tions where the communications facility furnishes the Modem and associated "clocks." In the continental U.S. it is anticipated that the great majority of the installations will not have the Univac Modem.

Question: What is the information transfer rate? How much time is required to transmit, check and rewind, say, 100 blocks of 720 characters each?

Answer: This information transfer rate depends on many factors among which are "on-line" bit rate, tape leader length, tape handler speeds, writing density, on line error rate, number of blocks per block group, number and length of bad spots, "end of message" designation, line reversal time, etc. An illustrative example representative within 20 per cent for all except the most unusual cases would be that with an 800 bits/second "on line" bit rate and a fair quality line, hence few requirements for retransmission. It would require about 7.8 seconds per block or 780 seconds plus approximately 20 seconds rewind time $\cong$ 800 seconds for 100 blocks or for about 500,000 bits of information.

Question: How long does the receiving unit require to reread the blockette and compare to stored information, and is the data transmission stopped during this time?

Answer: The information is read and checked at the receiving end in block groups rather than per blockette, so all the information sent during a block group is checked in one continuous operation. The information recorded on the tape is checked against *a priori* known criteria rather than against stored information. The check consists of insuring that each character of the block group has satisfactory character parity, that there are 120 characters per blockette and 6 blockettes per block. The time required to check a block group then depends on the number of blocks per block group. As an example, if 4 blocks per block group are chosen and a bit rate of 800 bits/second is used, the time to transmit and record the block group is about 32 seconds; whereas the time required to check the block group recorded at the receiving end and reposition the tape would be about 1.75 seconds, or about 5 per cent of the time is used for checking. During this checking time, transmission from the transmitting end is stopped pending receipt of a resume or retransmit signal from the receiving end.

Question: Why do you use five feet of blank tape to detect the end of message rather than use a specific code?

Answer: With the exception of the odd parity bit redundancy deliberately introduced for error detection, the Univac code is a very low redundancy, or highly efficient, coding scheme, so it is not possible to use a specific single character code to detect reliably a mark or signal of such important logical consequence as an "end of message" signal. Even to limit detection of, and action on, such a single character code to the intervals such as end of a block of information known *a priori* possibly to contain it is not sufficiently reliable for so important a logical operation. Hence, it would require instead an entire blockette or block of a very unusual code pattern to reliably establish an "end of message" signal at the transmiting tape, and then either its accurate transmission to the receiving end, or the sending of a less redundant signal to the receiver and the regeneration and recording there of a similar coded blockette or block. Further, such implementation would require considerably more instrumentation at both Transrecorders, as well as imposing such an "end of message" coding on all source data devices. The relative case of implementation and reliability of generation and detection of an "end of message" indication with a short erased section after the last useful data resulted in this choice.

Question: To what extent does the time required to reverse line echo suppressors affect transmission time; for example, percentage increase per packet of data?

Answer: This relationship also is a rather complex one in the general case. The higher the bit rate and the fewer the number of blocks per block group, the larger is the percentage of the total time assigned to echo suppressor stabilization (line reversal). Also in the "answer back" mode, two line reversal times per block group are involved. If a one block per block group mode is selected, and 800 bits/second is the "on-line" data rate, approximately 8 seconds are required to transmit the data. The maximum echo suppressor stabilization may approach 0.3 second or 0.6 second for the block group cycle, so a 6 to 8 per cent time increase may be involved. At significantly higher bit rates this effect would be more important.

Communication between Remotely Located Digital Computers

G. F. GRONDIN† AND F. P. FORBATH†

Introduction

THE usefulness of complex data-processing centers can be increased by rapid and accurate communication between remote locations. The problems encountered in the data transfer are not new to the communicator; however, the familiar characteristics of the communications link assume increased significance when the digital nature of the data, the high information rate and the required degree of accuracy are considered. The stringent requirements demand that the communication system place special emphasis on providing maximum utilization of channel capacity, on minimizing the raw error rate, and on using special coding techniques to achieve unprecedented error detection.

The reliability achieved even by near-optimum communications systems falls short of the accuracy demanded. In spite of the communication-link limitations, the desired degree of accuracy is attainable by error-detection techniques and data repetition. The burden of error control as well as the task of providing compatibility between the various data sources and the transmission equipment falls on special converters (input-output devices). Their design is dominated as much by the inherent limitations and peculiarities of the communication system as by the characteristics of the data source. One such special converter

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intended for high-speed punched card transmission over voice-quality circuits is described, and it illustrates how a particular combination of parameters meets this specific requirement.

General

Since common wire-line facilities represent a vast available network, economical data transmission depends on efficient utilization of the voice channel. Unlike speech, the inherent redundancy of digital data is extremely low and a single error may cause misinterpretation. Therefore, three important properties the transmission equipment must have are 1) efficient utilization of bandwidth, 2) minimum binary error rate in presence of noise, and 3) low undetected error probability. The first two are related to the binary communication system while the third is achieved by redundancy and coding techniques.

The system's basic error rate or susceptibility affects the information rate. It determines the percentage of data which needs to be retransmitted or corrected and the amount of redundancy that must be added to detect erroneous data. Although theoretically any desired accuracy can be attained, the complexity and cost of doing so are directly related to this factor, and may be prohibitive.

Any error-detection method should meet system requirements with minimum redundancy, simplicity of coding, and freedom from systematic errors.

Kineplex

A communication system known commercially as Kineplex, which uses "predicted wave" techniques, is particularly well suited to digital data transmission. Its theory of operation and performance characteristics over radio circuits have been described in several papers.[1-3]

Kineplex lends itself to frequency, time and phase multiplexing for spectrum conservation; near zero crosstalk between adjacent channels is effected by synchronous keying and sampling of infinite-Q detection filters. The detection method provides perfect integration of the signal over the pulse duration while noise which lacks phase coherence is increased only on a rms basis. Phase-shift coding permits two independent bits of information to be encoded on each pulse by resolution of phase into quadrature components. Thus, predicted wave detection yields a gain in signal to noise ratio accompanied by a lowering of usable signal threshold and a narrowing of the required bandwidth

Wire-Line Application

The above techniques have been applied in the design of the TE-206 Kineplex Data System (Fig. 1), a general-purpose, high-speed binary data transmission system for voice quality circuits. It features efficient bandwidth utilization, low susceptibility to noise, adaptability to use with a wide variety of inputs, and parallel data transmission. Its proven superior performance is derived from the phase-shift keying and the ideal detection techniques summarized and referenced above.

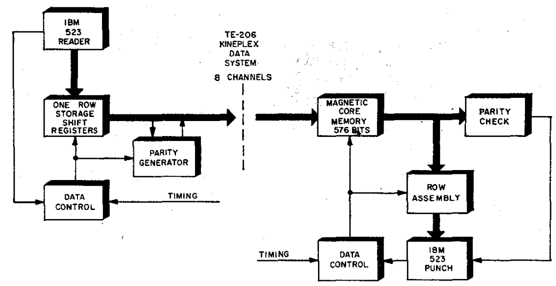

Fig. 1.

Specifically, it accommodates 2400 bits per second within a 2200-cycle minimum bandwidth. It provides eight parallel input channels and can therefore accept 8-bit characters at a rate of 300 per second. Each of the four tones, spaced 440 cycles apart, carries information from two input channels; the actual tone frequencies are determined by the line characteristic. To accommodate a majority of known facilities, tone frequencies of 935 cps, 1375 cps, 1815 cps and 2255 cps were selected for the TE-206. The 3.3-msec pulse length was selected to be several times longer than the expected duration of impulse noise, longer than the incremental delay distortion across the band of unequalized voice circuits, and yet short enough to provide frequency-error tolerance for carrier systems.

Since data can be handled in parallel by the transmission channels, the necessity of parallel to series conversion is avoided, and the cost and complexity of associated converters are reduced.

Kinecard (Fig. 2)

The wide use of the punched card as a versatile and reliable source document has produced the need to duplicate its information content at remote locations. The Kinecard converter system permits continuous and accurate transmission of scientific and business data from punched cards over common voice facilities. It illustrates how the various design parameters can be combined to maximize performance within the bounds of economic feasibility.

Punched cards are processed at a nominal rate of 100 cards per minute. This makes possible on-line use of IBM 523 Gang Summary Punches for local reading and remote punching of cards. Data are accepted from the card reader, indexing markers and check characters are added, and the information is presented as synchronous 8-bit characters suitable for Kineplex transmission equipment; at the remote end, the data are stored until required by the punch, its validity is checked, cards are punched and erroneous

[1] M. L. Doelz, E. T. Heald, and D. L. Martin, "Binary data transmission technique for linear systems," Proc. IRE, vol. 45, pp. 656-661; May, 1957.

[2] A. A. Collins and M. L. Doelz, "Predicted Wave Signalling," Collins Radio Co., Burbank, Calif.; June 22, 1955.

[3] R. R. Mosier and R. G. Claybaugh, "Kineplex, a bandwidth efficient binary transmission system," *AIEE Trans.*, to be published.

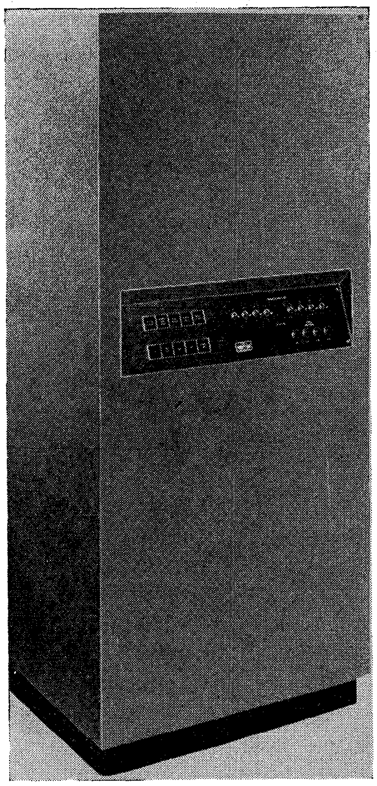

Fig. 2.

ones are offset. Operation is continuous without provision for answer-back or automatic fills.

Other than establishing a communication link prior to a card run, no special operational procedures are needed. Interlocks prevent initiation of a run unless Kineplex, Kinecard and IBM punch are ready. The converter controls parallel the punch controls and the system can be operated from either.

Design Considerations

It may be fairly stated that if cost and complexity are not considered, just about any combination of operating features may be provided. Features which were considered in Kinecard were code translation, format control, card verification, automatic error correction, and interchangeability of terminal devices. In its present form, Kinecard is a special-purpose device having reasonable efficiency and adequate error detection for wire-line applications.

The punched-card code contains twelve elements per card column to accommodate about 50 alphabetical, numerical and special characters. The 12-bit coding could be translated to a 6-bit code thus doubling the information rate of the transmission system. However, most card readers present the data row by row, 80 bits at a time, such that characters represented by each column can not be fully interpreted until a whole card has been read and stored. Transmitting the card as on a row-by-row basis eliminates extensive storage and code-translating circuitry.

The card reading and punching operations are not verified even though 2 or 3 machine errors per 10,000 cards are possible. Since these errors are not introduced nor aggravated by the communication equipment, their detection should be by routine accounting-type cross checks.

Transmission system detected bit error rate	10^{-3}	10^{-5}
Per cent cards in error (off-set)	60%	1%
Number of erroneous cards undetected	1 in 20	1 in 200,000

Fig. 3.

The error-detection scheme takes into account the nature of the noise over wire lines and the related error probabilities introduced by the Kineplex equipment in deriving its phase reference. The impulse noise which may affect all channels and the possibility of occurrence of adjacent bit errors are countered by deriving two separate lateral parity-check bits on each channel.

Assuming random-error distribution, the number of erroneous cards, detected and undetected, is tabulated as a function of system error probability (Fig. 3).

Operational tests are planned to determine the effectiveness of the error detection. If additional protection is required there is ample time between each card transmission to add more check bits.

Operation

Reference to the transmitted card format (Fig. 4) will help clarify operation of the converter.

Several control signals are derived from the card reader to indicate the start of the card-reading cycle and to identify each row of information.

A reader-card start impulse initiates the emission of several "start of card" characters which serve to index the remote punch-control equipment.

As each row of information becomes available from the reader it is transferred into eight 10-bit shift registers. A row-start character precedes each row-transmission cycle which consists of reading out all eight registers in parallel with synchronous pulses derived from Kineplex. The register is emptied before the next row is presented by the card reader.

At the end of the twelfth row the parity checks are inserted. Two parity-check characters are obtained from alternate data characters; two bits per row are derived. Each bit is formed by adding the number of punches and complementing to an even multiple of two. Fig. 5 is a simplified block diagram of the converter.

Since the reader undergoes speed variations, synchronization is achieved by inserting no-information characters between rows and between cards as required.

At the receiving terminal, card- and row-start markers are identified and they control the assembly of the incoming data into a magnetic core memory. The memory ca-