Present and Future Facilities for Data Transmission

By M. B. Williams

The use of standard communication channels for data transmission is considered. The different problems of private point-to-point and public switched circuits of telegraph and telephone types are discussed; the paper concludes with a review of the possibilities of using wideband channels corresponding to standard assemblies of telephone channels.

Introduction

This paper is intended to give a broad survey of the facilities available for data transmission from the point of view of a telephone engineer. In the United Kingdom, as in most countries, the provision of public telegraph and telephone services is a Government monopoly, although there is nothing except practical difficulties to prevent anyone from providing his own wired communication system between his own buildings or establishments for any purpose he may choose. Private radio systems, on the other hand, are subject to the granting of an individual licence.

For practical reasons, the public telegraph and telephone administrations are therefore called upon to provide transmission facilities for many kinds of communication other than strictly telegraph and telephone messages. The special field which is now of considerable interest and holds much promise of future expansion is that of the transmission of binary digital information. Naturally, these administrations will endeavour to meet this need by using plant and techniques which already exist, and which are thoroughly standardized not only nationally but internationally as well. This approach is in the ultimate interests of the data user since it is less costly than specially devised arrangements, can be provided more easily and gives the possibility of interworking on the largest possible scale.

The facilities for data transmission dealt with in this paper comprise the following general types.

(1) The telegraph-type circuit, giving a speed of about 50 bits per second.
(2) The telephone-type circuit having a capacity of up to, perhaps, 2,000 bits per second in favourable circumstances.
(3) Wideband circuits, especially those designed for carrying blocks of telephone circuits.

Telegraph and telephone circuits can be divided into two classes: private point-to-point circuits, rented on a permanent or part-time basis by a particular customer, and the much larger groups forming the switched networks of the public telex or public telephone systems. These facilities may be summarized as follows.

(*a*) Public telephone circuits for which (with subscriber trunk dialling in full operation) the user pays for circuit time at a rate depending on distance.

(*b*) Private speech circuits of a standard type (known as Tariff "D") for speech transmission only, or with certain guaranteed transmission characteristics (known as Tariff "E"). In these cases, the user has exclusive use of the circuits and pays a rental of £12 or £18 per mile per annum, respectively, or reduced rates for part-time hire for agreed periods of not less than two hours per day. The technical characteristics of speech quality circuits will vary within wide limits, and no assurance can be given to the renter as to technical tolerances. Therefore, for data transmission purposes, their use is limited. Tariff "E" circuits can, within practical limits, be made to suit customers' technical requirements, and special precautions are taken at audio connection points to improve the security from interruption. Consequently, where the use of the private circuit is justified for data transmission, the tariff "E" type offers greater advantage, but at extra cost. Both types of circuit are normally provided giving both directions of transmission. For very short distances, of the order of a few miles, a private speech circuit on unloaded and unamplified cable plant has no clear upper-frequency limit and could be used for as wide a band as desired; indeed, such circuits are often used for short-distance television transmissions.

(*c*) Public telegraph circuits known as *telex*, for which the user pays for circuit time at a rate depending on distances; the telex call charges are about half of those for the public telephone network, but the installation requires a teleprinter and associated apparatus which is used for setting-up a call and for which additional rental has to be paid.

(*d*) Private telegraph circuits rented on an annual basis have a rather complex tariff structure, but broadly the cost is £12 per radial mile for the first 25 miles, with lower rates for additional mileage down to £1 per mile over about 200.

If the relative call charges or rentals for speech and telegraph circuits are compared it will be seen that telegraph channels are generally cheaper than speech channels, because a number of telex or telegraph private circuits can be derived from a single speech-type circuit in the main network. However, from the point of view of data-handling ability, it may prove cheaper in certain circumstances to use speech rather than telegraph circuits either of the public network or private circuit types. An interesting point concerning the choice between a private circuit and the public switched service is that there is a financial break-even point which varies with distance and the particular circumstances, but in general is of the order of one hour per day for a five-day week. In other words, if considering a regular daily transmission of more than an hour's duration it may be cheaper to use a private circuit rather than to set up calls of long duration on the public network.

Telegraph Circuits

Telegraph circuits are already arranged for binary digital transmission, and therefore are a first choice for data transmission where a speed of, say, 50 bits per second is sufficient. Short circuits, e.g. up to 25 miles, would probably employ copper wire pairs throughout, with earth return (one wire being used for sending and the other for receiving) and are not inherently limited in signalling speed. Longer circuits would be extended for most of their length on multi-channel voice-frequency telegraph systems in the main network, and as a consequence could not work at much over 50 bauds. On private inland telegraph circuits, there is no limitation on the code or message structure up to this limit of modulation rate, if suitable terminal equipment is available to the customer. On telex circuits, however, calls must be set up using the normal teleprinter equipment at each end, but arrangements can now be made in the United Kingdom to switch to special data-transmission equipment on an established call, and then to use any code which does not happen to generate a continued "Start" polarity exceeding about 140 milliseconds, as that can lead to a false clearing of the connection.

Error rates on telegraph circuits have been studied for many years. Mutilations are caused by poor contacts, working party interruptions, and bursts of noise in the line plant, especially in the telephone-type line plant used to carry multi-channel VF (voice-frequency) systems. Measurements of the character error rate have recently been made in a programme of tests designed to show the performance for data transmission at 50 bauds. Typical results obtained on an inland private wire and on telex calls are given in Tables 1 and 2.

The Post Office is investigating methods of providing error control on telegraph circuits, particularly on the Inland Telex network, where the arrangement of the subscriber's local circuit is such that duplex working can easily be arranged. In one method, the received signal is returned continually to the transmitter where it is compared bit-by-bit with the outgoing signal. To take up the total transmission time of the loop, which will vary from call to call, and may amount to 600 milliseconds, an adjustable store is required at the transmitter, together with means of stopping the transmitter or repeating a character in the event of an error being detected. Several methods of implementing an error-detection system are being investigated and the aim is to offer the service as an additional facility to be rented to telex subscribers. Limited experience suggests that a substantial improvement in the error rate is possible, giving a typical undetected error rate of perhaps one character in a million, i.e. one undetected character error in 40 hours' continuous transmission.

Table 1

Tests on Telegraph Private Wire

Number of blocks of 426 characters* transmitted	1,668
Number of blocks with—	
0 element errors	1,660 or 99·5%
1 element error	1
2 element errors	0
14 element errors	1
32 element errors	1
35 element errors	2
56 element errors	2
126 element errors	1

* *Each character comprised* $7\frac{1}{2}$ *elements.*

(Length: 1,080 miles, national and international circuits.)

Table 2

Tests on U.K. Telex Network

NO. OF VF LINKS IN THE TRUNK CONNECTION	1,000's OF CHARACTERS TRANSMITTED	NO. OF CHARACTER ERRORS	AVERAGE ERROR RATE*
2	464	7	$1\cdot5 \times 10^{-5}$
3	2,619	218	$8\cdot3 \times 10^{-5}$
4	3,370	172	$5\cdot1 \times 10^{-5}$

* *Character error rate of* $7\frac{1}{2}$ *unit* 50 *baud signals.*

Telephone Private Circuits

Telephone private circuits can be rented without Post Office terminal apparatus, so that the customer may connect his own, approved, equipment. Such a circuit, if over a few miles in length, would probably include one or more loaded cable sections limiting the upper frequency to 3 kc/sec or, in some instances, to 2 kc/sec. If much longer than, say, 30 miles, audio amplifiers and a section of carrier-frequency working on a main multi-channel system would be included and would have the effect of introducing a band-pass characteristic with a range at most of 300–3,000 c/sec and sharp cut-off characteristics at each end. Thus for general use over private circuits, d.c. transmission is not possible and a modulated carrier form of transmission must be adopted. Much development work has been undertaken in several countries in producing suitable transducers (modulating and demodulating equipment) to permit data-processing equipment to be connected to telephone circuits.

There are two main types of transmission: serial and parallel, the most obvious example of the latter being multi-channel VF systems, of types already widely used for telegraph transmission, and which can be used on

Table 3

Tests on Private Circuits of Tariff-E Type. 100 to 500 miles

Percentage of minutes error-free	Less than 94	94	95	96	97	98	99	100%
Number of occurrences	1	1	2	2	2	2	3	2
Number of bursts of errors	20	10	7, 8	6, 6	4, 9	3, 2	1, 1, 1,	0

AM system at 1,000 bauds.
15 tests of 167 minutes (10^7 bits) each.

good quality circuits to permit up to 24 parallel tracks of binary digital information, each at 75 bauds, giving a total of 1,800 bits per second. Even more elaborate is the "Kineplex" phase-modulation system giving 40 parallel streams each of 75 bauds. Parallel systems of this kind tend to be very expensive in terminal-equipment costs. Most work seems to have been done on single-stream or serial systems using amplitude-, frequency- or phase-modulation of a carrier situated about the middle of the telephony band (e.g. 1,500 c/sec) and with side bands extending over 1,000 or 2,000 cycles. Transmission speeds of 1,000–2,000 bauds are possible without much difficulty over good quality private circuits. This has been demonstrated in tests made on private-wire type circuits set up for experimental purposes on the U.K. network with a number of different types of experimental single-stream transducers. Tables 3 and 4 summarize some of the results and conclusions.

Telephone Switched Connections

Telephone switched connections, as a class, include any call made from any one telephone subscriber to any other; perhaps from a PBX extension in one town to a PBX extension in another. With the extension of submarine telephone cables to give, in effect, a world-wide inter-connected telephone system, the two subscribers could be many thousands of miles apart. In every case, in the not too distant future, subscribers might reasonably expect not only to be able to converse with ease, but also to exchange data between machines.

These are possibilities only, at the moment, but development along these lines must be envisaged in the future even though long-distance transmission systems may contain many devices such as echo suppressors, compandors and band-width economy devices which depend upon the special characteristics of telephone speech for satisfactory working. Furthermore, radical changes in telephone exchange design and local line transmission systems are probable. Electronic exchanges may replace electromechanical switching, and the present analogue methods of electrical speech transmission may be replaced by digital methods. Thus the general introduction of data transmission over the switched telephone network is to be viewed with long-term developments in mind, and the requirements of terminal apparatus for this use may be very different from those of equipment for use on private circuits.

Table 4

Tests on Private Circuit of Tariff-E Type

Total duration of test	5,200 minutes (86·6 hours)
Minutes free of error	98%
Longest error-free run	985 minutes (16·4 hours)

PM system at 750 bauds; national and international circuits totalling 730 miles.

The American Telephone and Telegraph Company appears to have these considerations in mind in adopting a policy of permitting data transmission over its switched network only through transducers supplied and maintained by the Telephone Companies. A whole range of such devices under a general title of "Dataphone" is envisaged, and those already announced include "Sub-sets" giving serial transmission at 1,200 bauds in one model (Dataphone 200); up to 2,000 in another (Dataphone 300); and a very simple multi-frequency device for out-station use (Dataphone 400). These devices will accept standard forms of binary data and control signals from data-processing equipment, and will convert them into forms suitable for transmission over the switched network, converting back to the original forms at the receiving end. Error control and synchronization are not provided.

In the United States the Electronic Industries Association has already produced a Recommended Standard (RS–232) for the inter-connection of data terminal equipment with a communications channel, the plane of connection being known as the "Interface," where d.c. connections are made between data and control circuits from the customer's data-handling equipment on the one hand and the Telephone Company's transducer on the other. Error control, synchronization, and pulse-regeneration all lie on the customer's side of the Interface. Certain requirements, necessitated by characteristics on long-distance telephone systems, are met in this standard.

In this country, the Post Office has announced its intention of permitting data transmission over the Inland network; for the present, approved commercial devices may be connected to the public network, but the use of Post Office-supplied transducers may become obligatory in the future.

A specification for one such piece of Post Office-supplied equipment is now being drawn up. It provides for the following facilities.

(i) Serial transmission at up to 1,000 bauds (on favourable circuits) on a F.M. data channel occupying the band 900–2,100 c/sec approximately. No error control or synchronization facilities are provided.

(ii) An optional supervisory channel for feed-back of error-control information when required at up to 75 bauds in the band 340–410 c/sec.

(iii) Various d.c. control circuits for putting the modulator and demodulator under the control of the data-handling equipment and for switching between telephone and data transmission. In the absence of any national standardization on voltages, polarities, and impedances of the data-handling equipment which may be connected to the modulator/demodulator, certain assumptions have been made, but standardization of these parameters seems very necessary.

Technical approval of privately-owned data-transmission equipment will take account of protection of Post Office plant and personnel against dangerous voltages, limitation of signal power fed to line, limitation of signal bandwidth to guard against misoperation of signalling equipment, and the rather complex question of operating procedure, alarms and switching facilities, so that the normal standards of telephone service are maintained.

Tests on Switched Circuits

Table 5 gives the results of data-transmission tests made using experimental equipment over the local and trunk public telephone system. These are preliminary results from a small-scale test which, of course, cannot possibly be representative of the wide range of characteristics which may be encountered in calls set up between any two subscribers on the Post Office network. The tests were favourable for data transmission to the extent that one end of the connection was always in Central London; thus the limiting condition of two fringe-area subscribers was not met. Furthermore, the effects of manual-board operator intervention at public and private exchanges may not be adequately represented.

The principal causes of errors or mutilations to data transmission at speeds of the order 600–1,200 bauds on switched telephone calls appear to be impulsive noise and short disconnections which produce bursts of errors at intervals between relatively long periods of error-free transmission. Impulsive noise may be of quite large amplitude, e.g. 1 or 2 volts peak-to-peak, and up to several milliseconds duration, and probably arises through reactive couplings (capacitance unbalance or common inductive impedance) from dialling or switching signals on other circuits. The short disconnections are characteristic of those arising from the disturbance of dry contacts and imperfect joints. Occasionally, the circuits picked up in the course of setting up a call may

Table 5

Tests on Local and Trunk Switched Calls

Number of error-free minutes	0	9	12	13	14	15
Number of occurrences	4	1	5	5	5	6
Number of error bursts	*	26	10	27	3	0
			5	1	4	
			7	12	1	
			12	2	1	
			11	2	1	

* NOTE.—Three calls failed to transmit at 1,200 bauds; satisfactory at 600 bauds. One call was noisy, giving 65 bursts of errors (222 errors total).

FM, 1,200-baud transmission, 511-bit pseudo-random pattern. Each test comprised a 15-minute run of approximately $1 \cdot 08 \times 10^6$ bits.

give an overall unfavourable connection due to excessive loss or low cut-off frequency, so that speech quality is noticeably impaired and data transmission at these speeds results in a very large error rate. In such cases satisfactory results would often be achieved after clearing down and re-making the call when a different selection of circuits would probably be obtained.

The single-stream 1,000-baud system considered here may meet the requirements of users who wish to transfer substantial amounts of information, for example one million effective bits, in a call of perhaps 20 minutes' duration. A later section of the paper deals with the possibility of few users wishing to transmit far more information, but it seems likely that the most widespread application of data transmission over the public network may be that of the occasional transmission of small amounts of information (tens or hundreds of characters) from many out-stations to a central collecting point. The requirements at the out-station are low cost and simplicity in operation.

In the United States various forms of multi-frequency devices have been announced for this application.

The Dataphone 400, a "2-out-of-8" parallel data-transmission system, is intended for one-way data-transmission service over the switched telephone network. The system accepts and delivers a possible 16 characters asynchronously at any rate up to 20 characters per second. A single channel is provided in the reverse direction which operates alternately with the forward channel. The data receiver could be arranged to operate unattended if desired. The cost of the data transmitter is very much less than the cost of a receiver, as the service is particularly intended for data-collection applications where many transmitting stations feed into one receiver. The data transmitter at the outstation is connected to the telephone line and draws the power supply from the exchange battery. The principle of operation is essentially that of providing eight channels divided into two groups A and B of four channels each. The channels are controlled by closing of contacts. The permissible characters are those which operate one and only one channel from each of the two groups. Thus the system accepts and delivers a "2-out-of-8" code. It could be associated with a simple card reader or tape reader operating at up to the 20 characters per second speed previously quoted.

Considerations on Error Correction

Considerable effort is being devoted to the study of error-control systems, for use with various types of data-transmission system which are contemplated for use over telephone-type circuits. The effectiveness of the various digital error-control schemes available depends critically upon the statistics of the errors; as has been pointed out, errors are not random but highly correlated and occur in bursts. Since in the complete link between two data-processing machines the most important source of errors is likely to be the telephone channel, it may seem at first sight that the error-control features should be incorporated in terminal transducers supplied by the telephone administration. For general-purpose equipment, the conclusion is that this should not be done, the main reason for this view being that while the characteristic error pattern is determined by the communications-channel defects, their effect on the transmission of digital data depends upon the speed of transmission and upon the overall error requirements, which are fundamentally determined by the use to which the data is to be put. The means and techniques of error control appropriate to a particular situation obviously depend upon the interaction of these factors. Thus, for the telephone administration to incorporate in all its terminal transducers means for providing full error correction, for any type of data transmission which could use the data channel, would mean imposing upon all users the penalty of cost for the most difficult application as well as the penalty of reduction in effective speed. In brief, error detection and correction is a function of the overall system, including in this, with the communication channel, the data-processing equipment at each end. It is left to the user, or, more precisely, the designer of the data-processing equipment, to incorporate as much or as little error-control features as the overall system requires. There is no doubt that in many cases the data itself can carry sufficient inherent redundancy for the very simplest check and re-transmission system to provide adequate service.

Although it is possible to incorporate with the transmitted data sufficient redundant information to permit virtually all errors to be detected and corrected, this would be a highly inefficient use of the average telephone circuit, on which, for most of the time, the error rate would be low, as sufficient redundant information must be carried to cater for the relatively short periods when the circuit performance has deteriorated. Of course, even then, no system can operate when the circuit performance has deteriorated to the extent of the circuit being unserviceable or actually disconnected, and it is important that such a fault condition can readily be recognised by the user. It seems that the most efficient method of using the telephone circuit is to provide an efficient error-detection system, combined with means for re-transmitting characters or blocks where errors have been detected. Any such system will require additional bits to be transmitted and will thus reduce the effective transmission speed, but a figure of perhaps 10–15% redundancy seems reasonable.

The scheme outlined above requires a request for repetition of a character to be transmitted back to the data sender. This could be done in two ways: either by arranging for the transmitter to stop at the end of a convenient sized block to give the receiver an opportunity to request a repetition or, alternatively, by arranging for a supervisory channel to be transmitted continuously from the receiver back to the data transmitter. Which of the two methods is preferred depends on a number of factors. Certain telephone circuits, particularly those involving long-distance transmission of perhaps 1,000 miles or more, are fitted with devices which positively prevent the transmission in the two directions simultaneously. The possibility of disabling these devices to permit data transmission using different frequency carriers for the two directions simultaneously is being considered, but it does not appear likely in the immediate future. The adoption of a "burst" or "block transmission" method of working depends for its success upon the particular characteristics of the data-processing equipment and upon a careful choice of the block size. The American Standard RS 232, previously cited, took account of the possibility of "burst" working, and to cater for the particular properties of some telephone circuits requires a delay of up to 0·2 seconds to be introduced at the beginning of each period of transmission of data, to allow time for the changeover to a new direction of transmission.

Wideband Circuits

The methods used in main-line systems for assembling telephone channels into large blocks, for economical long-distance transmission, proceed by way of intermediate assemblies in groups of 12, supergroups of 60 and, in the future, mastergroups and supermastergroups of 300 and 900 channels, respectively. Complementary to these assemblies are defined transmission paths of 48, 240, 1,232, and 3,872 kc/sec, respectively. Wideband plant used for 900-channel telephony may alternatively be used to provide 3 Mc/sec television channels. In principle, between the main repeater stations at least, these wideband channels could be used for many purposes other than telephony and numerous studies have been made into the practicability of renting them for facsimile telegraphy, slow-scan television, etc. The use of a link of high capacity could be justified in permitting two or more locations to share one large computer, and, in addition to allowing transfer of large amounts of information in a short time, would permit remote program development.

It is necessary to ensure that the signals transmitted over such a wideband channel would approach fairly closely to the characteristics of the appropriate number of telephone channels which is replaced. This requires a fairly careful technical specification in terms of mean and peak power.

In the United Kingdom, attention has been directed fairly closely to the 48 kc/sec bandwidth for rental to customers as a wideband channel, without special terminal equipment, and available in the band 60–108 kc/sec at which it appears at the Group Distribution Frames in main repeater stations. A rough estimate of the rental of such a band between the main stations is about 60 per cent of the cost of the equivalent number of telephone speech private circuits, i.e. £88 per mile per annum for one or both directions of transmission. A serious problem outstanding is that of extending this 48 kc/sec band from the main repeater station to the customer's premises, without incurring great expense for special cable and equipment. For customers within, say, a few miles of a main repeater station where the group bandwidth is accessible (there are about 120 towns in the U.K. having such a station), the ordinary subscribers' and junction telephone cables could be used. For longer distances, up to perhaps 20 miles or so, similar plant could be used, provided that intermediate repeaters could be installed at low cost. It may be possible to do this in the not too distant future by making use of development in underground repeaters intended for other fields of application.

Little information is available on the possible data transmission speed for such a 48 kc/sec link, but it should be of the order of 20–30 kb/sec, and it is appropriate to consider carefully the merits of serial and parallel transmission. A quick review of published information on magnetic-tape input/output speeds for current British computers shows a wide variety of values covering the range 9,000 to 90,000 characters per second (say 70 to 630 kb/sec). It would seem short-sighted to consider developing terminal and link equipment for data transmission at every possible speed. A more prudent course in the long run would be to consider only a very limited range of speeds, i.e. those corresponding to standardized communication channels, and to arrange to use a channel at its optimum speed as, for example, by the use of a tape-to-tape buffer or time-sharing techniques.

It is reported from the United States that the A.T. & T. has announced standard tariffs for providing wideband channels for data transmission. These channels have bandwidths of, nominally, 48, 240, or 1,000 kc/sec; appropriate terminal transducers can also be rented which, it is assumed, would be obligatory. It is inferred that the local end problem can be solved. The 48 and 240 kc/sec channels are the group and supergroup bands internationally standardized and referred to earlier. The 1,000 kc/sec channel with the appropriate terminal equipment is particularly intended for association with a standard high-speed magnetic-tape equipment, permitting data transfer at up to 500,000 b/sec. The derivation of the 1,000 kc/sec channel is not known and may be particular to A.T.T. practice in utilizing wideband radio channels. However, it is of the same order as the bandwidth of 300 circuits now becoming recognized as an international flexibility unit, and which is available to a very limited extent in this country. For very long-term planning, this bandwidth seems very suitable for consideration as an alternative to the very much wider bandwidths which are available for television and are usually far too costly for any other purpose.

Conclusions

This paper has surveyed present and possible future facilities for data transmission from the point of view of using standard types of communication channels which are available, in principle, at least, world wide. However, the growth of data transmission, nationally and internationally, requires full co-ordination with the telecommunications networks, as they now exist and as they may be planned in the future.

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Summary of Discussion

The discussion was opened by **Mr. H. McG. Ross** (*Ferranti Ltd.*), who believed he expressed the appreciation of all those present for the very forward-looking view being adopted by the Post Office in connection with this work.

He drew attention to the announcement by Mr. Williams that the Post Office would now allow the British switched Telex system to be used for other than the standard Telex mode of operation and the standard Telex code. That was a most important advance because it meant that, once the call had been set up over the switched Telex network using standard Telex equipment, it became possible to transmit any kind of data. That threw open the possibility of transmitting any computer code over the system, not only all the 5-track tape codes currently used by the bulk of British computers, but also the 7-track tapes which were now coming into use with modern British systems.

All that was needed to make practical this transmission system was the development of suitable error-detecting equipment and, perhaps, means to make sure that a spurious character was not copied or printed at the far end. He felt we were within sight of having a low-cost data transmission system which, despite its slow speed, would still be very useful. Its potential value was shown by one of the tables presented as a duplicated document for Mr. Long's lecture. According to Table 4 (p. 97) in the survey of potential users of data transmission, a substantial proportion of those questioned had said they would be content with the Telex rate of transmission.

Mr. A. St. Johnston (*Elliott Brothers* (*London*) *Ltd.*) said that the tables supplied were most interesting, but he could suggest another set of figures to accompany those already presented. The normal computer man expects to see two figures: the first was a measurement of accuracy and the other a measurement of reliability. By this he meant the amount of "down time" of a circuit and he wondered whether Mr. Williams's figures included this, or whether the reliability—and not only the accuracy—of the public network was higher than his experience had led him to believe. He would be grateful to know whether Mr. Williams had any figures relating to attempts at calls at random, and of successful transmissions starting from random moments in time.

Mr. Williams asked whether Mr. St. Johnston was referring to rented circuits or switched calls.

Mr. St. Johnston said both! A man might be digging in the road, and cause the whole thing to break down for hours. It would be nice to have accompanying tables of reliability relating to all the tables presented.

Mr. Williams said that Table 4 had shown tests on a Tariff-E type circuit: a total duration of test of 86·6 hours, with one continuous error-free run of 16·4 hours. All the interruptions had been relatively short. The test was not taken immediately after setting up the circuit; work had been done over a period removing minor faults. In general, existing plant had to be taken as it was found, but if a circuit was reported as giving bad service it would be cleared up. Once a reasonably good state had been reached one could expect it to be maintained for a long period.

He did not have available any statistics of a particular circuit which would answer Mr. St. Johnston's question, but he thought it would be wise to recognize that circuit breakdowns did occur, and to have alternative arrangements planned.

Mr. Taylor (*Mullard Equipment Ltd.*) said that Mr. Williams had given the frequency range on which it was intended to use the frequency-modulated system of telephone circuits as 900–2,100. He had believed that any extension of the frequency band at the top, beyond 1,900, ran into difficulties in connection with some signalling tones. He asked whether Mr. Williams could confirm his figures, or make some observations on the matter.

Mr. Williams replied that the specification for the technical requirements of customers' apparatus limited the upper frequency which should be transmitted to a little below 2,000 c/s because it was not possible to guarantee transmission beyond this value, owing to the presence in the telephone system of much old cable plant with a low cut-off frequency. Modern signalling receivers were well guarded and even when the international standard of 2280 c/s was used, the presence of a substantial signal in the band 900–2,000 c/s would inhibit false operation of the receiver. Thus it might be possible to transmit data signals with energy above the 2,100 c/s mark, provided it could be demonstrated that guarding was maintained.

Dr. J. E. Flood (*A.E.I. Ltd.*) said that Mr. Williams had explained that a data subset for use on the switched network must be carefully specified to prevent it from interfering with operation of the telephone service. There was also the inverse problem of ensuring that operation of the service does not introduce errors into data transmission. Until the introduction of subscriber trunk dialling has been completed, telephone calls will be subjected to three-minute timing pips and intervention by switchboard operators: either can cause transmission errors. Operators must learn to recognize the sound of data-transmission signals and accept them as legitimate.

The presence of echo suppressors on telephone circuits can cause difficulties in using return signals for error-correction purposes. Fortunately, echo suppressors are used less in this country than in the U.S.A. However, data-transmission systems for use on the switched network should preferably be capable of use on international connections. It would therefore be useful to hear from Mr. Williams how much time the designer of a data-transmission system should allow for the turn-around of echo suppressors.

Mr. Williams thought that Mr. Flood had overstressed the importance of the interruptions which were due to the operation of timing pulses. With the extension of trunk dialling the presence of operators would become relatively insignificant, and timing pulses would disappear. At the moment tests were being made from various subscribers' locations, and very little trouble had been caused by the intervention of operators. If an operator came on to the circuit, there would be a short burst of errors when the key was thrown.

Timing pulses, of about 900 c/s, did not necessarily represent a serious cause of errors. The data modulator must not transmit anything below 900 c/s and therefore the receiver need not be sensitive to such frequencies. This was a matter for the receiver designer. Recent tests had confirmed this view.

As for echo suppressors, the American problem was different from that of the United Kingdom. There were only 200 echo suppressors in the U.K. network. The figure of 200 milliseconds was a maximum figure, and something like one-third of that would be ample for the U.K. inland telephone system. For international working the existence of echo suppressors must be recognized. The solution might be that referred to in the Paper, of disabling automatically the echo suppressor when a data signal was recognized. That possibility was being investigated in the United States.

Mr. P. W. Yates (*Bowater Paper Corporation Ltd.*) said that one method of avoiding the transmission of redundant error-correcting bits was to re-transmit the information-bearing bits completely on the return channel, comparing what was received on the return channel with what had been sent. He believed that the Post Office was doing some work on those lines, with 50-baud transmissions. What were the future possibilities of doing the same thing at higher speeds?

Mr. Williams pointed out the difficulty in arranging for a full-duplex working, transmitting at the same speed in both directions on a two-wire circuit. If the speaker had been thinking of using this system on the public telephone network, where only the band 900–2,000 c/s was available, he must either use half the band for each direction of transmission, or work at different speeds in the two directions of transmission. In the latter scheme the backward channel, continuously operating, need transmit information about the errors only, and not the full information itself. If private wires were used it might be arranged to have two uni-directional channels, each at 1,000 bits per second, so that information would be transmitted simultaneously in both directions.

Mr. F. C. H. Witchell (*Pressed Steel Co. Ltd.*) said that his company, as potential users in the early future, were a little perturbed by some of the questions and answers he had heard. At what date in the future would they be able to use the switched-telephone networks? Secondly, while operators were becoming accustomed to the strange noises and learning that this transmission had at last arrived, what precautions would be taken to protect users from the extensive interference that was almost certain to arise?

Mr. Williams said that he understood that manufacturers of apparatus suitable for use on the public telephone system had already made formal approaches to the Post Office for permission to connect apparatus to the telephone network and their proposals were under study at the moment.

Past experience had led to the belief that no special operating procedure should be introduced for a particular class of call. Interruptions that affected data were equally annoying to telephone subscribers. Possibly through experience operators would become familiar with data calls, and interruptions could then be expected to become relatively rare.

Mr. W. E. Norman (*I.B.M.*) asked whether Mr. Williams meant to imply that manufacturers' equipment would not be accepted, when he said that G.P.O. terminal equipment would be supplied.

Mr. Williams said that the present official view was that a manufacturer's design and equipment would be considered on its merits, but when Post Office equipment of comparable performance and of the same general type was available the position would be re-considered with a view to making the use of P.O. equipment mandatory. At the moment, a firm decision, one way or the other, had not been taken.

A Data Transmission Survey

By P. A. Long

This paper describes an investigation conducted by the Inland Telecommunications Department of the General Post Office during 1960. The object of the investigation was to determine the future general needs for data-transmission facilities with particular emphasis on the type of lines that will be required in the immediate future.

Introduction

As long ago as 1955, the Post Office, jointly with a punched-card machine manufacturer, was demonstrating the use of Telex for the transmission of data. Unfortunately, the idea did not catch on to any extent. However, like many other ideas, it was not abandoned but merely pigeon-holed for the time being.

At much the same time as these demonstrations, studies were being conducted in the United States into the possibilities of using telecommunication channels for data purposes (American Management Association, 1954). In due course, reports of these investigations and other American developments, inquiries from representatives of British Industry and the growing interest in computing generally led to the decision, within the Post Office, that a study should be conducted into the potential needs in this field, so that timely preparations could be made to meet any general requirements. Even at this early stage, it was recognized that the Post Office carried a heavy responsibility because of its position as the main United Kingdom provider of telecommunications channels (Long and Truslove, 1961), and because of the restriction that would be placed on national productivity if the appropriate services were not made available at the right time.

Preliminary Steps

Consideration of the steps necessary in conducting such an investigation showed that there were two main problems:

(*a*) How to obtain sound information about the probable use of facilities which were of a semi-technical nature and largely undeveloped. In this connection it was realized that the lack of general information in the computing field about line-transmission possibilities, likely facilities and techniques would, to a considerable extent, frustrate early efforts to obtain sound information about potential users' requirements.

(*b*) A market research, which normally relies on a sample of potential users, appeared to be somewhat premature, because of the difficulties of establishing the eventual market for computing machinery.

The first of these problems was tackled by a small publicity programme involving the distribution of a booklet on data transmission (G.P.O., 1958); establishing contact with computer users and manufacturers, and discussing their problems in this field; generally engendering interest in the subject through the medium of ADP journals, exhibitions, etc.

Secondly, the idea of a formal market research was abandoned and it was decided to distribute a questionnaire, on a "Survey" basis, to all known computer users and potential users in order to obtain information from a limited but informed field. For this purpose, use was made of the mailing list of applicants for the data booklet, together with such other information as had been collected during the initial contacts with users and manufacturers.

Distribution

Three hundred and thirty survey forms, together with suitable covering letters and copies of *Facilities for Data Transmission*, were issued. The addressees included banks, insurance, heavy and light engineering, chemical and electrical manufacturing, the distributive trades, oil companies, transport, computer manufacturers (in