DESCRIPTION

The teletypewriter to be described is an advanced, electronic, transistorized version of an earlier machine using the old principle of transmitting the "picture" of a character by a dot-matrix. A prototype developed in 1954-56 is shown in the attached photos and drawings. The prototype used mechanical means to code and decode the information.

The teletypewriter transmits and receives information to position and actuate a single vertical row of printing wires (styli) to reproduce a character by a series of vertical rows of dots. The information to actuate the styli is transmitted and received as coded pulses.

The dot-matrix concept as developed in this teletypewriter, Figure 1, is applicable for a wide range of uses, enables transmission and reception up to 600 words per minute or higher, and can be packaged in various shapes due to the transistorized electronics and the simplicity of the printing head (recorder).

The dot-matrix principle gives a very high degree of reliability to communications due to the go-no go indication inherent in this type of character formation. As opposed to the usual form of teletypewriter machine where one misplaced code pulse will result in a legible but incorrect character and garbling of the message, the dot-matrix printer will not garble as a result of misplaced pulses, but will just add or omit dots in the formation of the character. The probability that 10 or 15 randomly received interference pulses will be placed in a 35-dot matrix so as to give a legible character is extremely low and needs not to be considered. Only when the printed character is undiscernable as a result of the extra dots or noise, is the machine printing illegible but not garbled information. When you can read it, it's go.

A well-known machine representive of the dot-matrix type of teletypewriter was the "Hell" (name of designer) teletypewriter, developed about 1930 and used prior to and during the Second World War by the German Army.

The "Hell" printer was extremely simple and reliable. Because of the narrow bandwidth requirements, it was capable of transmitting and receiving legible characters over telephony circuits considered unusable for voice transmissions because of the high noise level. However, a serious disadvantage of the machine was that it required synchronous transmission. With this type of transmission, transmitting and receiving machines operated in step and continously. The operator had to touch the keys at the proper moment, and every lost time unit caused a space in the received print.

The PKT printer, developed in 1954-56, was an outgrowth of the "Hell" printer. The PKT printer continued the use of electromechanical means of coding, decoding, and printing the characters on a tape or on a page of paper, but did away with the need for synchronous transmission; using instead a start-stop method. While the start-stop method does require higher quality transmission links than Synchronous method, since a noise pulse could be taken for a start pulse, the advantages for outweigh the slight increase in bandwidth required.

"While the PKT printer was considerably smaller and lighter than the "Hell" printer, the majority of the space and weight were devoted to mechanical apparatus necessary for operation.

The presently described teletypewriter uses the same principles of the dot-matrix character, but can be reduced in size and weight because of the use of solid-state techniques in the construction of the coding and decoding apparatus, and of the reduction of mechanical apparatus.

It operates in a semi-synchronous transmission mode which combines the advantages of the old "Hell" typer of being able to operate through noisy channels, with the start-stop mode of the usual teletypewriter. The synchronism of the transmission and printing does not depend upon the accuracy of the start signal.

In addition to these advantages and the achievement of greater communications reliability, this teletypewriter is mechanically simple. There are few moving parts, much less moving mass, no motor, and no involved mechanical linkage. This results in a light-weight machine about the size and weight of a portable typewriter, that is very quiet, and gives off very little heat.

The recorder might be constructed as part of a page printer about the size and weight of a small portable typewriter or as a tape printer, even in conjunction with a chadless tape punch.

A possible use of a tape printer would be the communication with an aircraft where the tape printer would be made the same size as a standard flight instrument and mounted in the instrument panel to communicate flight orders to the pilot. This would allow the transmission of a number of symbols in addition to letters and numbers to aid in the direction of air traffic with the feature of permanency of the printed word and a reliability of transmission which hardly can be reached by the five- or seven-digit code.

In addition to being used to send the printed word or printed symbols, the same page-printing teletypewriter can be used to print pictures.

At the present time, the recorder is capable of reproducing a picture approximating a 50 dots-to-the-inch halftone picture.

In addition to printing directly on a sheet of paper or on a tape, the dot-matrix could be reproduced by electrodeposit of metal ions on treated paper by direct electrical contact. This method of printing would also provide printing of halftones and ultimate realization of printing speeds; exceeding 1,000 words per minute while maintaining the same advantages of reliability.

The present design permits a teletypewriter of very flexible design. Due to the solid-state coding and decoding equipment, the machine will operate with a low-power requirement, from commercial power or from batteries, making it particularly attractive for mobile or portable operation.

The teletypewriter requires a series of pulses in order to operate. These pulses can be transmitted on a polar or on a non-polar line, as single or two-tone modulation of a carrier, by a tone oscillator, or by frequency-shift keying.

While this machine can achieve ultimate transmission speeds only when used with others of the same kind, it is quite possible to operate this machine in conjunction with the common teletypewriter through buffer equipment, for instance as an extension of the teletyping network over local telephone lines into every home or office without the need for any additional installation.

PRINCIPLES OF OPERATION

GENERAL. The teletypewriter described is based on the use of a wire (styli) printing head (recorder) that prints characters with a dot-matrix formation of five vertical rows of seven dots each. The operation of the machine depends upon the printing of seven dots by a single vertical row of styli that moves along the paper in response to coding and timing pulses.

PRINTING. Printing is accomplished by pressing any of the seven styli against the paper in sequence as determined by the receiving and decoding apparatus. After each row representing a vertical scan has been formed, the recorder (or the paper in the case of the tape printer) is moved to position the styli for the next scan.

Spaces between characters are formed by the start pulse. In the case of receiving, the recorder is moved one vertical-scan space to the right after the last or fifth vertical scan. The recorder rests in this position until the next start scan is received. When the start scan is received, it is not printed but the recorder is activated to print the next following five scans.

In the case of transmitting, the start scan is transmitted before the five vertical scans making up the character. Thus, inter-character space is formed before the character is transmitting, and after the character in receiving. An inter-word space the length of one character is obtained by transmitting the start signal only. The recorder is activated the same way and moves six scans without printing.

Non-printing functions such as carriage return, paper advance, space, and others (there is no character shift) are keyed by transmitting pulses of non-harmonic frequencies. These pulses trigger tuning-fork resonators that in turn activate the mechanism to perform the function.

CODING. Each vertical scan consists of eight pulses, Figure 1. The first pulse (1) of each scan is the timing and synchronizing pulse for the receiver. The succeeding seven pulse positions (2 through 8) each represent one of the seven styli of the recorder in a vertical row. After each series of eight pulses or one vertical scan, the recorder is moved one space to the right and the vertical scanning is repeated for each vertical row; S, and A through E.

To transmit at a rate of 75 words per minute, a common rate of transmission on teletypewriter circuits presently in use, requires 7.5 letters per second or 45 scan lines per second (five vertical scans for the character and one for the space between characters). At eight pulses per vertical scan, this amounts to 360 dots per second or a frequency of 180 cycles per second of the master oscillator, Figure 2.

This basic frequency of operation (redundant code) requires a bandwidth approximately seven times as wide as the bandwidth required for the five-pulse (really seven since it also requires a start and a stop pulse) code presently in use. However, since this described coding can operate in the presence of a higher noise level in the channel, the bandwidth signal-to-noise product is the same or less than that for the commonly used seven-digit code.

The ability to operate in the presence of relatively high channel noise makes this new system particularly adaptable to such communications systems as the FAA's Automatic Ground to Air Communication System (AGACS). These systems suffer from not only the predictable thermal noise but also from unpredictable and unaccountable static and man-made noise with much higher random spikes of energy.

In addition to the ability to operate in high noise levels, the methods of coding and printing operate to prevent the presentation of false information and to permit the operator to recognize when a transmission is unreliable. Since the character printed is composed of dots, the addition or the omission of an occasional dot will not impair the ability to read the character. This is in direct opposition to the commonly used code where one pulse added or deleted can result in printing a perfectly legible but incorrect character.

Coding is based on vertical scans composed of eight units (dots). (1 through 8, Figure 1.) Five vertical scans make up the vertical portions of each character (A through E) and each character must be preceded by one vertical scan "S" called the start scan, which is also the space between characters. Although each vertical scan consists of eight pulses, only seven of the pulses are used to operate the styli of the recorder (2 through 8). The first pulse of each vertical scan "1" is a synchronizing pulse to keep the receiver continuously in synchronism with the transmitter.

This sort of operation makes the teletypewriter able to retain synchronism of the vertical scans even when operating on channels where the noise is nearly the same as the signal level.

The start signal "S" is received with a narrower bandwidth so that it indicates reliably the start of a transmission even when the signal level is down to a noise level that renders the printing nearly illegible. However, the start signal is not used to provide synchronism for the code transmission.

The start scan consists of the 1st, 3rd, 5th, and 7th pulses of the first vertical or "S" scan, Figure 2. These pulses are integrated in a special narrow-bandwidth portion of the receiver by applying the pulse to a tuning fork resonator ("S", Figure 3). The basic frequency of the resonator (180 cycles per second in the case of 75-words-per-minute operation) is one-half that of the basic pulse rate of each vertical scan. If the start pulses are in the correct phase, they will start to build up the tuning fork resonator at the proper frequency. When, during the time of the start scan, the amplitude of oscillation of the resonator reaches a critical level (bias level), the recorder will be turned on, allowing the five vertical scans following to be recorded.

While this teletypewriter operates start-stop with full synchronism of each character, there is a limitation on the occurrence of the start pulses. Each idling pulse "1" serves to insure synchronism of the tuning-fork generators in the transmitting and in the receiving machines as well as to reset the dot counter in the receiver. In addition, each idling or synchronizing pulse "1" represents a unit of time when a start signal may be transmitted.

At a rate of 75 words per minute, a start scan may be transmitted in any 22-millisecond time period. At higher word rates, the time period becomes less. Thus, for practical purposes, the machine has the capability of full, free, start-stop operation.

Once the start scan has been transmitted, the two machines run in synchronism for the time required to transmit the character, then return to idling operation with the master oscillators kept in synchronism by the pulses 1 in "I"; and the recorder stopped and ready to receive the next start "S". The transmitter has interlocks to prevent transmitting two characters at one time and to insure that each character is transmitted without overlap.

TRANSMITTING. Each machine (transmitter-receiver) contains a tuning-fork generator (master oscillator, Figure 2) that operates continuously at 180 cycles per second during the time the unit is on. The controlling frequency of 180 cycles per second is applied to a dot counter. The dot counter (Figure 4) consists of the master oscillator, two binary counters, and a matrix with eight outputs. Any time the unit is in the transmitting mode, a series of pulses will be sent to the receiving unit from the first output "1".

These pulses represent the "1" pulse of every vertical scan. When they are received as synchronizing pulses to keep the tuning-fork generator in step, they are designated as I_1,I_1 ..., and so forth. After the receiver has been keyed to start recording, these pulses are designated by S_1, A_1, B_1, C_1, D_1, and E_1, representing the first pulse of every vertical scan, including the start scan for a character. These pulses function to reset the dot counter in the receiving unit and to provide the basic synchronism between the 180 cycles per second generators in the transmitting and in the receiving units.

When a key in the transmitting unit representing the character desired to transmit is pushed down, a switch operated by the key connects the dot counter to the scan counter.

As soon as the dot counter flips to the "one" pulse of the first vertical scan "S_1", the scan counter starts to operate in the first location, transmitting pulses in S_3, S_5, and S_7, or in this special case of the start signal, at the frequency of half the total dots possible per second. This start sequence is necessarily part of every character.

As an example, the sequence for the transmission of the letter E will be given. By extrapolation, the transmission of any character can be determined.

Following the start scan, the next five scans contain the information to form the character. Pulse "one" is the synchronizing pulse and is present in every vertical scan. In the case of the letter E, the dot-matrix causes pulses to be transmitted in positions A_1, (synchronizing pulse) A_2, A_3, A_4, A_5, A_6, A_7, and A_8, (Figures 1, 2). After the completion of vertical scan A, the line matrix shifts and the dot matrix transmits vertical scan B.

Vertical scan B consists of pulses in positions B_1 (synchronizing pulse), B_2, B_5, and B_8. The line matrix shifts again and pulses C_1, (synchronizing pulse) C_2, C_5, and C_8 are transmitted. The line matrix shifts again, and pulses D_1 (synchronizing pulse), D_2, D_5, and D_8 are transmitted. The line matrix shifts once again, and pulses E_1 (synchronizing pulse), E_2, and E_8 are transmitted, completing the transmission of the letter E.

The transmitting matrices (Figure 4) operate in conjunction with the basic frequency of 180 cycles per second produced by the tuning-fork master oscillator. The basic frequency is counted down through binaries to provide the sequences necessary for the generation of vertical scans and of characters.

RECEIVING. The receiving portion of the unit uses the same tuning-fork master oscillator as used for transmitting. It is continuously synchronized by the pulses I_1, I_1,... . In the receiver, only the dot counter operates to provide the switching sequence for the recording distributor to operate the seven styli in the recorder.

The receiving apparatus contains two outputs. The first output is a narrow-band output that contains a tuning-fork resonator. This output is used to develop the start signal for the recorder. The wide-band, second output is connected to the recording distributor which in turn controls the action of the recorder.

The output of the narrow-band filter when the machine is receiving the synchronizing pulses, characteristic of the idle state, is very low and will not actuate the start mechanism of the recorder.

The synchronizing pulses transmitted during the idling condition are effectively blocked by the tuning-fork resonator, Figure 3A. However, if the pulse frequency of the start scan is applied to the fork resonator, the tuning fork will be excited into high-amplitude oscillations that are sufficient to overcome the bias on the input to the start-stop controller, starting the recorder (Figure 3B).

The narrow-band characteristics of the synchronization will keep the receiving machine in synchronism with the transmitting machine even in the presence of a level of noise that would cause 10 to 20 per cent erroneous dots to be printed and would render the printed characters just below the level of legibility.

After the receiving machine has been triggered for operation, the five following vertical scans, A through E, are permitted to code the styli, resulting in printing of the desired character on the paper.

The receiving machine is kept operating by the reception of start scans for every character. When start scans are no longer received, the recorder will stop. In this idling state, only the master oscillator and dot counter will be kept in synchronism by the synchronizing pulses "1" characteristic of the idling state "I".

In order to insure that the receiving machine stays in step with the transmitting machine, the initial pulse "1" of every vertical scan is applied through a synchronizing circuit to the master oscillator and dot counter.

THE CIRCUIT DIAGRAM

A. Transmitter (Figure 4)

The master oscillator is a tuning fork generator that maintains a very accurate frequency of 180 cycles per second (or any other frequency related to the required transmission speed).

It also operates as the first binary of the dot counter and puts out a rectangular wave which controls the second and third binary. These binaries operate continuously so long as the teletypewriter is turned on for receiving or transmitting. A dot matrix with eight outputs is controlled from the three binaries and it switches continuously with every half wave of the master oscillator.

The number "1" output is connected directly to the transmitter so that when the transmitter is turned on it transmits continuously the idling pulses "I_1" (Figure 2) during idling as well as "S_1, A_1 through E_1" during code transmissions.

A second set of three binaries, the scan counter, does not operate during idling time. It is connected to the third binary of the dot counter by the transmission start switch.

When a key is pressed, the start switch connects the scan counter to the dot counter and the transmission starts with the start signal "S" (Figures 1 and 2). The scan counter, through the scan matrix, counts six steps; S, A, B, C, D, and E. The "E" scan disconnects the start switch unless another key is down. When no key is down, the transmitter goes into idling state "I". (Figure 1 after transmitting letter E.) If another key is down, the transmission continues directly after scan "E" with the new start signal "S" (Figure 1, letters A, R).

When the start switch is turned off during scan "E", the scan counter remains in the "E" position but the output from the transmitting matrix to the transmitter is turned off by the scan "E" and the last dot "8" from the dot counter. In this position of the scan counter, the first and third binary are in position plus 1, the second binary is in minus 1 position. The connection between the binaries can be interchanged so that after the "E" scan, the third (instead of the second) binary flips with the first binary into minus 1 position and the second binary remains in the minus position when the next "1" is switched in the dot counter and the start switch is closed. Thus, the scan counter counts only six steps instead of eight and starts again with "S" after "E".

When a key is down, the "S" scan transmits dots "$S_{3,5,7}$" over a fixed matrix. The dots "S_1" and "A_1" are transmitted by the idling state. The sequence "$S_{1,3,5,7}$ A_1" is the start signal. After the start signal, the scans A through E are connected to individual matrix combinations which are activated by the keys. Each scan transmits a dot combination out of the number of available 7 dots, "2" through "8".

During the "S" transmission with the key down, the dot code combination from the key is transferred into the transmitting matrix and activates the special dot combinations A through E to be transmitted. After this, the key can be released and another (or the same) key may be pushed down before the end of the code transmission with scan "E". Then the transmission continues directly after "E" with the new start signal "S".

A mechanical interlock prevents two keys from being pushed simultaneously and an electrical lock may be used to hold the key down until the code is transferred into the transmitting matrix during scan "S".

The keyboard and transmitting matrix may be replaced by an automatic tape transmitter.

B. Receiver (Figure 4)

When the opposite transmitter-receiver is switched to the transmit mode, it transmits the pulses of the idling state (A, Figure 2). These pulses "I_1" are received and amplified in the receiver amplifier. This amplifier covers the required bandwidth; 360 cycles per second for 75 words per minute using a master-oscillator frequency of 180 cycles per second.

The received idling pulses are connected to the synchronization set. Here idling pulses are correlated with the master oscillator frequency and serve to keep the oscillator in the receiver in pace with that of the transmitter over a circuit with about 0.5 second integration time. The length of the integration time may be set to provide adequate synchronization in the presence of a high noise level.

Basically, a fork oscillator may be expected to keep its frequency to better than 0.1 per cent. This is 0.18 cycles per second for a frequency of 180 cycles per second. Thus, even without synchronization, the transmitter and receiver may have a phase difference of one cycle per 5 seconds. The synchronization will provide a positive or negative phasing bias to the receiving oscillator and pull it in step within 0.5 to 1 second. After the bias is set, it can keep the receiver in pace over a time of more than 10 seconds when no synchronizing pulses are received.

The "1" pulses from the dot matrix are correlated with the received "1" pulses and used to reset the dot counter to coincide with the transmitter.

After counter reset and synchronization has been achieved within the first 0.5 second, the receiver will run in step with the transmitter for at least 10 seconds and it will be kept in synchronism continuously by the pulses "1". During the idling state, the start circuit receives the idling pulses only. A narrow-band fork resonator receives these signals but reacts only with a mode-rate amplitude, Figure 3A. The pulse "1" induces an amplitude which is not sufficient to overcome the bias at the first hit and the oscillation fades out before another pulse arrives.

However, when a start signal arrives that consists of five pulses of the frequency of the master oscillator, it builds up a high amplitude oscillation which is able to overcome the bias threshold. (Figure 3B, marked within the two lines.) The start signal is accepted and the recorder is turned on by the timing pulse "1" from the dot matrix.

The recording distributor is controlled by the dot matrix output 2 through 8 and the received code pulses operate the styli 2 through 8 during the scans A through E.

At the same time as the styli are operated, the mechanical movement of the recorder or of the paper (relative to each other) makes six steps to record the five scans A through E and one space. The movement of the recorder, because of the mechanical mass, will be continuous rather than step by step resulting in a record like Figure 1 or the record shown from the prototype model 1956 with tilted vertical lines.

The start will not be activated by occasional flares of high noise level (statics and man made); a more continuous high noise level will render the transmission useless anyway.

The transmitted start pulses are coherent with the master oscillator frequency from the transmitter. Also, when the receiver is synchronized, they must be coherent with the receiver oscillator. As an additional precaution against incoherent noise pulses, the receiver oscillator frequency may be used in the start circuit as a correlation signal to receive and pass only those wanted signals that are originated in the transmitter. Other mechanical (or electrical) functions (except character shift which is not needed) may be provided by fork oscillators of non-correlated frequencies. Fork resonators of the same non-correlated frequencies may be used in the transmitter to generate a frequency and in the receiver to receive it and provide the control for those functions. The bandwidth will be narrow and related to the whole time for transmitting one character; 7.5 cycles per second. Therefore, they will operate well below the noise level that is the limit for the code transmission. During reception of these non-correlated frequencies, the whole transmitting part from the start switch through the scan matrix, transmitting matrix, and transmitter does not operate.

During transmission, the transmitting unit provides local copy, insuring that the proper signals are being presented to the system.

Conclusion

The experience obtained during the operation of the prototype models in 1954-57 provided much information on how to design a new solid-state circuitry teletypewriter. The new design, besides using solid-state circuitry, has been modified completely in order to achieve the most security for transmission in a high-noise environment.

In the conventional design of a five- or seven-digit code transmission, the start pulse is at the same time the synchronizing pulse for the code, even when the message is prepared on a tape and then transmitted synchronously.

In the new design, the start pulse indicates the start of a transmission only and may be transmitted on a much narrower bandwidth. The code synchronism is kept by other means also with narrow bandwidth.

The code arrangement is related to the "form" of the transmitted letter and with its seven times redundancy provides secure transmission in the presence of a noise level which would render a seven-digit code useless.

Finally, in this new teletypewriter, noise may render the transmission illegible but noise cannot introduce legible but false characters. This is of special importance in the transmission of ciphers or coded messages the meaning of which cannot be recovered as that of false characters in a clear text word.

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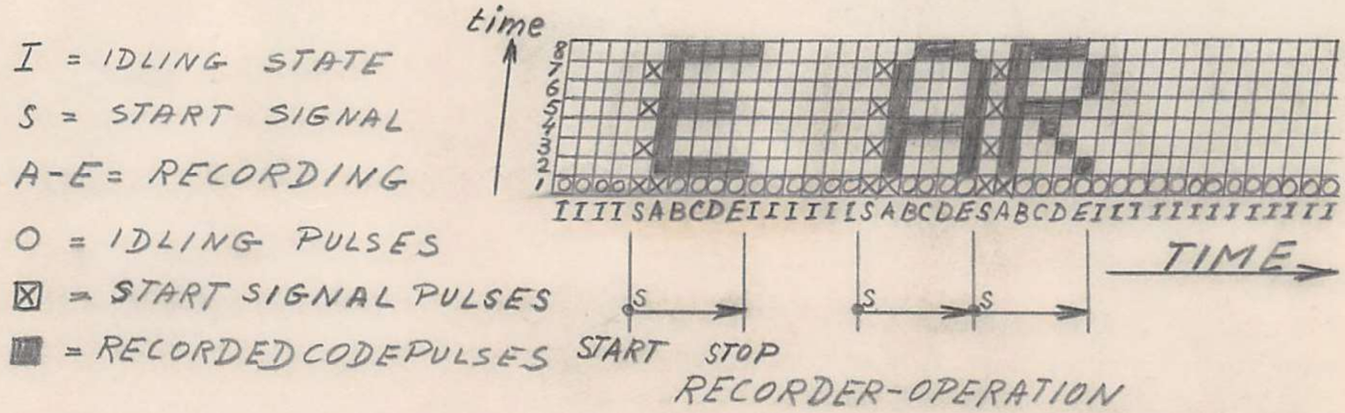


FIG 1. 5×7 DOT MATRIX

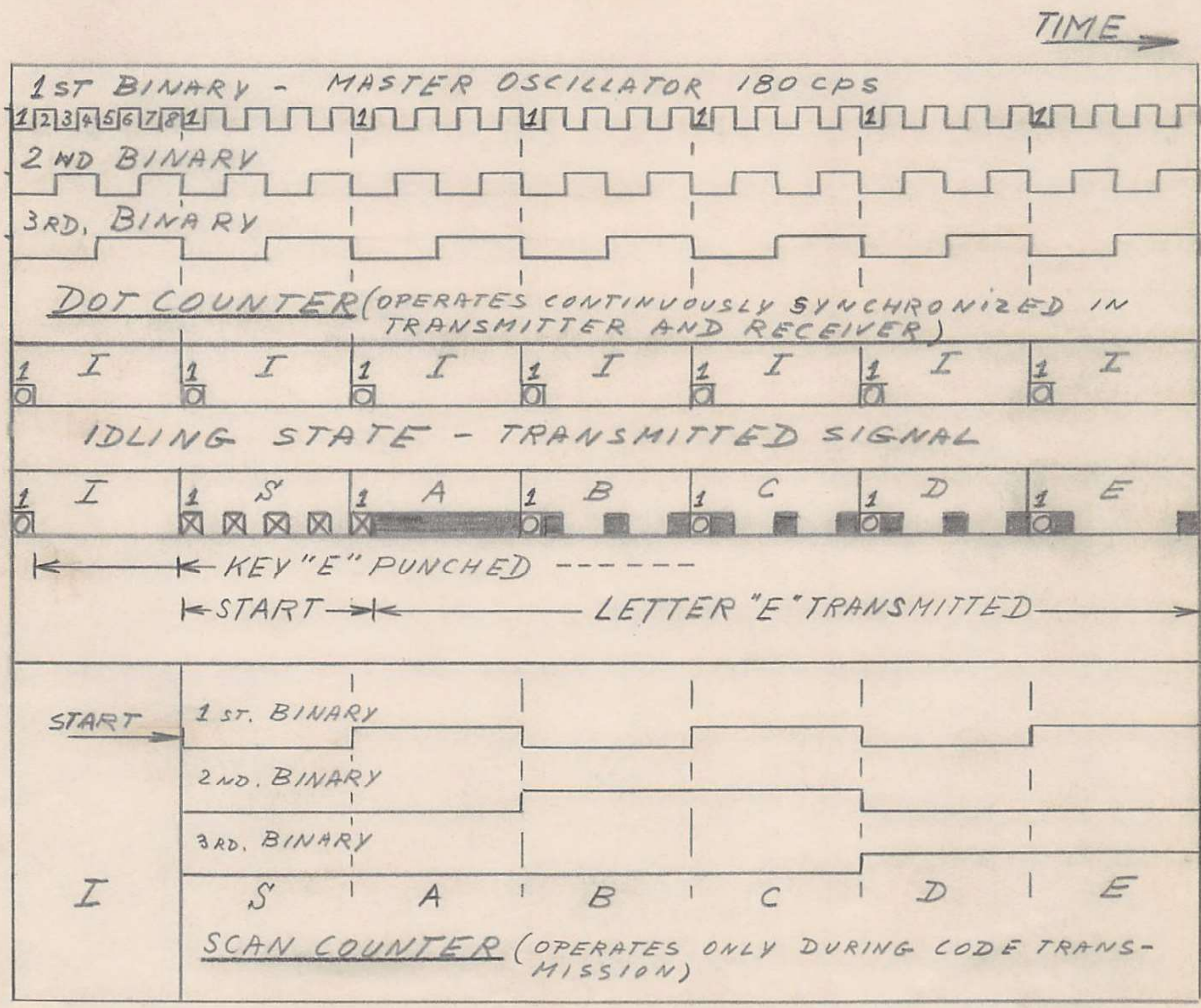


FIG 2. CODE TRANSMISSION.

R

1 SEPT. 61. F.L.P.

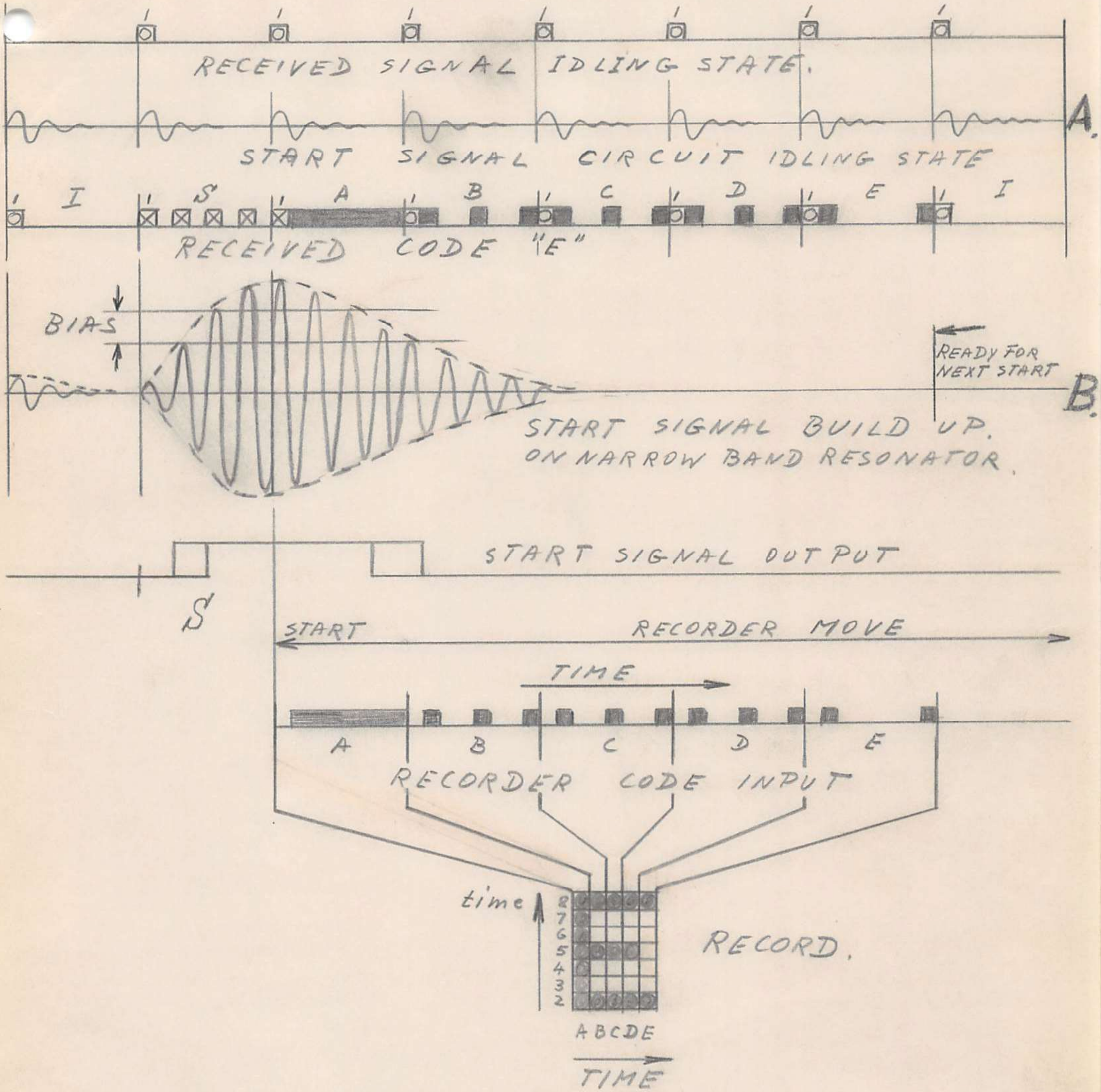
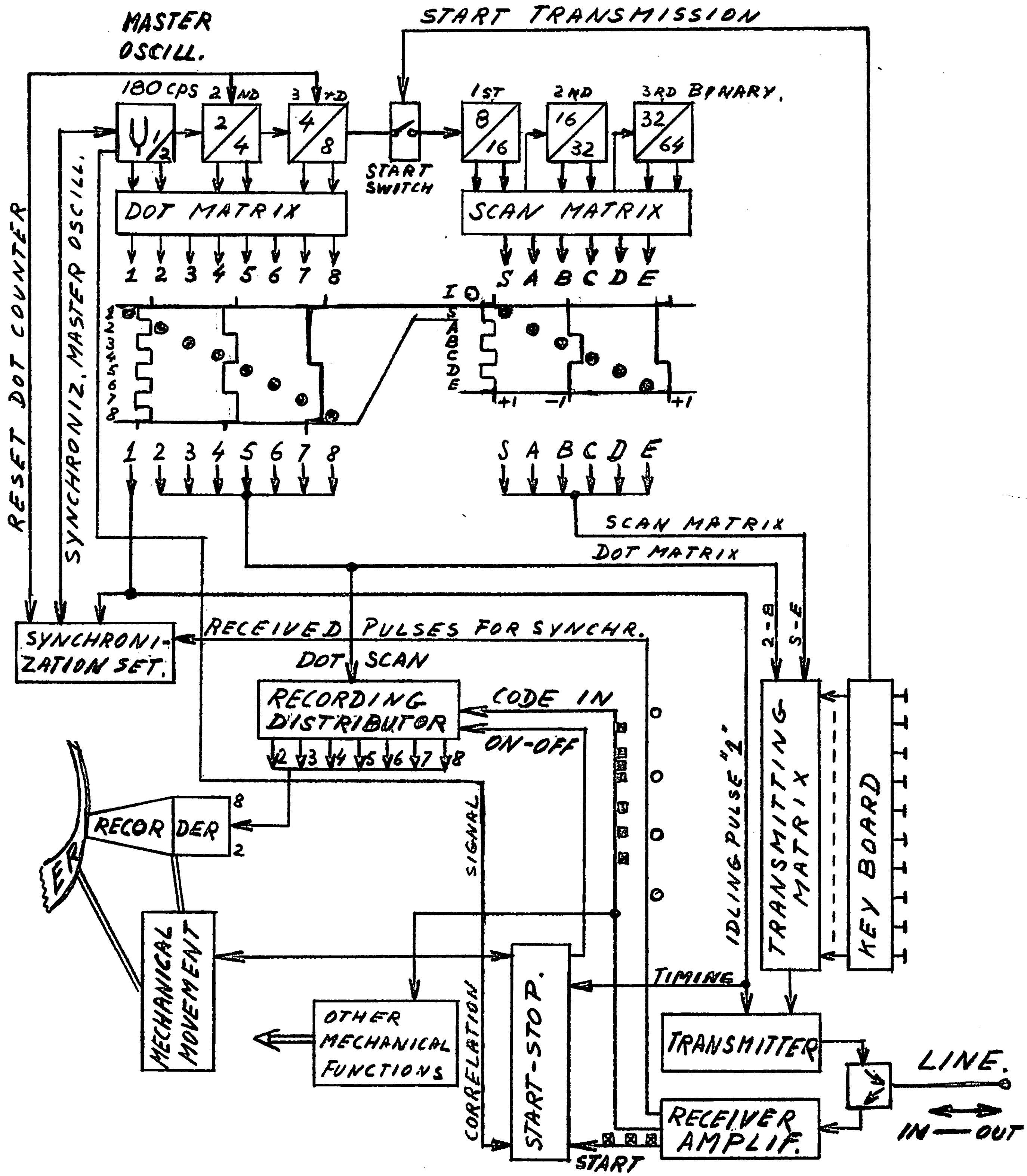


FIG 3. RECEIVING.

R

1 SEPT. 61. F.K.P.



TELETYPEWRITER
BLOCK SCHEMA.

FIG. 4.

1. SEPT. 61. F.M.P.