

Fig. 9

tion at the time. The specified maximum operating density was 100 bpi.

Summary

A method for magnetic head design has been presented which stresses a conceptual point of view regarding the recording process which gives considerable insight into the problem. Qualitative principles are made available as guides in design and allow a ready approach to evaluation and interpretation. Further, these methods can be usefully applied from crude estimates to any desired degree of refinement, and they lend themselves directly to a study of recording structures of a more radical nature.

Fig. 10

References

1. MAGNETIC DRUM RECORDING OF DIGITAL DATA, A. S. Hoagland. *AIEE Transactions*, vol. 73, Sept. 1954, pp. 381-85.
2. FIELD MEASUREMENTS ON MAGNETIC RECORDING HEADS, D. L. Clark, L. L. Merrill. *Proceedings, Institute of Radio Engineers*, New York, N. Y., vol. 35, Dec. 1947, pp. 1575-79.
3. STUDIES ON MAGNETIC RECORDING (Part II), W. K. Westmijze. *Philips Research Reports*, Eindhoven, Netherlands, vol. 8, June 1953, pp. 161-83.

A Terminal for Data Transmission Over Telephone Circuits

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THE Bell Telephone Laboratories has for some time been interested in digital transmission as a means of communication between automatic switching systems.

In a recent experiment, a simple terminal for data transmission has been demonstrated. Between two such terminals it would be possible to send data back and forth over ordinary telephone channels at the rate of 750 bits per second, or 1,000 words per minute.

The demonstration equipment involves magnetic tape to magnetic tape trans-

mission using amplitude modulation of a 1,200-cycle carrier. It employs a 7-bit self-checking code.

For a long time the Bell System has been interested in sending numbers from one place to another over ordinary telephone lines. When you place a call to someone on the other side of town, your central office must pass that party's number to his central office as part of the instructions for completing the call. This has been done over the same trunk that is used a few seconds later for the actual conversation. It has been done at speeds of less than ten bits per second—speeds comparable to that of the telephone dial. This has been extended to cover calls be-

tween cities, over a large part of our long-distance network. The speed has been doubled by the use of multifrequency signaling, which sends two out of five frequencies in the voice band.

Some time ago a study was made of various methods of transmitting digital data at considerably higher speeds. Part of this study is reported in a paper "Transmission of Digital Information over Telephone Circuits"¹ by Horton and Vaughan. With the coming of age of electronic digital computers and data processing techniques, it is apparent that this high-speed transmission may serve needs other than those of the control of telephone switching.

Bell research people have been considering what sorts of data transmission could occur over the great variety of transmission facilities that exist in the telephone system. Teletypewriter which is already in considerable use might be mentioned. For the most part a teletypewriter channel uses a narrow frequency band of something like 150 cycles and transmits digital information at the

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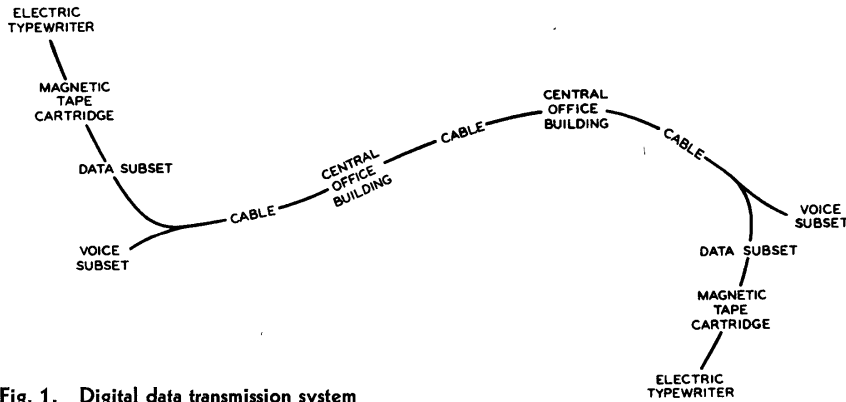


Fig. 1. Digital data transmission system

rather low speed of 50 or 75 bits per second. If the full width of a voice channel is used, a speed in the order of 1,000 bits per second can be reached. This can be done over existing telephone message circuits, the same kind of connection that people all over the country use every day to talk to each other. The use of this kind of data transmission in connection with centralized accounting schemes, centralized inventory control, the rapid handling of mail order business or insurance policy changes, and the like is easy to imagine.

For some of these purposes, or for others that may not have been thought of yet, still higher speeds may be needed. Specially treated lines may be necessary such as are used for certain data transmission jobs already undertaken.

In some of the carrier systems, several speech channels are modulated up in frequency and placed side by side to form what is called a group. This group then passes through cables, amplifiers, volume controllers, and equalizers as a single unit. The bandwidth of such a group is a dozen times that of a single speech channel, and its data transmission speed is proportionately higher. Perhaps these groups should be made directly available for some special data transmission jobs.

In the coaxial cable and microwave radio relay systems, these groups are combined into supergroups, and these supergroups into systems. One can imagine that someday whole batteries of high-speed computers might be scattered across the country, connected together by wave guides.

In the meantime some experimenting along these lines has been done. This is a report of a research group, and, therefore, does not describe any available service offering. If such a service becomes available it is possible, even probable, that the form will be different from that of the experiment.

There are many problems to be solved. As the business of data transmission is

approached there appear not only the obvious problems of transmission, but also the problems of technical compatibility between the business machine and the telephone network, and the problems of methods compatibility between office or computing procedures and telephone operating practices. It is highly desirable for the designer of business machines and the designer of business methods to work with the telephone man in solving these problems. This kind of co-operation has been going on for a long time. Currently a technical committee originated within the joint computer committee is quite active on just such problems.

Recent experimental work involves a system something like that of Fig. 1. A magnetic tape with the digital information on it is prepared on a machine that will be called the business machine. This tape is removed from the business machine and placed in a data subset, which is connected by an ordinary telephone circuit which is established through ordinary switching exchanges to a similar subset at a distant location.

The data set at one end reads the tape and transmits the information at high speed to the other end. The data set at the other end receives this information, checks it for plausibility, confirms reception or requests repetition as needed, and writes the received information on another magnetic tape. When this operation is completed, the tape can be taken from the data set, put in the business machine, and a hard copy can be printed out at the receiving end.

One of the important reasons for use of magnetic tape comes from the need for a speed translation. The normal telephone channel is capable of transmitting data much faster than a human being can operate a keyboard. But it lacks a great deal of being able to transmit data at the tempo of our modern digital computers.

It appears, therefore, that in most applications, some such speed translation will be desirable. Magnetic tape

provides an excellent means for writing at one speed and reading at a different speed. Magnetic tape can be easily stored and its associated equipment is quiet in operation.

This was the general plan. These are a few of the details. In the experiment an electric typewriter was used. Normally, it will prepare hard copy and paper tape from keyboard operation, or will print out from paper tape. It has been modified so that it will prepare hard copy, paper tape, and magnetic tape from the keyboard, and so that it will print out from either paper tape or magnetic tape.

On the magnetic tape a 7-bit serial code is used. The 7-bit code is an odd-parity check code. Actually this is restricted to a 3-or-5-out-of-7 code. At the beginning of each line the modification of the typewriter automatically inserts a 2-character START code on the tape. At the end of the line, or when the carriage return key is struck, it writes the carriage return character plus a 2-character STOP code. The normal typewriter mechanism performs the actual carriage return.

In the data set, the tape signals are used to produce simple amplitude modulated pulses of 1,200-cycle carrier. See Fig. 2. With a useful band of $1,200 \pm 500$ cycles, the theoretical limit on speed is a bit rate of 1,000 bits per second. When a factor of safety is put in, and when time

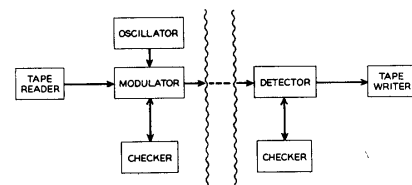


Fig. 2. Functions of the data subset

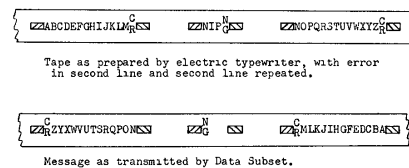


Fig. 3. Illustration of method of handling errors

is taken for start signals, stop signals and confirmations, there is an effective speed of a little less than 600 bits per second. This, on the 7-bit code, is a little less than 800 words per minute. With future developments, it may be possible to increase this speed.

The 2-character start signal is

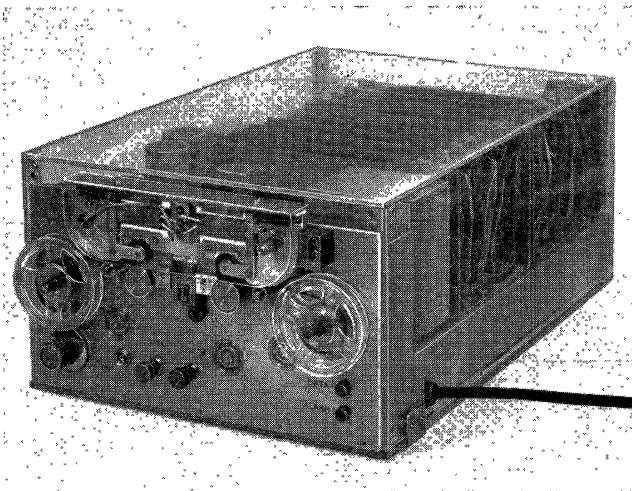


Fig. 4 (above).
Modified electric typewriter

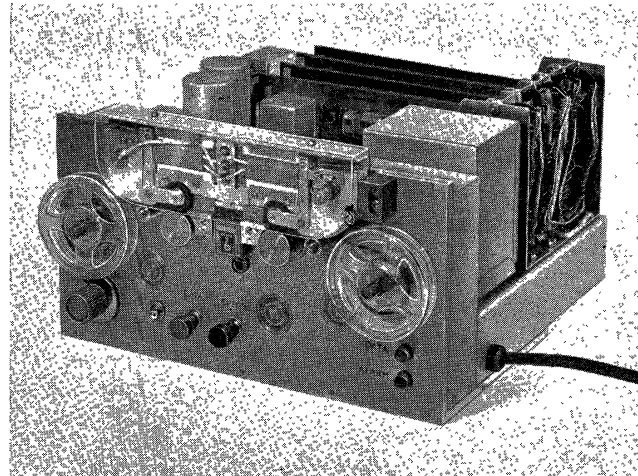


Fig. 5 (above right).
Experimental transmitter-receiver unit

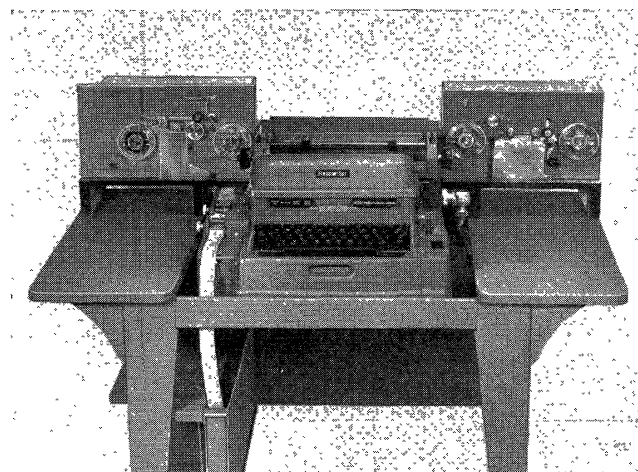


Fig. 6. Experimental data subset, complete with checker

1111111111001. On the long string of eleven 1's volume control is established, and synchronization on the final 1. A local clock oscillator in the receiver is kept in step after that by the bit structure of the message. With all characters in the age restricted to a 3-or-5-out-of-7 code, the longest possible string of zeros is eight. Such a string must be both preceded and followed by strings of at least three 1's. This permits satisfactory synchronization of the clock oscillator, and satisfactory volume control on the amplifier.

The magnetic tape is always reversed between writing and reading. That is, the tape is always read backwards. This avoids rewinding of the tape. Since there is one reversal at the transmitting end and one at the receiving end, a total of two which is an even number, the final copy comes out right end to. These tape reversals also permit a rather interesting method of handling errors.

If the typist makes an error and recognizes it she strikes the "Error" key. This prints an ERROR code and the STOP code on the tape, and operates the typewriter carriage return. Then she types the line again, this time presumably complete and correct. The magnetic tape now looks, symbolically, like the tape in Fig. 3.

The STOP code is the exact reverse of the START code. The transmitter, in handling this block, first finds a START code, then a block of the message, and then a STOP code. It transmits these signals, waits for confirmation that the receiver has made a satisfactory odd-parity check on each character, and then, after receiving that confirmation, starts again. It reads the START code, and then finds the ERROR code. This means that the block now coming up contains errors. So the transmitter simply stops

and waits for that false block to get out of the road. This is quite all right, of course, because the corrected block, although written later by the typist, has already been sent and acknowledged over the line.

In a similar manner, if a transmission error, as from noise on the line, produces an even-out-of-7 character at the receiver, the receiver remembers this till the end of the block. Then it writes a PLEASE IGNORE code at the end of this block, and asks the transmitter to back up and repeat that block. The typewriter, in printing out, now prints the good block, ignores the bad block, and thus produces only correct copy.

Fig. 4 shows the electric typewriter with the tape-handling equipment and circuitry used in its modification.

Fig. 5 shows the experimental transmitter-receiver without the error detection circuits. Fig. 6 shows the combination transmitter-receiver and checker.

The circuitry used here is similar to that now common in many digital computers. It is based on the use of transistors,

diodes, and magnetic cores. A general idea of its size can be obtained from the fact that in the complete transmitter-receiver checker a total of about 180 transistors are used.

In constructing and testing the data set mentioned here, a good many people have contributed in many ways. A few are H. W. Bode, T. L. Dimond, and J. R. Pierce who suggested the project, and W. D. Lewis and other members of the Switching Research Department of the Bell Laboratories who gave it advice and support. W. A. Malthaner has served as project engineer. J. E. Schwenker and G. P. Darwin have been responsible for much of the circuitry. J. F. Muller has been responsible for the tape-handling equipment. It is hoped that some of them will prepare more detailed reports on their work in the not too distant future.

Reference

1. TRANSMISSION OF DIGITAL INFORMATION OVER TELEPHONE CIRCUITS, A. W. Horton, Jr., H. E. Vaughan. *Bell System Technical Journal*, New York, N. Y., May 1955.

The Use of the Charactron with ERA 1103

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THE Charactron^{1,2} tube was invented by Joseph T. McNaney and developed by Convair since 1950. The main purpose for installing a Charactron on Convair's ERA 1103 computer was for real time simulation. However, other valuable uses for the Charactron on the 1103 have been found.

Physical Characteristics

This Charactron, with its cathode-ray display tube, type C7A, can display alphanumeric characters at a rate of 10,000 characters per second. The equipment which includes a cathode-ray tube with 7-inch-diameter screen can be used with either one of two cameras, easily interchangeable in a matter of a few minutes. Fig. 1 shows the Charactron with a Beattie camera using 35-millimeter film in a magazine. It is possible to remove the exposed film without removing or exposing the unexposed film. Fig. 2 shows the type of construction of the main body of the equipment. Fig. 3 shows the tube mounted vertically and viewed by the camera using a mirror mounted at 45 degrees to the camera lens and to the tube screen. The screen may be viewed through a filter during operation without impairing the results. The four drawers contain the power supplies.

The second camera, the Kenyon camera shown in Fig. 4, is a camera and photo laboratory combined. All operations, exposing, developing, fixing, and projecting, are performed in parallel. While the computer is calculating and displaying one page of answers, the camera is fixing and developing the previous pages. This process takes about 2 seconds, and if the calculations take more than 2 seconds a page, then the fixing and developing does not hold up the process at all. The finished film is extruded and can immediately be viewed on a film reader such as a Recordak. Editing can be done at this point to determine which frames are to be enlarged and printed. Fig. 5 shows the Charactron, with Kenyon camera attached, connected to the ERA 1103. A test generator is also included in this unit which enables alignment adjustments to be made without the use of the computer.

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A 6-bit code is used to select the proper alphanumerical character from a matrix in the Charactron tube. These characters are in a 6-by-6-array. Three bits are used for horizontal selection and 3 for vertical. A 20-bit code is used to position the characters on the face of the tube. Ten of these are used for horizontal selection and ten for vertical. Thus, a total of 26 bits defines the alphanumerical character and its position on the face of the tube. The IOB buffer on the 1103 has a capacity of 36 bits. The characters we chose to display are the numbers 0

through 9 and the alphabet not including the letters O or I. (The numbers zero and one do double duty.) A decimal point and a minus sign complete the list of characters.

Applications

As an aid in debugging, it can display the contents of memory, Fig. 6. Another common technique used in debugging a floating point program is a trace or auto-monitor, Fig. 7. This is an example of a concurrent trace giving the address, the command, and the result of each command. The trace operates at a rate of better than ten lines per second. The Charactron can also be used to edit input data. In this case, while the computer is calculating the results, the input data are plotted. Cases that show up with points obviously

Fig. 1

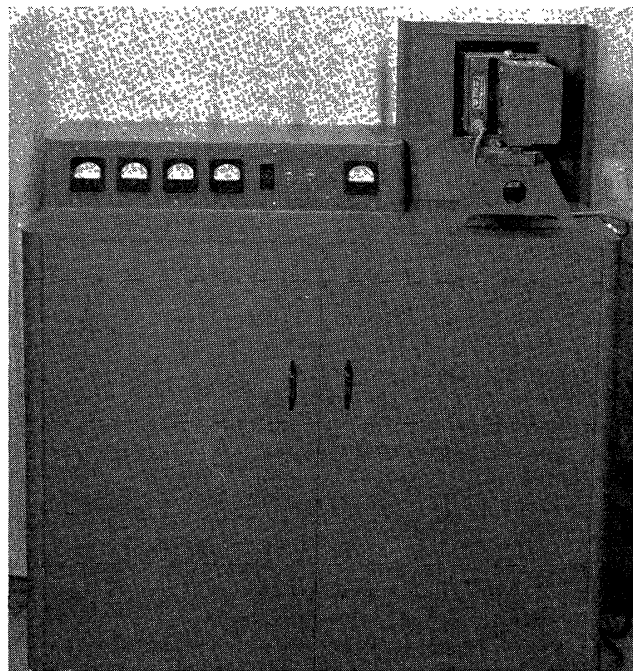


Fig. 2

