. The circuit order would be distributed to the Regional CPCs involved in the provision of the bearer.

Regional CPC

There are nine Regional CPCs, in which engineers are responsible for progressing to completion the digital circuit orders received. This includes the distribution of circuit orders and the programming of engineering work to be carried out at the repeater stations and switching units within the Region which are shown on the circuit order. Regional CPC engineers liaise with other CPCs, the Regional data management duty, and the Network Operations Centre to ensure co-ordination of effort and notification of completed work.

Repeater Station and Switching Unit Circuit Provision

Repeater stations and switching unit engineers conduct the circuit provision work required to meet the needs of circuit orders received. This includes the assignment, cross-connection and testing of specific equipment and tie-circuits, and the overall commissioning of bearers. The progress and completion of work are reported to the Regional CPC.

MANUAL METHOD OF SPECIFIC ASSIGNMENT

When the circuit order is received in a repeater station, for example, the equipment and tie-circuits needed are assigned. The bearer can then be cross-connected, in-station tested, and commissioned overall.

The specific assignments are selected from a local manual record known as the station *A61*. This document is the station specific terms inventory of equipment and tie-circuits. The A61 lists the equipment and tie-circuits which have a DDF port appearance in the station along with their unit (in the case of equipment) and DDF locations, and any bearer to which they have been assigned. Figure 3 shows some of the more common DDF transmission equipment connections. A digital tie-circuit is a coaxial cable pair between two DDFs. Suitable spare equipment and tie-circuits are selected from the A61 for the circuit order concerned. The selection made is normally that which minimises the number of cross-connections in the station and minimises the length of cross-connections in each DDF. The name of the bearer is entered in the A61 against those items which have been assigned to it. Other local records, known as the station *A833* and *tie-pair return*, are the station bulk-terms inventories for equipment and tie-circuits respectively; the bulk quantities in these documents are amended to reflect the utilisation of the items assigned to the bearer. The A61, A833 and tie-pair return together represent a local inventory of the assignable resources for the station.

When the bearer cross-connections have been made and the in-station tests completed, a card record of the bearer routing is prepared. This record is used for maintenance purposes when the bearer has been commissioned overall and accepted into service.

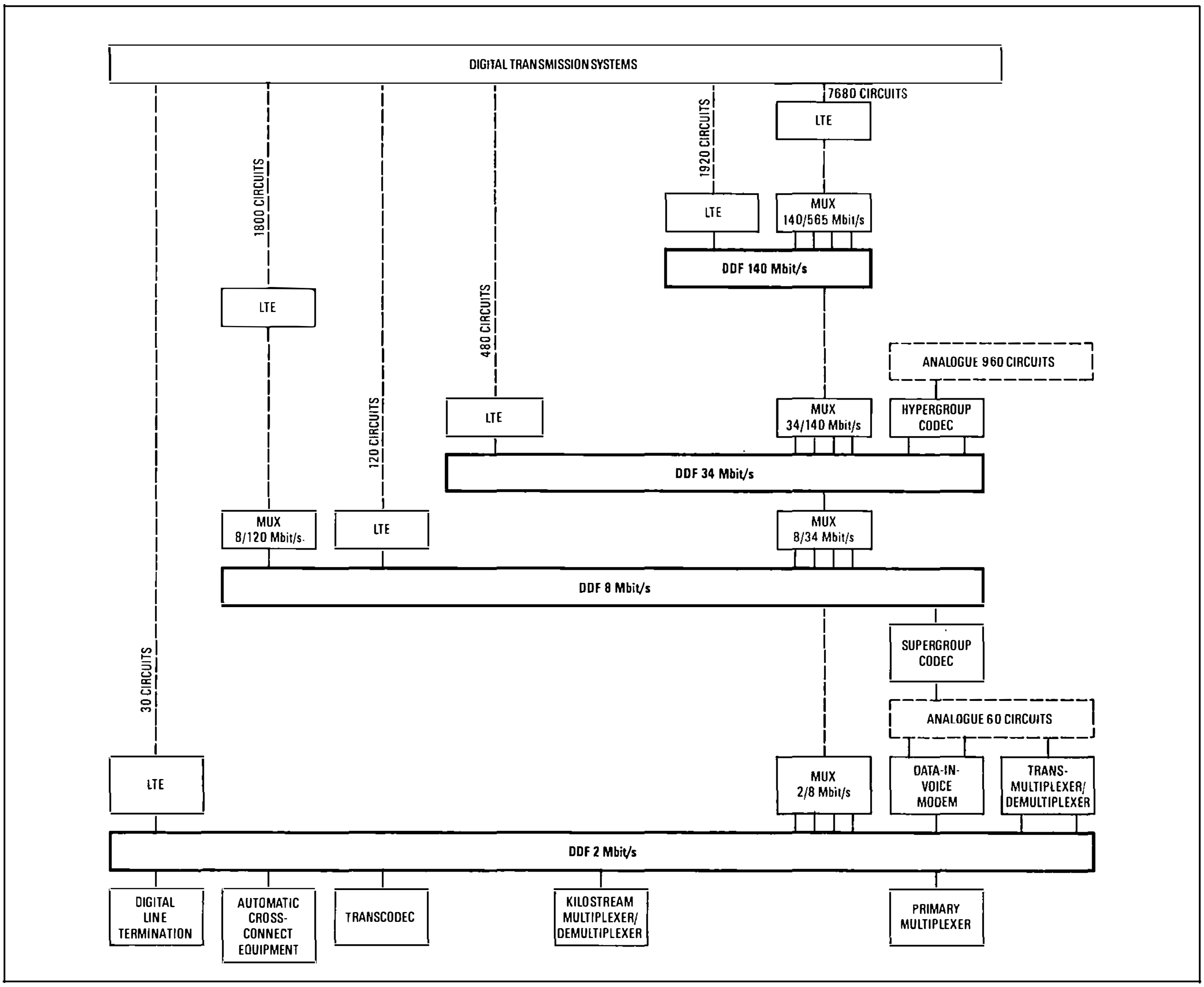
DSEA ORIGINS AND OBJECTIVES

The manual-records-based system of specific equipment and tie-circuit assignments described above has served its purpose. Network digitalisation, however, has created both a need and an opportunity for the introduction of an enhanced frame management system. The need has arisen for a centralised database which can be used to optimise and record specific assignments of digital network resources, while having the potential to support other network operations, management and surveillance functions. An opportunity exists because, provided data capture is implemented quickly while the penetration of digital capacity is progressing, the cost of this data capture can be minimised.

In the summer of 1985, senior trunk network managers made a general fact-finding visit to the US. The tour included a review of computerisation in network operations. The computer systems seen included a frame management system covering most of the North American long-distance network. As a result of this visit, it was decided that a feasibility study should be conducted to see if the US frame management system could be adapted for use in the UK.

FEASIBILITY STUDY

A feasibility study in the UK was carried out over a 2-week period in November 1985. The study team was charged with assessing needs in the trunk network for mechanised support of the frame management and order control functions, and the adaptation of the US frame management system as a first step towards meeting these needs. The team studied the operational environment in which a frame management system would be used and the computing environment in which it would be operated. The conclusion was that the US system could feasibly be adopted in the UK



LTE: Line terminating equipment MUX: Multiplex equipment

Figure 3
Common DDF equipment

provided that it was suitably modified, and that a phased approach would best ensure the early implementation necessary to meet operational needs.

SYSTEM DEVELOPMENT METHODOLOGY

Beginning in December 1985, DSEA was specified, designed and constructed by using the existing US frame management system as a starting point and employing prototyping techniques to make progressive modifications until the system met the requirements for application in the UK network.

Development Team

The structure of the development team is shown in Figure 4. The team was led by a project manager and included business analysts, computer applications experts and technical experts. This team was based on the members of the feasibility study team, but new expertise was brought in to give the changes in emphasis required as the project progressed.

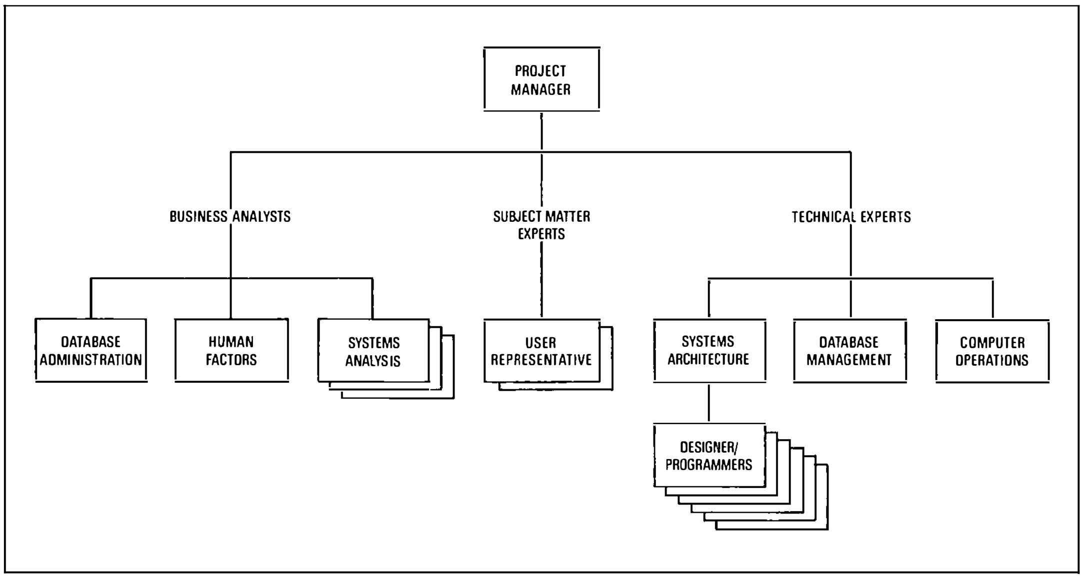
Development Environment

In a traditional software development environment, the application emerges at the end of a linear series of discrete development steps, which typically could include feasibility, definition, preliminary design, detail design, implementation, conversion and performance review.

In a prototype development environment, the application evolves through a series of stages where, typically, the feasibility, definition and preliminary design stages are replaced by an evolving prototype system; the detail design and implemenation stages are replaced by system construction and testing; and the conversion and performance review phases are replaced by site installation.

DSEA was developed in a prototyping environment by using fourth-generation language (4GL) products. The technique of prototyping gives visibility of the system as it evolves so that it can be successively enhanced to become the finished product; the use of 4GL products offers significant gains in development productivity. The combination of 4GL products and prototyping techniques makes

Figure 4
Development team structure



possible the accurate definition of user needs within short development time-scales. Three prototypes were developed during December 1985. Each one was designed, developed, walked through, and subsequently enhanced by the project team.

Development Time-scales

To meet operational needs, the system was delivered within 7 months of the feasibility study being concluded. This included 2 months for analysis and prototyping before a final decision was taken to construct the system. The program code was generated in the following 3 months and the system tested and installed in the final 2 months.

SYSTEM ENVIRONMENT

Operating System

The DSEA operating system is MVS/XA (multiple virtual storage/extended architecture). MVS/XA supports a virtual storage address space through which each user can be given the impression of working with 2 Gbyte of logical memory, even though this may exceed the physical storage available to the computer. Main storage, direct access storage, and dynamic address translation are used in the processor to simulate this logical address space.

MVS provides useful aids for application development, system management, and system operation. It controls and utilises the facilities available on large processors.

Database Management

The DSEA database is a group of interrelated files controlled by a database management system known as the *integrated database management system/relational* (IDMS/R). IDMS/R, release 10 of IDMS, incorporates the features of network and relational data structures; thus the flexibilities of the relational data structure retrieval are combined with the efficiencies of the network data structure updating.

IDMS/R uses a data dictionary to provide a central point of data control and access. Data can be integrated and viewed as an organised whole, but it can also be shared by many different programs. The dictionary data is set up to comply with standards for naming and format. Changing the data representation to improve efficiency and to take advantage of new software technology involves a change only for IDMS/R and not the application programs. Because IDMS/R is a central point of control, it can provide consistent security and recovery. IDMS/R can restrict the type of access to certain elements of data and it can prevent different users updating the same record at any one time. In the provision of recovery, the effects of an aborted program can be effectively eliminated.

APPLICATION SOFTWARE

DSEA was developed by using ADS/O (application development system/on-line), a software product which is closely related to IDMS and permits the quick development and execution of on-line applications for the inspection and update of a database.

An ADS/O application is composed of a set of interactions, each of which represents a discrete unit of work and performs certain basic operations. These operations include displaying a formatted screen at the terminal through which the user supplies requested information, receiving user-supplied information, and processing this information as directed by the user.

With traditional programming approaches, the application itself must perform the functions of terminal input/output, database housekeeping, screen formatting, resource management, data editing, decoding, encoding and error handling. ADS/O assumes responsibility for all of these functions, and allows the application developer to focus on the task at hand, which is concerned primarily with transactions which inspect and update the database.

ADS/O is a combination of four software products:

(*a*) an on-line integrated data dictionary, which provides the program developer with a full-screen editor to place source statements and record definitions into the data dictionary;

(*b*) an on-line mapping facility, which assists in the definition of the screen display that will be the interface between the program and the on-line user;

(*c*) an ADS/O generator, which creates the on-line program, called a *dialog*, from the statements, records, and map previously stored in the data dictionary; and

(*d*) an ADS/O run-time system, which is a control program that uses the dialog information created by the ADS/O generator to execute the dialog when requested by the end user.

ADS/O is an example of the established trend in which computer resources (which are becoming less expensive) can be sacrificed for human resources (which are becoming more expensive). As a productivity tool, it is claimed to reduce development time for interactive system transactions with savings in effort of between 60% and 90%, and has largely replaced COBOL as a development language for on-line programming. DSEA was constructed over a period of 3 months and is based on approximately 80 000 lines of program code.

DSEA DATA FILES

The DSEA database which is managed by IDMS can be considered as a set of files which includes the resource inventory file, specific assignments file, assignable resources file, and the system management file.

Resource Inventory File

The resource inventory file holds records of the DDFs, digital equipment and digital tie-circuits in the trunk transmission network. It also holds records of the works status and availability status for each equipment unit and tie-circuit in the inventory.

Specific Assignments File

The specific assignments file is created by the assignments process. This file holds records of those circuit orders for which specific assignments either exist, or are to be provided, rearranged, ceased or cancelled. In addition, the file holds records of the assignment status for specific equipment and tie-circuits in the resource inventory file.

Assignable Resources File

The assignable resources file holds records of the units of equipment and tie-circuits which are available for assignment. This file is used by the optimisation process along with the resource inventory file to find the optimum equipment and tie-circuit assignments for a bearer.

System Management File

The system management file contains those records which are used to regulate, directly and indirectly, the system processes. These records are related to system profiles, security management, error management, and system audits, for example.

SUMMARY OF DSEA FUNCTIONS

The main functions of the DSEA system can be divided into three categories (Figure 5):

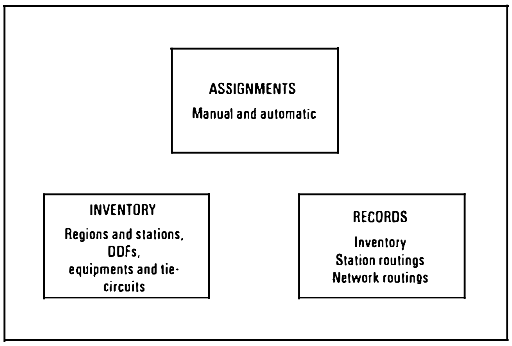


Figure 5
DSEA functions

(*a*) *Inventory Functions* DSEA maintains an inventory of the equipment and tie-circuits connected to the DDFs and direct flexibility suites in the trunk transmission network.

(*b*) *Assignment Functions* DSEA assigns equipment and tie-circuits from the inventory as required to meet the transmission connection needs of circuit orders. The assignments are made in a manner which results in the most efficient use of equipment, tie-circuits and DDFs.

(*c*) *Records Functions* DSEA maintains a record of the quantity, location and DDF port appearances of equipment and tie-circuits in the trunk network. The system also maintains a routing record for each bearer in the network, showing the specific equipment, tie-circuits and DDF port appearances used.

Figures 6 and 7 illustrate the data hierarchies which support these three main functions. The DSEA data type hierarchy is shown in Figure 6, and the DSEA bearer hierarchy in Figure 7.

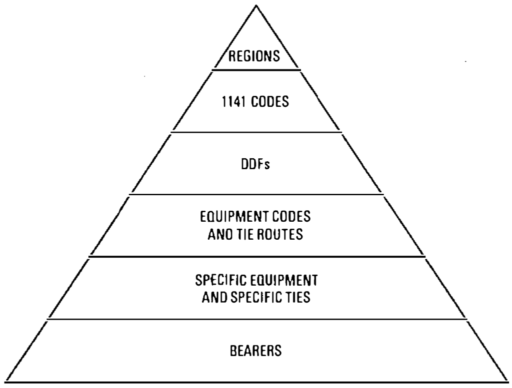


Figure 6
DSEA data type hierarchy

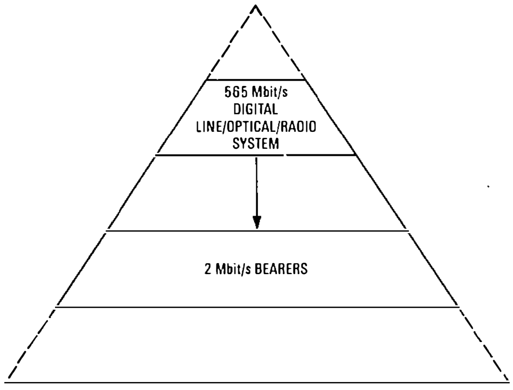


Figure 7
DSEA bearer hierarchy

DSEA ON-LINE PROCESSES

There are three main types of on-line process in the DSEA system:

(*a*) *Bearer Assignment Processes* This category of processes consists of those DSEA transactions which are used to process circuit orders in the system. The category includes both assignment and completions processes. Taken together, these processes form the main production workflow of DSEA operations.

(*b*) *Inventory Update Processes* This category of processes consists of those DSEA transactions which are required to maintain the network resource inventory database and support system administration.

(*c*) *Inspection Processes* This category of processes consists of those DSEA transactions which allow users to inspect information held in the database, such as bearer and inventory records for example.

The DSEA on-line processes have nearly 100 screens. Examples of some of these are shown in Figures 8–15. Figures 8 and 9 show two examples of the kind of information available from the equipment inventory, and Figures 10 and 11 examples of information available from the tie-circuit inventory. Figures 12 and 13 illustrate the kind of information available to monitor equipment utilisation levels and to indicate equipment works which have not been completed by their due date. Two examples of information available to show bearer routings are shown in Figures 14 and 15. It is beyond the scope of this present article to give a detailed explanation of DSEA data but the examples shown give a general idea of the kind of information held in the system. Terms used in Figures 8–15 are identified in Table 1. All of the examples show fictitious data.

DSEA OFF-LINE PROCESSES

The DSEA system has seven off-line processes: the optimisation process and six reports. The optimisation process selects the most efficient combination of equipment and tie-circuits for each of the circuit orders presented for automatic assignments. Of the six reports produced by DSEA, four assist with managing the system inventory: the equipment overdue works report, tie-circuit overdue works report, equipment utilisation report and tie-circuit utilisation report. The fifth report is the system audit report, which is used for system administration purposes. The sixth report is the deleted bearer status report, which is used to monitor bearer-related information being deleted from the database. All seven off-line processes are run at regular intervals but can be run at any time under the system administration procedures.

DSEA Optimisation Process

The purpose of the optimisation process is to assign automatically specific equipment and tie-circuits to circuit orders in such a way that network resources are efficiently used. The process assigns specific equipment and tie-circuits automatically for a given demand except when manual assignment is selected by the user.

The optimisation process can be divided into two parts: primary optimisation and secondary optimisation.

(*a*) *Primary Optimisation* The objective of primary optimisation is to maximise the probability that at any given time a circuit order demand for network resources can be met. This is done by attempting to select resources which will be available at a date as close as possible to, but preceding by a practicable period, the circuit order due date.

(*b*) *Secondary Optimisation* The main objectives of secondary optimisation for a bearer routing are (in order of priority):

(*i*) to minimise the number of cross-connections in an installation, and

(*ii*) to minimise the total combined length of cross-connections in an installation.

Primary optimisation takes priority over secondary optimisation because it is more important to meet circuit order due dates than it is to optimise the physical interconnection of network resources, desirable though the latter may be.

The automatic selection of equipment or tie-circuits can be restricted by specifying a

```
                              INSPECT EQUIPMENT
STATION-1141-CODE:LRG/T       EQPT CODE:  MX2
                                                              DDF                   STATUS
SEL  LOCN    <------ ERIC ----->  <------- FIC ------->       NO.   OWNER  ASG       WK   AS
 X   0003    01.033.0060.008.001  01.035.0001.01.    B.03     005   NN      Y        IW   EX
     0004    01.033.0060.008.002  01.035.0001.01.    B.04     005   NN      Y        IW   CC
     0005    01.003.    A.045.001  01.005.    A.01.   D.07     002   NN      Y        IW   CC
     0006    01.003.    A.042.001  01.005.    A.01.   D.08     002   NN      Y        IW   EX
     0007    01.003.    A.041.001  01.005.    A.01.   E.01     002   ICD     Y        IW   CC
             <----------------->  <------------------->
     0008    01.003.    A.039.001  01.005.    A.01.   E.02     002   ICD     Y        IW   CC
     0009    01.003.    A.036.001  01.005.    A.01.   E.03     002   ICD     Y        IW   IP
     0010    01.003.    A.033.001  01.005.    A.01.   E.04     002   ICD     Y        IW   IP
     0011    01.003.    A.030.001  01.005.    A.01.   F.01     002   ICD     Y        IW   EX
     0012    01.003.    A.027.001  01.005.    A.01.   F.02     002   ICD     Y        IW   CC
             <----------------->  <------------------->
```

Figure 8
Station equipment inspection

```
                           INSPECT EQUIPMENT AND TRIBUTARIES
       STATION-1141-CODE: LRG/T
       EQPTCODE: MX2         MANUF:          MARK: 2    MODEL: 6000
       WORKS NO: NP774562                    DUE DATE: 01/05/86
       STAGE: 0            STATUS: II        DUE DATE: 01/05/86
                                                                   DDF
   LOCAL NO    <------ ERIC ----->  <------- FIC ------->      NO.   OWNER   ASG
     0003      01.033.0060.008.001  01.035.0001.01.    B.03    005   NN       Y
                 TRIB         TRIBUTARIES          ST     STATUS
               NUMBER  <------- FIC ------->       AS    DUE DATE
                  01    01.030.0060.01.   Y.01     CC      /  /
                  02    01.030.0060.01.   Y.02     CC      /  /
                  03    01.030.0060.01.   Y.03     IT    19/06/86
                  04    01.030.0060.01.   Y.04     CC      /  /
                        <------------------->
```

Figure 9
Station equipment and tributaries inspection

```
                                  TIE INSPECTION
      BIT RATE: 0002
      1141-CODE:KCF/A                 1141-CODE:  KCF/D
      DDF NUMBER: 001                 DDF NUMBER: 001
TIE   <------- FIC -------->  <------- FIC --------> R OWNER ASG AS DUE DATE  WK
0039  01.001.   E.01.   H.04 01.001.   A.01.   B.06 N NN     Y  IP 12/07/86  IW
0040  01.001.   E.01.   H.05 01.001.   A.01.   C.01 N NN     Y  EX 12/12/86  IW
0041  01.001.   E.01.   H.06 01.001.   A.01.   C.02 N NN     Y  CC   /  /    IW
0042  01.001.   E.01.   H.07 01.001.   A.01.   C.03 N NN     Y  CC   /  /    II
0043  01.001.   E.01.   H.08 01.001.   A.01.   C.04 N NN     Y  CC   /  /    II
0044  01.001.   B.01.   C.01 01.001.   D.01.   T.01 N NN     Y  CC   /  /    II
0045  01.001.   B.01.   C.02 01.001.   D.01.   T.02 N NN     Y  CC   /  /    II
        .   .    .  .    .     .   .    .  .    .
        .   .    .  .    .     .   .    .  .    .
        .   .    .  .    .     .   .    .  .    .
      <--------------------> <-------------------->
```

Figure 10
Station tie inspection

```
                                          TIE INSPECTION
           BIT RATE: 0002
           1141-CODE:KCF/A               1141-CODE:  KCF/D
           DDF NUMBER: 001               DDF NUMBER: 001
      TIE   WORKS NUMBER           R    OWNER ASG  STG    DUE DATE WK
      0039                         N    NN     Y                   IW
      0040                         N    NN     Y                   IW
      0041                         N    NN     Y                   IW
      0042                         N    NN     Y                   IW
      0043  860619                 N    NN     Y    0      010886  IR
      0044                         N    NN     Y                   IW
      0045                         N    NN     Y                   IW
```

Figure 11
Station tie inspection (continued)

```
                      EQUIPMENT UTILISATION LEVEL INSPECTION
STATION-1141-CODE     EQUIPMENT CODE    CRITICAL LEVEL
  KCF/D                     PMB              85%
 TOTAL                       TOTAL      TOTAL        TOTAL       TOTAL       CURRENT
WORKING   TOTAL    TOTAL     TEMP      UNAVAIL       BEING       BEING       UTILISN
 UNITS    SPARE   ASSIGNED  UNAVAIL  FOR ASGNMT    RECOVERED   INSTALLED     LEVEL
   10       5        4         0          1            0           0          40%
```

Figure 12
Station equipment utilisation level inspection

Figure 13
Station equipment works jeopardy inspection

```
                    EQUIPMENT WORKS JEOPARDY INSPECTION
           STATION-1141-CODE: RBS/B           EQPT CODE: DLT
LOCNO  <----- ERIC ------>   WORKS NO    DUEDATE  STG WK DUEDATE  OWNER ASG AS
 0016  02.  A.0002.  F.023 B51234        01/11/85  0  II 01/11/85 NN     Y  CC
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
        .    .    .    .                   /  /             /  /
       <----------------->
```

Figure 14
Bearer network routing inspection

```
                   BEARER NETWORK ROUTING INSPECTION
   BEARER: KCF/S     LRG/T      3407    DK     AS: EX  DUE DATE: 13/08/86
   PRIMARY USE
   SERIAL NUMBER: 857747              BEARER CTL: KCF/S        INIT: ND
                                             TIENO             WK/AS
                   BEARER TIE                SLOT    WK  AS   DUE DATE
  01. RBM/P     KCF/S       1403     DK      02          EX   29/06/86
  02. RBM/P     RBM/K       003 003  T0034   0001    IW       01/05/86
  03. RBM/K     LRG/T       T/34     DRS     01          EX   28/06/86
                                                                /  /
                                                                /  /
                                                                /  /
                                                                /  /
                                                                /  /
```

Figure 15
Bearer network routing specific assignment inspection

```
          BEARER NETWORK ROUTING - SPECIFIC ASSIGNMENT INSPECTION
     BEARER: KCF/S    LRG/T      3407    DK      AS: EX  DUE DATE: 13/08/86
     PRIMARY USE:
     SERIAL NUMBER: 857747                BEARER CTL: KCF/S      INIT: ND
                 EQPCD LOCNO                                                L
     1141-CODE   TIECD TIENO<----- ERIC ------>  <------- FIC -------> DDF WK D
01.KCF/S         MX3   0004 01.005.0001.048.001  01.011.   8.01.  K.01 003 IW L
02.KCF.S         MX4   0003 01.009.0010.048.001  01.012.   A.01.  S.07 003 IW D
03.RBM/P         MX4   0001 01.007.0720.008.001  01.010.0120.02. BL.02 003 IW D
04.RBM/P         T0034 0001   .   .    .   .     01.009.0120.01.  A.01 003 IW
05.RBM/K         T0034 0001   .   .    .   .     02.025.   D.01.  W.01 003 IW
06.RBM/K         34RTE 0005 02.033.    C.018.012 02.026.   A.01.  C.04 003 IW D
07.LRG/T         34RTE 0004 01.039.0060.060.001  01.036.0960.02.  G.02 005 IW D
08.LRG/T         MX3   0002 01.033.0660.012.001  01.035.1020.02. BK.02 005 IW L
                            <----------------->  <------------------->
```

TABLE 1
Glossary of Terms for Figures 8–15

AS	Assignment status	L	Line-side
ASG	Assigner	LOCNO/ LOCN	Local number
CC	Assignment status 'not assigned'	MX2	Multiplexer 2–8 Mbit/s
CTL	Control	MX3	Multiplexer 8–34 Mbit/s
D	Drop-side	MX4	Multiplexer 34–140 Mbit/s
DK	Digital block	PMB	Primary multiplexer type 'B'
DLT	Digital line termination	R	Regenerated tie-circuit
DRS	Digital radio system	ST	Status
ERIC	Equipment rack identification code	STG	Works stage
EX	Assignment status 'existing'	TIECD	Tie-circuit code
FIC	Frame identification code	TIENO	Tie-circuit number
II	Works status 'in course of installation'	T34	Tie-circuit 34 Mbit/s
INIT	Initials	WK	Works status
IP	Assignment status 'in course of provision'	34RTE	34 Mbit/s radio terminating equipment
IR	Works status 'in course of recovery'	1141-CODE	Network node mnemonic
IT	Works status 'in course of release by rearrangement'		
IW	Works status 'installed and working'		

specific equipment unit or tie-circuit, or a works authority number from which equipment or tie-circuits are to be selected.

Equipment Overdue Works Report

The equipment overdue works report lists equipment units in the DSEA inventory for which a works completion report is overdue. This list is sorted by Region, station or switching unit, works information and equipment local number.

The report shows for each unit of equipment concerned the repeater station or switching unit, equipment code, local number, location, works authority and due date, stage number and due date, and assignment date.

Tie-Circuits Overdue Works Report

The tie-circuits overdue works report lists each tie-circuit in the DSEA inventory for which a works completion is overdue. This list is by Region, A-end† repeater station or switching unit, tie-circuit works number, works stage, and tie-circuit number.

The report shows for each tie-circuit concerned the A- and B-end repeater station or switching units, A- and B-end DDFs, the bit rate, tie-circuit number, works number and due date, works stage number and due date, assignment status, and assignment date.

Equipment Utilisation Report

The equipment utilisation report shows the current levels of utilisation of each equipment type in the DSEA inventory. A list is produced and sorted by Region, repeater station or switching unit, and equipment type.

The report shows for each equipment type: the number of units installed and working, assigned, not assigned, temporarily unavailable, being installed, and being recovered. Also shown is the current utilisation level, and a CRITICAL indicator if a critical utilisation level has been exceeded.

Tie-Circuit Utilisation Reports

Tie-circuit utilisation reports show the current level of utilisation of tie-circuit routes (inter-station and intra-station) in the DSEA inventory. The list produced is sorted by Region, repeater station or switching unit, and tie-circuit route.

The report shows for each tie-circuit route: the A- and B-end stations or switching units, the DDFs, and the tie-circuit route bit rate. Also shown are the number of tie-circuits installed and working, assigned, not assigned, temporarily unavailable, being installed, and being recovered. The current utilisation level, and a CRITICAL indicator if the critical utilisation level has been exceeded are included.

† A-end refers to the primary terminating network node, and B-end the secondary terminating network node

System Audit Report

The system audit report records transactions which result in certain events to which the user is potentially sensitive. Typically, such transactions are those which cause some data to be removed from the database and those which could have important implications for system administration.

The report shows for each of the transactions being audited: the user identification, transaction number, date, time, activity and audit text.

Bearer Process Status Report

The bearer process status report lists all the bearer process status records which have been removed from the database. The report enables the system administrator to monitor bearer-related information being removed from DSEA. Interface status records are removed from the database when these are at least three days earlier than the date on which the report is scheduled. The listing is by user identification and for each user identification by descending date.

The report shows for each deleted bearer: the bearer identification, user identification, circuit order serial number, assignment date, and assignment status.

DSEA INPUTS AND OUTPUTS

DSEA inputs and outputs can be divided into four main categories. Two of these categories cover those inputs and outputs which concern the updating and management of the inventory, and two cover those inputs and outputs which concern the assignments process. These are represented in Figure 16 and are described below.

Inventory Inputs

The DSEA inventory is updated each time a repeater station, switching unit, DDF, equipment unit or tie-circuit is added, changed or recovered in the trunk transmission network.

Inventory Outputs

In order to manage the inventory, DSEA produces the equipment and tie-circuit utilisation reports, overdue equipment and tie-circuit works reports, an audit report (each of which has been described above), and on-line inventory inspection processes.

Assignments Process Inputs

Information is input to DSEA for each bearer requiring trunk network equipment or tie-circuits. This information is received from MANUS, the Trunk Network Planning Division, and the Regional CPCs, in circuit order form.

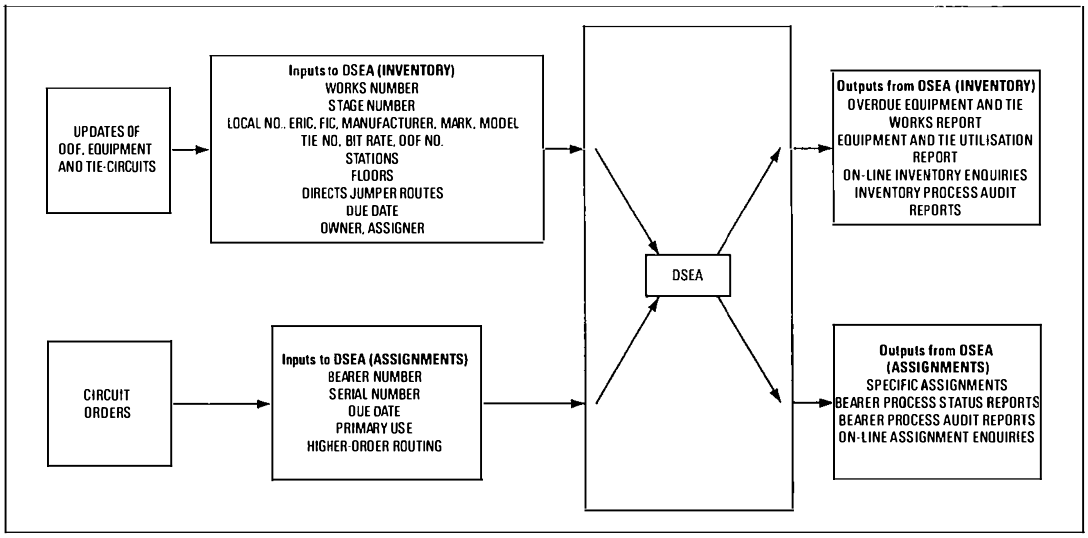


Figure 16
DSEA inputs and outputs

Assignments Process Outputs

The main output of DSEA is the specific assignments schedule, which contains the data shown in Figure 15. This schedule is distributed with the circuit order via the Regional CPCs to the repeater stations and switching units involved. Field unit engineers use the assignments information to make the cross-connections for the bearer concerned. The schedule identifies uniquely each equipment unit location by an equipment rack identification code (ERIC) and each DDF port by a frame identification code (FIC) to provide the specific routing for the bearer. The ERIC indicates the floor, suite, rack, shelf and unit (for example, 01.14.C.4.4) of an equipment. The FIC indicates the floor, suite, frame, vertical, level and port (for example, 01.12.120.3.R.6) of an equipment unit or tie-circuit appearance on a DDF. To assist in the management of the assignments process, DSEA produces a bearer process status report, an audit report (both of which are described above), and on-line assignments inspection processes.

SYSTEM TESTING

System testing was carried out in three distinguishable phases: technical tests, validation tests, and certification tests. The purpose of the tests was to ensure that the system would perform the functions for which it was designed and that it would operate satisfactorily in the computing environment. The tests, the expected results and the results obtained were documented and controlled by using specially designed test packs. Problems encountered were passed to the development team for investigation and correction.

Technical Tests

Each module of code was tested for internal consistency and satisfactory operation with other modules in the system. The overall functionality of the system was tested, as was the operation of the system in the computer centre.

Validation Tests

Detailed tests were made of the system data fields, editing and error trapping.

Certification Tests

Certification tests were conducted by a team comprising a team leader, two system functions testers and a system operations tester. The tests were carried out in the US and then repeated in the UK following installation of the software:

(*a*) *System Operation Tests* These tests were carried out to ensure that the system operated correctly. Back-up and recovery procedures were tested to check that operation was as specified.

(*b*) *System Function Tests* These tests were carried out to ensure that the functions specified for the system had been provided and would operate correctly. This was done by using a test database consisting of a model of the digital trunk network. The model consisted of five network nodes with a total of 12 repeater stations and switching units. Repeater stations and switching units in the model had layouts of DDFs, equipment and tie-circuits and were interconnected by digital bearers routed over line, radio and optical transmission systems in such a way as to cover as many as possible of the variants likely to be encountered in live operation.

The execution of the test programme simulated the way in which the production system would be brought into operation. The repeater stations and switching unit data were loaded into the system, followed by the DDF, equipment and tie-circuit data. Circuit order data were then processed to set up the transmission system and bearer hierarchy which interconnected the repeater stations and switching units in the model.

SYSTEM INSTALLATION

The installation of DSEA can be divided into three parts:

(*a*) the installation of system software,
(*b*) the installation of the network which will allow users to access the system, and
(*c*) the installation of the data.

Software Installation

Software installation was carried out in June 1986. After completion of certification tests in the US, a tape was brought to the UK and the system was installed on the mainframe machine in the computer centre. The certification tests were repeated to establish satisfactory performance of the software in the new environment. The tests were completed and DSEA was available for operation in July 1986.

Network Installation

Until recently, access to DSEA has been available only from the Network Operations Centre, but is now being extended to repeater stations. Access is also required from other network locations, including Regional offices. At the time of writing, there are over 100 users of the system and the number is increasing as access is extended.

Arrangements to support these users include the installation of VDTs and printers and the connection of these to DSEA via one of a number of access methods. The method of connection adopted for a terminal depends on such things as geographical location, the type of peripheral equipment to be connected, the class of service required, and the availability of communications capacity. Access can be via direct lines, local area networks, multiplexed links and switched network connections.

Data Installation

For DSEA to become fully operational in the shortest possible time-scale, it was necessary to capture and load data on the digital trunk transmission network dating from 1980 or earlier. A number of methods of achieving this were considered. The method adopted involves the completion of data input documents by repeater station and switching unit engineers, and the loading of data in a centralised data load unit in the Network Operations Centre. Around 250 000 data input documents with 25M characters of data will have been processed before the data load is complete. At the time of writing, over 230 000 documents have been processed.

Data capture and data load are the two elements of DSEA data take-on, which began in August 1986. The method and procedures used are illustrated in Figure 17.

Data Capture

Repeater station and switching unit engineers verify the bearer and inventory manual records and use this information to complete data input documents. These completed documents are forwarded, station by station, via a Regional DSEA liaison officer to the DSEA load unit in the Network Operations Centre.

The Regional DSEA liaison officer co-ordinates the data capture in repeater stations and switching units within the Region and liaises with the DSEA load unit.

Data Load

In the DSEA load unit, the data input documents are processed and the data is loaded into the system. The data is subjected to quality checks before, during, and after input.

Station Cut-Over

Repeater stations and switching units for which data capture has not begun make assignments by using the existing manual method. Those in the process of data capture make assignments in this way but ensure that assignments are entered on data input documents and forwarded via the Regional DSEA liaison officer to the DSEA load unit.

As the data load is completed for each repeater station or switching unit, the Regional DSEA liaison officer arranges a cut-over date after which assignments are made by DSEA and are received by repeater stations and switching units with the circuit order from the Regional office.

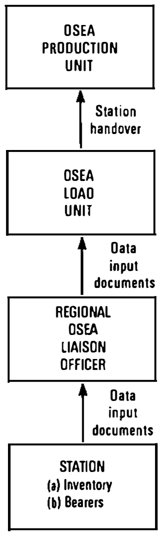
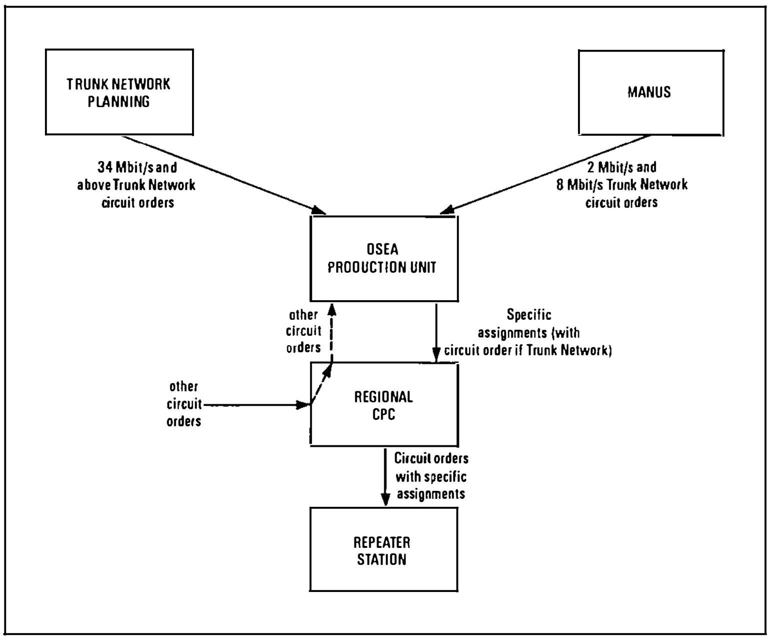


Figure 17
Outline of DSEA data take-on

DSEA OPERATIONS

DSEA operations in the production environment are outlined in Figure 18.

Figure 18
Outline of DSEA production



DSEA Production Unit

The DSEA production unit is in the Network Operations Centre. Within this unit, both DSEA system administration and DSEA operations are handled. The update and inspection transactions in DSEA are used to maintain the inventory and operate the circuit order bearer assignment processes. DSEA production unit engineers liaise with Regional office and repeater station and switching unit engineers.

Inventory Update and Maintenance

Inventory updates of tie-circuits and equipment are received from the network planning and works offices. Apart from planned works, other updates to the inventory are also required, and this information is received from Regional planning and works offices, Regional CPCs, repeater stations and switching units.

MANUS Bearer Demands

MANUS bearer demands for specific assignments originate in the line plant utilisation unit in the Network Operations Centre. All MANUS circuit orders for which equipment or tie-circuits are required from the DSEA inventory are issued from MANUS to the DSEA production unit. These bearer demands are processed in DSEA. The specific assignment schedules obtained are printed on the reverse side of the circuit orders, which are then dispatched to Regional CPCs.

Non-MANUS Bearer Demands

These can be divided into two categories:

(*a*) *Trunk Network Planned Bearers and Systems* Trunk network planners issue circuit orders for bearers with bit rates of 34 Mbit/s and above. These are received in the DSEA production unit and processed in DSEA. The specific assignment schedule is obtained and printed on the reverse of the circuit orders, which are then dispatched to Regional CPCs.

(*b*) *Other Bearers* A small number of other bearer demands for trunk network equipment and tie-circuits are received directly in Regional CPCs. If these demands require trunk network equipment or tie-circuits, the Regional CPC can request the issue of a specific assignments schedule for the circuit order concerned from the DSEA production unit. These demands can be handled within minutes. When the specific assignments are received in the Regional CPC, they are attached to the circuit order which is sent to the stations concerned.

Production Procedures During Data Installation

DSEA makes specific assignments for bearers at repeater stations and switching units which have been cut over. When repeater station and switching unit engineers receive the circuit order with the specific assignments, those at stations which have been cut over use the assignments on the document. Engineers at stations or switching units which have not been cut over assign tie-circuits and equipment locally in the manual manner.

FUTURE DEVELOPMENT

Four main areas of further development are planned. First, direct access to DSEA will be extended to an increasing number of network locations. Second, it will be necessary to develop automatic interfaces between DSEA and other existing network support systems. Third, DSEA will be enhanced to accommodate new systems currently being developed and which will share direct access to DSEA data. Fourth, the data held in the system will be extended to cover other BT networks.

Through these proposed developments, it is the intention to automate the inventory and specific routing records of the digital transmission network by using on-line records generated by DSEA. It is also the intention to make further reductions in the transmission of documents supporting circuit provision work. Beyond this, the development of automatic interfaces and the sharing of DSEA data with new systems is expected to bring benefits to a broader area of network operations.

CONCLUSION

The digital trunk network has a computerised frame management system to maintain an inventory of DDF equipment and tie-circuits, optimise the assignment of these resources, and hold a record of the DDF port, equipment, tie-circuit and line routings for each bearer. The implementation and future development of DSEA will aim to extend the coverage of the system, broaden access to the data, and computerise further the circuit provisioning function supporting network operations.

ACKNOWLEDGEMENTS

BT's DSEA system was developed by the American Telephone and Telegraph Company under contract with BT. The author wishes to thank his colleagues throughout BT who have contributed to the various stages of the DSEA project.

Biography

Geoff Dunn joined BT in 1964 as a Youth-in-Training. After training, he worked on long-distance transmission operations in the Manchester Area. In 1976, he studied at Liverpool University where he gained his B.A. (Hons.) in Economics. In 1979, he undertook postgraduate research at Manchester University into the diffusion of technological innovations, during which he gained his M.A., also in Economics. In 1984, he joined Trunk Network Operations to work on circuit provision liaison and support duties. He is currently working in the National Operations Centre on the implementation and operation of the DSEA computing system.

Document Quality—Inspection

F. J. REDMILL, C.ENG., F.I.E.E., F.B.C.S., M.I.Q.A.†, E. A. JOHNSON, B.ENG., C.ENG., M.I.E.R.E.†, and
B. RUNGE, M.SC., LIC.TECHN.*

UDC 651.5.004.58

Even within the current drive for quality, documentation quality is often ignored or forgotten. This article cites a number of ways of improving the quality of documentation and, in particular, describes and discusses the inspection method.

INTRODUCTION

Despite many imperative statements, BT's current drive for 'quality' is often seen to be on rather general lines. In many parts of the business, documentation quality is ignored or considered incidentally. Many, if not most, managers 'don't have time' even to check documents for which they are responsible. Yet the company relies on documents for every aspect of its business, both internal and external, and early correction of errors at source is always cheaper than dealing with the results of incorrect documents. How much cheaper is it to check and correct a contract than to renegotiate it after it has been placed with an important clause missing? How much is saved by correcting a specification rather than redesigning a useless product? How much time, frustration and money are saved by getting an internal telephone directory right first time?

The authors wish to exhort the reader to address the issue of documentation quality specifically and earnestly. In the next section, reference is made to four ways in which this can be aided. One of these is 'inspection' and the remainder of the article describes and discusses this and makes recommendations for its use.

IMPROVING DOCUMENTATION

Four methods of improving documentation are briefly proposed. The first three were discussed, to some extent, in the context of specification documents, in reference 1. The fourth is the main topic of this article.

(*a*) Much can be gained from the choice of an author with appropriate writing ability and a suitable background in the subject. The development of authors needs encouragement, insistence on high standards, guidance and, perhaps, training; and all of these require management participation.

(*b*) Managers need to accept responsibility for documents written by their staff. After all, the responsibility is theirs anyway, since the document emanates from their groups, sections, etc.

(*c*) Standards and guidelines for the form and content of documents should be used. (An example of a guideline used in development projects is given in reference 2, which is published in the *Supplement* to the current issue of this *Journal*.) Standards and guidelines are applicable to most types of document and should be acquired or developed locally, though it would be preferable to have company-wide standards.

(*d*) All documents should be subjected to inspection.

THE INSPECTION PROCESS

Background

Document inspection entered history as inspection of computer software. In the early 1970s, at IBM, Michael Fagan insisted that there had to be a way of improving the quality of software by using techniques which were well-proven in other fields (see also reference 3). Despite the discouragement of his peers, he persisted in making trials, and his 1976 paper [4], now a classic, not only showed the way, but also announced startlingly good results. Fagan showed that the inspection process revealed 80% of all errors found in the software. This improved the quality of the software, increased reliability, and reduced maintenance costs. These factors were so marked in Fagan's projects that he received an award of $50 000 from his company. Later, Runge [5] reported on the application of inspection in small projects with the involvement of fewer than four people.

Experience also showed that many of the errors which later revealed themselves in the code were due to defects in earlier documents, such as the design or specification documentation. Application of inspection to these documents and, indeed, to all documentation throughout the development life cycle of a project substantially improved the quality of the final product. Further, since it found most errors where they occurred, rather than after they had had an effect on later stages, it reduced development time and cost as well as

† Planning Directorate, British Telecom International
* Runge-Data, Denmark

maintenance costs. The cost of correcting an error early may be 100 times less than correcting it when the system is operational [1 and 3].

The value of inspection can thus be demonstrated dramatically in a development project. However, the process is effective when applied to any documents; for example, objectives, plans, contracts, articles and papers, standards, guidelines, user documentation, maintenance documentation, pseudo-code, program code, and, very importantly, test cases. Indeed, 'it appears that virtually anything that is created by a development process and that can be made visible and readable can be inspected' [6].

To obtain maximum benefit from inspection, the rules of the method must be strictly adhered to. Some companies modify inspection and ignore some of its principles, but statistics show that this decreases effectiveness. Management needs to create and maintain the attitude and environment necessary for inspection in its most effective form.

Also, several proprietary inspection packages are available, usually marketed as a course and a manual. One of these is QSTAR [7], with which some readers will be familiar, but which does not meet the full specification for inspection as described in this article.

Some Benefits of Inspection

Whereas inspection may be the first step towards a total quality management system, and thus have far-reaching benefits in such areas as quality, cost-effectiveness, customer satisfaction and job satisfaction, some of the identifiable benefits are listed below:

- Quality documents are achieved.
- There is an increase in the number of projects completed on time.
- Project end-products are of better quality.
- A quality 'culture' is developed.
- Resources are saved because errors are found and corrected at a time when correction is cheap. On average, inspection adds about 15% to the resource requirement in the preparation of a document (and this should be planned for), but the total development time of a project can be reduced by 20% to 50%.
- Inspection is an excellent tool for observing deviations from standards. The observations may be used to decide whether the standard or the deviation is 'right'.
- If an organisation has no documented standards, inspections will highlight that some ways of doing things are better than others. A *de facto* standardisation process will be initiated in which the more efficient methods triumph over the less efficient.
- There will be a general proliferation of knowledge about the different products and development activities in the organisation. Studying documents carefully is a much more efficient method of learning than attending seminars or lectures.
- The participants in inspections learn about the strengths and weaknesses of each other. This helps to overcome prejudices and dogmas.
- The frequent, short, formalised meetings teach the participants the differences between disciplined and undisciplined meetings.

Overview of the Process

Inspection is a formal, efficient and economical method of finding defects in documentation. It is performed in predefined steps (see Table 1) and controlled, according to well-defined rules, by a trained 'moderator'. Whereas inspection is a practical technique and needs to be experienced, the following brief overview considers the steps in sequence.

TABLE 1

Participants in the Stages of Inspection

WHAT	WHO				
	Moderator	Author	Inspector(s)	Reader	Secretary
Document is written		R			
Is document ready for inspection?	R				
Planning the inspection	R	P			
Overview meeting	R	P	P	V	P
Inspection of the documentation	R		R	R	V
Inspection meeting	R	P	P	P	P
Collection of statistics	R				
Third hour (not mandatory or official)	V	R	V	V	
Rework (corrective action)		R			
Follow-up (inspection of corrections)	R	R			
Signing off document	R				

KEY: R = Responsible P = Present V = Voluntary presence

Any difficulties in understanding on the first reading may be clarified by reference to the next section, which lists the functions of the participants in the process.

When the document has been completed, the author, who must first be completely satisfied, seeks a moderator to preside over the inspection process. Fagan [6] recommends objectivity (yet familiarity) by choosing a moderator from a different but similar project. In some companies, a list of trained moderators is held in the quality department, with provision being arranged by the quality manager.

The moderator and author select the inspectors and provide them with a copy of the appropriate documentation; that is, the document to be inspected and any relevant background material (standards, higher-level documents and checklists). One inspector will be designated as reader (see below).

At the start of a project or when the inspectors are unfamiliar with the background of the document to be inspected, an overview meeting is held. Here the author (or group of authors) gives an overview of the project, so the inspectors will be able to relate the details or individual documents to the whole. For a single document, the author explains its background and purpose.

A date for the inspection meeting is agreed between the participants, and the moderator arranges a meeting room (preferably without a telephone) and suitable refreshments for the break. Prior to the inspection meeting, the inspectors and the moderator study the document, noting its defects in the margins. Notes should never be on separate sheets, since this diminishes concentration during the inspection meeting. Checklists aid the defect finding by presenting, in the form of questions, typical defects for the current type of document. The reader must additionally prepare for interpretation of the text.

At the meeting, the moderator starts by welcoming the participants and recording their preparation times. Each section is then read by the reader. Reading the document aloud has been shown to be the optimal speed for inspection. The author or moderator may ask the reader (or the reader may decide) to paraphrase a section, whose interpretation is thus revealed, and misinterpretation is recorded as a defect. At the end of each section, the moderator asks the inspectors, one by one, if they have discovered any defects, and the secretary (usually the author) records the classification and details of all defects. The order of questioning is rotated so that no inspector is consistently first to be asked.

A discussion on possible solutions to a defect may start at any time and, since the only purpose of the inspection meeting is to reveal defects, the moderator, kindly but firmly, should stop this discussion. In order to avoid frustrations, the moderator may decide to add the initials of the inspector to the defect record for reference or defer the discussion until after the inspection meeting, when the author may convene a 'third hour' meeting for the purpose.

When a page is inspected, the moderator asks the secretary to read the recorded defects, so that they may be agreed on. After one hour, the moderator may call for a 5–10 minutes break; and the inspection meeting is limited to a maximum of 2 hours.

During the inspection meeting, the moderator collects statistics on the process (such as how long it took each inspector to study the document), and on the defects. On the basis of the latter, the moderator decides if a further meeting is necessary. The author, who is responsible for correcting the document, gives an estimate of when the next draft will be ready.

The author may derive further help from the inspectors, in the form of explanations or proposals for solutions. A discussion, immediately following the inspection meeting, but not a formal part of the process, may therefore be convened by the author. This is referred to as the *third hour*.

When all corrections have been effected, they are reviewed by the moderator and author, although, in some cases, perhaps for technical reasons, a particular inspector may be required to validate certain corrections. Responsibility for signing off the document then rests with the moderator.

The use of statistics, for the benefit both of the particular inspection and the inspection process within the company, is an integral and important part of the process. It will be dealt with in more detail below.

The Participants

Role playing is used to enhance the effectiveness of inspection. The main titles given below comprise one comprehensive means of defining the roles, while other equivalent titles are shown in brackets. It should also be noted that some of the participants' functions differ from company to company.

Author

The functions of the author are

- to write the document;
- to decide, with the co-operation of peers and in-line management, that the document is ready to be submitted for inspection;
- to request inspection;
- to present the document at the overview meeting;
- to participate in the inspection meeting, preferably as secretary;
- to correct the document as a result of the inspection; and
- to present the corrected document to the moderator for signing off.

Moderator

The functions of the moderator (chairman) are

- to decide if the document is ready for inspection;
- to choose the inspectors, in co-operation with the author;
- to arrange and chair the overview meeting;
- to give guidance to the inspectors as to what is expected of them;
- to issue forms to the inspectors for the recording of statistics;
- to choose and instruct the reader;
- to ensure that all participants prepare for the inspection;
- to arrange the inspection meeting;
- to moderate (chair) the inspection meeting according to strict rules;
- to ensure that all defects (errors) are recorded and classified;
- to collect inspection statistics;
- to decide if a further inspection is required;
- to ensure that corrections are carried out by the author; and
- to sign off the document.

Reader

The functions of the reader are

- to read the document aloud at the inspection meeting and interpret its meaning; and
- to be an inspector.

Inspectors

The functions of the inspectors (reviewers) are

- to understand the author's presentation at the overview meeting;
- to prepare for the inspection meeting by studying the document and recording the defects discovered in the margins;
- to report on the defects at the inspection meeting;
- to assist the author, if required, during the third hour or later, to find solutions; and
- to sign off individual corrections, if this is requested by the moderator.

Secretary

The function of the secretary is to record the defects and their locations in the document.

Principles of Inspection

If used well, the inspection process is cost-effective in improving documentation quality. The moderator, who controls the process, must therefore be fully trained.

No document should be inspected until it is as good as the author can make it. The author's management should assist in this and it is the moderator's task to check the document before arranging an inspection. If the defect rate later turns out to be too high, the moderator should postpone the inspection until the author re-submits an improved document.

An aid to the author is a guideline or standard for the document being produced. Either of these would contain a table of contents or checklist of what the document should contain and, preferably, how it should be structured. In most cases, there should also be a 'higher-level' document available. For example, a design is a translation of a specification which, therefore, is the higher-level document at the inspection of a design document. They should be supplemented with a checklist of defects repeatedly found in this type of document. The guideline or standard, higher-level documents and checklist should be used as tools by the inspectors during preparation.

Preparation is important, and unprepared inspectors find only trivial defects. If the moderator encounters an unprepared inspector at an inspection meeting, it is often best to postpone the meeting, though it may be polite to allow peer pressure to act on the inspector.

Inspection meetings are limited to a maximum of 2 hours. It is found that the defect-detection rate diminishes if this time is exceeded, because the participants get exhausted and lose concentration. This time constraint also limits the number of pages that can be inspected, and experience has shown this limit to be 20 pages. These limits are frequently opposed by newcomers to inspection, but they should never be exceeded, except, perhaps, under extreme political pressure—and then only after formal protest. The cost of correction at a later stage, when the document has been used (for example, when a defective contract has been placed, or when a defective specification has been translated into a product which is not fit for its purpose) is far higher than that of having several inspections of a large document. It is the moderator's task to choose the most appropriate method, in any given situation, of co-ordinating the inspection meetings for the same document, and this should be discussed and agreed at the overview meeting. For example, at each inspection meeting there may be a review of what has taken place to date.

The optimal speed of inspection is reading the text aloud. Another reason for reading is that the attention of all participants is concentrated on the same piece of text.

The atmosphere must be harmonious, or too much energy is spent on conflicts rather than on finding defects. It is the document and not the author that is inspected. Conflict solving is an important part of moderator training. If conflicts persist, the moderator may decide to stop the inspection.

Another key to effectiveness is the fact that inspection is intended to identify defects and not solutions. It is the author's task to find ways of correcting the defects and to discuss these with individual inspectors, if necessary.

To facilitate this, many companies allow an unofficial third hour immediately after the inspection meeting. The third hour also benefits the moderator, whose duty it is to eliminate superfluous discussion at the meeting. It is easier, and less likely to provoke antagonism, for a moderator to refer a defensive author to the third hour than simply to curtail discussion.

Inspections do not end with the inspection meeting. Two important things remain to be attended to by the moderator: inspection statistics (see below) and 'follow-up' on corrections. It is important that the author corrects the inspected document within the estimated time. The moderator must follow-up on this, and check that all recorded defects have been considered. The appearance of a revised draft at the scheduled time makes the inspection effort visible within the organisation.

Categorisation Of Defects

The categorisation of defects not only is an asset to quality control, but also helps the inspectors to find defects. A checklist of defect types should therefore be given to inspectors by the moderator.

A classification may be contrived to suit a particular inspection, but the following example is both comprehensive and general. The Software Quality Assurance Department of Christian Rovsing in Denmark divides defects into six types:

Missing Something which should be in the document is not there.
Wrong Something which is there is wrong.
Extra Redundancy or superfluity.
Ambiguous Something that can be misinterpreted.
Standard Non-conformity of the document with a standard or guideline.
High Level Inspection shows an error in the higher-level document of which the inspected document is a translation.

It also categorises defects into two classes of severity, minor and major, with the following definitions:

Minor The defect makes the document difficult to read locally. There is a small possibility of wrong interpretation, and the defect could produce further defects in dependent documents or products.
Major The defect causes the possibility of misinterpretation in a larger part of the document (typically 2–3 pages). The defect will probably cause further defects in dependent documents or products.

Such definitions are, to some extent, subjective, but it is the moderator's role to be clear on such matters. It is also to a company's advantage to have inspection guidelines which ensure consistency of interpretation and compatibility of statistics.

In addition, typographical errors are regarded as trivial and, though recorded and corrected, are not included in the above categorisations.

Statistics

Quality implies improvement. Evidence of improvement is found by measurement and improvement itself is achieved by the feedback of results into the process. The collection of statistics during inspection is therefore an integral and important aspect of the inspection process.

With regard to defects, the moderator should record the numbers of major and minor defects of each type found by each inspector. Although this data is not for public view, it provides peer pressure which encourages inspectors to do a good job. Sometimes employees fear that statistics will be used for job evaluation. A manager unwise enough to use them for this kills inspection. At Christian Rovsing, only inspection-specific statistics are made generally available. A separate database, accessible only to the quality department, stores participant-specific information, in order to assist authors in finding moderators and inspectors.

Because new errors come to light during the inspection meeting and some defects are found by more than one inspector, the total number of actual defects of each type and severity in the document should also be recorded.

With regard to the process, the moderator should find out, from each inspector, the time taken to inspect the document. The duration of the meetings and the number of pages in the document are also relevant.

From these data, useful statistics, such as the following, can be deduced:

(*a*) numbers of major and minor defects in the document,
(*b*) numbers of major and minor defects per page,
(*c*) total inspection time (sum of each participant's time during both study and meetings),
(*d*) preparation time per page,
(*e*) preparation time per page per inspector,
(*f*) preparation time per defect,
(*g*) inspection meeting time per defect,
(*h*) inspection meeting time per page,
(*i*) numbers of major and minor defects per inspector per hour,
(*j*) numbers of major and minor defects per inspector, and
(*k*) numbers of major and minor defects per page per inspector.

The raw data and these statistics (and any others of interest) should be stored in databases. Preferably, these should be held by a central quality department or team, so that the data from all inspections are brought together. Then, averages over a period of time can be derived to give moderators, inspectors and authors an idea of quality norms. Further, a comparison of inspections over time may be made. Improvements may be observed in the quality of documents or the quality of the process itself. The cost-effectiveness of inspection can also be observed. Curves may be plotted to show, for example, the optimum number of inspectors.

EFFECTIVE USE OF INSPECTION

For maximum effectiveness, an inspection must be conducted strictly within the rules and according to the principles stated above. In particular, no more than 20 pages should be inspected at a time and the inspection meeting should not exceed 2 hours. Fagan [6] finds that defect-detection ability is restored after a 2-hour break, but that no one should participate in more than two 2-hour inspections in a day.

The choice of inspectors also has a significant influence on the quality of an inspection. If all inspectors view the document from the same perspective, some defects are almost certainly missed. It is therefore judicious for the moderator to select a team which embodies as wide a range of expertise, and even bias, as appropriate to the document. And it is helpful if the reader is the person who will have to interpret it. For example, the reader of a requirements specification should, if possible, be the designer.

A moderator also needs to have a feel for norm values, within the company, of inspection statistics, and is then in a position to evaluate the relative quality of the document and the inspection. Figures from 57 inspections at Christian Rovsing show the following:

(*a*) The optimum number of inspectors (including the moderator) is four, though five can sometimes be useful. Additional inspectors do not seem to increase the number of defects found, and therefore introduce inefficiency.

(*b*) Administration time per inspection (mostly by the moderator in setting up the inspection) is 30 minutes.

(*c*) Preparation time per inspector per inspection is about 1·5 hours (for 20 pages); that is, about 4·5 minutes per page.

(*d*) An average of one major defect is found per 3·3 pages.

(*e*) An average of one minor defect is found per 0·7 pages.

It is now Christian Rovsing's practice to use the results of (*d*) and (*e*), above, as guides, with significant deviation from them being investigated. (Better figures suggest either an above-average author or a poor inspection. The latter can be due to lack of preparation, or to a poor choice of inspectors.)

Such results as those above may change as a company gains experience, proficiency and confidence in inspections, and it is recommended that a quality department should publish results frequently and review trends. Moderators will then be able to judge inspections against the latest company averages.

THE INTRODUCTION OF INSPECTION

The successful introduction of inspection into an organisation depends largely on the management. The first step is the honest admission that documentation quality can and should be improved. The next and most important step is the active participation of managers in ensuring the quality of documents. This would normally include the introduction of standards (one being the inspection method), the insistence that no document leaves the organisation (group, section, etc.) unless it has been inspected and correctly signed off, and continued involvement to ensure that the standards are adhered to invariably.

The nominal introduction of inspection is simple: staff are sent on the course and told to use the method. However, although staff are usually keen to achieve quality, their incentive is limited unless management is seen to insist on high quality, to check documents for which they are responsible, and to reject those which are not up to standard.

The successful introduction of inspection implies a change of culture and this is evolutionary, though it may be rapid. At first, staff with a deadline to meet are likely to say, 'The document is already late, so we won't be able to inspect it before it is issued.' Unless management insists on inspection and allows time for it, improved planning is improbable. Later, when inspection is accepted, the statement is likely to be, 'The document will be a bit late because, although it has been written, we have yet to inspect it.' As inspection becomes a planned stage in the production of a document, the statement becomes, 'The document will be ready on time.' Here, 'ready' means written, inspected, corrected and signed off.

The existence of a quality department or centre can aid inspection by providing trained moderators, either from the centre itself or from a list, by providing supervision and advice, and by keeping statistics and insisting that all moderators provide defined data from their inspections. If there is no quality centre within the organisation, management should ensure that all moderators are trained and that statistics are collected, processed and published centrally within the organisation.

CONCLUSIONS

In this article, it was suggested that attention could usefully be paid to document quality. Four complementary ways of achieving this were proposed in brief. One of these, the inspection method, was then described and discussed at length. It was noted that the role of the moderator was crucial and that all moderators should undergo appropriate training.

Inherent in the method are ways of measuring its effectiveness in the current situation and its cost-effectiveness to the business. Recommendations on its effective use were made, including which data should be collected, which statistics derived and how they may be interpreted. Advice was also offered on introducing inspection into an organisation.

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BIOGRAPHIES

Felix Redmill is currently Network Information Systems Manager in British Telecom International's Implementation and Design Division. Prior to this, he was responsible for maintenance support for telephone exchange and computer systems. His career in BT has taken him into many areas of both telephony and computer systems, including teletraffic engineering, stored-program control and computer system development standards and, more generally, quality.

Eric Johnson joined BT as a student in 1978 and obtained a degree in Electrical and Electronic Engineering from Sheffield University in 1982. After graduating, he joined British Telecom International in what is now the Network Information Systems section, where he has been involved in the development of a number of computer systems to support the international network. He is currently implementing a total quality management system for the section and is involved in the production and approval of standards and procedures for systems development.

Bjørn Runge is a software and quality consultant, operating from his own business, Runge-Data, in Denmark. He has successfully assisted a number of organisations to install the inspection method and he runs inspection courses both for managers and moderators. He was instrumental in installing inspection at Christian Rovsing, the company referred to in the article.

LEKTOR Encryption System

J. TINKLEY†

UDC 621.394.4 : 681.327.8

This article discusses the use of encryption for the secure transmission of data and describes how British Telecom's LEKTOR® encryption system makes use of public key encryption to provide secure data communication.

NEED FOR DATA SECURITY

With today's increasing use of sophisticated computer and communication technology for the transmission of sensitive data, the need for adequate security is readily apparent. Widespread dependence on high technology in military, government and business organisations has increased the magnitude and complexity of data security problems. Anyone intending to communicate sensitive information is increasingly subject to the risk of interception and sabotage through unauthorised access, resulting in loss of data, data integrity and money.

To safeguard the data against such attacks, British Telecom has developed the LEKTOR* encryption equipment (Figure 1) which can be incorporated into almost any type of communication system linking two or more parties.

FORMS OF ATTACK

There are essentially two forms of attack that have to be guarded against; namely, *passive* and *active*.

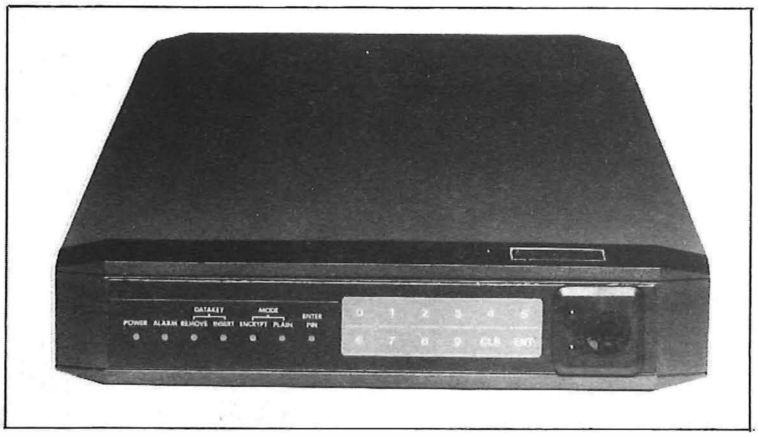
The passive attack, more commonly known as *eavesdropping*, has historically been the usual form of attack. It is where an unauthorised party monitors the data that is being transmitted between two parties, but leaves no trace of the attack. Because the eavesdropper merely monitors the data, the communication is allowed to proceed and the eavesdropper can continue to monitor it. For this reason, this type of attack is the most difficult to detect and undermines the confidentiality of the data. The eavesdropper not only has unauthorised use of the data, but perhaps more seriously, it has been acquired without the knowledge of the real owner of the data.

The second form, the so-called active attack, or *hacking*, is on the increase. It is normally achieved by electronic impersonation, whereby sufficient knowledge of the target system is gained to enable the attacker to masquerade as an authorised user. The attacker either wilfully changes the meaning of transmitted data, or interferes with the transmission or reception of data. In an active attack, the data can be attacked at its source, but it may equally well be attacked on the data path by data substitution.

Large amounts of data are being stored nowadays on databases. Many of these databases have access points via the public switched telephone network or other external circuits. There is often no protection on these external access points: any telephone user can call the appropriate numbers either intentionally or by accident.

Once this kind of attack has happened, the validity of the data is suspect: indeed, it may cease to be usable. The information contained on such a database could be rendered totally useless by just one attack. LEKTOR provides a method of protecting databases from such attacks.

Figure 1
The LEKTOR encryption system



ENCRYPTION KEYS

The basic objective of a secure system is that only authorised users should be able to exchange meaningful data over the communication link.

The most used way of protecting data

† Government and Advanced Projects, British Telecom International Products Division.

* LEKTOR® is a Registered Trade Mark of British Telecommunications plc.

against eavesdropping is to change its form in some way. The modern way of achieving this is to encrypt the data that needs to be protected. Data that has been encrypted should not resemble the original data in any way, shape or form. The encrypted data should not have any relationship to the original data except that given to it by the algorithm used to encrypt the original data. There should be no indication in the encrypted data as to how the encryption was carried out.

Obviously, the transmitter and receiver of the data must have reached a prior agreement on the method/algorithm that is to be used to encrypt the data. Whichever method is chosen to encrypt the data, the intended receiver must also know how the method was used so that the original data can be recovered. This gives rise to the need for a key to be used to encrypt the data.

The chosen key must be known by both the transmitter and the receiver before encrypted data can be successfully exchanged between them.

Traditionally, the chosen key has had to be distributed previously to the authorised users of the system before the system can be used. This has required an alternative secure channel/method for key distribution such as a courier. It has meant that every user of the system has had to have prior knowledge of the key and that the key had to exist in many places. It also means that all users were using the same key or set of keys. To maintain the security of the system, these keys have had to be changed on a regular basis or even for every message.

If any of these keys becomes known to an unauthorised party, the whole system is put at risk.

PUBLIC KEY ENCRYPTION

Public key encryption is a well established method which applies various mathematical number theories to encrypt data. Such systems are all theoretically capable of being broken in time, given sufficient computing power. However, for practical purposes, they are effective because the size and type of numbers that are used place the required computing power at an impractical level.

There are two keys required by each user of the system. One is for encryption and the other for decryption. Knowledge of one key gives no information about the other. Thus a user can choose a pair of keys, making one public and keeping the other secret. Anyone with suitable equipment can encrypt a message using the public key, and this message can only be decrypted by the intended recipient who has the secret key.

Since the public keys can be widely known and each secret key is only known by one user, the problems of key management are eliminated.

Method of Operation

The basic method of operation using the public key encryption system is as follows:

(*i*) The communicating parties exchange their public key variables.

(*ii*) They each generate a random number.

(*iii*) Each of them then encrypts the random number under the other party's public key variable. This data is then transmitted to line.

(*iv*) The received random number is then combined with the transmitted own random number to form a third number.

(*v*) This third number is the encryption key that will be used for the encrypted data exchange, using an agreed algorithm.

The encryption key, which is different for every session, can only be determined by an eavesdropper who knows the secret keys of both parties.

Calculation of Key Variables

For the Rivest, Shamir and Adelman (RSA) public key encryption system as implemented in the LEKTOR system, the public key variables are derived in the following manner:

Two random prime numbers are chosen, say p and q, where p and q are up to 128 bits in length. The product N of p and q is then calculated. N will be up to 256 bits in length.

The value ϕN is then found, where ϕN is defined for positive integers as the number of integers less than N which are relative prime to N. (Two numbers are defined as being relative prime, when they have no common factor except unity).

For p and q which are prime numbers, ϕN is given by:

$$\phi N = (p-1)(q-1)$$

A third number e (8 bits) is now chosen and from the relationship

$$ed \bmod \phi N = 1$$

d is found.

It can be shown that where the greatest common denominator $(e,\phi N)$ is 1, a solution for d is given by

$$d = e^{(\phi N-1)} \bmod \phi N$$

[*Note*: In modular arithmetic (mod), to evaluate $n = Y \bmod x$, discard all complete values of x in Y to give a value of n between 0 and $(x-1)$; that is, n is the remainder when Y is divided by x.]

User Token

These calculations have given the three numbers which the user requires to be able to use the system. These are the public key, e, the modulus, N, and the secret key, d. These are very large numbers, and there is no way that a user will be able to remember all of this data. It is therefore necessary to provide the user with some form of portable storage medium. All sensitive information is therefore contained in a removable user token which is used in conjunction with a personal identification number (PIN) memorised by the user. Possession of a user token and its associated PIN is all that an authorised user needs to use the system. Without both a user token and the associated PIN, an unauthorised person could not use the system. The public key (e) and the modulus (N) are also known as a *public key pair*. Knowledge of these two, which are used for encryption, gives no indication as to the value of the secret key (d) which is only used for decryption.

Each user token has a different set of user variables. The public key (e) may be repeated, but for each pair (p and q) the value of d will be different. The user tokens are issued by the Key Management Centre (KMC). The KMC is the user-trusted interface to the system. At the KMC, the public key variables for each user are programmed on to the individual tokens, which are then distributed to authorised users. The PIN relating to the token is also distributed from the KMC, but under separate cover —just like the method used for the PIN for a bank cash card. No records are kept at the KMC: each set of numbers is destroyed as soon as it has been loaded on to a user token. There are no copies of user tokens, and the KMC only holds a stock of unissued blank tokens.

Principles of Key Encryption

The general method is as follows:

For simplicity, one end is referred to as the transmitter and the other as the receiver. In practice, the operation would be carried out in both directions to enable a secure dialogue to be carried out.

The transmitter, having first received the public key pair of the receiver, encrypts the data representing the message m by using the receiver's public key e_r and modulus N_r.

C is the data actually transmitted to line, where:

$$C = m^{e_r} \bmod N_r .$$

The receiver then has to solve $C^{d_r} \bmod N_r$ in order to recover m, the plain text.

If it is assumed that the data has been intercepted, the eavesdropper will now have a copy of C, e_r and N_r. Even if the encryption method which has been employed is known, the eavesdropper still has to solve

$$(C \bmod N_r)^{(1/e_r)}$$

in order to discover the plain text. There is no known algorithm for this solution. Trial and error would eventually give an answer, but because large numbers (that is, up to 256 bits) are used, trial and error would take an extremely long time, even with a large fast computer. An example of the above calculation, but using small numbers, is given as an Appendix at the end of this article.

The basic public key scheme requires a large amount of processing power and as a method of encryption it is too slow for transmitting bulk data. It is nevertheless an ideal method for exchanging encryption keys to be used in faster systems. With such a method, there is no longer any need for each user to be in possession of the encryption key prior to the data exchange. Indeed, the key does not exist prior to the encrypted data session, so it cannot be distributed. Using the public key exchange to obtain the encryption key means that the latter only exists for the duration of a single encrypted data session and even then it is only known by the two parties on the line.

Real-Time Encryption Algorithm

Once the encryption key has been established by using the public key method, the system reverts to the application of a much faster conventional encryption algorithm for the exchange of data in real time.

The recommended algorithm is B-Crypt† which was developed at the British Telecom Research Laboratories. However, for customers who prefer it, the equipment can also use the Data Encryption Standard (DES), an encryption algorithm widely used in the USA.

User Certification

By incorporating additional data in the messages exchanged at the public key stage, a method of user certification is possible. Each user can be allocated a certificate and an identification (ID), which together identify the user as well as the user group to which he belongs. (The ID is not encrypted: the certificate is, in effect, a suitably encrypted version of the ID.)

The ID and certificate are exchanged at the same time as the public key variable at the start of the encryption set-up procedure. This enables each user to check the identity of the other party on the line before any data is exchanged. It also allows for the creation of closed user groups within the overall set of authorised users of the encryption system.

LEKTOR ENCRYPTION UNIT

The equipment developed by British Telecom offers the following features:

- Data protection against eavesdroppers.
- Access protection against active attack.
- User authentication.
- Simplified key management.
- High security: a different key for every session.
- Removable user tokens for user convenience.

† B-Crypt® is a Trade Mark of British Telecommunications plc.

● PINs to guard against unauthorised use of user token.
● Encryption unit contains no sensitive information.
● Two encryption algorithms available: B-Crypt and DES.
● Connection to most communication links.
● Closed user groups.

METHOD OF USE

When first switched on, the unit operates in plain text mode. Either user inserts the user token to request encryption and enters the appropriate PIN on the keyboard (see Figure 2). The request is signalled to the other user who then inserts his user token and enters his PIN. After a very short pause whilst the session encryption key is generated, communication continues with encrypted data.

If desired, either party can examine the authentication information which is held on the user token of the other party and cannot be forged.

Alternatively, if required, encrypted communication between strangers is perfectly possible.

FACSIMILE ENCRYPTION

The LEKTOR encryptor is also available in a form that will encrypt facsimile transmissions. The encryptor is primarily intended to interface to the British Telecom range of facsimile units, but connection is also possible to other facsimile machines.

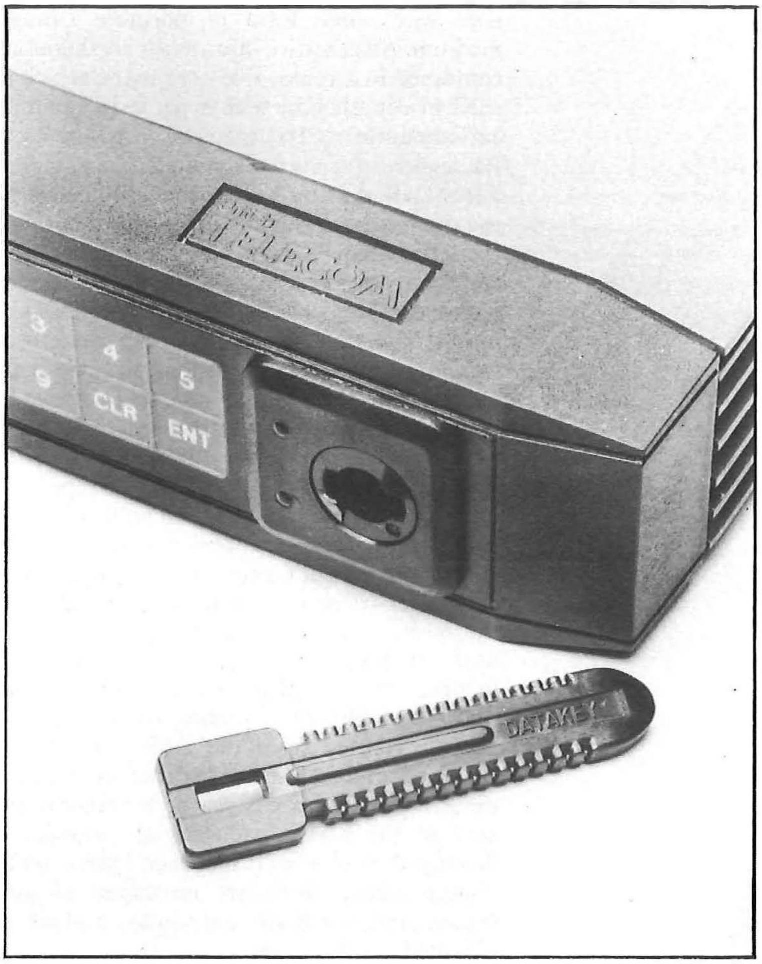


Figure 2
User token

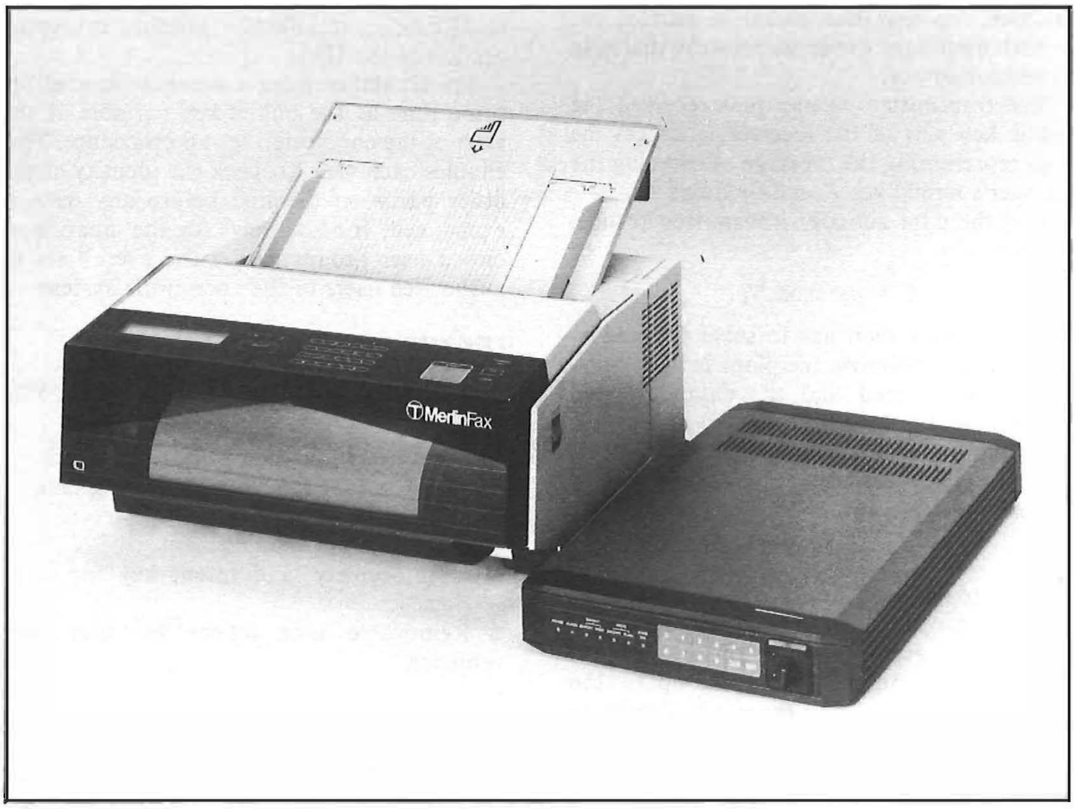


Figure 3
LEKTOR unit for facsimile working

The LEKTOR units perform a modified public key exchange before facsimile transmission takes place. They do not place any overhead on the facsimile transmission speed, the exchange of picture data being at the normal speed.

The facsimile machine remains CCITT Group 3 compatible for facsimile working. The choice of encryption or plain text working lies with the transmitter. If encrypted transmission is chosen then the receiving facsimile machine must also have a LEKTOR attached to it (Figure 3). If it has not, then the transmission will not be received. The user requires only a user token and the associated PIN to be able to use the machine within his own user group.

ACKNOWLEDGEMENTS

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Biography

John Tinkley joined British Telecom in 1967 as a Trainee Technician in the Telegraph and Data Systems Laboratory where he worked on various projects including the Modem 7 development, a Telex broadcast system, satellite engineering circuit switches and the Solent Callout System. In 1982, he moved to British Telecom Enterprises to work on the Merlin office automation systems and provided technical support for the M3300 wordprocessor and the M2105 Messaging terminal. He joined International Products Division in 1985 where he has been responsible for the design and development of the LEKTOR encryption equipment.

APPENDIX

EXAMPLE OF ENCRYPTION

Suppose the numbers 5 and 11 are chosen as the random primes. Then N is the product, 55, of these two, and

$$\phi N = (5-1)(11-1) = 40.$$

Choosing $e = 3$, then from

$$ed \bmod \phi N = 1$$

$$3d \bmod 40 = 1$$

that is, $d = 27$

The public key variables are thus:

public key	=	3
modulus	=	55
secret key	=	27

To use this information to send, for example, the number '8'

$$\begin{aligned} C &= m^e \bmod N \\ &= 8^3 \bmod 55 \\ &= 512 \bmod 55 \\ &= 17 \end{aligned}$$

The data sent to line would thus be '17', and the decryption would be as follows:

$$\begin{aligned} m &= C^d \bmod N \\ &= 17^{27} \bmod 55 \\ &= 8 \end{aligned}$$

The eavesdropper would have to solve
$m = (17 \bmod 55)^{(1/3)}$.

Intermail

R. WAKELING, M.A.†

UDC 621.397.12 : 681.327.1

In the past, the many electronic mail systems have been unable to intercommunicate with each other and with other telematic services. To overcome these problems, the X.400-series of Recommendations has been developed as an international standard for the implementation of message handling systems. This article describes Intermail, British Telecom's own internal message service.

INTRODUCTION

Electronic mail is no longer new technology. Most computer system suppliers now offer some sort of messaging for their users. Major computer manufacturers such as IBM and DEC have now also standardised the systems on their various models, so that, within a network consisting solely of their own range of equipment, messages can be sent to any other user. Messaging is now available on almost every system from large mainframes down to small PC networks.

In companies like British Telecom (BT), however, this does not go very far towards solving the need for company-wide electronic mail. Consequently, a number of messaging bureaux have sprung up to provide dedicated computer-based messaging facilities—the largest of which is Telecom Gold.

The use of a bureau service by a company which has large computing facilities of its own does not seem the most efficient or economic way of providing messaging. However, until recently, there was no established standard for message handling which would allow the exchange of messages between different computers.

With the ratification, in 1984, of the CCITT X.400-series Recommendations[1] for message handling systems, the situation changed. Since then, computer suppliers, bureaux and software houses have been developing systems which will conform to the Recommendations and provide for the potential interconnection of messaging systems.

WHAT IS X.400?

The X.400-series of Recommendations provides a set of protocols which enable messages to be transmitted between users on different mail systems. It also allows these mail systems to interwork with Telex and telematic services such as teletex and facsimile. The Recommendations define a naming and addressing structure, and two 'agents', known as a *user agent* (UA) and a *message transfer agent* (MTA), which act, respectively, like a Post Office box and a sorting office in the postal service.

The user puts messages into his or her UA, and the UA submits these to its MTA. This MTA then transfers the message to another MTA which may be either the destination MTA (one which knows the UA for the intended recipient) or may be a relaying MTA, which passes the message on until the destination is reached.

In order to ensure that all these MTAs do not simply play 'pass the parcel' with messages, the Recommendations lay down a hierarchy of management domains. It is up to a private management domain (PRMD) to arrange how relaying and destination MTAs know of each other's existence and which UAs they serve. At a higher level, there is an administration management domain (ADMD) which is responsible for exchanging messages between different PRMDs. (See Figure 1.)

DESIGN OF INTERMAIL

BT is not only a supplier of such systems and services, but also a major potential user of the service. While there are many different interests involved, it was clear that a company-wide X.400 service would not only transform its own internal communications, but would also demonstrate to external companies BT's ability to provide a coherent range of messaging products and services.

This possibility was recognised by the Corporate Information Technology Division, in 1985, when project *Intermail* was set in motion. Its remit was to provide an internal X.400 messaging service for BT Headquarters, and to co-ordinate the introduction of compatible standard messaging within the operating divisions.

The design of the Intermail service was dictated by three considerations:

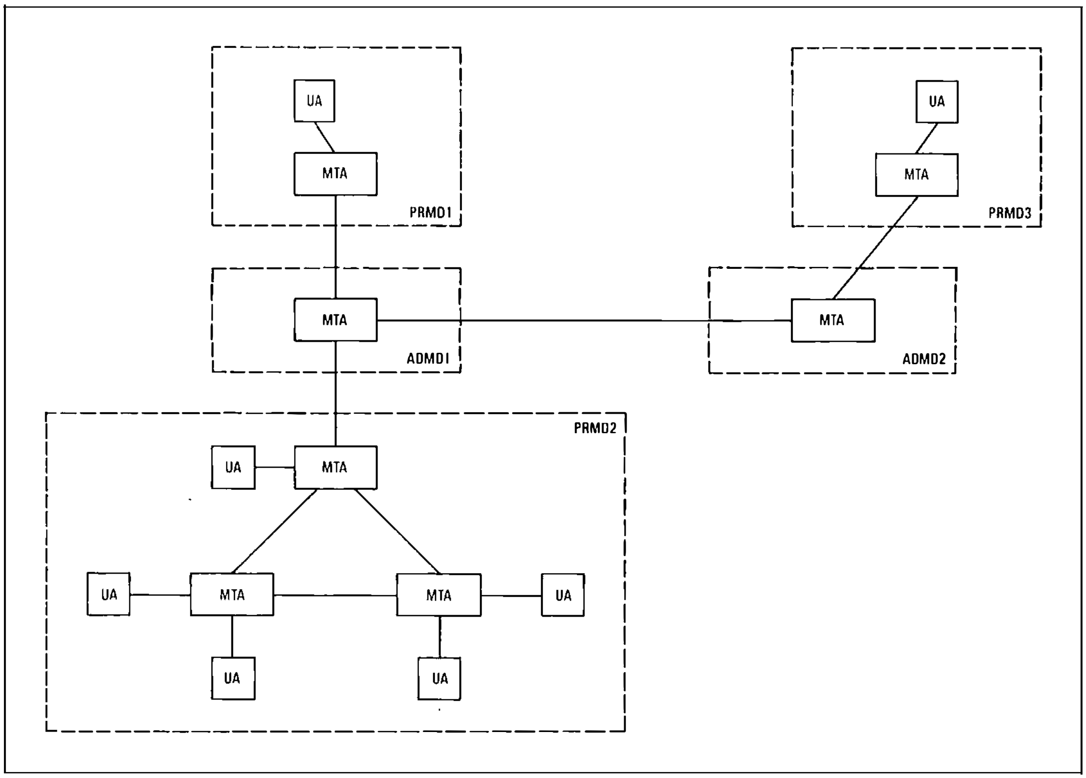
- The X.400 Recommendations.
- The distribution of users of existing systems.
- The public services and products which BT planned to provide.

The first two criteria suggested a design as in Figure 2. This was agreed with the various business units interested in supplying parts of the service, although specific plans of the products to be supplied were not available.

In order to minimise the impact of Intermail

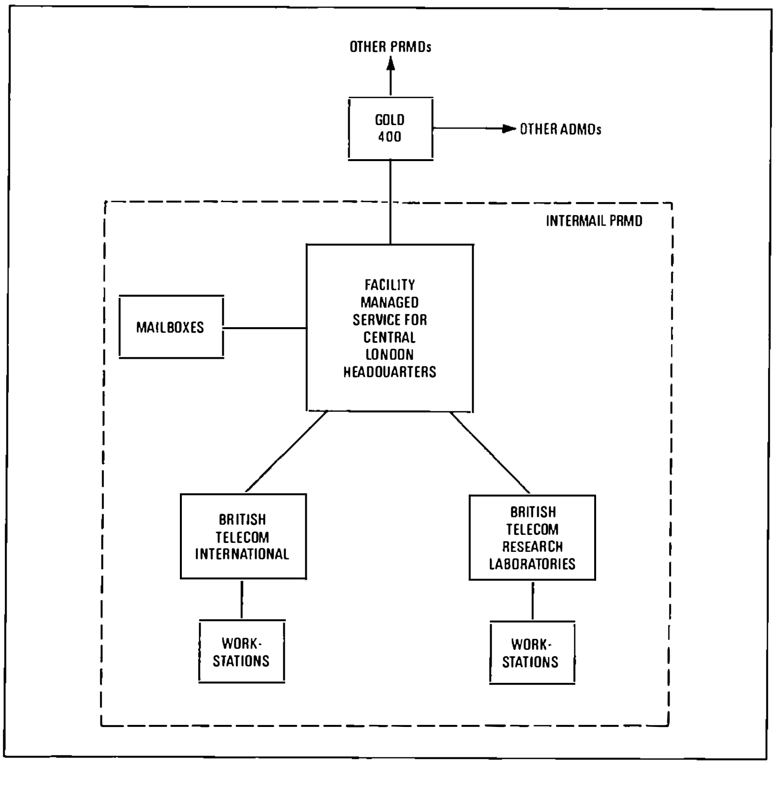
† Corporate Information Strategy Unit, British Telecom

Figure 1
Message handling hierarchy



ADMD: Administration management domain
PRMD: Private management domain
MTA: Message transfer agent
UA: User agent

Figure 2
Intermail network



on the quality of the public service, the internal BT messaging service would be (in X.400 terminology) a single private domain with numerous MTAs each serving a particular group of users via collocated or separate UAs. Because it was recognised that there would be administrative and practical problems in maintaining complete and up-to-date routing tables within all of these MTAs, a central MTA would provide certain services for them such as relaying to and from the administrative domain, relaying within the private domain, as well as being a source of information about changes in routing tables.

Subsequently, these relaying facilities could be devolved to other MTAs within the domain, or indeed to every MTA. The point at which the cost of relaying a message (which entails two X.25 calls as well as the central relay processing) was greater than providing the necessary routing information locally would determine when such devolution were practical.

Naming, Addressing and Directories

The intention of the originator/recipient (O/R) naming and addressing scheme specified in X.400 was that these names should be easily intuited or remembered, because they would be familiar things one would know about someone. Two forms with three different variants of one of them were defined. The required attributes for form 1 (variant 1) of an O/R address are:

country name
administration domain name

and at least one of the following:

[private domain name]
[personal name]
[organisation name]
[organisational unit name]
[domain-defined attributes]

In order to identify uniquely everyone in BT and still adhere as closely as possible to widely known information about people, it was necessary to use the personal name, organisation and (in some cases) organisational unit names. Unfortunately, the naming convention requires that these details are exact and unique, whereas neither human memory nor intuition appear to be so.

The Recommendations also give no guidance as to how routing should be done. It was assumed that this would be a matter for national initiative by the PTTs who make up the CCITT.

Given the complexity and rigidity of the O/R addressing scheme within X.400 (1984), it was recognised that a lookup directory would need to be available for on-line interactive enquiry. This would also be provided as a single central service as part of ***Inter-View***, an on-line interactive directory service to replace the internal telephone directories.

CCITT work on the X.500-series of Recommendations[2] for directories, and in particular for their automated use by message handling systems was too immature and unstable for implementation to be possible within the initial years of the project. Moreover, the way in which the directory would be used by the message handling system presumes additions and modifications† to the X.400 Recommendations themselves which would necessitate revision of the initial systems. The process of upgrading Intermail MTAs to X.400 (1988) will coincide with the devolution of central relaying facilities and the provision of standard directory facilities.

In the interim, a directory for O/R names will be offered, as part of Inter-View. This will subsequently be upgraded to support X.500 facilities and allow fully-automatic name validation and routing.

IMPLEMENTATION

After this abstract design had been agreed, the difficult job of matching it to available BT products and services began. The main problem here was the range and variety of office automation systems currently in use within BT. Several large sites had well established communities of users on DEC All-in-One systems, there were numerous PC networks with different office automation systems running on them. In addition, there is a large base of IBM equipment within BT, although little of this is used for office automation at present.

Interfacing existing office automation software to X.400 messaging software is a non trivial problem. Most of the vendors provide some sort of messaging facilities within their office automation packages, but invariably the addressing mechanisms and general facilities are different from those standardised within the CCITT Recommendations.

Facilities such as reply request, receipt or non-receipt notification, importance or sensitivity indications seldom map cleanly onto a proprietary messaging system while local naming conventions seldom allow for the complexity of an O/R name. Consequently, name and address conversion tables are required, which may restrict messaging to predetermined destinations. Some vendors are cautious about modifying their software to support X.400. They do not have the necessary expertise and have not yet seen the demand for such support. It is also sometimes difficult to get access to the internal workings of their software in order to interface between it and an X.400 module.

A trial link had been set up between London and British Telecom Research Laboratories (BTRL) at Martlesham Heath during the last quarter of 1986 as part of the field trials of a DEC X.400 implementation, and engineering trials of GOLD 400. Heavy investment in DEC equipment at Martlesham Heath and within British Telecom International (BTI) and the widespread use of All-in-One at both sites, suggests that an implementation on DEC VAX equipment, integrated with All-in-One, could provide Intermail with its first users at minimal cost.

Negotiations with Telecom Gold, their suppliers Dialcom, and other potential MTA providers within BT had agreed that other major sites would be provided with their products, on PC networks or DEC VAX equipment. Where no economic alternative was available, existing Telecom Gold mail users would be upgraded to Telecom Gold's 'Mail 400' user interface and a mail bridge between this service and the GOLD 400 would permit two way access from other MTAs within Intermail.

Discussions as to how best to extend Intermail to the Districts, which have considerable investment in IBM hardware and a wide range of office automation products, are still proceeding.

GOLD 400, the public X.400 service or administration domain (ADMD) opened for business in July 1987. At the moment, a PC version is being tested, using the GOLD 400 service as a relay. This pilot service will be extended to include the VAX-based systems at BTI and BTRL and will soon enable them to interwork with existing Gold mailboxes.

† These modifications or enhancements are currently under review by CCITT Study Group VII and are due to be ratified during the study period ending in 1988. The 1988 modifications include provision of security and a message store.

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2 CCITT Recommendation X.500 (ISO 9594) Information processing systems—the directory.

Telecommunications and International Finance

This article highlights some of the most spectacular aspects of telecommunication advances essential in the globalisation of international banking and finance. They will not be confined to countries with a high telecommunications sophistication. In close co-operation with telecommunications authorities of Third World countries, the local branch offices of banks from highly industrialised countries may contribute to accelerate the establishment of McLuhan's 'global village'.

This article is based on a feature prepared by the Public Relations Division of the ITU in connection with TELECOM 87.

INTRODUCTION

Transportation of information in the broadest sense of the word has been at the root of finance ever since trading and currency exchange emerged. When the first coins were minted in Lydia in the seventh century BC, professional currency exchange at the important commercial crossroads was made by the many monetary sovereignties. The crossroads had two advantages: affluence of both clients and information, which promoted the formation of banks, originally the mere money-exchange tables in medieval Italy. When the Medici, or the Fugger and Welser families installed their own messenger service, ships and gazettes reporting about wars, crop failures, gold finds or natural catastrophes in foreign lands, the first news-gathering network was in place to condition large-style lending and cross-border commercial operations.

'The classical values of a bank, that is, gold bullion and coins, currencies, shares and securities stored in a bank's safe, have today been replaced by information about gold, money and shares, stored in huge databases and carried over telecommunication networks around the globe.' This is how a Zurich-based official of a large Swiss bank describes the staggering increase in the importance of telecommunications in banking today. In fact, he adds, there are now analysts who allot ratings to banks on the basis of the relevant company's investments in telecommunications in addition to such standard criteria as profits, cash-flow or reserves.

But stock quotations on television monitors in bank buildings are just the tip of the iceberg. Specialised organisations like Dow Jones, Telerate, Reuters or Telekurs gather information on the development of quotations, exchange rates or price quotes of all major stock and commodity exchanges around the world, and transmit it at once to any investor, trader or currency exchange desk which needs the information instantly. Tens of thousands of telephone, Telex and data lines leased from the telecommunications carriers and postal authorities around the world spread the news 24 hours a day, 7 days a week, with background information on economic and financial indicators, crop prospects, commodity supply reports and price trends. In several countries, the telecommunications authorities have built transmitters which radio foreign exchange rates around the clock. Any trader may pick up the signals with a small pocket-calculator-size receiver. Thereby, high-volume data transfer, faster connections and high-speed information transmissions are key factors for the competitive edge of financial institutions.

SWIFT SYSTEM

With banks networking globally to run accounts for their clients and for themselves, the need to exchange the state of their financial positions with respect to one another became an urgent necessity. Thus, in May 1973, a total of 239 banking institutions from 15 industrialised countries founded the Society for Worldwide Interbank Financial Telecommunications (SWIFT). This organisation became one of the most formidable single users of telecommunications equipment and lines in the world today. In fact, the first system, SWIFT-1, became fully operational in 1977. Today, over 1300 member banks in 60 countries use this system, which handled in the single month of March 1987 over 18·5 million world-wide transactions.

The SWIFT network functions via two fully redundant central processors, one in Holland, the other in the State of Virginia (USA), operating according to the store-and-forward method, linked by leased telephone lines to all terminals in a given country via one or several regional processors. Transmission speeds on SWIFT-1 are between 4·8 kbit/s and 9·6 kbit/s. The system handles information categories such as foreign currency transactions, investment information, issue and collection of bills, transactions in securities and other relevant data on interbank settlements. Great attention has been given to security, including such measures as passwords, indication of operational mode, embargoes, sequence checks for incoming or outgoing messages and cryptographic methods for text transmission. The use of special cryptographic equipment between bank and regional processors for security reasons is widespread.

A higher-powered system, SWIFT-2, is gradually being introduced. Instead of using the centres in Holland and the USA as central processors, they will become control centres in a star-like network configuration with sub-processors.

NATIONAL INTERBANK CLEARING SYSTEMS

Forerunners to SWIFT as an international clearing system were national clearing systems designed to speed up settlement of the accounts of national banking institutions among themselves. Since the late-1970s, such national clearing systems, usually co-ordinated by the national bank note issuing bank, have gradually moved to on-line operations using leased lines from the national telephone carriers or telecommunications authorities.

Today, virtually every country with a developed banking network operates with such an interbank clearing system whereby a central computer system has on-line or special user device connections with all banks adhering to the system and the national (issuing or reserve) bank. In some countries with a postal cheque system, even the national post office may have links with the interbank clearing system. Clearing transactions on public telecommunications links include *inter alia* the payments by one bank to the other, payments to and by the national post office's postal cheque system to PTT clients and suppliers, and all those invoice settlements by postal cheques into bank accounts.

In Switzerland alone such clearing operations reached in 1986 a daily amount in excess of $78 billion. Conservative estimates believe the consolidated world-wide national interbank clearing operations to exceed $2000 billion per day with over 25% using the telecommunications facilities provided by ITU member organisations.

TOWARDS ISDN IN GLOBAL BANKING

To grasp the importance of the current and future telecommunications challenges which face small and large banks, it is interesting to shed some light on two typical examples: those of Union Bank of Switzerland (UBS) and the British Barclays Bank.

USB Example

This 125-year old universal bank with 325 offices, subsidiaries and representations at home and abroad invested in its private networking equipment over $220 million in the last few years. In 1986 alone, annual investments in telecommunications equipment increased to an annual $28·6 million and for 1987 they are expected to reach approximately $57·2 million.

In 1978, the bank began developing a fully integrated, future oriented on-line telematic system, called *ABACUS*. Today, more than 10 000 terminals are linked on-line with two central and several branch computing centres. This network required the use of over 1200 telephone lines leased from the national telecommunication authority. Only recently, ABACUS was digitalised and now runs partly on 64 kbit/s and two 2 Mbit/s lines. The international leased lines were fully automated in 1983.

Today, ABACUS is still considered to be one of the most performing networks for banking operations in the world. It is a traditional data processing system with mainframes in the centre and dumb terminals at the user periphery which use vendor specific procedures. The networks are closed networks.

Recently, the bank's management decided to develop a new high-performance high-quality network to include professional and management information systems. To cover this 'backbone' of the corporation in the years to come, its telecommunications team began a costly evaluation of available systems and equipment. After a two-year evaluation, it decided to pass from a closed to an open network with standardised interfaces to be connected with other users as well as internal and external information centres.

With this open network, called *UBINET*, the bank is strongly committed to the ISDN concept for voice and data communications. Such an ISDN system would include gateways to public services and networks. By using multiplexers, the old analogue links of ABACUS have been transferred to the digital network. The domestic carrier UBINET-Swiss is in fact already an integrated digital network which allows an easy migration into ISDN once it becomes available. Yet, the corporation knows that an ISDN service limited to 144 kbit/s will not cover all its needs. It is, therefore, already looking to broadband ISDN.

Barclays Bank Example

Barclays Bank plc, one of the four principal clearing banks in the UK, has been in the banking and financial services industry for some 200 years. Over one half of Barclays' consolidated assets are denominated in currencies other than sterling (principally US dollars), which befits an international banking group of some 4000 branches in over 70 countries.

Barclays' investment in telecommunications is considerable. In 1986, for the UK alone, they invested $50 million in pure telecommunications hardware, which will rise to $74 million in 1987. Barclays' overall spend on telecommunications in the UK in 1987 will be in the region of $118 million, servicing some 10 000 data circuits, 17 500 exchange lines and 68 000 extensions.

In 1985, the bank embarked upon the evaluation of a private X.25 packet-switched network to provide an 'open' transport mechanism to service its corporate management information systems and its 2700-plus branch network in the UK. The principal switching nodes and field-switches are interconnected by 64 kbit/s digital links and their key computing centres make significant use of 2 Mbit/s digital links.

Installation of Barclays' UK data network began in late-1986 and is scheduled for completion in the third quarter of 1989. The bank is extending its corporate network and global banking services to its main locations worldwide by installing a private X.25 network between its major overseas offices.

Barclays is committed to voice and data integration whenever and wherever possible. Presently, they are major users of multiple 2 Mbit/s digital links in the UK, maintain one of the largest private video-conferencing networks in Europe, and were one of the first signatories for TAT-8 services (the digital transatlantic optical-fibre cable expected in service June 1988).

Automatic Banking

The world's first fully electronic and automatic public bank was opened in Switzerland in 1986. The office, open seven days a week and around the clock, contains 11 automatic teller machines, six terminals and two public telephones. If customers have a Eurocheque card and an account card from the bank, they can perform virtually 80% of all their usual banking operations, including purchasing traveller's cheques, gold coins, depositing valuables, drawing on their bank accounts, changing eight foreign currencies.

The six TV terminals are, like the other automatic tellers, linked by leased lines to the bank's system and provide telebanking services as well as stock market, foreign exchange and economic information.

TELEBANKING

An emerging service already offered by several banks in co-operation with Videotex or Viewdata, telebanking is an international service discussed by CCITT's Study Commissions I and VIII in 1978 and 1979. The service is tailored to home television sets by TV transmitters (broadcast Videotex) or through telephone lines (interactive Videotex). TV sets or PCs equipped with appropriate decoders or modems and linked by telephone lines with bank computers permit the handling of personal banking business (obtaining account statements, passing purchase orders for securities or payment orders for bills, etc.) at home or in the office. Several well-informed sources indicate that 80% of private banking transactions could well be handled by telebanking at the turn of the century.

CREDIT CARDS

After timid beginnings at the start of the century in the United States, credit cards have become a widespread payment instrument in industrialised countries and key cities of the Third World. While client credit cards were first issued by gasoline and other retail organisations, travel and entertainment cards (American Express, Diners or Eurocard), and bank credit cards (Visa) witnessed a tremendous upsurge after the Second World War. Most of these cards are nowadays equipped with a magnetic strip containing a personal identification number (PIN code). This strip is in the process of being replaced by a computer chip to be incorporated in the card (smart card). The chip incorporated in this smart card not only contains the PIN code, but may also be a small computer and contain credit limits and other information.

Eurocard, founded by a Swedish group in 1965, serves as an example for the globe-spanning services and telecommunications implications connected with such a consumer credit instrument. The organisation, now headquartered in Geneva, has passed agreements with the US MasterCard organisation, the British Access card, the Japanese Diamond, Union and Million card, and several other national card organisations. Thus, it is today valid in 165 countries and in over 5 million contractual shops, hotels and airlines.

Once a month, all purchases made by purchasers in whatever country, are debited from their bank accounts through telecommunications. In addition, and in order to protect the card organisation from misuses, any purchase over and above a limit has to be authorised by the organisation's local representative. This instant information around the clock and seven days a week conditions an on-line computer information exchange using mostly leased lines via cable or satellite.

With the appearance of the smart or chip card, reading terminals at the point of purchase will permit the instant reading of the card information contained in the chip; by telecommunications, the owner's bank account will be debited or a print-out of the bank account statement will be provided.

BRANCHING OUT INTO THE THIRD WORLD

The astounding development of finance-related telecommunications—experts estimate the current annual growth rates between 10% and 20%—will certainly not stop at the door of developing nations. In close co-operation with the national telecommunications authorities, the local branch offices of multinationally active financial institutions, commodity trading houses and raw materials dealers will extend the global telecommunications links into the capitals of Third World countries. Experts believe that the financial and trading companies will play an important part in assisting telecommunications authorities in the development of local infrastructures. In addition to serving their own business interests, they would thus share in helping the lesser developed areas of the world to bridge the information gap.

Routining of Metering-over-Junction Circuits

G. T. BAKER, and E. S. REARDON†

This article describes a simple circuit modification to the first-generation trunk and junction routiner to provide routiner facilities for metering-over-junction circuits. The authors received a prize in BT's New Ideas Competition for this work.

INTRODUCTION

Metering-over-junction (MOJ) circuits between local exchanges and group switching centres are not tested automatically by first-generation trunk and junction routining equipment. Consequently, MOJ circuits have been tested manually with portable test equipment. A simple low-cost modification to the trunk and junction routiner has enabled the routiner to be used also for testing the MOJ circuits.

TECHNICAL DETAILS

The modification involves inserting a circuit element in the positive-, negative- and P-wire outgoing access of the routiner test circuit. The circuit element (Figure 1), based on two 3000-type relays, recognises a successful test call by detecting the positive battery metering pulse and assimilating a line reversal, which is acceptable to the routiner test circuit.

The pulsing element of the trunk and junction routiner is also modified (Figure 2) to cater for up to 6-digit sending. This ensures that the trunk and junction routiner can test MOJ circuits terminated on all GSC types, including Strowger, crossbar and System X digital main switching units.

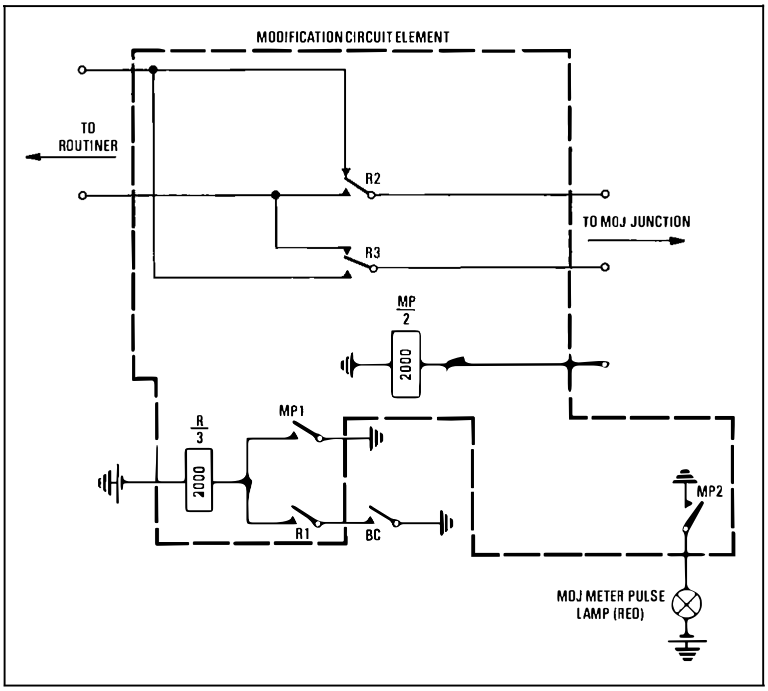


Figure 1—Circuit modification

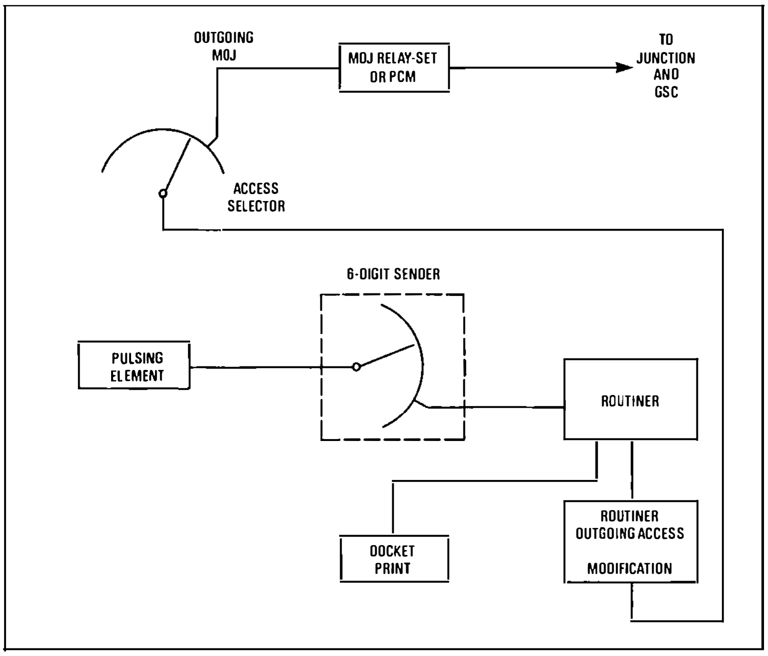


Figure 2—Schematic pulsing element

Circuit Operation

The operation of the circuit shown in Figure 1 is as follows:

Distant answering tone received
Relay BC (in routiner) operates
Positive battery meter pulse detected
Relay MP operates; lamp indication
Relay R operates; MP relay releases
Received tone tested
Relay BC (in routiner) releases
Relay R releases
Routiner steps to next circuit

The test of the MOJ circuit does not continue if metering does not occur (stops on test 5—docket print).

ADVANTAGES

The modification thus increases the facilities of the existing trunk and junction routiner by

† South Wales District

enabling MOJ circuits to be tested sequentially and automatically at negligible extra costs. The trunk circuits can now be tested daily on a nightly routine under time control. The print-out provided enables maintenance staff to identify faulty circuits and rectify them before they affect the service to customers. Circuits can be tested for initial metering, and the transmission test and other functional tests provided by the routiner can be carried out. Tests can also be conducted during the day as necessary; for example, if the measurement and analysis centre or customer complaint identifies a suspect circuit, this can easily be investigated. The modification is compatible with all exchanges where MOJ signalling systems exist, for example, PCM, DC2 etc., and where trunk and junction routiners exist. Access to individual circuits can be obtained via the existing routiner test jack so that call sending can be carried out to check subsequent metering.

CONCLUSIONS

The modification has been introduced in several exchanges in the South Wales District and has significantly enhanced the reliability of trunk circuits. The capability of being able to carry out the routiner transmission test has proved invaluable. This simple modification can potentially bring greater efficiency by relieving staff of routine manual testing.

Further information about this modification can be obtained from South Wales District, EP14 (Tel: 0222 379635).

Biographies

Mr. Baker joined the then British Post Office (BPO) in 1947 after leaving the armed forces. He worked initially on overhead construction and then on subscribers' apparatus fitting and house exchange systems. He became a Technical Officer in a large non-director exchange, and then took charge of a large UAX14, subsequently changed to a TXK1, and two UAX13 exchanges. He is currently in charge of a large TXK1 unit at Blackwood, Gwent.

Mr. Reardon joined the BPO in 1965 as a TTA; after successfully completing his 3-year apprenticeship, he became a Technician 2A covering all aspects of customer apparatus and line maintenance. He was promoted to Technical Officer in 1971 and worked on apparatus switch maintenance at Newport GSC. He subsequently transferred to the new Newport crossbar GSC, which replaced the Strowger switch. He transferred to his current post at Blackwood TXK1 local exchange in 1981, where he works on exchange maintenance duties.

Transport and Telecommunications—Major Changes Under Way

Telecommunications which are related to transport are especially important, since they have until now been primarily concerned with safety; that is, with the protection of human life. More recently, however, a great many other potential applications have appeared, so that the telecommunication facilities in use with modern means of transport have been undergoing major changes. This article considers in turn the situation and prospects in the three main traditional fields of sea, land and air transport.

This article is based on a feature published by the Public Relations Division of the International Telecommunication Union in connection with TELECOM 87.

MARITIME COMMUNICATIONS

Present Situation

Maritime communications, which at the beginning of the twentieth century were operated with spark transmitters, have for some years been making use of some highly sophisticated transistorised radio equipment. Some ships now communicate through error-corrected automatic teleprinters or through satellites of the International Maritime Satellite Organization (INMARSAT) for computer-to-computer communications.

Most ships, however, still use relatively simple equipment and communicate in Morse. Ships of less than 1600 gross tons generally rely on telephony, using a VHF (150 MHz) FM system for short-range (about 30 miles) communications and a 2 MHz system for long-range distress calls (about 30–100 miles). It is also possible, optionally, to install equipment operating in the 3–30 MHz band for ship-to-coast commercial communications. Ships of over 1600 tons have to be equipped with a 500 kHz Morse code system for distress calls and commercial communications. They are also equipped with a VHF FM system and usually with a 2 MHz telephone distress system, which is compulsory in some countries. These ships are normally fitted with Morse/telephony HF equipment for their commercial communications.

Transition to Satellite Systems

Satellite telecommunication systems for ships made their appearance around 1970. The first system of the kind, MARISAT, which was introduced in the Atlantic region in 1976, was eventually extended world-wide. INMARSAT was set up in 1979 and leased the MARISAT satellites, which were being used by some 1000 ships, to launch the INMARSAT system. This now serves over 4000 ships, with a further 1000 being added each year. The installation of terminal stations on board ship and the use of the INMARSAT satellite system are entirely optional, since they are not necessary under any current international rules. The International Maritime Organization (IMO), however, with its new Future Global Maritime Distress and Safety System (FGMDSS), is now in favour of regulation.

The maritime world is now on the threshold of a new era with the change-over from simple Morse radiotelegraphy to satellite telecommunications (facsimile, teleprinters and computer-to-computer communications). Over the past ten years, shipowners have voluntarily devoted over $185M to equipping their ships with terminal stations, which shows how useful and necessary satellite telecommunications are for their activities. During the transition period, another type of communication system has been introduced as a step towards satellite telecommunications, consisting of a very sophisticated HF radioteleprinter system, known as *SITOR*, with incorporated error correction. For ships already carrying modern and very stable radio equipment, it is both very easy and advantageous to add a SITOR function, which will enable them to transmit more data in less time for less cost than Morse code and to exchange messages in conditions of poor propagation. All MF and HF radio systems, however, are limited by the effects of propagation, ionospheric disturbances and solar activity.

The change-over to satellite telecommunications was due mainly to an increasing need on the part of shipping companies for a more effective management control system, with a view to improving profitability. With the new system, it is possible to exchange not only the usual type of message, but also real-time information concerning staff, technical data, data concerning the state of supplies, fuel consumption, etc. Computers can be used in the chain of communications to cut down on staff. Instead of being an isolated and occasional unit of a company, a ship becomes an integrated part of the enterprise, able to establish contact with any station on earth practically at a moment's notice.

Prospects

The satellite terminal stations used on board ship are currently of the Standard-A type. These operate with a directional mobile antenna and related electronic devices for telephony and data transmission (teleprinters, facsimile, computer) at different bit rates. Over the next few years, the use of Standard-B and Standard-C terminal stations will be permitted, which should have the effect of improving the service.

The Standard-C type of station offers the best possibilities. This is a non-voice low-bit-rate terminal station, which uses a low-gain fixed antenna and limited inexpensive electronic equipment, the ideal solution for small fishing boats, pleasure craft, supply ships, etc. It would also be worth installing on larger ships to replace the current 500 kHz 'reserve transceiver', which is compulsory under the Safety of Life at Sea (SOLAS) Convention. This type of station does not require any antenna direction-finding mechanism and can operate on batteries. As it is used for immediate real-time communications, it will considerably improve the safety of maritime communications. It could also be used with equipment which has to be carried under the SOLAS Convention by powered rescue craft and may even be included eventually as part of compulsory portable equipment for survival. It could also be used for emergency communications on land, for instance during earthquakes, tornadoes, volcanic eruptions, whirlwinds, typhoons and other natural disasters, when normal telecommunications are either destroyed or out of action. It could be used as part of a land mobile satellite service, such as is now being developed to meet an increasing number of needs in the road transport industry with a view to increasing the speed and reliability of communications.

Another item of equipment which is evolving rapidly is the satellite emergency position-indicating radiobeacon (EPIRB), which was officially recognised at the 1979 World Administrative Radio Conference. Two systems are at present being tried out: one, known as *Cospar-Sarsat*, operates on two or three radio frequencies (121·5, 243 or 406 MHz). The other, known as the *L-band* system, operates on 1·5–1·6 GHz with INMARSAT satellites. These two systems could substantially improve maritime safety. Even though it may be preferable to have only one EPIRB satellite system, it is still by no means sure whether the international community will opt for such a solution, considering that no agreement has been reached on a common terrestrial maritime radiobeacon system for the last twenty years. There are still two such systems, operating on 121·5 MHz and 2182 kHz, both using telephony. It has been proposed, however, that only a single frequency (406 MHz) should be adopted for the present satellite EPIRB system instead of the frequencies 121·5, 243 and 406 MHz. The two present systems, which operate either on 121·5 and 243 MHz or on 406 MHz, are quite different and incompatible. It is still uncertain whether the aeronautical community will agree to using 406 MHz instead of 121·5 MHz. So far, there has been no clear sign of change.

The short-range 150 MHz VHF FM telecommunication system is widely used throughout the world and will definitely be included in the future system. If the number of channels allocated to maritime communications has to be substantially increased in the future, the present FM system will then probably have to be replaced by a single-sideband modulation system. In view of the economic effects of such a change, however, it could be introduced only gradually over a long period of time, and only if there is a definite requirement for more channels.

Computers are being increasingly used in the world and the maritime community is no exception. A growing number of shipping companies are expanding their coastal computing facilities to assist their ships at sea. Some companies offer shipowners a computerised telecommunication system and software for the management of personnel on board, supplies, technical data, finances, etc. This trend is likely to continue and will affect more and more ships as more young people enter the scene, since the latter will be familiar with computers and will use them as a very economic means of operating and managing maritime transport concerns.

These new telecommunication systems will continue to be integrated without difficulty in the land network thanks to the activities of the CCITT, and they will in fact merely be extending the present use of terrestrial data transmission systems (computer-to-computer and other).

Relations with the ITU and other International Organisations

International organisations such as the International Telecommunication Union (ITU) and the IMO have provided the driving force behind the changes described above. The various organs of the ITU—the International Radio Consultative Committee (CCIR), the CCITT and the International Frequency Registration Board (IFRB)—have played a leading role in the development of the new systems. Work on the maritime mobile satellites service first began in the IMO in 1966, at the first meeting of its Sub-Committee on Radiocommunications, and in the CCIR in 1969, at the Interim Meeting of its Study Group 4 (fixed satellite service). This work and subsequent follow-up activity led to the creation of the MARISAT satellite system in 1976 and the INMARSAT system in 1979.

The CCIR and the CCITT are still working to improve and complete mobile satellite communications in general and the three subservices (aeronautical, land and maritime) in particular.

It may finally be noted that the World Administrative Radio Conference for the Mobile Services (WARC-MOB-87) has prepared regulations for the Future Global Maritime Distress and Safety System (FGMDSS).

Future Global Maritime Distress and Safety System

Present System and the Need for Improvements

The present maritime distress and safety system, as defined in the International Convention for the Safety of Life at Sea, 1974 (the 1974 SOLAS Convention) is based on the requirements that certain classes of ships, when at sea, keep continuous radio watch on the international distress frequencies assigned in accordance with the ITU Radio Regulations and carry radio equipment capable of transmitting over a specified range. The master of any ship at sea should, on receiving a signal that a ship or aircraft or survival craft is in distress, proceed with all speed to the assistance of the persons in distress, informing them that he is doing so. Since the minimum specified range of communications provided by the required shipborne equipment is 100 to 150 nautical miles, assistance to a ship in distress could only be rendered by other shipping in the vicinity of an incident, which means that the present system is primarily intended for ship-to-ship operation. However, in accordance with the ITU Radio Regulations, coast stations open to public correspondence are required to maintain a continuous watch during their service hours on the distress frequencies.

The present system for ships under the 1974 SOLAS Convention includes two major manually operated subsystems:

(*a*) The Morse telegraphy system on 500 kHz for all cargo ships of 1600 tons and over, and all passenger ships. Since Morse competence is essential to the operation of this system, a Morse-qualified radio officer is required on all ships having a radiotelegraph installation.

(*b*) The radiotelephony system on 2182 kHz and 156·8 MHz for all cargo ships of 300 tons and over and all passenger ships, which provides common distress communications for all ships, subject to the 1974 SOLAS Convention.

It has proven difficult to make any significant progress in the communication arrangements for a ship in distress when it is beyond the range of medium-frequency coast stations, although various measures have been implemented to improve the situation.

Introduction of modern technology, including satellite and digital selective calling techniques, enables a distress alert to be transmitted and received automatically over long range and irrespective of meteorological and interference conditions.

Basic Concept of the Global System

The basic concept of the system is that search and rescue authorities ashore, as well as shipping in the immediate vicinity of the ship in distress, will be rapidly alerted to a distress incident so they can assist in a co-ordinated search-and-rescue operation with the minimum delay. The system will also provide for urgency and safety communications and the dissemination of marine safety information, including navigational and meteorological warnings. In other words, every ship will be able, irrespective of the area in which it operates, to perform those communication functions considered essential for the safety of the ship itself and of other ships operating in the same area.

Recognising that the different radio subsystems incorporated in the global system have individual limitations with respect to the geographical coverage and services provided, the equipment required to be carried by a ship will be determined in principle by the ship's area of operation, which has been designated as follows:

Area A1 within range of shore-based VHF coast stations (20–30 miles);
Area A2 within range of shore-based MF coast stations (excluding Al areas) (around 100 miles);
Area A3 within the coverage area of geostationary maritime telecommunication satellites (excluding Al and A2 areas) (approximately between 70°N and 70°S); and
Area A4 the remaining sea areas outside areas Al, A2 and A3.

In all areas of operation the continuous availability of alerting should be provided.

LAND COMNUNICATIONS

Introduction

In the early days of mobile radiocommunication, an organisation could easily obtain a private radio frequency for its mobile units and could therefore use simple radios working on a single frequency. With the growth in demand for radio channels, several different groups of users had to share each frequency. Then private systems for the sharing of several channels were established, which allowed the same series of frequencies to be used by different groups of users.

Until recently, public systems generally worked on the same sharing principle, the main difference compared with private systems being their connection to the switched telephone network. Now private systems are also connected to the switched telephone network, and these add a need for individual invoicing to the demand for selection and control of free channels and make the system more complex.

Because of their inherent simplicity and their particular availability, private systems have been favoured by organisations which are large enough to justify the necessary infrastructure outlay. This has led in general to the allocation of more frequencies to the private sector than to the public service. The recent advent of cellular public mobile systems, offering highly efficient use of the spectrum through carefully regulated reuse of frequencies, has given rise, however, to more balanced frequency allocation in the mobile services.

The rapid development of every form of mobile service has resulted in a need for more complex mobile equipment, which has been produced thanks to continuous technical progress still within an acceptable cost, size and power range, so long as the quantity of items manufactured is sufficiently large. Thanks to recent technical breakthroughs, a lot of sophisticated equipment of great interest to the mobile user is now available in portable form.

Land Mobile Equipment

Future land mobile systems will offer a wide range of new services. The equipment required should provide a cheap, reliable and easy-to-use interface between subscribers and the new services.

Land Mobile Services

The mobile communications market and technology have now reached a stage where they can provide many new and very elaborate user services. From the subscriber's point of view, demand for these services will depend on their application:

(*a*) *Public Safety* The police, fire brigade and health services require secure and very reliable mobile communications for the dispatch and support of emergency units.

(*b*) *Public Services* The electricity, gas and fuel services have two main applications: the dispatch and support of service personnel, and remote reading of electricity, gas and fuel meters.

(*c*) *On-Site Maintenance* Maintenance organisations have to send out technicians and require remote access to technical information.

(*d*) *Commercial Transport* Taxi, mail and freight companies require mobile communications, especially for dispatching.

(*e*) *Businesses* Managers and specialists alike need mobile communications in order to work while on the move; small businesses have to dispatch small fleets of vehicles.

(*f*) *Consumers* Consumers, who probably constitute the largest group of potential users, require mobile services for personal communications and for access to public information systems.

The requirements of these six categories of users cover the whole range of the future mobile services. While the consumer sector will be very well served by a public system providing easy low-cost access, the public security sector will need a high-performance private-access service, which will inevitably be more costly. A single mobile system could cover all these services, so long as its mode of operation was transparent to the user. Although a small taxi firm, for instance, should be able to use the same dispatch service as a public service, it will probably subscribe to an inferior quality service on the grounds that its requirements are less stringent. The system would allocate resources to services in accordance with their order of priority.

Analogue telephone transmission is the most widely used service at present. Future systems will also provide digital data services, since data have proved much more reliable and efficient than vocal messages for many land mobile services. In many applications, mobile data could replace the traditional telephone service; voice transmission would become superfluous except, where necessary, as a back-up.

Users requiring mixed voice and data services will look for the same level of cost-effectiveness as that provided by each service separately. A mixture of digital data and analogue voice transmissions, however, usually results in poorer performance, so that digital voice transmission is to be preferred. When the system becomes completely digital, its complexity and hence its cost will diminish.

The main mobile data services will be message systems, on-line data transfer, dispatch, automatic vehicle tracing, videotext, automatic vehicle tracking on a mobile map, the accessing of private databases and access to the public network. Many services, such as videotext, are not acceptable to certain users unless their cost is sufficiently low. Thanks to technical progress in land mobile systems, more sophisticated services will gradually be offered at more accessible prices.

Description of Mobile Equipment

Land mobile equipment should always be small, light, low-powered and unaffected by dust and vibration, which are inherent in a mobile environment. Mobile equipment is moving towards enhanced performance at reasonable cost in order to ensure easy access to the many new mobile services.

In the telephone service alone, improvements in mobile equipment have included a reduction in the size, power consumption and weight of miniature units and the addition of user facilities such as automatic dialling, voice recognition and speech synthesis. The most important improvement in the telephone service itself—digital voice transmission—will be user-transparent. For applications requiring both voice and data, the two services will be combined: one interesting solution is a telephone set with keyboard screen.

All mobile data services will require a mobile data terminal, a digital modem and a transceiver. The data terminal must have sufficient processing power and memory to accommodate the necessary functions for a number of new services. There will generally be a keyboard and a screen, and perhaps one or more peripherals, such as a printer, a reading pen or a large-capacity memory.

The digital modem and the transceiver will provide different data flow rates in the waveband available. Rates of 4800 bit/s are already in use and rates of 16 000 bit/s should soon be available in 25–30 kHz bandwidths. The digital modem and the transceiver will often be incorporated in the mobile data terminal, especially when the equipment is portable.

The technology developed for the portable computer market has now begun to supply compact low-power robust components for mobile data terminals, including printers, large-capacity disc memories, large-size flat screens, sophisticated microprocessors and high-density transistorised memories. Low-power very-large-scale integration will be extremely useful in the miniaturisation of complex electronic equipment for transceivers, digital modems and error correction systems. Thanks to progress in this field, not only vehicles will be able to accommodate the new mobile services, but many of these services will be available on portable miniature equipment.

Ease of use and reliability of the user interface will be the key to acceptance of land mobile services. People are naturally reluctant to learn new procedures and are quickly discouraged by difficulty in mastering equipment. The user interface and its interaction with the system must be transparent and easy to use. One ergonomic aspect of mobile equipment, which not only facilitates use but also contributes to the safety of the driver of a moving vehicle, is the possibility of non-manual operation.

Some of the new services will need special equipment. In the most viable designs, mobile equipment will be specially adapted to the needs of individual groups of users. These users cannot be expected to pay for equipment providing functions they do not require. The market for land mobile equipment can accommodate a great variety of products, each designed for a specific application.

Conclusion

The challenge confronting mobile systems designers in the future will be that of conveying the idea of ISDN to the mobile user. The differences between public and private systems are already being eroded, a tendency which should be reinforced by the integration services which use frequencies very efficiently.

Some standardisation based on the use of large-scale integration is required if these increasingly complex but efficient systems are to be made available at accessible prices. Standardisation should also encourage the international use of mobile services, which would further increase the cost effectiveness and attractiveness of the services provided.

At the end of CCIR study period 1982–1986, an interim working party (IWP 8/13) was established to ascertain the future requirements of public land mobile telecommunication services. So far, 24 administrations, as well as the International Electrotechnical Commission (IEC) and the European Space Agency (ESA), have been participating in this work.

At its first meeting in May–June 1986, IWP 8/13 decided to extend its work on the development of the current, essentially vehicle-based cellular mobile systems to 'personal' communication systems of the future. The spectrum requirements of these personal systems are also being studied. The aim is to increase the compatibility of the new services being developed in different countries, with the possibility eventually of establishing a global public mobile system.

AERONAUTICAL COMMUNICATIONS

Introduction

The aviation sector (air traffic services and airlines) developed an active interest in the applications of aeronautical satellite services in the early-1960s. A series of experiments and trials showed the full potential of such services, which could perform many functions in:

- air traffic control,
- airline operation control,
- commercial company management, and
- passenger services.

The main reason for the initial reticence of air space users was the lack of economic justification for such services, which were seen as considerably more expensive than the methods of communication then in use, as well as the apparent absence of economic incentives to incur the necessary investment and consequent operational expenditure.

Historical Background

Some airlines had experimented with early satellites, but it was not until the launching of the ATS generation of satellites by the United States National Aeronautics and Space Administration (NASA) that the aviation industry co-ordinated this type of activity on a large scale for the first time.

Shortly after that, the International Civil Aviation Authority (ICAO) set up a group of technical experts, aptly christened *ASTRA* (application of space technology relating to aviation) to study the potential uses of satellites and to plan the application of space technology to civil aviation.

Although first the ASTRA group worked well, it later lost sight of the economic consequences of its ambitious plans for aviation.

The period was marked by the rise and fall of the Aerosat project. A phoenix rose from the ashes of Aerosat, however, in the form of the Aviation Requirement Committee (ARC), which was purely administrative in nature. A wide-ranging study entitled *Oasis*, financed by the United States Federal Aviation Administration (FAA) and conducted by Stanford Research Inc., produced a report which prompted the ICAO Council to set up the Future Air Navigation System (FANS) committee.

A proposal in the ARG/Oasis report for the use of 'opportunity' satellites elicited a response from the International Maritime Satellite Organization (INMARSAT), in the form of studies and work in collaboration with industry and consumers, leading to the first serious examination of the technical, economic and operational aspects of world services for aviation as a whole covering a wide range of functional requirements.

With hindsight, it is easy to see why a high-technology activity such as civil aviation was not immediately attracted by the use of satellite services. At the time of the ASTRA group, and even later in the early days of the FANS group, the advertising concern was air navigation safety. Every discussion about satellites led to nothing, as there appeared to be no immediate economic benefits to compensate for the very high level of investment in equipment and the considerable running costs required to equip every airline and airport, a task which would in any case take a very long time to complete.

A radical reconsideration of the situation overcame the paradox. When British Airways announced the opening of a public telephone service in three of its aircraft, airlines began a rapid revision of their plans. The commercial incentive of competition between airlines and the income produced by the new telephone service overcame the obstacle of a nil financial return. Competition between airlines ensured that all the major companies vied to offer an equivalent service to their passengers and resulted in a rush to install telephones on board; this removed one more impediment to clearing the financial obstacle of satellite communications.

This recent change in attitude on the part of the air transport sector has led to a burst of new activities. Instead of opposing the project, the sector has become a driving force for the establishment of an aeronautical satellite telecommunication system.

Requirements of the Aviation Users Industry

There would seem to be at least four main classes of communication traffic, each containing separate subdivisions, as follows:

(*a*) *Air Traffic Control* communications concerning safety and involving direct links between pilots or aircraft and air traffic controllers in the form of exchange of verbal messages or data, including supervision control. Traffic information services (weather reports, systems status, traffic, etc.) and all services concerning navigational information may be regarded as subcategories of air traffic control.

(*b*) *Aircraft Operational Control* by means of which an airline can supervise its aircraft wherever they may be. This service, too, involves the transmission of voice and data; it offers secure and rapid service, and economical use of very expensive equipment.

(*c*) *Commercial Messages of Aircraft Operators* all airlines need routine commercial communications not involving safety as defined in ITU and ICAO regulations, in accordance with the annexes of the Chicago Convention on civil aviation. Such messages concern seat reservations, ticket sales, passenger information, etc.

(*d*) *Public Correspondence* services offered by the airline to enable its clients (passengers, etc.) to gain access to public telephone and data networks throughout the world from any location. This service includes access by telephone, Telex and even computer to information systems or databases on the ground.

Other services may be offered in future, such as in-flight shopping, special services for technical groups, video transmission and the reception of broadcasting, as discussed at WARC-MOB-87.

Now that the various kinds of communication have been described, a word may be said about quality of service and interfaces with other communication networks. Air traffic safety services require circuits which are highly reliable, whatever their nature. Within reason, they should be available constantly and immediately to priority traffic. They should also be on hand literally everywhere in the world, even for transpolar flights also, an aspect of future development which may call for integrated synchronous orbiting satellite systems.

Although the commercial services of airlines do not have priority, users should be able to count on reliable uninterrupted service, even when the 'system' is recovering from partial breakdown.

While they do not have the same priority as air safety, public correspondence services should be able to operate regularly. An exception could be allowed in the case of reduced service, giving priority to air traffic safety communications.

Aircraft 'avionic systems' are now tending increasingly to use digital technology, a trend which also applies to air traffic service installations and large public switched networks. This is why, despite stringent bandwidth limitations, the development of agreed norms and recommended practices for international aeronautical satellite telecommunications is concerned almost exclusively with signalling, protocols and digital applications.

With the introduction of a variety of services for aviation companies, the question of 'standardisation' has been raised by several institutions, while safety services for international civil aviation are dealt with by the ICAO.

CCITT norms for access to telephone and public switched data networks often differ from those of the ICAO. Furthermore, all civil aviation authorities in the world rely for the establishment of airborne equipment approval standards on two organisations which work alongside each other, the Radio Technical Commission on Aeronautics (RTCA) in the United States and the European Organization for Civil Aviation Electronic Equipment (EUROCAE) in Europe. Almost all airlines comply with the aircraft equipment and installation standards defined by the Airlines Electronic Engineering Committee (AEEC), which formulates specifications for avionics and on-board equipment respected by most manufacturers of aircraft and avionic systems. This standardisation has led to a virtually open avionics market for aircraft operators.

Thus, in aeronautical satellite telecommunications, there is considerable pressure on systems, equipment and operations to conform to a variety of international standards. This is no easy task, and it is only one aspect of the institutional and legal problem that confronts an industry which until now has shown great cohesion.

Systems and Equipment Today

Perhaps the most formidable technical problem, given the constraints of signalling in space at the two ends of the propagation path between aircraft and satellite, is producing an aircraft antenna which can provide sufficient system gain and coverage volume without an excessive direct current power requirement from satellite to aircraft.

After the considerable amount of research on this subject in the aviation sector since the days of the ASTRA Group, and several specially commissioned studies, INMARSAT has initiated a number of purchasing programmes for different types and makes of aircraft antenna and avionics equipment; while INMARSAT member States now have a standard for the related coast earth station and network, all these elements being compatible with the systems definition handbook published recently by INMARSAT, which should be ready for issue in 1987/88. INMARSAT recently amended its international Convention so that it could offer aeronautical services to the aviation industry. Ideally, second-generation INMARSAT satellites will carry repeaters which will cover not only the spectrum allocated by the ITU to the maritime service, but also part of the waveband allocated to the aeronautical mobile service.

Alongside the full global INMARSAT system operating with the satellites now in orbit over the Atlantic, Pacific and Indian Oceans, another service has appeared, offered by a new organisation known as the Aviation Satellite Corporation (AvSat).

Although AvSat services are still at the planning stage (they have no equipment, no network of coast earth stations and no satellite), their potential strength resides in the fact that they are derived from a long-standing airline communication service operated by Aeronautical Radio, Inc. (ARINC).

Conclusions

A full series of tests and demonstrations of aeronautical (digital) telephone and data telecommunications based on INMARSAT satellite/ground stations and network is planned for 1987/88. These operations are expected for sure to lead at least to the adoption of provisional international telecommunication standards, particularly the CCITT.

Despite many fruitless attempts, several false starts and the prodigious expenditure of effort, time and money involved, there now seems no doubt that aeronautical satellite telecommunications have come to stay.

British Telecom Press Notices

IBM-Compatible Data Services

Users of IBM and IBM-compatible equipment can now communicate over BT's public data network. This will enable users to adapt and expand their networks to meet changing business needs without investment in new hardware or departing from established protocols. The new services, known as *MultiStream BPAD* and *SPAD*, are now commercially available after extensive trials.

This development marks the successful completion of customer trials of these MultiStream synchronous services. They support IBM communication protocols and are an important facility available from the public data network. Several organisations have already benefited from using the network in this way for a wide variety of data transfer applications, and now any business can use these services.

MultiStream SPAD offers support for SDLC/SNA communications; it provides connection through the public data network, which is transparent to SNA communications, and enables maximum communications efficiency.

MultiStream BPAD is for BSC data communications; this MultiStream service enables 3270 terminals to connect independently and simultaneously to multiple hosts and applications.

Among the applications for SPAD and BPAD are the transmission of database information, interactive financial transactions, electronic mail, manufacturing and distribution control, and inter-company communications. Both services offer accurate and error-free communication. They provide complete data integrity and ensure that the information sent arrives safely and securely at its appointed destination.

As well as offering a networking service, MultiStream SPAD and BPAD provide full back-up support including 24-hour real-time network management. A special MultiStream synchronous service support desk has been set up to deal with technical and installation questions. Further enhancements are being considered for later introduction.

Business Centres Mark New Customer Policy

The first of a new generation of business centres, specifically for commercial customers, was opened by BT on 12 October last year in Milton Keynes. Together with around 30 others, it will offer advice and 'one stop shopping' for the whole range of 4000 products and services provided by BT.

At the launch, Mr. Mike Bett, Managing Director of BT's UK Communications Division, said: 'These new centres have one aim, to provide a coherent and improved service for all levels of business customers.

'With such an enormous range of products and services we decided to take a radically new approach. We are doing this by providing the level of knowledge and expertise in these centres to help our customers make the right decisions about the products and services to meet their existing and future needs.

'Our business is communications and we are leaders in the field. We intend to maintain this position and the best way to achieve this is by helping customers to identify their needs and then responding to them precisely. We intend to ease the product selection process and make our comprehensive range more accessible.'

The new centre at Milton Keynes has the latest communications technology on show, all connected to the appropriate networks and ready for live 'hands-on' demonstration. By providing the environment where customers can try out equipment for themselves, BT hopes to make its business customers more aware of how integrated products and services can provide real solutions to business needs.

The centre is connected to the digital network to allow the demonstration of advanced facilities like star services and integrated digital access (IDA). Unlike BT's retail outlets, the new centres will not be open to the general public on a casual walk-in basis. Instead, by inviting customers and knowing their needs in advance, BT can provide a specialist team to discuss particular communications problems and offer expert guidance and advice in total privacy. This confidentiality, together with in-depth planning and management assistance, is just part of a new service which will include seminars, demonstrations and exhibitions to smaller customers who have a shared interest.

BT Invention Licensed for Commercial Production

A precision machine invented at British Telecom Research Laboratories for everyday use in breaking optical fibre cleanly and squarely is now to be made commercially in Britain for sale around the world. The machine will be manufactured and marketed by K. W. Kirk and Sons, of Milton, Cambridgeshire, under a license agreement with BT.

Optical fibres are joined by butting their ends together and then fusing them electrically or by mechanically splicing them. The ends must be as near as possible optically flat and square to the fibre to ensure maximum transfer of light across the join. Such flat square ends are produced by breaking the fibre in a special machine known as a *cleaver*.

BT's optical-fibre cleaver, developed at its Martlesham laboratories, consistently provides squarely cleaved faces on the fibre to an accuracy better than half a degree. The machine is designed to be used by technicians at the roadside during normal optical-fibre cable installation.

The optical-fibre cleaver formed part of BT's portfolio of technology offered for licensing at the Techmart exhibition during 1986. Core Consultancy Group, a firm of technology and business consultants, identified the cleaver as being suitable for addition to the range of precision engineered products made by its clients, K. W. Kirk and Sons. Core's market research indicated that the use of optical fibres in communications is growing at an annual rate of 22% and that demand for a precision, easy-to-use and cost-effective cleaver is set to rise considerably in the next few years.

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(Founded as the Institution of Post Office Electrical Engineers in 1906)

General Secretary: Mr. J. H. Inchley, NPW2.3.2, Room 543, Williams National House, 11–13 Holborn Viaduct, London EC1A 2AT; Telephone: 01–356 9020.
(Membership and other enquiries should be directed to the appropriate Local-Centre Secretary as listed.)

IBTE CENTRAL LIBRARY

The books listed below have been added to the IBTE Library. Copies of the 1982 edition of the library catalogue are available from the Librarian, IBTE, Room GJ, 2–12 Gresham Street, London EC2V 7AG. An abbreviated catalogue was included in the October 1987 issue of the *Journal*. Library requisition forms are available from the Librarian, from Local-Centre and Associate Section Centre Secretaries and representatives. The forms should be sent to the Librarian. A self-addressed label must be enclosed.

Alternatively, the IBTE Library is open on Wednesday mornings between 11.00 and 13.30. Members are advised to telephone the Librarian (01–928 8686 Extn. 2233) to confirm their visit. Members wishing to reserve books or check availability should contact the Library during opening times on 01–356 7919.

The Library is open to Full, Associate Section and retired Members of the IBTE.

5450 *Digital Interfacing with an Analogue World.* (2nd edition.) J. J. Carr.

This book shows how microcomputers can be used for a variety of applications. It explains how to convert energy produced by pressure, force, position, temperature and other sources into an electrical voltage or current that a microcomputer can deal with. Information is given on all types of transducers, operational amplifiers, digital codes, as well as analogue-to-digital and digital-to-analogue converters. Invaluable information is also included on analogue and digital multiplexing, read-out and display devices and much more. Details of microcomputer and small computer interfacing is featured with an emphasis on such low-cost computers as the Apple II and Commodore 64.

5451 *The Invisible Universe Revealed—The Story of Radio Astronomy.* G. L. Verschuur.

Radio astronomy burst into full flower within a generation. Amazing discoveries came yearly: the microwave remnant of the Big Bang, celestial masers, quasars, pulsars and 'jet-sets'. The author was involved in the field during those times and his book captures all the excitement of that era. The incredible imaging power of modern radio telescopes, when combined into arrays and computer correlated, has produced pictures every bit as aesthetically striking and scientifically significant as their optical counterparts. The book presents a glimpse of a vibrant, dynamic and chaotic universe.

5452 *What Every Engineer Should Know About Lasers.* D. C. Winburn.

This valuable reference describes how a laser works, the types of lasers available, basic information for evaluating laser beams, and a wide variety of applications currently used in numerous industries as well as in science and research. It reviews the fundamental physics of laser beams, describes how coherent beams are generated, identifies in detail laser beam hazards plus methods of controlling them and presents marketing forecasts through the 1990s. Illustrated with diagrams and photographs, this volume is an important reference for engineers and technicians in any engineering discipline.

5453 *A History of Linear Electric Motors.* E. R. Laithwaite.

Within the industrial world of electric motors, the linear motor occupies only a small part. It is therefore possible to write a complete history of the subject without leaving huge gaps. The reader need not be an expert in induction motor theory, nor in business methods, in order to appreciate the sequence of events that led from small beginnings to a whole new industry, with much of the development occurring during the past two decades.

5454 *Repair, Protection and Waterproofing of Concrete Structures.* P. H. Perkins.

The objective of this book is to bring together up-to-date information on the causes of deterioration in reinforced concrete structures and the latest methods of investigation, diagnosis and repair. The book covers reinforced concrete buildings, water-retaining and water-excluding structures. The ten chapters also include chapters on deterioration and renovation of concrete floors, repair and waterproofing of concrete roofs, and failure and remedial work to external wall tiling and mosaic. Chemical attack on Portland cement concrete is discussed in detail and the problems of alkali silica reaction are summarised.

The Library Committee thanks Mr. M. D. Bexon for donating the following books to the IBTE Library:

Microwaves by A. J. Baden-Fuller.
Practice of Electrical Engineering by Gray Wallace.
Telecommunications by W. Fraser.
Communication System Analysis by P. B. Johns and T. R. Rowbotham.
Servomechanisms by L. A. Stockdale.
Transistor Switching and Sequential Circuits by John J. Sparkes.
High Frequency Communications by J. A. Betts.
Communication Systems—An Introduction to Signals and Noise in Electrical Communication by Carlson.
Switching Circuits for Engineers by Mitchell P. Marcus.
Electrical Power Systems by B. M. Weedy.

IBTE LOCAL-CENTRE PROGRAMMES, 1988

Unless otherwise stated, members must obtain prior permission from the Local-Centre Secretary to bring guests.

Aberdeen Centre

9 February 1988:

The Operation and Control of Digital Exchanges by K. Richardson, UK Communications. Meeting will be held in New Telecom House, Aberdeen, commencing at 14.00 hours.

9 March 1988:

Active Control Technology—Fly-by-Wire by T. D. Smith, Senior Flight Test Engineer, British Aerospace. Time and venue to be advised.

Bletchley Centre

17 February 1988:

Centrex by Business Exchange Services, UK Communications. Meeting will be held at Bletchley Park, commencing at 14.15 hours.

16 March 1988:

Professor Bryan Carsberg, Director General, Office of Telecommunications. Meeting will be held at the Moathouse, Bedford.

13 April 1988:

Telecoms Networks (some possible developments over the next decade) by Dr. D. M. Leakey, Chief Scientist, British Telecom. Meeting will be held at Cambridge University Centre, Granta Place, Mill Lane, Cambridge, commencing at 14.00 hours.

Central Midlands Centre

Meetings will be held in Room UG35, Ground Floor, Berkley House, 245 Broad Street, Birmingham.

2 February 1988:

CEGB National Grid and Nuclear Reactors by G. Golding, CEGB, Solihull, Birmingham. Joint meeting with Birmingham/Coventry Associate Section. Meeting will commence at 19.00 hours with buffet from 18.00 hours.

10 March 1988:

System X Future Developments by J. Dawson, Plessey Communications, Nottingham. Meeting commences at 14.00 hours.

14 April 1988:

Independent Broadcasting Authority—Direct Broadcasting Satellite by B. Randall, Information Services, IBA, Winchester. Meeting commences at 14.00 hours.

East Anglia Centre

10 February 1988:

The Regulation of Telecommunications by Professor Bryan V. Carsberg, Director General of Telecommunications, Office of Telecommunications. Meeting will be held in the Council Chamber, The Guildhall, Cambridge, commencing at 14.00 hours.

16 March 1988:

Towards Zero Defects by K. Freeman, Quality Programme Manager, IBM. Meeting will be held in The Music Room, Assembly House, Norwich, commencing at 14.00 hours.

13 April 1988:

Lecture by Dr. D. M. Leakey, Chief Scientist, British Telecom. Joint meeting with Bletchley Centre.

11 May 1988:

Computer Graphics by F. G. Cole, Head of Computer Graphics, BT Scotland West. Meeting will be held in LTB5, University of Essex, commencing at 14.00 hours.

15 June 1988:

The Technology of Weather Forecasting by Alan Brown, Birmingham Airport Meteorology Office. Meeting will be held in LTB5, University of Essex, commencing at 14.00 hours.

13 July 1988:

BT and Information Technology, A Strategy for the Future by David Green, Technical Products Manager, Systems Development and Architecture, British Telecom. Meeting will be held in the Council Chamber, The Guildhall, Cambridge, commencing at 14.00 hours.

East Midlands Centre

17 February 1988:

Easily the Meanest District—True or False by R. Bateson, EMD Manager. Meeting will be held at Leicester University, commencing at 14.00 hours.

27 April 1988:

Optical Character Recognition by R. Powell, Post Office Research. Meeting will be held at Nottingham University, commencing at 14.00 hours.

East of Scotland Centre

10 February 1988 (Dundee);
24 February 1988 (Edinburgh):

The Operation and Control of Digital Exchanges by K. Richardson, UK Communications.

9 March 1988:

Active Control Technology—Fly-by-Wire by T. D. Smith, Senior Flight Test Engineer, British Aerospace. Time and venue to be advised.

Lancs and Cumbria Centre

Meetings will be held in Lecture Theatre H155, Lancashire Polytechnic, Corporation Street, Preston, commencing at 14.00 hours.

24 February 1988:

The Mercury Network by D. Bamford, Divisional Manager Switching, Mercury Communications Ltd.

30 March 1988:
Possible Trends in the Telecommunications Network over the Next Decade, by Dr. D. M. Leakey, Chief Scientist, British Telecom.

Liverpool Centre

Except where stated otherwise, meetings will be held in the Liverpool Museum, William Brown Street, Liverpool, commencing at 14.00 hours.

18 February 1988:

Direct Broadcasting by Satellite by Mr. A. J. Harwood, Principle Engineering Information Officer, IBA.

17 March 1988:

Vanderhoff Remote Line Testing by Mr. I. F. Blake, Operational Systems, UK Communications.

21 April 1988:

British Telecommunications, The Next Decade by Dr. D. M. Leakey, Chief Scientist, British Telecom. Meeting will be held in the Royal Insurance Lecture Theatre, New Hall Place, Liverpool.

London Centre

Associate Section members and the guests of members are welcome to attend meetings. Meetings commence at 17.00 hours, with buffet at 16.30 hours.

1 February 1988:

Britain and the Sea by the Royal Navy Presentation Team, led by Commander Richard Moore. Meeting will be held at The Institution of Electrical Engineers, Savoy Place, London WC2.

22 March 1988:

High-Speed Letter Sorting by R. Vick and K. Willy, Research Engineers at The Post Office Research Centre, Swindon. Meeting will be held at The Assembly Rooms, 2nd Floor, Fleet Building, 40 Shoe Lane, London EC4 (Shoe Lane entrance—passcards required).

10 May 1988:

Power and Building Service Management Systems by P. Allen, Manager Power and Building Services. Meeting will be held at The Assembly Rooms, 2nd Floor, Fleet Building, 40 Shoe Lane, London EC4 (Shoe Lane entrance—passcards required).

Manchester Centre

Except where otherwise stated, meetings will be held in Room D7, Renold Building, UMIST, Manchester.

17 February 1988:

Electronic Fund Transfer at Point of Sale by A. Kerrison, BT Data Networks.

9 March 1988:

Managing a District by E. Jackson, District General Manager, Manchester District.

21 April 1988:

Telecommunications—The Next Decade of Change by Dr. D. M. Leakey, BT Chief Scientist. Meeting will be held in the Royal Insurance Lecture Theatre, New Hall Place, Liverpool.

18 May 1988:

Parcel Sorting Machines by C. McMillan, Post Office Research.

Martlesham Heath

Meetings will be held in the John Bray Lecture Theatre at British Telecom Research Laboratories, commencing at 16.00 hours.

17 February 1988:

Meganetworks and Teracomputers (the future of large computers and access to them) by Professor R. Rossner, University of London.

3 March 1988:

BT & D: Light Engineering Returns to Ipswich by Dr. J. Speight, BT & D.

29 March 1988:

Design: Three short papers by staff from British Telecom Research Laboratories.

North and West Midlands Centre

16 February 1988:

Future Alternative Energy Sources by G. Peers, Production Manager, Ironbridge Power Station. Meeting will be held in Video Room 1, Central Building, BTTC, Stone, commencing at 13.45 hours.

14 March 1988:

An address by J. Tippler, Director Networks, UK Communications. Meeting will be held in the Staff Lounge, BTTC, Stone; time to be advised.

North East Centre

9 February 1988:

Railway Electrification by J. Morris, British Rail Engineering. Meeting will be held in Neville Hall, Newcastle, commencing at 14.00 hours.

29 March 1988:

Quality in Engineering by A. Stevens, General Manager, North East District. Meeting will be held at Teesside Polytechnic, commencing at 14.00 hours.

April/May (date to be announced):

Team Valley Warehouse by A. Sarginson, District Materials Manager. Meeting will be held at Team Valley Industrial Estate.

North Wales and the Marches Centre

9 February 1988:

Whatever Happened to the Candlestick? by Dr. I. S. Groves, Head of Consumer Products Division, British Telecom Technology Applications Department. Meeting will be held at Whittington House, Oswestry, commencing at 14.00 hours.

8 March 1988:

The Future of the Local Exchange Network by K. E. Ward, Chief Engineer, Network Planning and Works, UK Communications. Meeting will be held at the Beauchamp Hotel, Shrewsbury, commencing at 14.00 hours.

Northern Ireland Centre

Meetings will be held in the YMCA Minor Hall, Wellington Place, Belfast, commencing at 15.30 hours.

10 February 1988:

Derived Services Network by N. Jefferies, Systems Engineering Planning, UK Communications.

9 March 1988:

Tommorow's External Plant by D. Clow, Local Line Services, UK Communications.

13 April 1988:

High Definition Television by H. Price, Head of Information Department, BBC, London.

Severnside Centre

Meetings will be held in Nova House, Bristol, commencing at 14.15 hours.

3 February 1988:

Operation and Control of Digital Exchanges by K. Richardson, UK Communications.

2 March 1988:

Accountants and Accounts—Do Engineers Need Them? by J. D. Haberfield, Finance Manager, South Downs District.

Solent Centre

Unless otherwise stated, meetings will be held in the 7th floor coffee lounge, Solent District Office, commencing at 18.30 hours; refreshments from 18.00 hours.

23 February 1988:

Faraday Lecture: *The Intelligent Car* by The Ford Motor Company. Meeting will be held at The Mayflower Theatre, Southampton, commencing at 14.00 hours. Tickets from G. Nunes, Local-Centre Secretary.

25 February 1988:

Cellular Radio by D. Wordly, Director, Market and Product Development Group, British Telecom. (Previously scheduled 19 November 1987.)

24 March 1988:

Network Modernisation by K. E. Ward, Chief Engineer, Network Planning and Works, UK Communications.

28 April 1988:

Visit to Pirelli cable plant.

26 May 1988:

LinkLine/Centrex by J. Brown, Product Development Manager, Centrex/VFN.

South Downs Centre

Meetings will be held in the Lecture Theatre, Central Library, Worthing, commencing at 12.00 hours.

16 February 1988:

The Changing Role of the Engineer in BT by J. W. Young, Territory Engineer, Central Territory, BT.

15 March 1988:

To be announced.

Thameswey Centre

Meetings will be held in the BT Business Centre, Reading, commencing at 12.30 hours.

9 February 1988:

Fibre Optic Cabling—Cost Reduction by Sub-Duct Techniques by L. Webb, Wedge International.

23 March 1988:

The Major Customer Service Centre by Business Customer Support Group.

26 April 1988:

CSS—Fundamental Principles by K. Smith, Information Services Manager, Thameswey District.

West of Scotland Centre

25 February 1988:

The Operation and Control of Digital Exchanges by K. Richardson, UK Communications. Meeting will be held in the Mitchell Library, North Street, Glasgow, commencing at 14.00 hours.

9 March 1988:

Active Control Technology—Fly-by-Wire by T. D. Smith, Senior Flight Test Engineer, British Aerospace. Time and venue to be advised.

30 March 1988:

Stock Exchange Communications. Time and venue to be advised.

Westward Centre

17 February 1988:

The Future of the Local Network by K. Ward, Chief Engineer, Network Planning and Works, UK Communications.

17 March 1988:

The Future of the Socket on the Wall—I.420 Interface and Beyond. by M. J. De Lapeyre.

Yorkshire and Lincolnshire Centre

23 March 1988:

Providing Communications for Leeds University into the Next Century by B. Greenwood, J. Wiseman, and R. Drane, MYD Business Systems Division. Meeting will be held at the Rupert Beckett Theatre, University of Leeds, commencing at 13.45 hours.

12 April 1988:

Network Management by N. Milway, Head of Network Administration and Management Systems Division. Meeting will be held in the Library Theatre, Bradford, commencing at 13.45 hours.

IBTE ANNUAL GENERAL MEETING

Tuesday, 10 May 1988 at 4.30 p.m.

(refreshments 4.00 p.m.)

Fleet Building, 40 Shoe Lane, London EC4

Institution of British Telecommunications Engineers

Associate Section National Committee

NEW ASSOCIATE SECTION PRESIDENT

The Associate Section's new President is Alan Bealby, General Manager Network Operations Support. After graduating from Edinburgh University in Electrical Engineering, and then working for 15 months in Sri Lanka, Alan joined BT in 1969 as an Executive Engineer. He became a member of a team which examined the feasibility and subsequent implementation of trunk and junction plant computerised planning and provisioning. He then moved to Exchange Planning, where he undertook a variety of duties including computer-aided provisioning and design, and switching economics.

On the formation of the System X Launch Department in 1980, he was closely involved with System X planning and the launch of the early System X local exchanges. Prior to his current appointment, he headed the Local Digital Exchange Operational Support Division which formulated the guidance and has given support to Districts to allow the roll-out of the digital exchange programme.

Alan is married with two daughters and two sons; his leisure activities include sports and outdoor pursuits and he enjoys music and gardening.

ASSOCIATE SECTION

In the recent past, the Associate Section has had much success in achieving its aims of furthering telecommunication engineering and allied subjects by keeping its membership up-to-date with the rapidly advancing technical developments both in BT and the Post Office. It will be apparent that these changes are affecting all domains of the business and there is a need for us all to have a good appreciation of the technical changes around us as each part becomes more specialised as the company enters new fields of high technology.

We are members of a company-sponsored professional body that organises and runs itself within approved guidelines, which give a great deal of flexibility in the organisation and planning of technical events by local centres. To this end, a closer co-operation with the Senior Section in the joint production of some lectures and visits would maximise the effort and allow resources for new ventures.

Within the Associate Section exists an enormous resevoir of experience and technical expertise which needs greater stimulation in order to bring forth the new ideas and developments for the future.

Membership is open to all engineering grades below M & PS, or as determined locally, and resourses are made available for the running of Associate Section centres and their programmes. The National Committee oversees the framework of organisation and resource availability for centres and will assist in the solution of problems that cannot be resolved with the assistance of the District Liaison Officer locally. (See Oct. 1987 issue of the *Journal*, p. 211.)

It is up to all current members to be involved in local centre activities and bring this unique organisation to the attention of their non-member colleagues, so that full advantage may be taken of the opportunities offered by membership of the Associate Section.

C. J. WEBB
National Chairman

CONTRIBUTIONS TO THE JOURNAL

Contributions of articles and items of engineering or educational interest for *British Telecommunications Engineering* are welcome from Associate Section members. Members who feel that they would like to contribute an item is invited to contact the editors at the following address: *British Telecommunications Engineering*, Room 107, Intel House, 24 Southwark Bridge Road, London SE1 9HJ. (Telephone: 01–928 8686 Ext. 2233.)

ASSOCIATE SECTION NATIONAL EXECUTIVE COMMITTEE

The following is a list of the national officers to whom enquiries concerning the Associate Section should be addressed.

Chairman	C. J. Webb	NE35, Telephone Exchange, South Street, Exmouth Devon EX8 2RZ. Tel: (0395) 272070.
Vice-Chairman	N. V. Clark	LTR/LW, EMB96, Colindale House, The Hyde, London NW9. Tel: 01–205 7404.
Secretary	A. Johnstone	TNO/S132 Woodcroft TE, Pitsligo Road, Edinburgh EH10 4RZ. Tel: 031–667 8467.
Assistant Secretary	R. Craig	EN15, BT, Guild Centre, Third Floor, Lords Walk, Preston PR1 1RA. Tel: (0772) 267236.
Treasurer	R. V. Parton	Stafford Walton ATE, Eastgate Street, Stafford ST16 2LY. Tel: (0785) 46330.
Assistant Treasurer	T. Turner	72 Putteridge Road, Stopsley, Luton, Bedfordshire LU2 8HP. Display Pager: 0774759.
Editor	G. Lyall	NJ3.4 Telephone House, 357 Gorgie Road, Edinburgh EH11 2RP. Tel: 031–345 4120.
Quiz Organiser	K. McMonagle	NG1.3, Heron House, 255 St. Vincent Street, Glasgow G2 5BA. Tel: 041–220 2707.
Project Organiser	B. Comber	BT LS/EPC23, Telephone House, Masons Hill, Bromley, Kent. Tel: 01–464 6793.

Product News

TSX50 Switch System

The TSX50, a future-proof digital switch system for businesses needing up to 24 exchange lines, 80 extensions and eight private circuits, is now available through BT Districts. Designed and built in Britain, the TSX50 is BT's most advanced fully digital PABX of its size. It has been developed to take full advantage of BT's developing digital network.

The TSX50 has a wide range of special features providing a high level of flexibility which enables it to be tailored to a business's exact needs. The TSX50's console has 26 function keys and an 80-character liquid-crystal display showing the status of each call; this gives the switch operator precise control over the system. The facilities not only speed up call answering, but also mean calls are handled accurately.

The TSX50's digital technology will enable new communications opportunities to be provided in the future, without the need to replace equipment as technology changes. The TSX50 is a flexible system which can be expanded to meet a company's growth. Later this year, it will have the ability to trade off between 128 extensions, 32 exchange lines and 20 private circuits.

The TSX50 offers a wide range of features designed to maximise the efficiency of both the operator and extension users. Features include conference calls, paging, automatic call diversions, abbreviated dialling, message leaving facilities and logging, automatic ring back on busy lines, group pick up, call transfer and last number re-dial. The system also provides a comprehensive call information facility that allows companies to control costs by providing an automatic monitor on the calls made from each extension. An additional facility allows calls to be answered by priority, which enables extra fast response time for certain lines, such as dedicated customer sales lines.

BT's new compact TSX50 digital switch system (shown with the TX14 Featurephone bottom right)

Consort

BT has launched *Consort*, a new one-line telephone system with up to four extensions. Ideal for small or expanding businesses, Consort offers all the facilities of a modern switching system for little more than the cost of a featurephone.

Consort has been designed as a flexible expandable system compatible with all BT telephones. For the small business, Consort can operate as a one-line, two-extension system. Third and fourth extensions can be added as the business grows. Consort can also be 'piggy-backed' on most switching systems, and so add up to four linked telephones to each existing extension. For the 'boss and secretary' team, Consort can serve as a one-to-one switch system, linked to either a single outside line or to a company's main telephone system. It is also designed for home-based businesses and could be useful for many residential customers, particularly those with large family houses.

Consort, which was designed and is built in Britain, comprises a sleek compact key unit which is placed alongside a standard telephone instrument. All the electronic components of the system are contained in the key unit, so there is no bulky central box to accommodate. Consort offers a wide range of features normally found only on large switching systems. They include intercom facilities; holding or transferring a call; automatic return to calls on hold; handfree buzz; a 'night service' so that incoming calls ring on all extensions; conference calls; a PAGE ALL button to call all extensions for an internal conference; a bell on/off button to leave the user undisturbed by ringing tone and the ability to connect an answering machine.

Consort also has separate light displays for intercom calls, exchange calls and one to show when the bell has been turned off. The exchange call light flashes to signal an incoming call, and flickers when a call is placed on hold. All Consort's features are easy to operate with each button on the key unit clearly labelled. There is also space to write the name of each extension user beside the appropriate keys.

Consort has been developed in response to demands from BT's customers for a low-cost single-line switch system. Its flexibility makes it an ideal system for a wide range of customers; typical users will be doctors and dentists, retailers, restaurants and other small businesses. The boss and secretary team in large and small companies will also benefit from Consort.

Consort, BT's new one-line four-extension telephone system

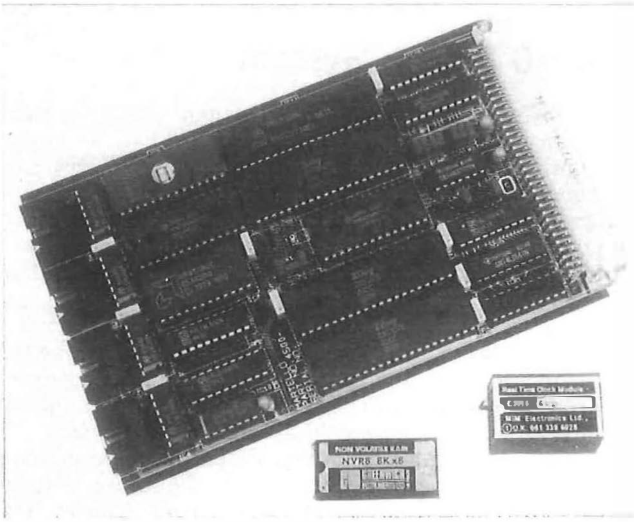
Intelligent Serial Input/Output Module for STEbus

An intelligent serial input/output (I/O) card—the first for the STEbus—is now available from British Telecom Microprocessor Systems. Offering four fully-buffered serial channels, the 4500 features an on-board processor which minimises bus I/O by processing data locally, freeing up the STEbus and optimising system bandwidth. High-performance arithmetic and real-time clock functions can be included on-card, and provide significant enhancement capabilities for STEbus systems.

The provision of local intelligence by an on-board Z80A CPU provides systems designers with the means to process serial data prior to accessing the system's internal STEbus. Such a distributed processing scheme relieves the STEbus master CPU from significant processing overheads, so that overall system performance and bus bandwidth are optimised. For example, incoming data from up to four sensors can be concentrated and analysed before transmitting a status report to the master; or outgoing data could be sent to a number of seperate VDUs and printers with data protocol conversion being handled locally.

All four I/O channels are driven by two Zilog Z8531 SCCs, and offer flexible asynchronous RS232 communications facilities. This capability is backed by an extensive 48K RAM buffer. Each channel is brought to the front edge of the card on a 10-way shrouded header; when connected via ribbon cable to a 9-pin male D-type connector, this offers compatibility with the serial port of an IBM AT or compatible computer.

The 4500 also offers powerful enhancement features for any STEbus system. A socket for AMD's Am9511A arithmetic processor allows the board to handle complex fixed- or floating-point mathematical operations, including full trigonometric functions. This chip is designed specifically for 8 bit I/O systems, but employs internal 16/32 bit architecture for maximum precision, to allow the computational capability of an STEbus system to be extended in a cost-effective manner. Another socket for a real-time clock extends the applications potential of the 4500 to timing/dating communications, and/or implementing programmable-alarm/stopwatch facilities. This facility is battery-backed for up to 10 years.



4500 intelligent serial I/O card for STEbus

Forming part of BT's Martello range of STEbus systems building blocks, the 4500 comes with a monitor in ROM, and epitomises the thought behind this series of systems products: by distributing intelligence throughout the STEbus and relieving the master CPU of many tasks, true parallel processing can now be achieved, so that technically-efficient solutions can be realised in the minimum of time.

68000 STEbus Processor

A new high-performance CPU card from British Telecom Microprocessor Systems offers designers exceptional processing power on an extremely cost-effective bus---STE. Prior to this introduction, users would almost certainly have had to purchase such a CPU implemented on an expensive high-performance bus like VME.

The board, designated the *4020*, is based around a full 16 bit 68000 running at 8 MHz without wait states. To maximise this device's computational power, 16 bit implementation is preserved right across the card. The fact that STEbus offers only an 8 bit data path has minimal impact on overall system throughput, because the module has enough memory to allow the CPU to operate locally in most applications.

Up to half a megabyte of RAM, or ROM, or a mix of memory types, can be fitted on board. Moreover, the PWB is designed to accommodate future device technology: its three pairs of JEDEC 32-pin byte-wide memory sites are fully word and byte addressable, which allows a potential 6 Mbyte of memory to be fitted (when the devices are available). A software-controlled memory overlay facility is also provided: once the system boot-up sequence has been completed, the ROM can be switched out of the memory map in favour of RAM, in order to suit differing operating system requirements.

The board is designed for systems requiring extensive processing power, and incorporates arbitration circuitry that allows it to operate in multiprocessor STEbus environments. A software locking feature gives designers the freedom to retain sole use of the bus during time-critical data transfer operations. However, the 4020 will also operate as the sole CPU in an STEbus system. The board also includes logic for handling all of STEbus' *attention request* lines and the *transfer error* signal, plus system clock and counter-timer facilities.

During system development, an on-card RS232 port can be used as a terminal driver, and a basic start-up monitor is included in ROM. In the target system, this port can be redeployed as a simple serial I/O channel: it is brought to the front edge of the card on a 10-way shrouded header, and when connected via ribbon cable to a 9-pin male 'D' type connector, provides compatibility with the serial port on an IBM AT.

The 4020 card, which forms part of BT's Martello range of STEbus systems and peripherals, sets a new standard in STE price and performance. Designed for use with any modern multi-tasking operating system—including OS/9 and Tripos—the card brings the computational power of true 16 bit processing to STE systems. A flexible approach to memory expansion, coupled with the inherent cost advantages of the STE standard, means that high-performance future-proof systems can now be cost-effectively realised.

First STEbus Modem

British Telecom Microprocessor Systems has launched the first STEbus-compatible modem which provides systems designers with an easy means of building remote STEbus control and instrumentation systems capable of communications over the public switched telephone network. The modem operates to V.21 or V.23 standards and has built-in intelligence to allow control by a high-level Hayes-like command protocol.

The modem, designated *4300*, comes on a single-Eurocard form-factor, integrated with a BT603A line connector inside a small shielded enclosure to conform to BABT requirements. LED indicators and a loudspeaker for line monitoring are also included in the package.

In addition to the standard V.21/23 communication capability (300/300 or 1200/75 baud transmit/receive data rates respectively), the 4300 can switch under software command to a 75/1200 baud configuration for high-speed bidirectional data transmission. A further software-selectable option provides a back channel of 150 baud for use on leased telephone lines.

The high-level command set includes control over a wide range of modem functions including dialling, answering, operating mode, line monitoring transmit carrier, console echo, loopback, reset, identification request, and status codes.

Book Reviews

Radio System Design for Telecommunications (1–100 GHz)
Roger L. Freeman.
John Wiley and Sons Ltd. xxii pl 560 pp. 219 ills. £41·25.
ISBN 0-47181-236-6.

The author states that the objective of the book is to provide essential design techniques for point-to-point radio links in 1–100 GHz frequency range, and that the book has been prepared with both the student and working engineer in mind.

The first chapter is a short one and covers general radio propagation up to 100 GHz. Free space propagation, diffraction effects and various fading mechanisms are some of the topics covered in this chapter. In view of its importance in digital systems, the treatment of multipath fading in this and subsequent chapters could have been a little more extensive. Equations are presented separately for use with different units, for example, feet and kilometres, and different units are frequently encountered as material from different sources is used in some cases.

Chapter 2 covers in detail the four steps of a radio link design; that is, initial planning and site selection, the drawing of a path profile, path analysis and site survey. The emphasis seems to be on analogue system design, which is illustrated with many worked examples. Also included in this chapter is a brief useful section on radio link availability. One would have liked to see a more thorough treatment of the effects of multipath on digital system design, and the effectiveness of counter measures employed to meet CCIR/CCITT objectives.

Chapter 3 is devoted to the various aspects of designing tropospheric scatter links. Transmission loss equations and curves for diffraction and troposcatter paths are empirical, and it is claimed that the NBS method is the most widely accepted one world-wide. Link performance calculations (including multipath effects) are described in great detail and illustrated with simple examples for analogue systems. Digital transhorizon radio links are discussed very briefly at the end of the chapter.

Chapter 4 discusses the design of analogue satellite systems. It includes a section on satellite orbits (mainly geostationary) and determination of range and elevation for earth stations. Link analysis, the concept of noise temperature, G/T etc. are explained well with many illustrative examples. A small section on access techniques (frequency-division multiple access (FDMA), time-division multiple access (TDMA), code-division multiple access (CDMA)) is also included. There is also a very large reference section on INTELSAT system parameters (necessary?).

Concepts of satellite TDMA system and digital speech interpolation are introduced in chapter 5. A brief introduction of satellite-switched TDMA is followed by a discussion of various coding techniques with emphasis on convolutional codes. There is also a brief introduction to very small aperture terminals (VSATs).

Chapter 6 is devoted to the design of systems above 10 GHz, where the effects of atmospheric absorption and rainfall attenuation become significant. Calcuations of excess attenuation due to atmospheric absorption and rainfall on terrestrial and earth-to-space links are illustrated with worked examples.

The final chapter is on the design of the radio terminal. Useful reference material on a number of subjects such as antennas, transmission line feeders, diversity combiners, antenna towers, satellite antenna tracking and pointing etc. are included for radio, transhorizon radio and satellite systems.

This book covers many topics, the various concepts are introduced with good illustrative examples, and with its extensive reference material, it will be a useful reference text for the practising engineer. The revised edition of the book will no doubt use reference material from CCIR Recommendations of 1986.

S. A. Mohamed

Notes and Comments

BT NEWS MISCELLANY

AS part of BT's strategy to enhance its presence in world information technology markets, the company is investing up to Cdn $60M (£28M) in research and development projects related to the Mitel SX-2000 integrated communications system (ICS). This work will be carried out under contract by Mitel Corporation, in which BT holds a 51% interest, at Mitel's Canadian headquarters, and will run until early-1990. BT will receive a levy based on sales of the SX-2000 resulting from these new developments.

The SX-2000 ICS is one of the world's most advanced PABXs. Its digital operation and computer control enables it to handle data and text with the same facility as speech. More than 500 SX-2000 ICS installations have been supplied world-wide. The product is serving major telecommunications users in seven countries.

ON 3 November 1987, the Rt. Hon. Norman Tebbit, MP, was appointed as a non-executive director of British Telecom.

WITH effect from 1 October 1987, Dr. Sydney O'Hara has been appointed as Managing Director of British Telecom Enterprises.

THE British Standards Institution's first Quality System registration of an international standard has been won by BT. The award was made to Network Systems, the division of British Telecom Enterprises (BTE) which designs software packages for advanced computer and communications projects. BTE Network Systems is the first software organisation for the UK and probably in Europe to be assessed against the new ISO 9001 (BS 5750 Part I) Quality System Standard for the application software systems it produces.

A MAJOR step forward was taken in BT's commitment to improve the public payphone service when the company announced, last October, that it had ordered a further £23M of equipment as part of its £160M payphone modernisation programme. A large part of the new order was for equipment for the national launch of an automatic version of BT's credit card service by October this year.

The orders, which were placed with Plessey Telecoms Products Ltd., were for the development and supply of the cashless services processor units (CSPUs) which will be installed in the national network to handle automatic credit card calls, and for a further 10 000 public payphones and parts. The first CPSUs are due for delivery in May.

BRITISH Telecom International (BTI) has awarded Delta Communications plc an order worth over £500 000 for digital trunk translators (DTTs). The DTTs will be used at BTI's new digital international switching centre at Mondial House. They will provide a link between the new digital exchange, which uses R2 signalling, and older overseas networks that use C4 signalling.

BT is to run Saudi Arabia's Telex network under a joint venture agreement that forms the company's biggest-ever overseas contract. The 3-year deal is worth SR 161M (nearly £25M) and starts in January 1988. It covers the management, operation and maintenance of the country's Telex, teletex and data networks as well as maintenance of the telegraph network. Training of Saudi nationals also forms part of the contract. BT holds 49% in the joint venture, the balance being held by a local company, Haji Abdullah Alireza Ltd.

BT Label Centre, a major manufacturer of labels and signs to BT and other major companies, has developed a new method of cable identification labelling, specifically for telecommunications, but also generally in electronics, computing and switchgear.

The labels are designed to provide ease of identification of individual cables in wiring harnesses or wiring systems, for rapid location and ease of fault finding, often encountered in telecommunications, but also in electronics and electrical industries. The labels are made of self-adhesive vinyl, with radius corners and have 4-digit numbers at both ends of the label. The numbers are both upright when the labels are wound around a cable. The labels are supplied in reels, and with dispensing cases on selected sizes, and are offered in a range of colour combinations. The labels are sequentially numbered, with one or two labels per number, for use at one or both ends of the cable respectively.

AT the end of October 1987, Cellnet introduced extended total access communications (ETACS) to its network. Some 200 ETACS channels are initially available for Cellnet, located within the band of frequencies just below those of the current TACS system. They allow the system to continue its rapid expansion, without loss of quality. The use of the 872–888 MHz and 917–933 MHz bands means that frequencies allocated for the Pan European network are not needed to support Cellnet's London capacity. New base sites and mobile equipment are required for ETACS, and the company has invested heavily to bring ETACS to the market-place. ETACS cellphones are able to operate on either their own frequencies, or, when one is not available, on TACS frequencies. When Cellnet began ETACS, the new frequencies were available within a 6-mile radius of Charing Cross, to give a further two-and-a-half-times capacity increase within Central London.

ON 3 December 1987, BT announced that it is to spend £87M on providing itemised telephone bills for its customers, after extremely popular earlier trials. No charge is to be made for this service. More than 30 000 customers in the London area are to be offered itemised telephone bills from January in the first stage of the scheme. Availability is being extended progressively throughout London and the rest of the UK as BT pursues its accelerated programme to complete the modernisation of its 7000 local telephone exchanges. By the spring, customers in Birmingham, Edinburgh, Glasgow and Bristol will also start to receive itemised bills. By 1990, almost 90% of London telephone customers and about half of BT's customers in the rest of the country should be able to get itemised bills.

Itemised listings will cover all dialled calls of 10 units and more (that is, those which cost more than about 50p, including VAT). Bills will show the date and time that a call is made, the number called, the duration of the call, and the cost of the call. The cost of making all other calls will be shown as a bulk figure on the bill. Operator-assisted and special service calls will continue to be itemised as at present.

NEW services and equipment to help disabled customers use the telephone are featured in the revised edition of the *Blue Guide* published on 3 December 1987 by British Telecom

Action for Disabled Customers. The 37-page guide, available free from BT's sales offices, is designed to assist disabled customers in choosing the most suitable product for their needs from an ever-expanding range.

New services featured in the 1988 guide include the 'Protected Service Scheme', to safeguard against the disconnection of service when a disabled or elderly customer is in hospital, away from home or too ill to deal with the telephone bill; a 'talking telephone bill' service for visually handicapped customers; phonecards with a notched edge to help blind customers; inductive coupling for hearing-aid users on the Tribune telephone, and from Spring 1988 models will also be available with amplification and lamp signalling facilities; most modern public payphones now allow full operator access when the display shows '999 calls only'; and *Means of Contact*, an information package consisting of a video and support material outlining the products and services available. Details are also included of where to go for help with the cost of installing and running a telephone; and of arrangements for chronically sick and disabled people to receive free priority fault repair service.

CORRESPONDENCE

Dear Sir,

EVENTS UP TO TELSTAR, 1962

There is a reference in this article [*Br. Telecommun. Eng.*, Oct. 1987, **6**, p. 170] to the 'maser' amplifier used for the TELSTAR experiments, which is somewhat inaccurate and I think needs correcting.

The *active* element in this type of maser is a thin monocrystalline slab of synthetic ruby (that is, corundum doped with 0·05% chromium). The comb referred to in Mr. Lawson's article forms a slow-wave structure, to increase the coupling between the signal and the crystal, and to provide magnetic coupling to a reverse-wave attenuator.

The gain of a ruby maser is very temperature dependent, and in order to provide the gain required for the Goonhilly installation, it was found necessary to cool the maser elements below 4·2K, the boiling point of helium at atmospheric pressure, to approximately 2·1K. The very low temperature was achieved by reducing the pressure within the maser to about 30 Torr, using large mechanical vacuum pumps. The need for such low pressures introduced major design problems into the mechanical design of the receiving system—and was also one reason why some hours were needed to bring the maser into operation.

Yours sincerely,
H. N. Daglish

STATISTICAL WORKSHOPS FOR ENGINEERS

Statistics for Industry (UK) Ltd. is running a series of practical statistical workshops for engineers throughout 1988. The aim of the workshops is to show exactly how, when and where to use statistical techniques which are of proven value to electrical, electronic and mechanical engineers. Computer-simulated case studies give practise in applying statistical techniques to real industrial problems.

Workshops include: 'Introduction and Statistics for Engineers', 'Reliability Analysis', 'Statistical Process Control', 'Statistics in Quality Assurance', 'Statistics in Research and Development' and 'Design of Experiments'. A new workshop, to be run in June, is entitled 'Off-Line Quality Control', and is designed for process, design and chemical engineers.

Further details and booking forms can be obtained from: Christine Robinson, Courses Manager, Statistics for Industry (UK) Ltd., 4 Victoria Avenue, Knaresborough, North Yorkshire HG5 9EU. Telephone: (0423) 865955 or 868090.

PUBLICATION OF CORRESPONDENCE

A regular correspondence column would make a lively and interesting feature in the *Journal*. Readers are therefore invited to write to the editors on any engineering, technical or other aspects of articles published in the *Journal*, or on related topics. Letters of sufficient interest will be published under 'Notes and Comments'. Letters intended for publication should be sent to the Managing Editor at the address given below.

IBTE ANNUAL REPORT, 1986–87

Copies of the IBTE *Annual Report and Financial Statement* for the year ended 31 March 1987 are now available from Local-Centre Secretaries. Copies can also be obtained by writing to The Administration Manager, Room 107 Intel House, 24 Southwark Bridge Road, London SE1 9HJ. A self-addressed adhesive label must be enclosed.

DISTRIBUTION OF THE JOURNAL

Many IBTE Members and other employees of British Telecom and the Post Office who subscribe to the *Journal* by deductions from pay have still not yet supplied their home addresses to the IBTE Administration Office so that copies of the *Journal* can be sent directly to their homes. Back issues of the *Journal* since October 1985, when this new method of distribution was started, are being held in store for these Members and readers until this information is received. Members and readers are asked to remind their colleagues to supply this information as soon as possible if they have not already done so; a form for this purpose was included with the April 1985 issue of the *Journal*. These Members and readers will then be sent the back issues and all future issues to their home address. Any enquires about this notice should be directed to The IBTE Administration Manager, Room 107 Intel House, 24 Southwark Bridge Road, London SE1 9HJ; Telephone: 01–928 8686 Extn. 2233.

CONTRIBUTIONS TO THE JOURNAL

Contributions of articles to *British Telecommunications Engineering* are always welcome. Anyone who feels that he or she could contribute an article (either 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 try to arrange for help with the preparation of an article if needed.

Educational Papers

The Editors would like to hear from anyone who feels that they could contribute further papers in the series of educational papers published in the *Supplement* (for example, see the paper entitled *The Purposes of Teletraffic Engineering and its Application*, included with the October 1987 issue of the *Supplement*). Papers could be revisions of British Telecom's series of *Educational Pamphlets* or, indeed, they could be completely new papers. It is intended that they would deal with telecommunications-related topics at a more basic level than would normally be covered by articles in the *Journal*. They would deal with, for example, established systems and technologies, and would therefore be of particular interest to newcomers to the telecommunications field, and would be useful as a source for revision and reference and for those researching new topics.

Intending authors should write to the Deputy Managing Editor, at the address given below, giving a brief synopsis of the material that they would like to prepare. An honorarium would be offered for suitable papers.

Guidance for Authors

Some guidance notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in the 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 six pages, although shorter articles are welcome. Contributions should preferably be illustrated with 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 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, and authors should seek approval, through supervising officers if appropriate, before submitting manuscripts.

EDITORIAL OFFICE

All correspondence relating to editorial matters ('letters to the editor', submissions of articles and educational papers, requests for authors' notes etc.) should be sent to the Managing Editor or Deputy Managing Editor, as appropriate, at the following address: *British Telecommunications Engineering*, Room 107, Intel House, 24 Southwark Bridge Road, London SE1 9HJ. (Telephone: 01–928 8686 Extn. 2233.)

APRIL 1988 SPECIAL ISSUE

CCITT Signalling System No. 7

The April 1988 issue of *British Telecommunications Engineering* will be a special issue covering the implementation of the CCITT Signalling System No. 7 in British Telecom's network. The topics covered will be as follows:

- Message Transfer Part
- National User Part
- Signalling Connection Control Part
- Integrated Services User Part
- Transaction Capability
- Mobile Application Part and Operation and Maintenance Application Part
- CCITT No.7 Testing

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