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WESTERN UNION Technical Review

Switching System Plan 55-A

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Data Transmission Testing Set

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Telefax Instrument

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"MITE" Teleprinter

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Six-Channel Multiplex for Submarine Cables

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W/U

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Automatic Telegraph Switching System Plan 55-A

A new world-wide military communications system has been designed for the U. S. Air Force by Western Union engineers. Now, fully automatic telegraph switching equipment with substantially greater message capacity will replace push-button apparatus, also designed by Western Union, which has been used by the Air Force in its highly effective 200,000-mile domestic network since 1951.

Operating normally at high speed with a minimum of skilled personnel, the automatic system is compatible with other military systems and is operable manually if desired. Its features include efficient distribution of multiple-address messages and automatic preference in switching for telegrams of high priority.

THE 200,000-mile private wire network of the United States Air Force, in operation since February 1951, includes five Plan 51 switching centers in the United States, leased from Western Union. These centers are interconnected by trunk lines and each center has lines radiating to tributary stations in its area. Gateway centers near the Atlantic and Pacific coasts extend the network over radio channels to numerous Air Force installations overseas. Satisfactory experience in operating this network, with its push-button operated switching centers, has led the Air Force to request Western Union to engineer a fully automatic switching system for world-wide use. It is expected that automatic switching will increase the speed and efficiency of message handling and result in considerable reduction in operating labor. It will also provide for additional circuit capacity.

This new switching system (Figure 1), known as Plan 55-A, has been developed for the Air Force for handling military traffic. It is expected that Plan 55-A automatic switching centers will be installed to replace the present Plan 51 centers in the United States and for overseas use as soon as equipment is available.

In order to meet the needs of the U. S. Air Force for rapid and secure transmission of very large volumes of military traffic over a world-wide network, a switching system should fulfill the following requirements.

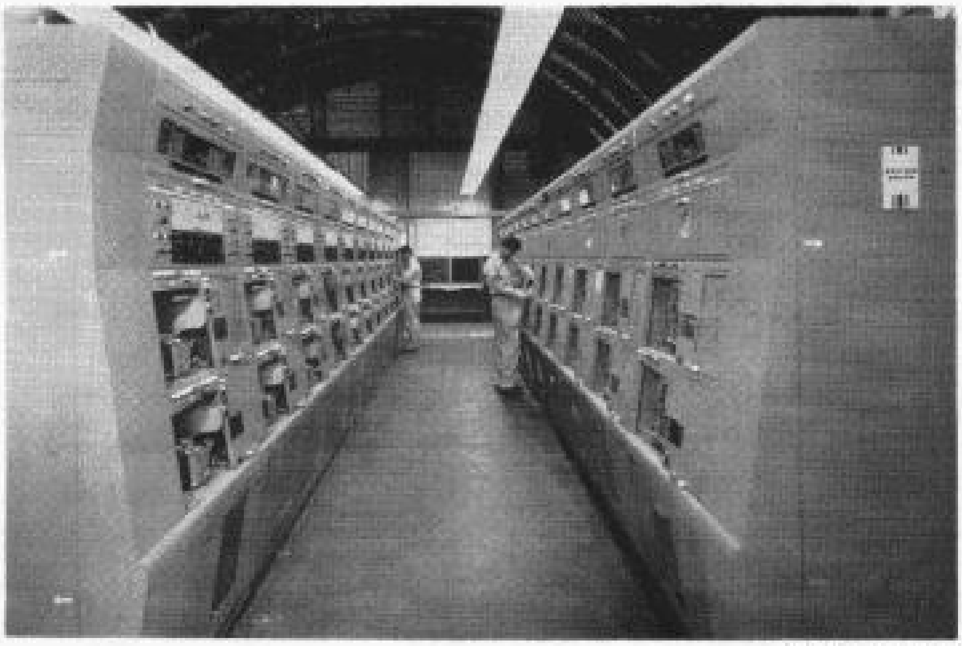

Photo R-11,029

Figure 1. Plan 55-A prototype, set up for test

1. It should provide for rapid automatic switching of messages through any number of switching centers without operating attention.

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., February 1958.

2. Where defects in a message or trouble conditions prevent automatic switching, means should be available for immediate manual (push-button) switching of messages to avoid delay.

3. The switching system must be compatible in operation with the equipment used by the other military services, so that messages can be relayed from one service to another without manual retyping. Obviously, the switching system must also be compatible with any other message relaying system in use by the Air Force.

4. The switching equipment must be capable of either automatically or manually switching multiple-address messages.

5. The equipment should be designed on the "building block" principle, with the minimum number of different types of cabinets, each complete in itself, with plug-in connections to the other cabinets arranged for quick installation, or quick removal and reinstallation at another location, of all or part of a switching center as may be required. The common use of essential equipment should be avoided.

6. Fast handling of all traffic, but with preference in switching being given to messages of high precedence, is essential.

The Plan 55-A Switching System, developed by Western Union to meet these requirements, consists of groups of equipment units installed in switching centers interconnected over a network of lines or radio channels to form an operating system for automatically relaying telegraph messages. A typical Plan 55-A network, such as that shown in Figure 2, has a number of reperforator switching centers interconnected by trunk lines, with lines radiating from each center to tributary stations in the area served by that center. Messages originated at any tributary station are relayed automatically through one or more switching centers to their destinations at other tributary stations. This system can be operated over a nation-wide network of trunk lines or radio channels and can be expanded beyond national and continental boundaries. A Plan 55-A switching center can exchange traffic with centers using other types of switching equipment, including Plan 51 reperforator switching or semiautomatic ("torn-tape") relaying equipment.

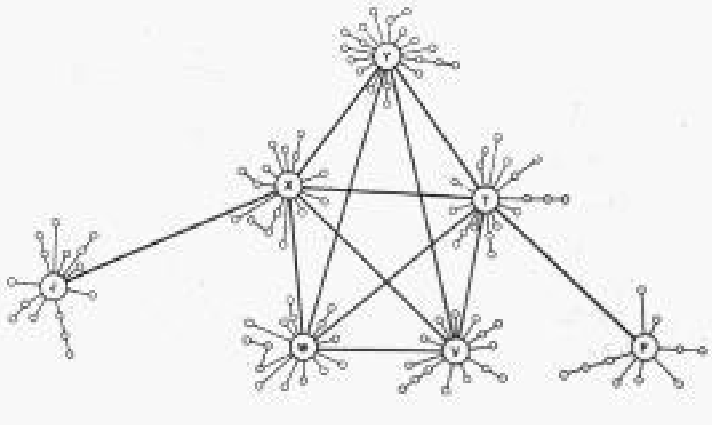

Figure 2. Hypothetical network

In Plan 55-A switching centers, messages are received and retransmitted automatically in the form of perforated tape. Routing is controlled by routing indicators (normally groups of six letters) recorded in the tape as part of the heading of each message. The form of message conforms to standards agreed upon among the armed services and the switching equipment has been designed to be compatible in operation with the equipment used by the other military services.

Messages can be switched automatically through several switching centers without requiring the attention of operators, except at the points of origin and destination. However, each receiving position at a switching center can be converted to manual (push-button) switching, at any time, by operating an "auto-manual" switch. It is expected that automatic switching will be the normal operating method for use in all cases where the quality of reception at the switching center and the quality of tape preparation at the point of origin will permit. However, in case of failure to switch automatically, due to incorrect routing indicators, or other errors in the received message tape, a supervisory signal is operated to call in a switching attendant so that the message can be manually switched without delay. It is also contemplated that small centers might be set up quickly in an emergency, with the automatic switching equipment omitted to save time in installation.

Message Security

Numerous safeguards and alarms are provided throughout the system to prevent errors, avoid delays and guard against lost messages. Each message is numbered in sequence as transmitted to an outgoing line or channel and these channel numbers are checked automatically as the messages are relayed. For this purpose, automatic message-numbering machines are provided to transmit the office call, channel designation and serial number ahead of each message. For each incoming circuit a number comparator device, known as a sequence-number indicator (or SNI), is provided to check these numbers automatically. The SNI is similar in design to the automatic numbering machine and is shown in Figure 3.

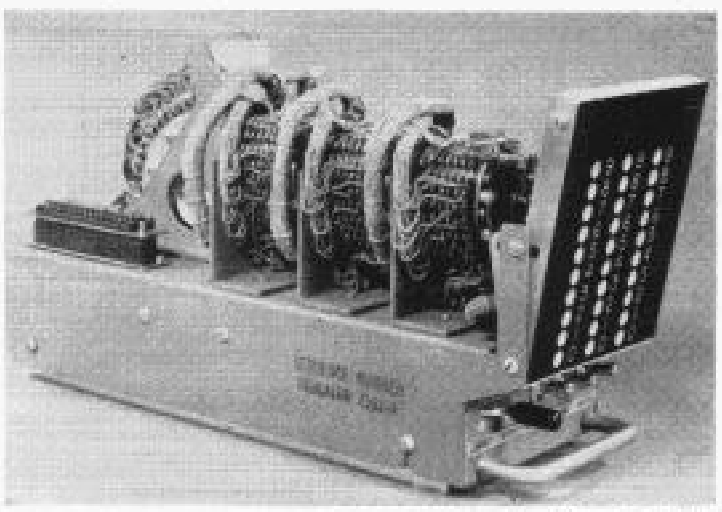

Photo R-10,111

Figure 3. Sequence number indicator

It is contemplated that some messages will be transmitted in code or cipher. For this purpose either "on-line" or "off-line" automatic ciphering equipment can be used. As this cryptographic equipment is not part of the Plan 55 switching equipment, it is not discussed in detail. With "on-line" cryptographic equipment, messages are deciphered automatically as received in a switching center, pass through the center in the clear and are automatically enciphered again as transmitted out of the center. In such cases it is necessary to control the distributor-transmitters that send to outgoing lines, so as to maintain synchronism with the encrypting equipment. The distributor-transmitters are of a type permitting this control. With "off-line" cryptographic equipment, messages are enciphered at the point of origin, transmitted through the switching centers in cipher, and deciphered at the point of destination. Such messages must have clear headings for routing purposes and must avoid the chance occurrence of the message-termination character combination (normally LF NNNN) in the ciphered message text.

Message Precedence

Messages are transmitted from the office of origin in order of precedence and are delivered at their destinations in the same order. There are six precedence classifications designated in the message by repeated characters called precedence prosigns. For switching purposes the first three precedence classifications are normally considered as "high precedence" and the last three as "low precedence." High precedence messages are given preference in switching to avoid any possible delays.

Message Transit Through Switching Centers

The transmission of a single-address message from origin to destination, through two switching centers, is illustrated in Figure 4. At each switching center the message is perforated and transmitted twice. The first reperforation is at a receiving or incoming line position. The message is then switched and transmitted across office to a sending or outgoing line position where it is reperforated and transmitted again.

Message Format

The form of the message, at each stage, is shown below the blocks in the drawing. As transmitted from the office of origin and recorded by the printer-perforator at the first switching center, the start-of-message (SOM) characters ZCZC and the message serial number are followed by the precedence prosigns and routing indicator, or indicators, the text of the message and the end-of-message (EOM) characters LF NNNN.

Both automatic and manual switching are controlled by certain characters which acters which may have been inserted by the printer-perforator for feed-out, or by the station of origin, are treated as extraneous characters that are stepped through the transmitter and discarded.

The incoming message channel number consists of circuit identifying letters and a 3-digit serial number. These characters are checked by the sequence num-

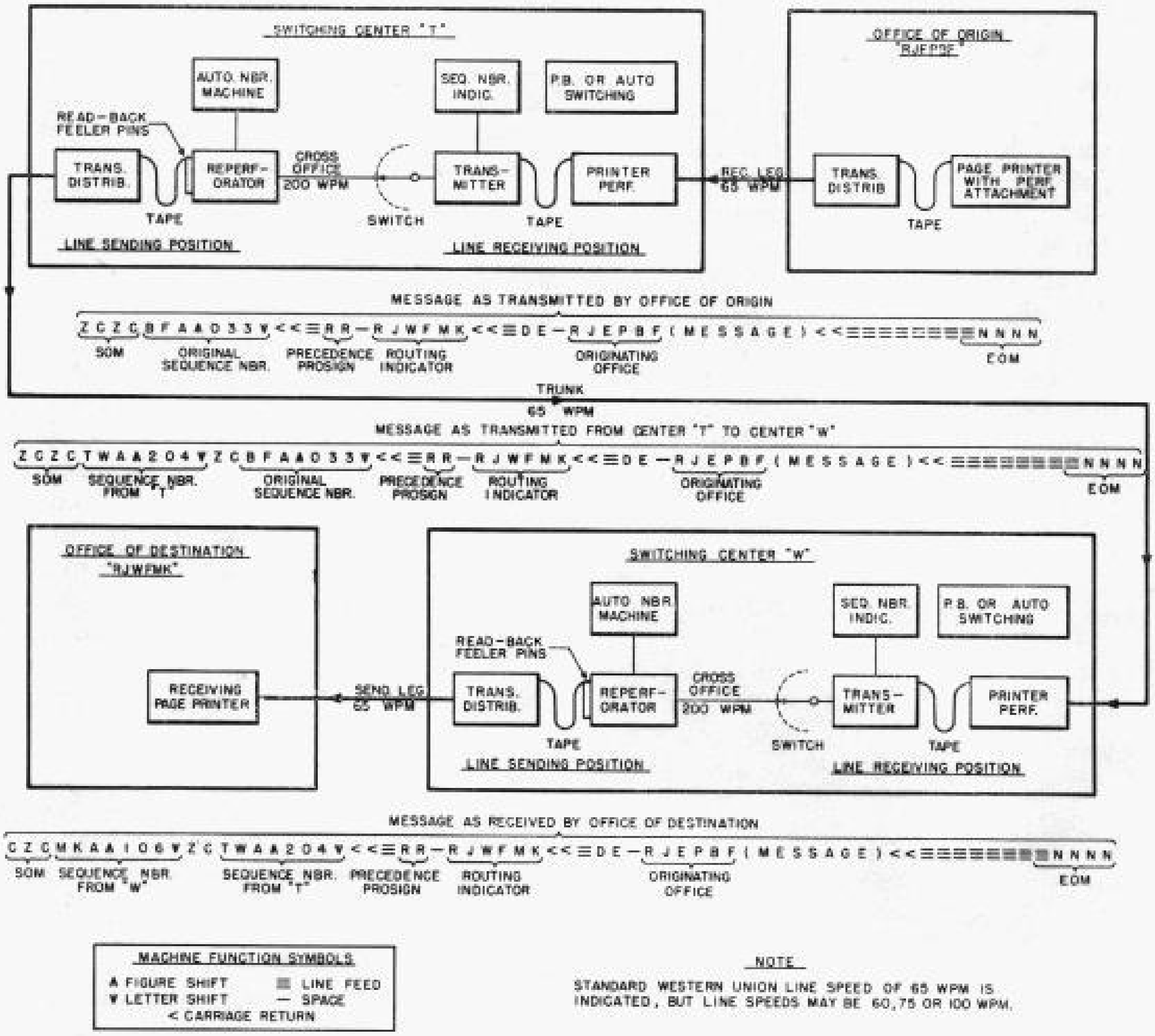

Figure 4. Switching single-address message through two switching centers

appear at specific places in the message. An extra character (X, Y or Z) may appear after the SOM characters ZCZC. This character is used for selective control in certain cases, particularly in the case of multistation lines or way wires. Following the end of the preceding message, the first significant characters of the next message are ZCZC. Intervening char- ber indicator (SNI), before the message is switched. Checking each received message serial number, as it appears in the tape, prevents loss of messages, facilitates identification of messages for reruns, and also serves as a periodic transmission check on the line and on the operation of the transmitter and printer-perforator. In case of a wrong number comparison transmission is stopped immediately and supervisory alarm signals are actuated. As this occurs before the message has been switched and transmission across office has not started, it is not necessary to send a cancellation notice.

Extraneous characters may appear in the message tape after the number. These characters may have been introduced into the tape at the point of origin, or at a torn-tape relay center, for the purpose of providing sufficient nonintelligence tape for insertion in manually operated tape relay equipment. One or more channel numbers associated with preceding transmissions may also appear at this point. All such characters are treated as extraneous information and are idled through the transmitter, which stops automatically when it reaches the LINE FEED character preceding the precedence prosign characters.

As described later, the transmitter at the receiving position is designed so that it can step through and read the precedence characters and routing indicators twice, first for switching control and second to transmit them across office. After the first passage through the transmitter, indicated route connections are set up by switches in the receiving position, but actual cross-office line connections are not established until the end-of-message (EOM) characters are received, except that in the case of "flash" or emergency messages, such connections are established immediately.

When the cross-office connection is set up, a new outgoing channel number is recorded in the tape at the sending position, transmitted from the automatic numbering machine. The incoming channel number is then transmitted across office by the SNI and the text and EOM characters are sent by the transmitter. After the EOM characters the cross-office circuit is disconnected.

From the sending position the message may be sent to a tributary of the same switching center, but in most cases it will be switched through at least two centers. The message, as received by the printer-perforator at the second center, is the same as when it was received at the first center except that it now has two serial numbers, an outgoing channel number and an incoming channel number. The operations involved in transmitting the message through the second center are the same as those described above for the first center, except when the first number is checked by the SNI, the second number steps through the transmitter and is discarded. A new outgoing channel number is added at the head of the message by the numbering machine and the former outgoing channel number becomes the incoming channel number at the second center. Only two channel numbers are carried along with the message as it is relayed from center to center, thus providing adequate identification while conserving line time.

Multiple-Address Messages

Multiple-address messages are recognized as such by the presence of more than one routing indicator. Each routing indicator is preceded by a space character and the last routing indicator is followed by a carriage return character. All routing indicators are printed in one line and the number of routing indicators in a message is limited to nine. Multiple-address messages are automatically processed so as to transmit an individual copy of the message to each ultimate destination. In this process the routing indicators are segregated so that each final copy of the message contains only one routing indicator, corresponding to its destination. At a switching center several of the routing indicators in a message may require the same circuit outlet. For example, two or more routing indicators may be for tributaries of another switching center, or for more distant centers to be reached through the same intermediate switching center. Such messages are transmitted to the intermediate center containing only the routing indicators for which that center is responsible.

Any receiving position can switch a multiple-address message directly to not more than four outlets. As relatively few messages require switching to more than four circuit outlets, most messages can be switched directly from the receiving positions. All preliminary operations for a multiple-address message are the same as for a single-address message up to the point where the first routing indicator has been processed. The space character following the first routing indicator is identified and the transmitter is restarted to process the second routing indicator. This process continues until a carriage return character, after the last routing indicator, identifies the end of the routing line.

In relatively rare cases a message may need to be switched to more than four circuit outlets. In such cases, all routing indicators requiring an outlet different from the first three are sent with a copy of the message to an extra operating position assigned for this purpose. The messages as recorded at this extra position contain at least three fewer routing indicators than appeared in the original message. In very rare cases a message with eight or nine routing indicators may need to be transmitted to an extra position a second time.

Switching Center Components

The two principal items of equipment required in a Plan 55-A switching center are the incoming and outgoing line consoles or cabinets. Each cabinet houses two operating positions. The incoming line cabinet has a control cabinet installed behind it to provide additional mounting space for equipment. These cabinets are interconnected by cables terminated in multiconductor plugs and sockets. To meet military requirements, all cabinets of each type are alike and require no essential common equipment to set up an operable center for manual switching. The incoming and outgoing cabinets are linked together by cross-office switching circuits over which messages are transmitted electronically at 200 wpm. In Figure 1, the incoming or receiving cabinets are at the left and the outgoing or sending cabinets at the right side of the aisle.

These cabinets contain all the equipment needed for reperforating, transmitting and push-button switching. The building block principle thus obtained en-

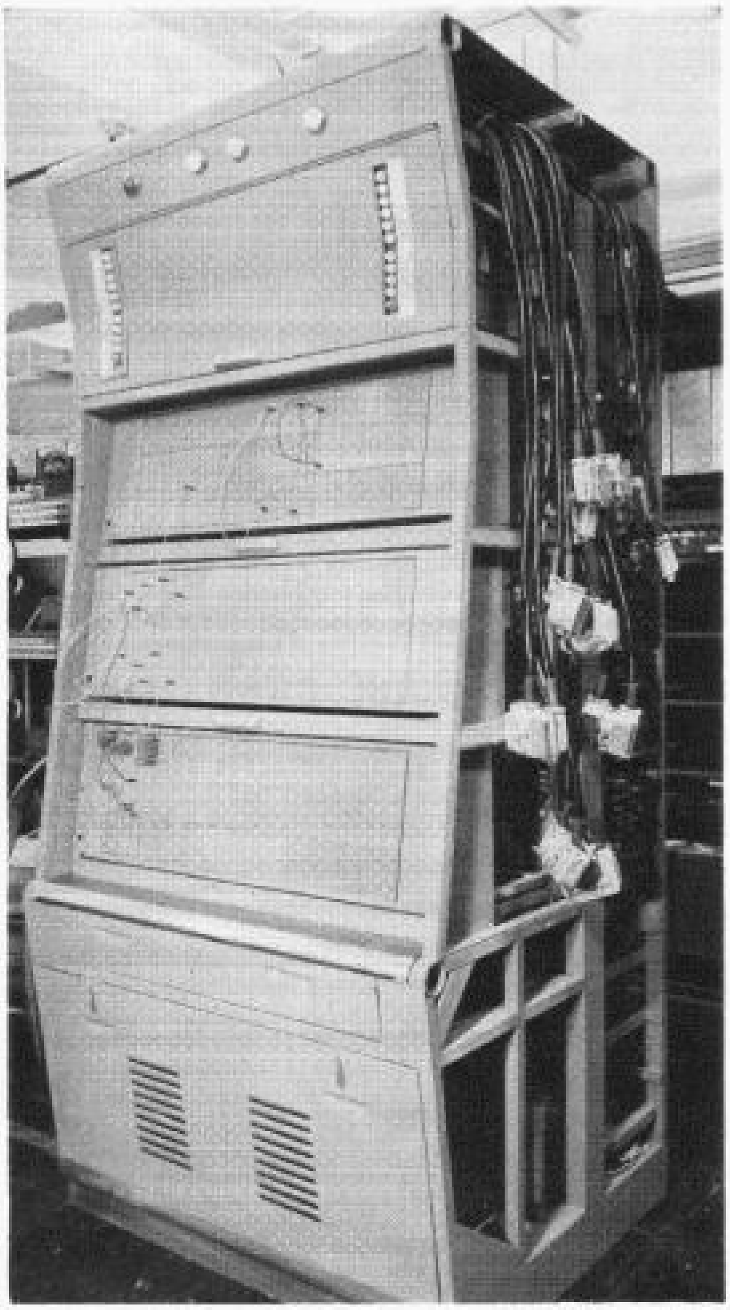

Photo R-10,306

Figure 5. Director-translator cabinet

ables a center to be expanded or contracted as circumstances dictate with the minimum of disturbance to traffic handling. As initially equipped, each incoming line position can switch messages to a maximum of 200 circuits and 100 destinations, by providing a suitable number of outgoing line consoles. By adding switches, the equipment can be expanded to 400 circuits and 200 destinations.

A third type of equipment, a director-translator cabinet shown in Figure 5, is required for automatic switching. The cabinet houses two directors and a translator. It is similar in design to the receiving cabinets and is normally installed at the end of a receiving row. The director receives routing information from the message tape and controls switching operations at the start of each message. The translator receives routing indicators from the director and translates them into switch settings. As these operations take only a few seconds, a relatively few directors and translators are required. It is proposed to install them in the ratio of one director cabinet for every 25 incoming line cabinets.

Photo R-11,028

Figure 6. Maintenance aisle behind receiving cabinets

The cabinets of all three types are 84 inches high, 38 inches wide and 33 inches deep. Associated with each receiving or incoming line cabinet is a receiving control cabinet, shown at the left in Figure 6, which contains rotary switches and other control equipment. The control cabinet is installed directly behind its associated receiving cabinet, with a maintenance aisle in between. The control cabinets can be installed against a wall or another row of cabinets to conserve floor space. A similar arrangement is used for the director cabinet, with two directors housed in the rear cabinet and a translator and associated connecting relays in the front cabinet.

In addition to the three types of cabinets described above, certain common equipment is normally provided at a traffic control center. Although a switching center can be operated without this common equipment, it is desirable to provide it to facilitate traffic handling and supervision. This equipment includes a connection indicator board, a traffic routing board, a close-out indicator board and supervisory printer sets to be described later.

Receiving Positions

Each incoming line cabinet contains equipment for two receiving positions. Either position can be used to terminate an incoming trunk or single-station tributary circuit. The upper position can be used also to terminate a multistation circuit or a trunk having separate high and low precedence number sequences.

Printer-Perforators

Each receiving position is equipped with a Type 28 printer-perforator (Figure 7), for reproducing incoming messages in printed-perforated form. Associated with this machine is a message-waiting indicator with associated control circuits designed to detect and count bell signals (upper case S), the start-of-message (SOM) signal ZCZC, and the end-of-message (EOM) signal LF NNNN. The bell signals are used to detect flash and emergency messages. The EOM signal controls the message-waiting indicator (MWI), adding one on its dial for each message received. The transmitter circuit subtracts one for each complete message transmitted, so that the MWI dial indicates the number of complete messages on hand that have not been completely transmitted. The MWI also controls tape metering and is so arranged that blank tape will be fed out if incoming reception stops after the EOM, if the MWI indicates not more than one message on hand. The SOM and EOM signals are received alternately, as they occur at the start and end of each message. If the EOM signal is missing or defective, as received, there will be two successive SOM signals. This disables the MWI "add" circuit and operates a "no EOM" alarm, when the MWI pointer restores to 0. This action blocks cross-office transmission, thus preventing a message from following through to the same destination after a preceding message with a defective EOM combination. The operating attendant restores service by restarting the transmitter, stopping it

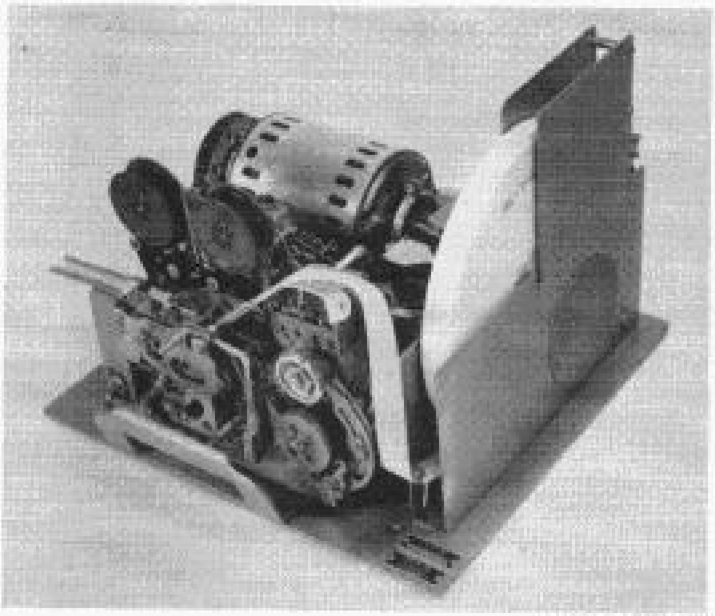

Photo R-10,500

Figure 7. Type 28 printer-perforator for incoming messages

again at the end of the message and then operating a XMIT EOM switch to initiate automatic transmission of a correct EOM signal.

Loop-Gate Transmitters

Each receiving position has a loop-gate transmitter, shown in Figure 8, for reading characters in the message tape and transmitting them at 200 wpm to the automatic switching director or across office to a reperforator at a sending position. Associated with the transmitter is a sequence-number indicator (SNI) for checking incoming message numbers, as recorded in the tape, and retransmitting them across office at the proper time. The transmitter also has associated electronic means for detecting certain characters in the tape as they pass through the transmitter. A motor-driven tape winder is provided to store message tape after transmission. An electronic transmitter is also provided to transmit messages and to transmit and receive control signals across office.

The loop gate is a slidable latch which holds down the tape and permits sending certain portions of the message twice. With the loop gate in its right-hand position the transmitter functions like any conventional magnet-stepped transmitter to idle blank tape through past the sensing pins. The SOM characters (ZCZC) start the SNI which checks the call letters and message number in the tape. If the message number is incorrect, the transmitter stops and a wrong-comparison signal lights to call an attendant who will take necessary corrective action. If the message number is correct, the transmitter steps the tape ahead until it detects a line feed (LF) character, thus stepping through and deleting any extra numbers or other extraneous characters that may appear in the tape at this point. Upon detecting the line feed, the loop gate on the transmitter slides to the left, holding the tape so that it cannot pass completely through the transmitter, but can step past the sensing pins forming a loop above the transmitter. Characters fed into this loop can be transmitted a second time.

Automatic Switching

For automatic switching, with the loop gate at the left, a connection is obtained to a director and the precedence prosign characters and the routing indicator or indicators are transmitted to the director, which returns switching information to the receiving position for setting up the cross-office connection to the desired destination. The loop gate then returns to its right-hand position, placing the original

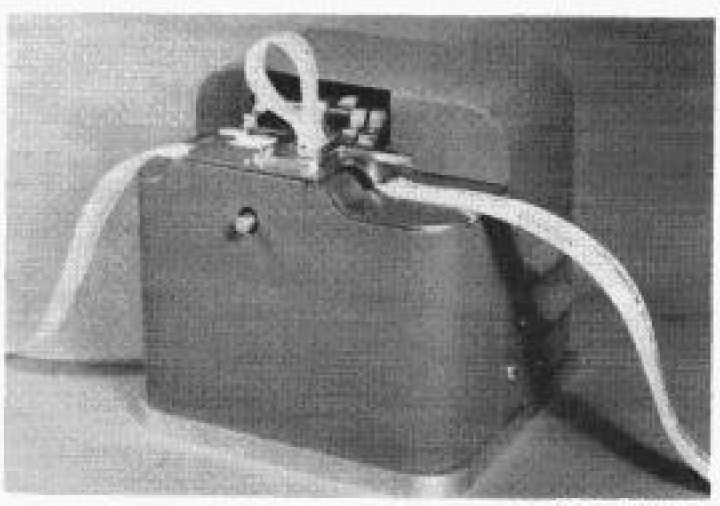

Photo R-10,113

Figure 8. Loop-gate transmitter for sending messages across office

character (the first character after the line feed) over the sensing pins. The transmitter is now ready to transmit the message across office at the proper time.

Manual Switching

For manual switching, when the loop gate slides to the left a message-waiting lamp lights to call the attendant, who looks at the precedence prosign characters on the tape and depresses a high or low precedence push button, which associates the transmitter with the push-button panel, advances the prosign characters through the transmitter, extinguishes the MSG WTG lamp, and lights a switching control lamp. The attendant now depresses a panel push button for each routing indicator and then a start push button to complete the manual switching operations.

Electronic Cross-Office Transmission

Electronic methods are used for transmitting signals across office over a single conductor. The electronic transmitting and receiving equipments are synchronized to the 60-cycle power supply. The message characters are transmitted at 200 wpm (20 characters per second), which is equivalent to one character for every third cycle of the 60-cycle power supply. Certain control pulses are transmitted over the same cross-office line conductor, in either direction, at the rate of 60 pulses per second. As compared to other switching systems, the use of a single conductor in this system greatly reduces the number of cable conductors, multiconductor plugs, sockets and switches required. For example, eight levels of a single 25-point rotary switch serve to select any one of 200 sending positions.

The electronic units consist essentially of a pulse generator, common to the two operating positions in each cabinet, an electronic transmitter for each receiving position, and an electronic receiver for each sending position. These units generate, transmit and detect the message and control pulses that are sent across office and, in addition, step the tape transmitter and numbering machine, detect and indicate trouble conditions, read certain message characters as they are being transmitted at high speed, test the idle or busy condition of selected routes, and control the operation of other equipment such as the sequence-number indicators, message-waiting indicators and the automatic switching directors. The pulse generator and electronic transmitters are shown at the top of Figure 9.

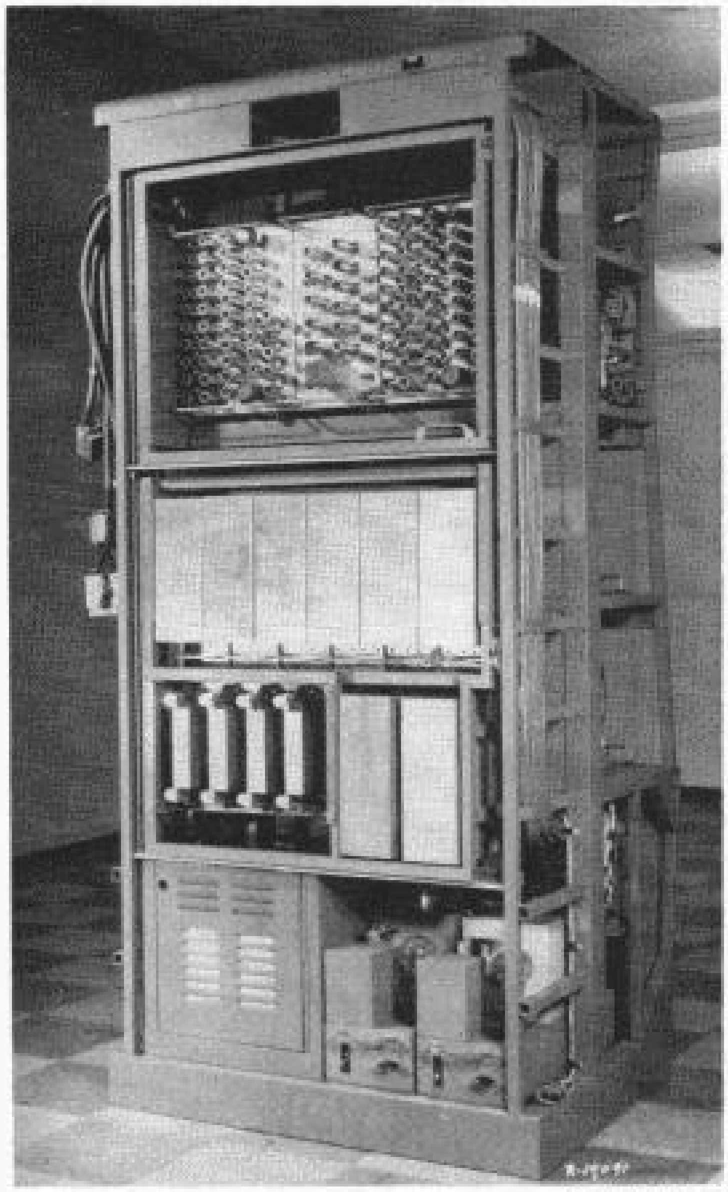

Photo R-10,091

Figure 9. Receiving cabinet, rear view, with electronic units at top

Sending Position Cabinets

Each outgoing line cabinet contains equipment for two sending positions. The upper position can be used to terminate any type of outgoing line, including a multipoint circuit (way wire). The lower position can terminate any line except a multipoint circuit. Either position can be used as part of a multichannel group.

Sending Positions

Each sending position is equipped with a Type 28 multimagnet reperforator, shown in Figure 10, for reproducing messages received over cross-office circuits in perforated (not printed) tape form. This reperforator is associated with an electronic receiver which operates on signals received across office at 200 wpm as sent from an electronic transmitter associated with the loop-gate transmitter at a receiving position. The reperforator also receives signals from an automatic message numbering machine at the same sending position. In the case of multipoint circuits terminated at upper sending positions, there may be two or three numbering machines (one for each way station) any one of which can send into the reperforator.

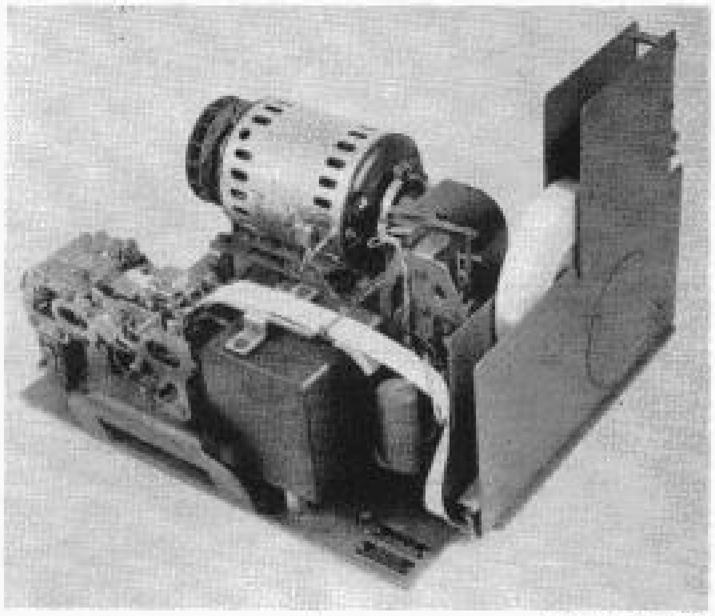

Photo R-10,498

Figure 10. Type 28 reperforator for receiving across office

When a cross-office connection is established, the numbering machine automatically sends, into the reperforator, the SOM characters (ZCZC), a multistation selector code character (X, Y or Z) if required, the station and channel designation letters and the message number. This number is followed by the incoming channel number transmitted from the SNI at the receiving position. This latter number is always preceded by the characters ZC and followed by CR CR LF. The message is then transmitted across office by the loop-gate transmitter, first the precedence prosign characters and routing indicators from the tape loop and then the remainder of the message, including the EOM characters LF NNNN. At this point, the loop-gate transmitter stops, the numbering machine sends two blanks into the reperforator and the cross-office circuit is released.

Character Checking

The reperforator is equipped with read-back contacts operated by an extra set of sensing pins located five characters to the left of the punch pins. These pins read certain character groups in each message to verify the correct operation of all equipment involved in cross-office transmission. The SOM characters ZCZC from the numbering machine are the first characters checked. The appearance of this combination indicates that the local equipment of the sending position is operating properly, including the numbering machine and the reperforator. The ZC characters ahead of the incoming channel number verify the operation of the SNI and cross-office transmission. At the end of the message, when two blanks are transmitted by the numbering machine after the EOM characters, the line feed and first N are fed over the read-back pins and checked, thus verifying that the reperforator is still operating properly at the end of the message. The cross-office connection is then released.

The ZC characters must check to start cross-office transmission of the message. Failure to check prevents transmission, locks out the sending position, operates an alarm signal at the sending position and a reswitch signal at the receiving position. A number cancellation notice is then transmitted automatically from the receiving position. The sending position remains out of service until manually restored after the trouble is cleared. At the receiving position an attendant sets the tape back to the start of the message and releases it to be reswitched. It will be automatically switched to the same destination through another sending position, if one is available, or it will be switched to an intercept position for storage until the original sending position is restored to service.

If the LF N combination at the end of the message fails to check, the sending position alarm signal is operated as described above and the switch-to-supervisor signal is lighted at the receiving position. In this case the attendant at the receiving position sets the tape back to the start of the message and switches it manually to the supervisor, who resends it designated as a suspected duplicate, as a complete or nearly complete message may have been transmitted before the trouble occurred. The attendant at the sending position operates a transmit cancellation notice switch to cancel any partial message that may have been recorded in the tape at that position.

Multichannel Destinations

To handle heavy traffic loads to a particular destination several outgoing line circuits and sending positions may be required. All sending positions in such a multichannel group represent the same destination. Any message for that destination can be switched to any sending position in the group that is available for use at the moment. The selection of a particular position is controlled by a load distributor circuit. This circuit gives first choice to any sending position that has a tight-tape condition, since such positions have no other messages on hand for outgoing transmission. During busy periods, when no position in the group has tight tape, each sending position in the group is selected in rotation as cross-office connections are established, so that the traffic is evenly divided among the channels.

Transmitter-Distributor

Each sending position is equipped with a Type 28 multicontact transmitter-distributor, shown in Figure 11, for transmitting to the outgoing line the messages that the reperforator has recorded in perforated tape form. The transmitter-distributor operates at 60 or 100 wpm. It has two cam shafts; one a transmitter shaft that drives mechanisms for feeding the tape and sensing the perforations, and the other a distributor shaft for sending character signals to the line in start-stop code. The shafts can operate together or separately, so that blank tape or other characters can be idled through the transmitter without sending to line and special character signals, controlled by a rotary switch, can be sent to line by the distributor contacts without stepping the tape through the transmitter.

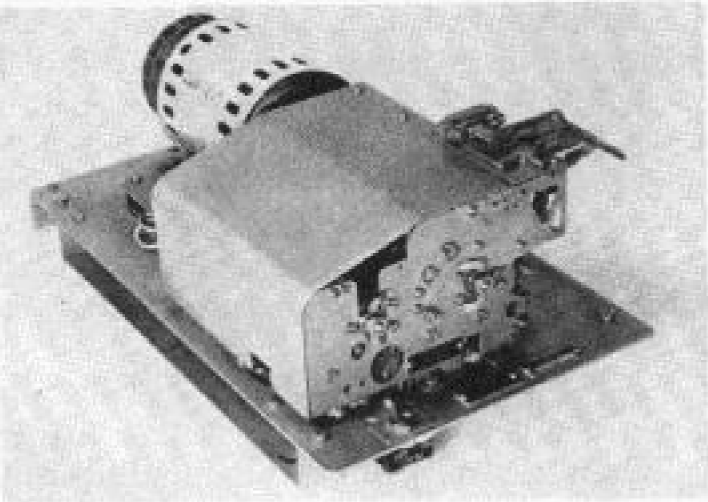

Photo R-10,503

Figure 11. Type 28 transmitter-distributor for sending to line

When a message is received across office, slack tape allows the transmitter-distributor to start. At first, any blank tape is idled through the transmitter, with the distributor stopped, so that the blank characters are not sent to line. When the first character in the tape that is not a blank reaches the transmitter sensing pins, the transmitter shaft stops, the distributor seizes a connection to line and then both shafts operate to send the message to line. When the sensing contacts detect the EOM combination (LF NNNN) both shafts stop and the line connection is released. These operations are repeated as each message is transmitted to the outgoing line.

Two-Position Outgoing Line Termination

Two sending positions can be arranged to send alternately to the same outgoing line circuit. Normally one position is used for high precedence traffic and the other for low precedence traffic. The transmitter-distributor of the low precedence position releases the line at the end of each outgoing message to allow the high precedence position to cut in, if it has a message to send. When this occurs, all high precedence messages on hand are transmitted to line before the low precedence position can seize the line again. This arrangement makes it possible to send a high precedence message to line ahead of previously stored low precedence messages. If the line is part of a multichannel group, the low precedence position can be so arranged that it will accept and store not more than one message during periods when the high precedence position is sending to the outgoing line. This is to avoid accumulating any considerable number of messages at the low precedence position during periods when it cannot send to line.

Added End-of-Message Characters

When an outgoing line is used as a trunk to certain other types of switching centers or to a multistation circuit (way wire), it may be necessary, for the proper operation of the other switching center or way station, to send certain added characters after the normal end-of-message. These added characters are controlled by setting a switch located inside the console. This switch has five positions as follows:

POSITION	ADDED EOM CHARACTERS
1	None (for sending to Plan 55 centers or tributaries)
2	5 Blanks (for sending to U. S. Army automatic switching centers)
3	3 CR's and 2 LTR's (for sending to Plan 51 centers)
4	10 LTR's (for sending to torn-tape stations or centers)
5	Blanks and pauses (for disconnecting a way station)

Multistation Circuits (Way Wires)

Multistation circuits extend from a switching center to two or three tributary stations. These circuits are operated duplex. Each station is equipped for selective control so that each message transmitted from the switching center is recorded only at the station to which it is directed. A selecting letter (X, Y or Z) is assigned to each station. This letter is transmitted by an automatic numbering machine immediately after the SOM characters (ZCZC) and is recorded in the tape ahead of the message serial number. The upper sending positions are arranged to mount two or three numbering machines for this purpose, and to maintain an individual message number sequence with each station. As it passes through the transmitter-distributor, the selecting letter, in the tape, selects the proper calling signal so as to cut in the printer at the particular station that is to record the message. The printers at the other stations are locked out until the end of the message.

At each way station, messages are prepared in perforated tape form for transmission to the switching center. Only one station can send at a time. Each way station uses its own sequence numbers for transmitted messages. These numbers are checked automatically at the switching center by sequence-number indicators (SNI's) individual to each station. The SNI's are selected by selecting letters similar to those used for outgoing messages. The upper receiving positions in the incoming line cabinets are arranged to mount the additional SNI's. Depressing either a high precedence or a low precedence push button at a tributary station indicates, at the switching center, that a message is ready for transmission from a way station. The switching center equipment determines whether a high precedence message is indicated and, if so, invites each station in turn that has such a message to send, automatically accepting high precedence messages as long as any are indicated. If there are none, low precedence messages are accepted in a similar manner. The invitation sequence always starts with the station following the one that has just previously transmitted a message, so as to give all stations an equal opportunity to send messages within the same precedence group.

Advantages of High-Speed Cross-Office Transmission

Messages are received over incoming lines at 60 or 100 wpm, are transmitted across office at 200 wpm and are then retransmitted to outgoing lines at 60 or 100 wpm. With the cross-office speed at least twice the speed of transmission to outgoing lines, enough messages can be sent across office to any sending position to keep the outgoing line busy, while the cross-office side of that position is idle at least half of the time. It is obvious, therefore, that the receiving positions will usually obtain an immediate cross-office connection and no appreciable amount of unsent tape should accumulate at these positions. If an occasional busy condition should cause an accumulation, however, the differential between the high cross-office speed and the lower incoming line speed would transmit messages away from the receiving positions at least twice as fast as they are being received, thus rapidly reducing the tape accumulation. The line circuits can thus be operated at a very high utilization factor, without causing any appreciable traffic delay. The transmitter-distributor at a line sending position automatically functions to send continuously as long as there is any traffic at the sending position to send. Therefore, the cross-office line need operate only intermittently to provide a full outgoing circuit load.

Switching to Busy Destinations

If a receiving position has a single-address message that is to be switched to an outgoing circuit that is busy, the message waits until a circuit to the desired destination becomes available. If the wait is unduly long, or if the message is a flash or emergency message, an alarm will operate to call an attendant to the position to take suitable action, such as interrupting a less important message or switching the message over an alternate route.

In the case of a multiple-address message, cross-office connections to the desired destinations are established one at a time. After a connection is established to the first available destination, any additional required connection that is delayed by a busy condition is diverted automatically to an intercept position after a timed interval of about 30 seconds. This is a standard sending position which has its outgoing line connected as an incoming line to an intercept receiving position, at which a copy of the message is stored and retransmitted to the required destination when a circuit becomes available.

When the required cross-office connections have been established, the numbering machine associated with each sending position selected transmits the next consecutive channel number for its circuit outlet. The SOM characters (ZCZC) are checked at each sending position and, if they are correct, the receiving position sends the incoming message number from the SNI and the precedence prosign characters from the tape to all connected sending positions. The routing indicators are then transmitted, sending each routing indicator to only one sending position, as required. The end-of-routing characters (CR CR LF D) are then broadcast to all connected sending positions, followed by the remainder of the message and the EOM characters (LF NNNN). The cross-office circuits are then released.

If the ZC characters fail to check correctly at any of the connected sending positions, the message is not transmitted across office, but instead a number cancellation notice is transmitted and the cross-office lines are released. As in the case of a single-address message, alarms are operated at the sending position in trouble and at the receiving position. An attendant called to the receiving position reswitches the message. If the EOM characters fail to check correctly, the message is resent as a suspected duplicate. Two copies of the message may be received at some destinations, but one will be designated suspected duplicate.

Traffic Control Center

Although a switching center could be operated without a traffic control center, this equipment is normally provided as it facilitates traffic handling and supervision. The traffic control center equipment includes a connection indicator board, a traffic routing board, a close-out indicator board and receiving and sending printer sets.

Connection Indicator Board

This board has a neon signal lamp and a push button for every receiving and sending position. It provides means for readily determining which sending and receiving positions are connected over cross-office lines at any time. Operating a push button on the board associated with any operating position lights the neon lamp for any operating position with which it is connected. This information is useful for maintenance purposes and also for certain operating conditions. For example, assume that a flash or emergency message has been received at a receiving position, and switched across office to some sending position. Such messages include bell signals which call an attendant to the receiving position. The attendant notifies a supervisor at the traffic control center that such a message is being transmitted from a particular receiving position. The supervisor depresses the push button corresponding to this position and ascertains the sending position to which it is connected. The supervisor then sends an attendant to that position to insure that the message is not delayed by equipment or line trouble or by a large accumulation of message tape previously switched.

Traffic Routing Board

This is a jack board for making temporary changes in the routing of messages by the use of patching cords. Two pairs of jacks marked FROM and TO are provided for each destination to which this switching center is connected. One pair of jacks is for high and the other for low precedence traffic. Changes in routing are made by patching the FROM jack of one destination to the TO jack of another, thus diverting traffic from the first to the second destination. High and low precedence traffic can be independently routed. For example, if a trunk route between two switching centers becomes overloaded with traffic, or unuseable for some other reason, the high precedence traffic or all traffic can be temporarily sent over an alternate route through a third switching center. By patching only the high precedence jacks, high precedence traffic for stations that are closed at night can be diverted to a separate position for commercial refile, while the low precedence traffic is allowed to accumulate at the sending position simply by stopping the transmitter, for later transmission when the station reopens.

Close-Out Indicator Board

This board contains groups of signal lamps to indicate the operating status of the sending line positions for the information of the supervisory personnel. These signals show which sending positions are closed out on the cross-office side or have their transmitters stopped for any reason.

Gilbert S. Vernam, Assistant to the Systems and Equipment Engineer, graduated from Worcester Polytechnic Institute in 1914 with a B.S. degree. After 15 years with the A. T. & T. Engineering Department, he transferred to the International Communications Labs, and in 1932 to Postal Telegraph which later merged with Western Union. While with A. T. & T. he invented a method of using printer equipment to encipher and decipher messages automatically that is widely used by our armed forces, and took part in the early development of the TWX system. For Postal he developed an automatic concentrator, and supervised the development of the semiautomatic "torn-tape" relay system and its installation in a number of switching centers for Postal and for the Signal Corps and Navy; he also prepared a technical manual describing the system for the Signal Corps. More recently he has worked on the development of push-button switching systems Plans 51 and 54 for leased wire patrons and Plan 55-A for the Air Force. Mr. Vernam holds about 60 patents relating to telegraph systems. He is a Professional Engineer, a member of Tau Beta Pi, Sigma Xi and AFCEA, and a Life Member of AIEE.

J. EDWIN BOUGHTWOOD, Assistant to Radio-Wire Transmission Engineer

THOMAS A. CHRISTIE, JR., Lenkurt Electric Company

Data Transmission Testing Set

Evaluation of telegraph circuits under development for movement of digital data at high speeds required a new family of instruments with which to measure transmission efficiency and accuracy. First and most urgently needed was a new electronic transistorized bias and distortion testing set which has been designed by the Telegraph Company's transmission research engineers.

UNTIL recent years the transmission of data in binary form was confined almost exclusively to telegraphic or similar low-speed communication systems. Transmission speed was limited by the rate of operation of printing telegraph or other terminal equipment. Distortion measuring devices for determining the efficiency of synchronous or start-stop telegraph transmission circuits or equipment were well known to the art.[1,2] The recent introduction of integrated data processing systems and computer centers requires the transmission of voluminous information in binary form and at high speeds. To develop circuits and equipment intelligently to handle these data first required the development of a transmission measuring tool capable of operation at the high speeds involved. It is the purpose of this paper to describe an all-electronic transistorized testing set which will measure bias distortion, characteristic distortion, and peak fortuitous distortion at transmission speeds from 200 to 1400 bps.

BASIC PRINCIPLES

Distortion in binary pulse transmission may be defined as the deviation in length or relative time relationship of the received pulses from the length and time relationship of their transmission. A signal is defined as unbiased when the unit marking and spacing pulses are of the same length or time duration. Bias distortion usually results from improper adjustment of terminal or circuit equipment. A means for measuring this type of distortion should be included in a data transmission testing set.

Distortion which is caused by electrical or magnetic characteristics of the equipment or circuit under test is defined as characteristic distortion. It is the amount by which a given pulse is lengthened, shortened or displaced due to the presence or absence of neighboring pulses and is caused by "memory" effects in the transmission path. More exactly, the maximum amount by which the space-to-mark and mark-to-space transitions of a selected pulse are shifted from their ideal locations by the presence or absence of neighboring pulses is a measure of the characteristic distortion. A device to measure characteristic distortion might then consist of a pulse pattern generator for sending various combinations of marking and spacing pulses, a circuit for selecting one of the received pulses for examination, and a circuit for comparing the distorted received pulse with the undistorted transmitted pulse to indicate the amount of distortion. The characteristic distortion would be taken as the largest value indicated for all possible combinations of pulses from the pattern generator.

Fortuitous distortion is that displacement of signal transitions resulting from extraneous electrical interference in the transmission circuit. This interference is

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statistical in nature and has a random relation to the testing signals. The "instantaneous" distortion caused by fortuitous interference will vary widely although the "average" effect on a repeated pulse will integrate to zero. It is conventional to measure fortuitous distortion as the largest transition displacement encountered in a given period of time. The measurement of fortuitous distortion should not be influenced by the characteristic distortion of the circuit under test. A device to measure fortuitous distortion might then consist of a pattern generator for sending alternate marking and spacing pulses of equal length, a circuit for selecting one of the pulses for examination, and a peak reading instrument for measuring the largest transition displacement during the period of observation.

DESCRIPTION

In contrast to telegraph codes, data codes have not yet been standardized as to transmission speeds or number of code elements per character. For the design of a testing set a code of ten elements and speeds from 200 to 1400 bps was arbitrarily selected.

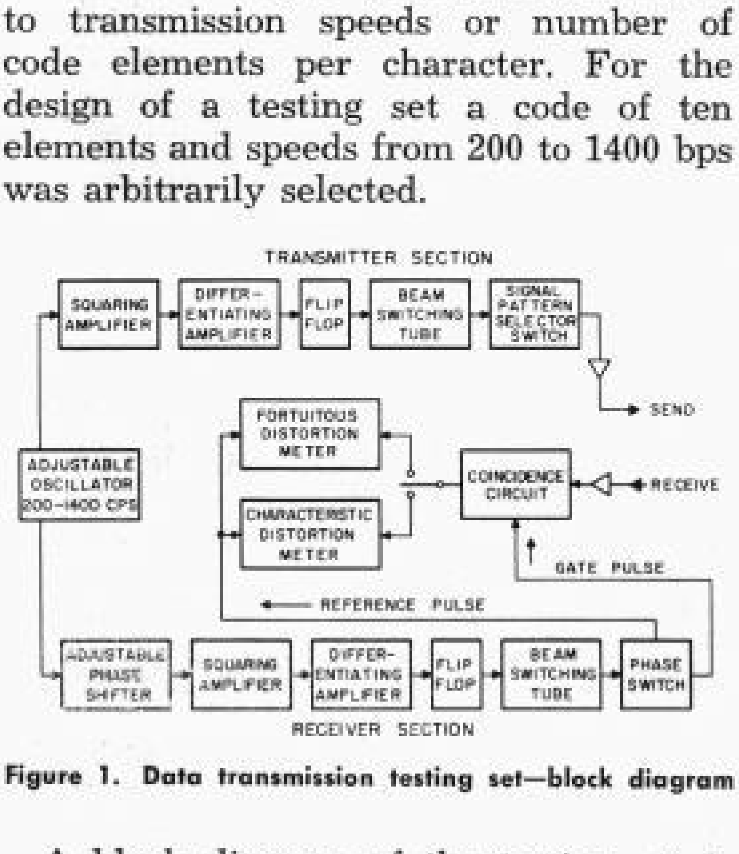

Figure 1. Data transmission testing set—block diagram

A block diagram of the testing set is shown in Figure 1. It is completely transistorized except for two magnetron beam switching tubes and a subminiature electrometer tube. Both transmitter and receiver sections are controlled by the output of a 200-1400 cps sine-wave oscillator adjustable in steps of 200 cycles. The oscillator frequency enters the transmitter section through a squaring amplifier. The square wave from this amplifier is then differentiated and the resultant pulses used to trigger a standard bistable flip-flop stage. Since the flip-flop reverses once per cycle of the applied frequency, its output is a highly symmetrical or unbiased square wave; i.e., the time duration of the negative and positive loops is equal. Two appropriately phased outputs from the flip-flop drive the odd and even grids, respectively, of a 10-position beam switching tube to advance the beam one position for each reversal of the flip-flop. A 10-position signal pattern selector switch associated with the beam switching tube permits any one of ten signal patterns to be selected for transmission at a bit rate equal to the oscillator frequency in cycles per second.

The adjustable oscillator also operates a second beam switching tube in the receiver portion of the test set so that both tubes run at exactly the same speed. The drive circuit for the receiver tube includes a continuously adjustable phase shift network of 360-degree range. This network, in conjunction with a phase switch associated with the beam switching tube, permits a gate pulse and a reference pulse to be obtained once per revolution which can be placed in any desired time relationship with the transmitter signal pattern. These pulses have precisely the same length as the transmitter pulses. The gate pulse selects the leading or trailing portion of a given signal pulse to be measured by means of the coincidence circuit. The output of the coincidence circuit is applied to the characteristic distortion meter circuit where it is compared with the reference pulse for characteristic or bias distortion measurement. To measure peak fortuitous distortion the output of the coincidence circuit is applied to the fortuitous distortion meter circuit.

Ten signal patterns each consisting of ten bits are available for transmission as indicated in Figure 2. The polarity of transmission can be as shown or reversed as desired. After transmission through the circuit or equipment under test, pulse number 9 is normally selected for characteristic distortion analysis. The signal patterns have been selected to include combinations closely approximating the maximum distortion of the number 9 pulse that would occur with normal random message traffic.

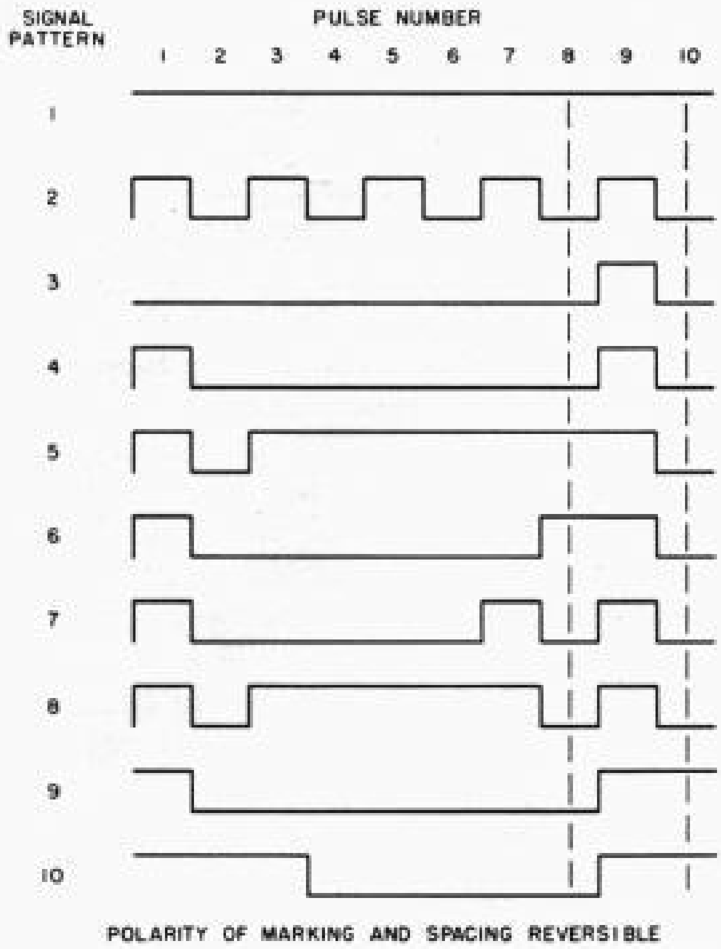

Figure 2. Signal patterns available from transmitter

Bias and Characteristic Distortion Measurement

A circuit for the selection of the leading or trailing portions of a received signal pulse for bias or characteristic distortion measurement is shown in Figure 3. After transmission over the system under test, the signals enter a coincidence circuit at A. A gate pulse from the receiver beam switching tube is selected by means of the phase switch and enters at B. Transistors Q1 and Q2 comprise a coincidence circuit and transistors Q3, Q4, and 50-0-50 scale meter comprise a differential metering circuit. The output of the coincidence circuit enters the metering circuit through transistor Q3 and a reference pulse from the receiver beam switching tube enters through transistor Q4. Since the pulses are applied differentially to the meter, a zero reading will result when the pulses have equal area. The manner in which the amount of bias or characteristic distortion is indicated is illustrated in Figure 4. Bias measurements are made on a-c signals, signal pattern 2, position 2 of the signal pattern selector switch. Any pulse of the pattern may be selected for bias distortion measurements but the

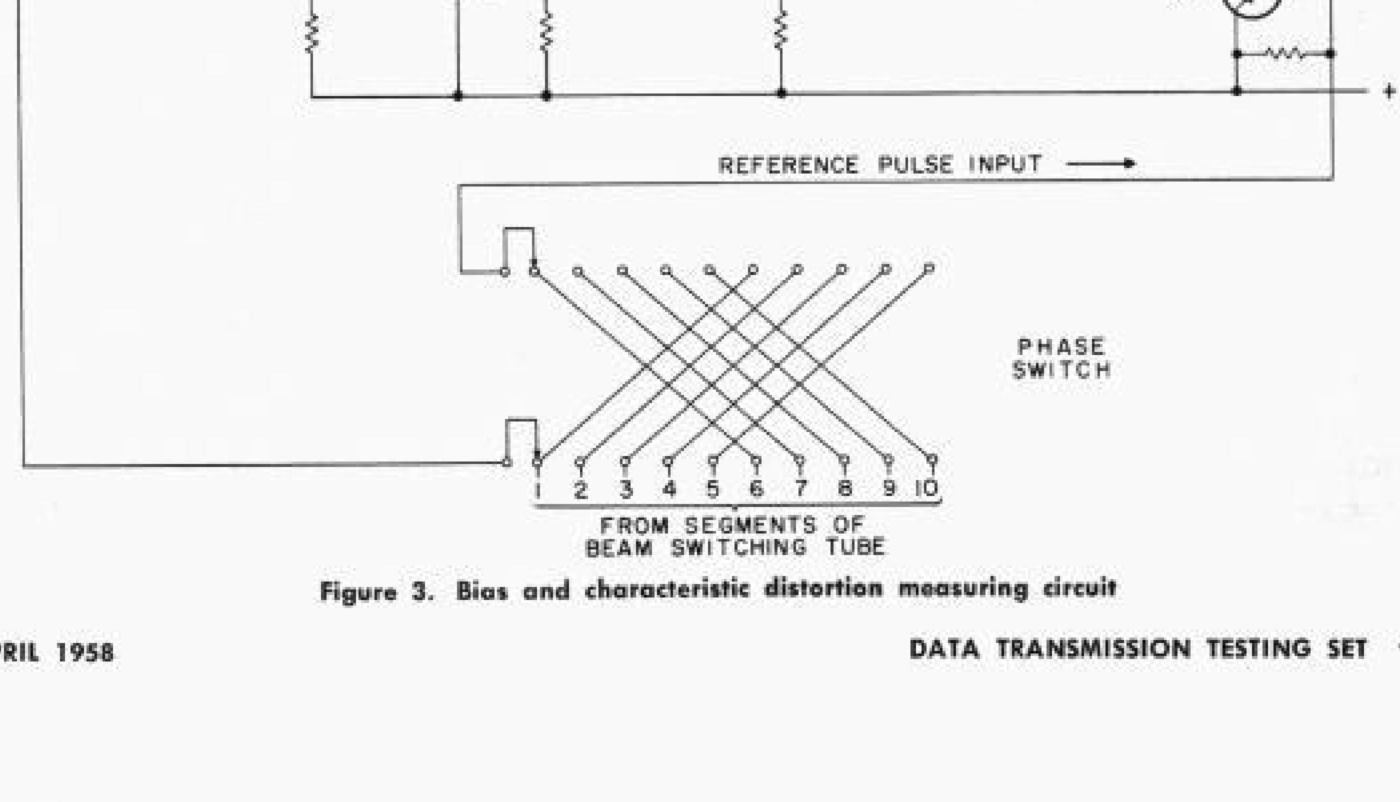

Figure 3. Bias and characteristic distortion measuring circuit

number 9 pulse is used for characteristic distortion measurements. It is necessary to measure the displacement of the leading transition and the trailing transition of the pulse with respect to their undistorted positions in order to determine the amount of distortion. These transitions are measured separately as indicated in Figure 4. The received a-c signal pattern is shown at A. If these signals are unbiased they will have exactly the same length as the gate pulse from the receiver beam switching tube shown at B. The gate pulse can be made to straddle either the leading or trailing edge of a received pulse by means of the phase switch and the adjustable phase shifter included in the receiver beam switching tube drive circuit.

The output of the coincidence circuit is shown at C and the reference pulse at D. The length of the D pulse is exactly the same as the B pulse but its amplitude is made to be precisely one-half the amplitude of the C pulse. By properly adjusting the phase of gate pulse B, the C pulse for the leading transition of the number 9 signal pulse can be made exactly the same length as the C pulse for the trailing transition of the number 9 pulse so that both C pulses have the same length and area. If the signals are unbiased then both C pulses are also equal in area to reference pulse D. Since the D pulse and a C pulse are applied alternately and differentially to the zero center d-c meter, a zero reading of the meter will result. If the received signals at A are biased the length of the C pulses for the leading and trailing edges will still be equal. However, the C pulses will be greater or smaller in area than the D pulse, depending on whether the bias is marking or spacing, and the differential meter will indicate directly the direction and magnitude of the bias in percent of the duration of an undistorted pulse. An integrating condenser in the differential meter circuit produces a steady meter reading by eliminating the effects of fortuitous interference. A bias measurement is made by switching alternately between two adjacent positions of the phase switch to select alternately the leading and trailing transitions, and simultaneously adjusting the phase shift network for the same meter reading.

Before characteristic distortion measurements can be made, all bias should be removed from the signals to be measured using the above procedure to indicate the unbiased condition. As previously described, characteristic distortion is measured by selecting signal pulse number 9, and observing the displacement of the leading and trailing transitions for the various signal patterns. The displacements are measured relative to the location of the leading and trailing transitions for signal pattern 2 (a-c).

Pulse number 9 is selected for measurement by transmitting signal pattern 3, consisting of a single pulse in position number 9. If gate pulse B, Figure 4, is coincident with any other pulse position than number 9, the differential meter will read minus 50 percent distortion since only reference pulse D is applied to the meter circuit. The leading edge of pulse number 9 is located by rotating the phase switch in a clockwise direction until the meter reads other than minus 50 percent. The meter reading is a direct measure-

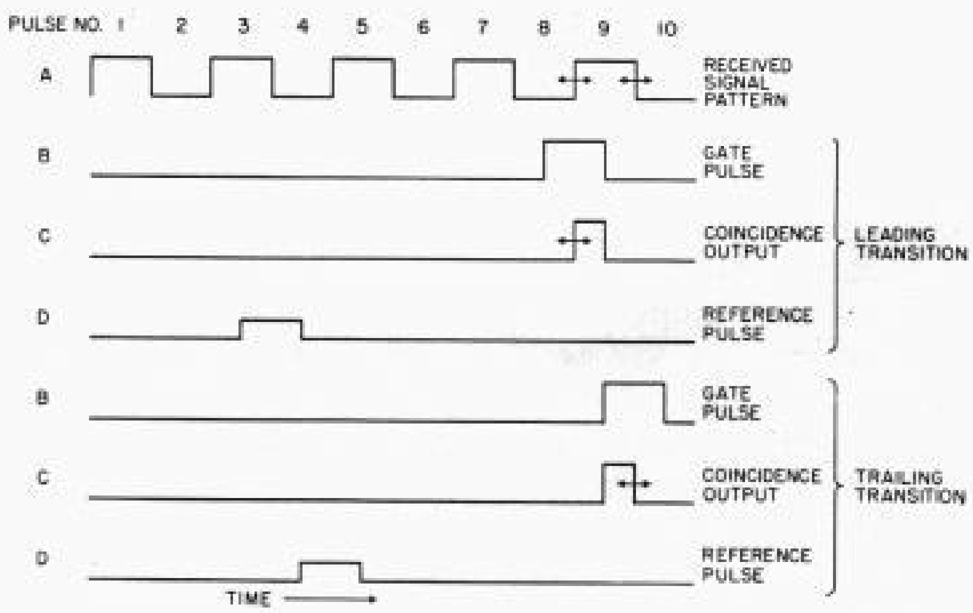

Figure 4. Theory of bias and characteristic distortion measurements

ment of the leading edge displacement in percent of the length of an undistorted pulse. This reading can be converted to time if desired since the pulse transmission rate is accurately known. If the leading edge is not affected by characteristic distortion it will have the same location as for pattern number 2 (a-c), and the meter will read zero.

The displacement of the trailing edge can similarly be measured by rotating the phase switch to the next adjacent clockwise position. In such fashion the displacement of the transitions are measured for signal patterns 3 through 10. The amount of characteristic distortion for the particular transmission speed is taken as the largest meter reading of the series. To delineate completely the characteristic distortion characteristic, measurements must be made for a range of speeds. Typical curves of distortion versus speed measured in a medium speed data channel are given in Figure 5. The effect of speed on the leading transition of the number 9 pulse for pattern 3, and the trailing transition of the number 9 pulse for pattern 6 is clearly shown.

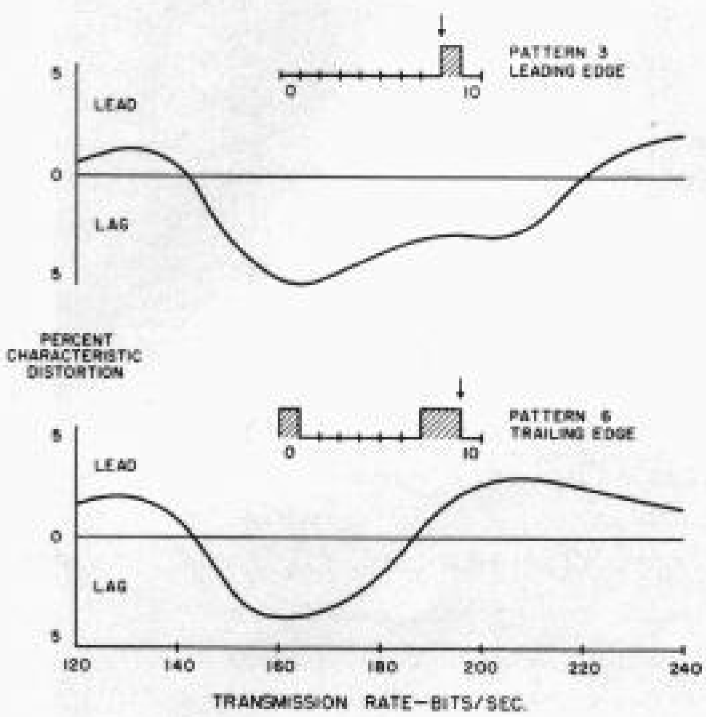

Figure 5. Typical characteristic distortion curves

Fortuitous Distortion Measurement

Fortuitous distortion displaces the leading and trailing transitions of a signal pulse in a random manner. It is customary to measure the greatest displacement occurring in a specified time interval and define this value as the peak fortuitous distortion of the circuit or equipment under test. Fortuitous distortion measurements are made on a-c signals, signal pattern 2, to eliminate any meter deflection due to characteristic distortion. The signals must also be checked for bias and corrected if necessary. The circuit used to measure peak fortuitous distortion is illustrated in Figure 6.

Pulses from the coincidence circuit are applied to transistor Q5, and the reference pulses from the receiver beam switching tube to transistor Q6. The fixed amplitude pulse from the coincidence circuit is applied to integrating capacitor C1 through a resistor and diode CR1. Capacitor C1 charges to a voltage directly proportional to the time duration of the pulse and is bound by the action of diode CR1. Capacitor C2, which is small compared to C1, charges through diode CR2 to the same value as C1. The reference pulse from the receiver switching tube discharges C1 by driving transistor Q6 to conduction leaving a bound charge on C2. If the next pulse from the coincidence circuit is longer than the preceding pulse due to fortuitous distortion, then condenser C1 will charge to a higher value as will capacitor C2. In this manner a

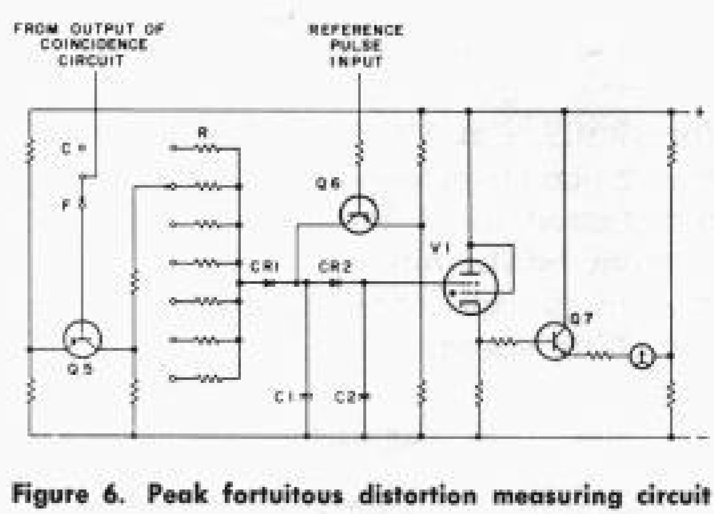

Figure 6. Peak fortuitous distortion measuring circuit

charge is accumulated on C2 which is proportional to the largest displacement of the pulse transition. The voltage of condenser C2, due to its accumulated charge, is measured by electrometer tube V1. The cathode current of V1 is thus a measure of the widest pulse occurring during the measuring period. This current is amplified by transistor Q7 and displayed on a 0-40 scale meter calibrated to indicate distortion in percent of the length of an undistorted pulse. Both the leading and trailing transitions are measured, the larger of the two being the peak fortuitous distortion for the particular speed of transmission. Calibration is maintained for different speeds of transmission by the automatic selection of the proper charging resistor R for a given signalling speed.

Photo R-10,921

Figure 7. Data transmission testing set—front view

RESULTS

A prototype model of the transmission testing set is shown in Figure 7. This model was constructed for laboratory use only and requires that both ends of a transmission circuit be available in order to perform measurements. Models for field use would require a highly stable frequency source to permit accurate synchronization and phasing of units at the ends of an intervening circuit being tested. The prototype has been in use for several months and has proved of valuable assistance in the development of data transmission circuits and equipment. It has been of particular use in studies concerning the effect of envelope delay distortion on high-speed data transmission.

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2. A PORTABLE TELEGRAPH BIAS AND DISTORTION MEASURING INSTRUMENT, W. D. CANNON, *AIEE Transactions Part I*, Vol. 74, 1955, pp. 401-406.

J. Edwin Boughtwood came to Development and Research upon graduation from Northeastern University in 1930. His early work in d-c telegraph transmission resulted in increased speed and reliability in time-division multiplex working. Since 1937 he has been associated with the development of carrier current methods and systems for wire line and radio relay applications and has made numerous contributions in this field. More recently he directed the development of Telegraph Terminal AN/FGC-29, now in production for the military. His current interests involve the development of transistorized carrier telegraph and carrier data systems for general application in the telegraph plant. Mr. Boughtwood received the F. E. d'Humy Memorial Award for 1957 "for fundamental scientific explorations and basic inventions in the field of frequency-modulated carrier telegraph systems." He is the author of numerous technical papers, holds many patents in his field, and is a Member of AIEE and IRE.

Thomas A. Christie, Jr., graduated from Clarkson College of Technology in April 1942 and spent four years in the U. S. Navy as an officer aboard PT boats in the Pacific. He joined Western Union in April 1946 and spent eleven years in the Wire Transmission Division of the D. & R. Department. Some of the projects worked on included voiceband channelizing systems for radio relay, Telegraph Terminal AN/FGC-29, high-speed data circuits, and the data transmission test set. Since May 1957 Mr. Christie has been Product Planner with Lenkurt Electric Company. He is a member of Tau Beta Pi, Associate Member of AIEE and Senior Member of IRE.

Cablegrams By Desk-Fax At London, England

At The Texas Company (Iran) Ltd., at Wellington House, a cablegram is dispatched by Desk-Fax to (right) . . .

. . . Western Union House where the message is recorded automatically at a Desk-Fax concentrator position.

At Kensington Palace Hotel, as a guest writes his cablegram others from Western Union House (left) are readied for transmission.

HAVANA, CUBA. (1) Western Union office, 351 Obispo Street, where (2) Señorita Maria Colino at Desk-Fax concentrator answers a call from (3) Señorita Rosa Stabile in office of Ambar Motors Corp., distributors for General Motors. (4) At black and yellow counter, Señor Primitivo Armesto, sales manager, waits upon Manager G. F. Bruna of F. W. Woolworth Co., whose offices are nearby. (5) Señorita Olga del Real of Esso Standard Oil, S.A., sends a cablegram by Desk-Fax. (6) Sr. Armesto; Srta. del Real; Sr. Miguel Soria W.U. commercial representative, and Mr. Herbert S. Hilton, in charge of communications at Esso.

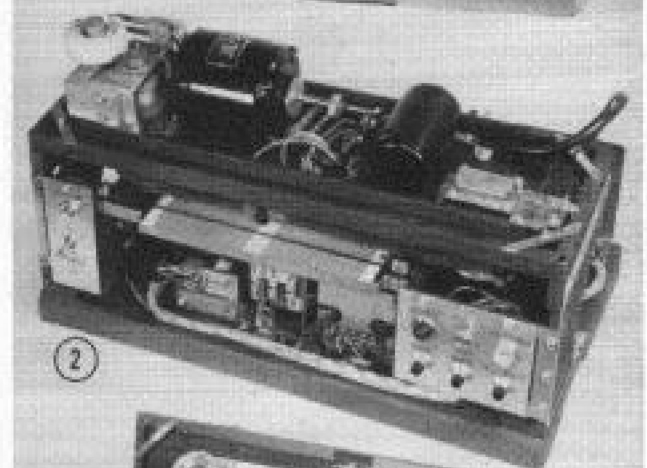
Cablegrams By Desk-Fax At Havana, Cuba

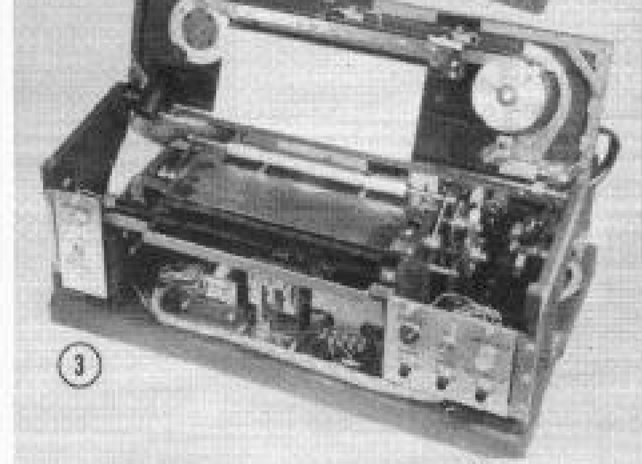
Telefax Instrument for Industrial Charts

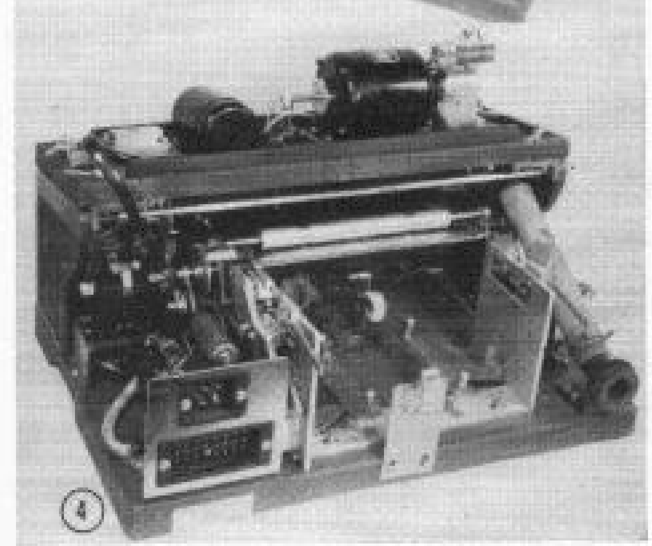
An industrial Telefax instrument which produces recorded charts instead of telegrams has been made by Western Union research engineers *(photo 1)*. It is a multiple-stylus recorder similar to Telefax message recorder 7219-B. Using a "Teledeltos" paper roll 8½ inches wide the instrument will record two charts each 4⅛ inches wide simultaneously from two separate transmission sources *(photo 2 shows recorder without cover)*.

Either four or eight stylus holders may be mounted with uniform spacing on the toothed belt of the recording head which is hinged to the base section of the instrument *(photo 3 shows recording head raised)*. The recording head also includes the belt drive motor, reduction gears, synchronizing contacts, driving pulley, idler pulley assembly, belt track, stylus advance mechanism and an air exhaust duct.

The base section contains the "Teledeltos" electrosensitive recording paper, paper feed mechanisms, instrument control panels and external connection sockets *(photo 4 shows rear of instrument without recording paper roll)*.







Photos R-11,064-7

BERNARD HOWARD, Vice President for Engineering, Teleprinter Corporation

The "MITE" Teleprinter

New, small telegraph page printers now under development by the Teleprinter Corporation weigh only 12 pounds and are entirely compatible with existing teleprinter apparatus. They embody radical innovations in design and are said to be the first practical teleprinters of their weight and size. Companion equipment will include a miniaturized transmitter-distributor and a reperforator.

A NUMBER of new "data read-out" devices have been developed in recent years to keep pace with the requirements of automatic digital computers. The outputs have taken the forms of cathode-ray indicators, magnetic tape, punched cards and tape, smoke printing, magnetic printing and electrostatic printing, as well as alphanumeric page printers.[1] Page and tape printers have been used for many years in communication circuits and have been made to operate in response to as many as eleven types of Morse, synchronous printer and start-stop printer codes.[2] Many of the new types of equipment, however, have required special input signals, operate at high speed, or are otherwise not compatible with existing communication equipment.

Civilian and military users have indicated that, although they anticipate a need for higher speeds in their communication circuits, they will probably use printers operating from the telegraph start-stop code for some time to come.[3,4] The armed forces find it increasingly desirable to add electronic aids to their mobile and airborne units but are naturally reluctant to increase the size of vehicles and aircraft. Civilian users are increasingly aware of the desirability of printed communications and of a print-out device compatible with those systems most generally in use. In both these connections the characteristics of reduced weight and cube, lower power consumption, and lower initial costs and maintenance become increasingly important.

Figure 1. MITE with keyboard in operating position

General Characteristics

It was with these facts in mind that the Miniaturized Integrated Telegraph Equipment (MITE) was developed. The initial machines were designed with a view toward both commercial and military

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., February 1958.

specifications. It is believed that this small, lightweight printer has a place both in communication services and in certain computer applications. It is not intended to compete with high-speed units such as a recently announced digital printer which prints 10,800 lines (the equivalent of an average book) in one minute. The MITE is a page printer which weighs only 9 pounds when receiving only and 12 pounds when fitted with a keyboard, for sending as well as for receiving. The printer unit is 3½ by 8 by 12 inches. The keyboard unit is 1½ by 8 by 12 inches. The carrying case is 5 by 11 by 12½ inches. The carrying case weighs approximately 4 pounds so the whole equipment weighs 16 pounds when packed up and ready to move. Figure 1 shows the MITE with the keyboard in the operating position. The keyboard can be pushed back under the printer, or it can be removed altogether as shown in Figure 2.

The machine operates up to 100 words per minute with the standard 7.42-unit Baudot code but future models are expected to operate up to 200 words per minute if the code pulses are fed to the machine simultaneously. The machine is completely compatible with 7.42-unit code machines and can be converted in a matter of minutes to 60, 66, 75 or 100 words per minute operation by changing one externally mounted gear. Actually there is nothing inherent in the design of the machine which limits it to this type of code and special machines are being built to operate with other codes. Both the keyboard and type cylinder can be changed to accommodate weather symbols or, in fact, to any desired selection of characters or functions up to a maximum of 64. (Two of these are shift from lower to upper case and the reverse shift from upper to lower.)

A New Approach to Character Positioning

One of the design objectives was to produce a machine capable of high-speed operation wth a minimum of high-speed mechanical motions. This demanded a radically new approach to the method of deriving 64 mechanical positions from the five intelligence pulses in the start-stop code.

One of the basic principles used in the MITE is illustrated in Figure 3. This uses a unique application of one of the six "simple machines"—the pulley. It will be seen that if one end of the string is fixed and the other end is attached to a weight,

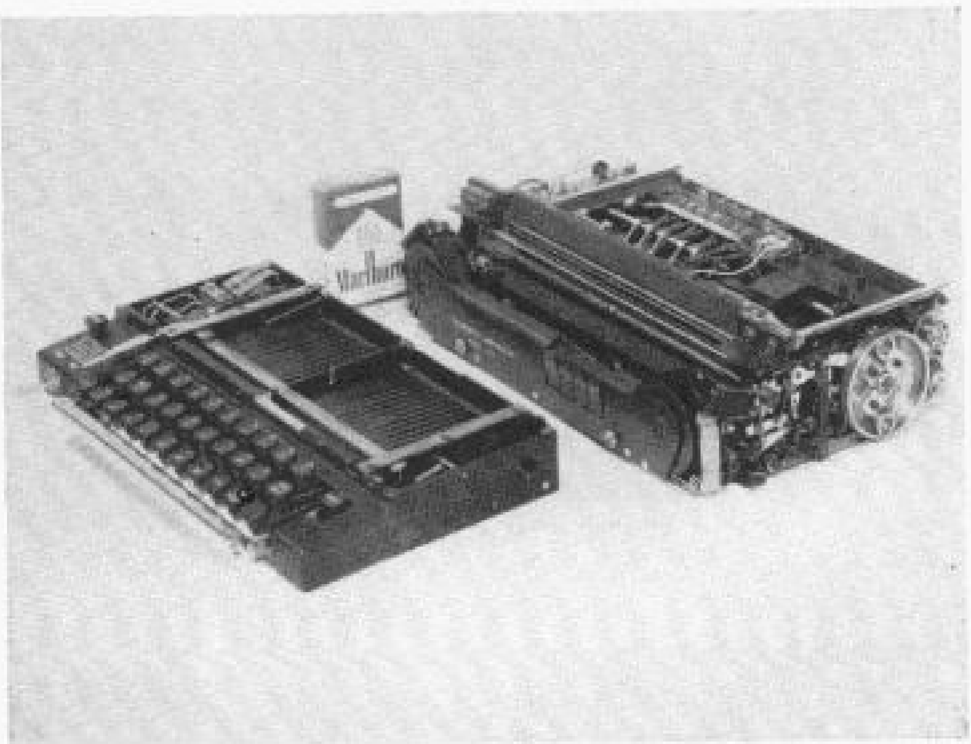


Figure 2. MITE with keyboard removed

a ½-inch movement of any pulley in a vertical direction will move the weight one inch. Next, suppose that each pulley is moved a different distance. Then the weight can be moved to any one of five different positions, depending on which pulley is moved. Finally, consider the possibility that each pulley is moved from its resting position twice the distance that the previous pulley travels and consider, also, that from one to five pulleys are moved at the same time. It can now be seen that there are 32 evenly spaced positions of the weight for all of the possible combinations of pulleys moved or not moved.

If a strip of type were substituted for the weight, then an elementary character positioning device will have been provided. The 32-character length of the strip would, however, require a rapid motion of the type strip if the first and last letters on the strip were called for sequentially.

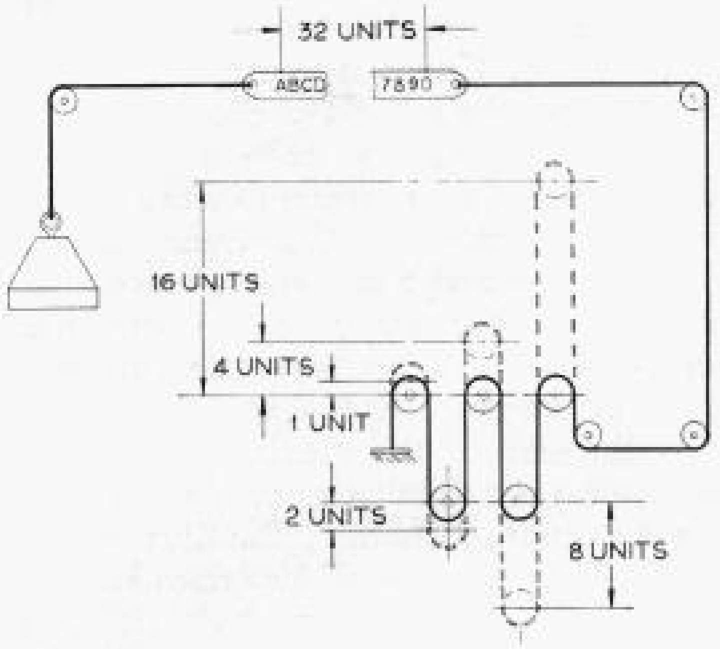


Figure 3. Schematic of a simplified print positioning device

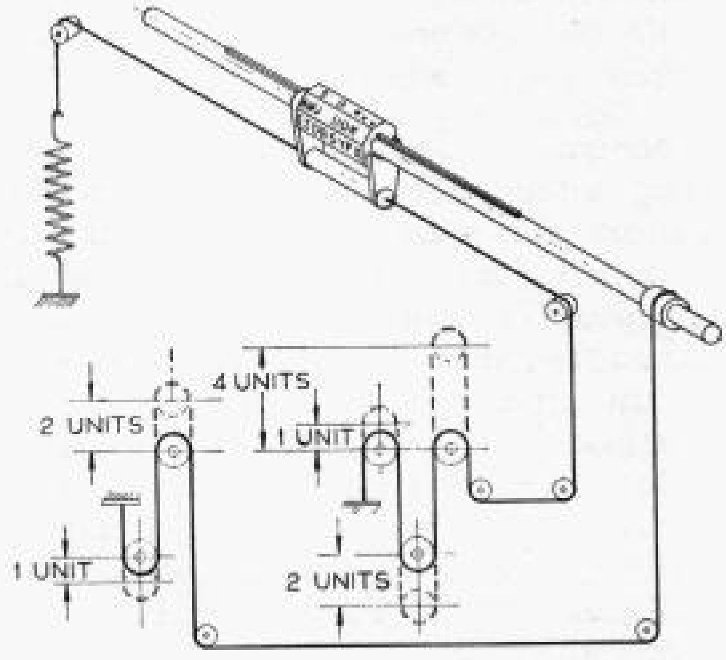


Figure 4. Schematic of print cylinder positioning method used in the MITE

The space and motion requirement could be reduced by arranging the letters in the form of a rectangle 8 characters long and 4 characters high and employing 2 coordinate motions. The space and motion requirement could be still further reduced by folding the rectangle into a half cylinder 8 characters long and with 4 faces, and converting the linear coordinate motion used to choose one of the four up and down positions of the rectangle to rotary motions up to 180 degrees. This has been done in the MITE with an 8-sided type cylinder which is 8 characters long. (See Figure 4.)

The 32-position half cylinder derived from the 5-pulley system is represented by 4 faces of the 8-sided cylinder and 8 lateral positions along those faces. The opposite 4 faces of the cylinder and the 8 lateral positions along those faces represent the "upper case" of the 32 basic positions so that the cylinder is rotated 180 degrees by the selection of "letters" or "figures" (lower or upper case), and the selection within that 180-degree segment is achieved by the basic 5-pulley system. Since a space is designated on the cylinder for every character or function that can be selected, the cylinder provides for 64 possible characters and functions, two of which are "letters" and "figures." In this way a small cylinder can accommodate 64 characters of standard teleprinter type. In operation the first two of the five intelligence code pulses control the rotary selection motions of the type cylinder while the last three pulses control the lateral motions.

The Selector

The problem of arranging for the proper pulley to respond to the appropriate signal pulse is met by the selector in conjunction with motor-driven camshafts.

Synchronization. Synchronization of the MITE printer with the transmitted signal, as with other 7.42-unit code printers, makes use of two pulses in addition to the five intelligence signal pulses. These are referred to as the "start" and "rest" or "stop" pulses. The start pulse effectively starts the rotation of the timing camshaft by releasing the start clutch. The rest pulse which is 1.42 units long occurs between the fifth signal pulse and the start of the next start pulse, and allows a margin of error to exist between the motor speeds in the sending and receiving machines. The receiving camshaft rotates faster than the corresponding transmitting camshaft and comes to a stop during the stop pulse, while the transmitting camshaft will rotate continuously during a continuous automatic transmission such as from a tape transmitter.

Reduction of Mechanical Speeds and Load. In the MITE, the mechanism which controls the pulleys, and consequently the type cylinder, is arranged to reduce the speed of operation and mechanical load on the machine by gradually positioning the type cylinder while the signal pulses are being received, rather than by storing the pulses mechanically as they are received and beginning the positioning of the type after the receipt of the last intelligence pulse. For this reason, and because the type cylinder is located behind the printing medium, there is no need for a neutral position of the type cylinder; consequently, in the case of a repeated character, the pulleys and cylinder do not move.

Selection. Each of the five type-positioning pulleys described above is positioned by a cam follower passing through the pulley housing. The cams which move these followers are each coupled to a clutch. The five clutches and their cams are mounted on a continuously driving shaft on which the clutches freewheel when not engaged and to which they are capable of being sequentially coupled.

In response to its signal as received by the magnetic selector, each clutch will either engage the driving shaft for a 180-degree rotation or hold its position. The action of the clutch in each case depends on whether a mark or space signal is received and whether the clutch was left in mark or space position by the previous selection. If, for example, the No. 1 pulse for a given selection is a mark pulse, and if the No. 1 pulse of the preceding selection was a mark pulse, the No. 1 clutch will remain stationary. If a spacing pulse is received for No. 1 and the preceding No. 1 was a mark, the clutch will engage for a 180-degree rotation turning the cam affixed to the clutch correspondingly. The cam follower and the pulley controlled by it will go to the second of their two possible positions.

The actual release of each clutch is controlled by a pair of levers, one of which will engage the clutch and the other of which will stop it after 180 degrees. Each pair of levers is controlled by the selector and the instant of their release is determined by a sequence shaft which starts rotating upon receipt of the "start" pulse. The control of the clutch releases by the sharp drops in the sequence shaft cams is a feature which contributes markedly to accurate response and good range in the receiver.

At the end of the receiving cycle the sequence cam shaft rests while the main driving shaft on which the five pulley clutches now freewheel continues to turn. The rotation of the main shaft after the receipt of the fifth intelligence pulse releases the special function causing mechanism and either performs a mechanical function when one is selected or releases the print hammer to complete the character cycle.

Range Adjustment. The relative time at which the magnet armature position is sensed can be adjusted by moving the angular position of the timing camshaft with respect to the point at which the camshaft is released by the start clutch. This angular position of the start clutch release mechanism is connected to a calibrated dial which is marked in terms of percentage of one signal pulse. The variation in angular position which is possible without mutilation of a message is known as the "range" of a teleprinter. The MITE has regularly been observed operating with ranges in excess of 75 points at 60 wpm in the laboratory, and has tolerated signal distortions in excess of 35 points under the same conditions. This range adjustment permits the printer to operate correctly from distorted signals such as may be received over long telegraph lines.

Keyboard

General. The mechanical and electrical connections between the keyboard and the printer are very simple. The keyboard circuit is in series with the printer signal circuit and when it is removed from the printer or put in storage position, the contacts on the printer are automatically shorted. A spur gear couples the printer motor to the keyboard operating shaft. The keyboard can be operated separately as a unit remote from the printer by using a separate motor. It operates as follows: The striking of any key, or the space bar, releases a clutch which permits the motor-driven keyboard camshaft to make half a revolution. At the same time five code bars are set up in a particular sequence according to which key is struck. These code bars will permit or block the motion of a series of cam follower levers, which in turn will permit a series of five contacts to make contact or stay open and thus transmit the proper signal. The contacts are in series with the signal line and when no keyboard is pressed the contacts are closed.

Regulation of Transmission. In order to transmit the correct signal, these contacts must make and break at particular times, which would normally require a very accurate adjustment of each contact. This is avoided by providing a "master pulsing cam" on the keyboard camshaft. This operates a pair of contacts which accurately determine the timing of transmission while the five contacts affected by the code bars only determine whether or not each of the pulses is transmitted. The stop, two and four contacts are connected to one of the pulsing contacts and the number one, three and five contacts are connected to the other pulsing contact. In this way the adjustment of the five contacts is made noncritical and only the single pair of master pulsing contacts requires adjustment.

Motors

The rotational inertia of the motor serves to integrate the pulses of mechanical power required for the printing cylinder positioning operations over the full character cycle. The total power required by the machine is 25 watts including the power for operation of the magnets, so it can be seen that quite a small motor is used. When the power source is alternating current, the motor operates at 3600 rpm for 60 cps and 12,000 rpm for 400 cps. These motors are synchronous with the line frequency and no speed adjustment is possible. When the power source is direct current, a 10,000-rpm motor is employed and an adjustment governor is used for speed adjustment. A 101.69-cps tuning fork is used for speed adjustment purposes. The motor speed is the same for all operational speeds, a single gear being changed for the various sending and receiving speeds. (The 25-watt figure given was observed with the d-c power source and the a-c figure may be somewhat higher.)

Printing Out

Paper-Type Relation. The type cylinder prints from behind the paper and the print hammer presses the inking ribbon against the front of the paper. This unusual arrangement maintains the type face clean at all times and also has the advantage of reducing mechanical wear on the inking ribbon which is struck by the smooth, regular hammer face rather than a sharp, irregular type face. The main advantage is that the operator has greater visibility of the printing as it is being received. A standard typewriter inking ribbon is used. The ribbon tilts back and downwards after each operation of the print hammer so that the last letter printed can be read. The placement of the type does not affect the ability of the printer to make carbon copies.

Carriage Return. Unlike in an ordinary typewriter, the paper does not move laterally but only the type cylinder moves. However, the term "carriage return" is still used. Since the type cylinder is quite light (about ½ ounce), fast return action is possible. This is important to ensure that the first character at the beginning of the new line is to be clear when only one character space is allowed for the carriage return operation. The MITE is fitted with automatic carriage return and line feed which are triggered when the end of a line is reached without receipt of carriage return and line feed signals. The MITE prints 72 characters per line on standard 8½-inch rolls.

Nonprinting Functions and Special Outputs

The nonprinting functions of the machine include all standard communication printer functions such as carriage return, line feed, shift, signal bell, repeat key and the break key. Four of these functions can be directly controlled mechanically from front panel buttons. These buttons will not put a signal on the line but can cause the following operations: carriage return, line feed, figures and letters. In addition, auxiliary outputs can be provided for special functions.

In series with the two pulley-controlled cables which position the type cylinder rotatively and laterally are two slotted plates which slide laterally parallel to one another. The arrangement of the slots in these plates is such that the selection of a nonprinting function will align a certain pair of slots in the two plates. A series of function clutch release levers attempts to sense the alignment of any two slots during each character cycle. When the slots are not in alignment, the levers are deflected. When a nonprinting function signal is received, the appropriate lever is not deflected, but passes through the aligned pair of slots releasing its clutch. These slotted plates can easily be adapted with added slots and function clutch release levers and clutches, so that additional nonprinting functions can be provided. There is a position on the type cylinder for each of these functions. Normally, in these positions there is no character on the type cylinder and the print and character advance functions are suppressed. A character could, however, be printed simultaneously with the introduction of a special function if so desired.

In addition, there are about 30 points in the MITE at which contactors, mechanically actuated by the machine, can be installed. These contactors can be used to set up electrical circuits in combinations determined by the characters or groups of characters selected by the MITE.

Design and Construction

Design. Certain basic design principles were adhered to in designing and developing this equipment. While miniaturization of the over-all machine was a basic goal, the utilization of full size components was considered a necessity. The miniaturization of the machine is, therefore, a result of its simplified design and of new approaches to certain problems which permitted that simplification.

Reduction of mechanical speeds within the equipment was considered paramount as was reduction of distances travelled by moving parts. Reliance on rotating components was considered preferable to reciprocating components and the weight of moving parts has been kept at a minimum.

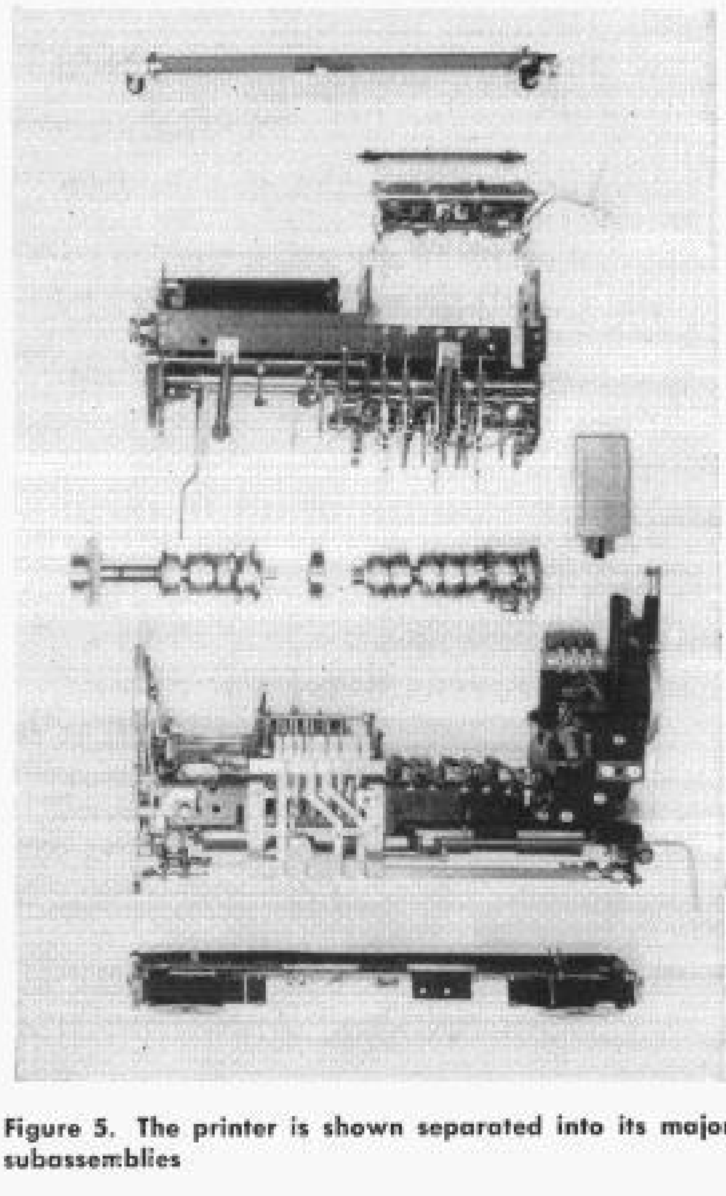


Figure 5. The printer is shown separated into its major subassemblies

The MITE has been designed so that gravity restoration is avoided permitting operation of the machine in any attitude including upside down. While the standard carrying case accommodates the printer and keyboard, a standard full size roll of paper, spare parts and field service tools, other special cases are being worked on. The standard roll is 8½ inches wide and 4½ inches in diameter. The machine lends itself quite readily to rack mounting either while still in the carrying case or after removal from it.

Unitized construction was adopted to permit complete replacement of whole sections. Figure 5 shows the machine broken down into its main subassemblies. These are, from bottom to top, the ribbon magazine, the printer section, main shaft and the selector section. The breakdown into subassemblies is accomplished with the removal of eight screws and requires less than ten minutes. The reassembly requires less than 20 minutes. All parts are readily accessible for inspection, lubrication and servicing. It is estimated that personnel with previous experience in servicing teleprinter equipment can be taught to service this machine in about one week, while personnel experienced with typewriters and other business machines can be taught in two weeks. There is a total of approximately 70 mechanical adjustments on the machine, many of which are one-time factory adjustments to take up tolerances and which do not require readjustment in the field.

Materials. The selection of materials used in construction is in keeping largely with military requirements. Special attention was devoted to those parts where there was a possibility of wear and carboloy inserts were used where necessary. The main structural members are stamped aluminum. Precision castings were used where difficult machining operations could be reduced. Considerable effort was required to determine the most suitable material for the cable in the cable and pulley mechanism.

Many types of chain and metallic cable were tried before it was found that the best material was synthetic fiber cable. This was checked in a test jig for 3,000.000 operations using a test which caused stainless steel cable to fail after 3600 operations. After the 3,000,000 operations there was only minimum evidence of wear.

Companion Devices

Other apparatus under development as companions to the MITE include a miniaturized transmitter-distributor and a reperforator. A "stunt box" which delivers electrical outputs upon certain signals or combinations of signals will also be built as a separate item, independent of the adaptations referred to above.

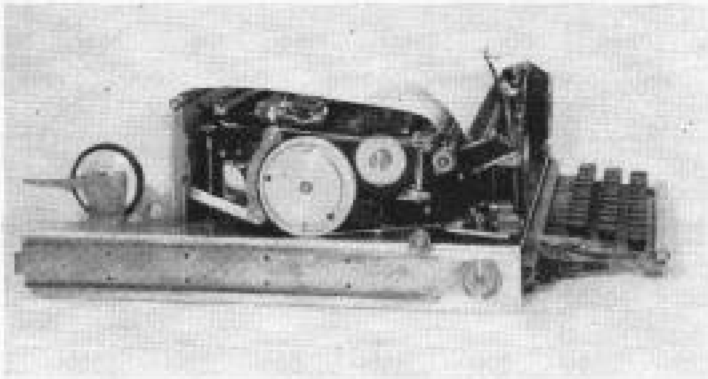


Figure 6. The printer, keyboard and paper roll are shown mounted on a chassis

The transmitter-distributor which automatically transmits signals when fed with standard five-hole perforated tape, will weigh less than two pounds including the motor. If the unit is to be used in conjunction with the printer, a common motor will be utilized and the printer motor will have adequate reserve power to drive the tape transmitter. This additional section will add about one inch to the width of the printer and seven ounces to the weight.

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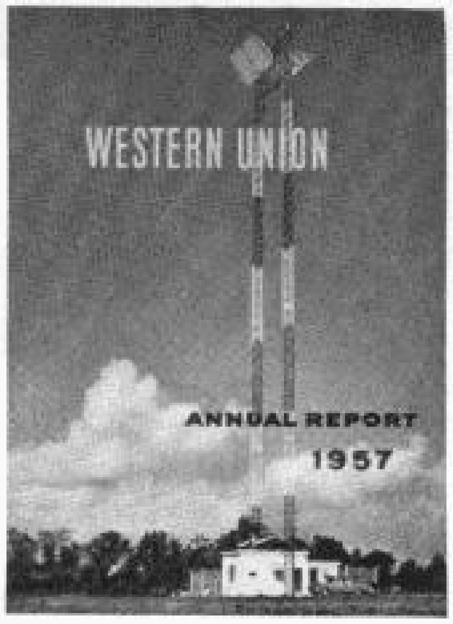
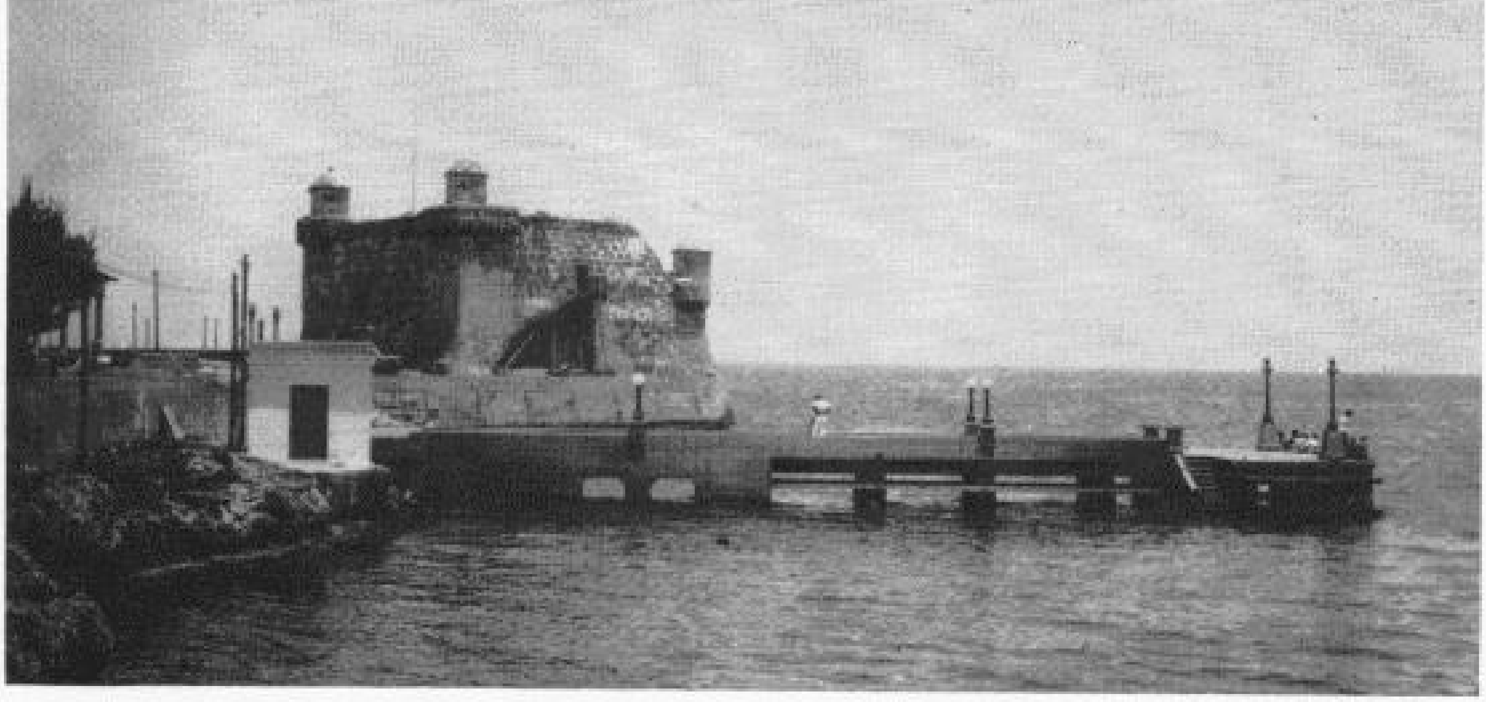
Bernard Howard, Vice President for Engineering of the Teleprinter Corporation, attended the University of Idaho and the New Mexico School of Mines. He has spent the past 15 years doing engineering design in the fields of aerial navigation, communication and wire recording, for such corporations as Bendix Aviation, Federal Telecommunications Laboratories, Fada Radio and Electric Company, and Air Associates. Mr. Howard holds many patents (in addition to those awarded in connection with his work with the Teleprinter Corporation and assigned to them), encompassing inventions in the fields of magnetic recording devices, preselector tuning mechanisms, aircraft instruments, and for several classified navigational and communications devices.



NEW MICROWAVE TOWERS

Pictured on the cover of the Company's Annual Report for 1957 is one of Western Union's new microwave towers installed in 1957 near Cincinnati, Ohio. The Company's radio beam system, now linking New York, Philadelphia, Washington and Pittsburgh, is being extended to Cincinnati and Chicago.

An Improved Six-Channel Time Division Multiplex for Submarine Cable Telegraphy



Cojimar Castle near Havana, Cuba, where Western Union submarine cables from Key West, Florida, come ashore. Telegraph cables terminate at white building in left foreground. Lines are aerial and underground into city.

HAROLD F. WILDER, Assistant to Electronics Applications Engineer

Successful operation of a six-channel multiplex circuit on a submarine cable between Key West and Havana has not only doubled the message capacity of the cable but simultaneously has improved traffic handling arrangements in an area of growth in diversified record communication requirements. Additional multichannel equipment of Western Union design is under construction for similar improvement of other cable circuits serving Cuba, Puerto Rico, the islands of the Caribbean, and South America.

THE developments of recent decades have sustained the prediction made in 1890 by Mahan that if a successful transisthmian canal were to be built in Central America, the Caribbean would become a great commercial area and crossroads of transportation, not only of local and South American traffic, but between Europe and Asia as well.[1] The importance of Havana, Cuba, in the day of the sailing ship seated in a geographical position so favored by winds and ocean currents as to command the only passage to Europe, has not been diminished but enhanced by the prophesied burgeoning trade and intercourse. To meet the communication needs of this market place and the richly cultivated area to which it gives access, the Telegraph Company operates three submarine telegraph cables between Havana and Key West, Florida, an average distance of 101 nautical miles. The second cable of the three was laid in 1889 almost as if in anticipation of Mahan's observation and the third cable was laid in 1917, three years after the completion of the Panama Canal and seemingly in confirmation of it. Until recently, these duplex operated cables were terminated in differentially connected polar relays reflecting the land-line practice of those decades, a condition sustaining three-channel multiplex opera-

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers at New York, N. Y., February 1958.

tion or a signalling capacity three times that of the earlier Morse circuits.

Lines to Cuba

Probably no other division of the submarine cable network of the Telegraph Company presents as many diversified traffic requirements as these connections to Cuba and their extensions to South America and the islands of the Caribbean. One requirement, automatic exchange of traffic with the recorder code operated cable of Cable and Wireless, Limited, to San Juan, Puerto Rico, was effected by translating the three-position signals, dot, dash, or space, to two-element signals of twice the line frequency and superposing the latter on appropriate segments of one of the New York three-channel multiplexes. Now a second interconnection of this nature is in operation. This circuit, the Island Chain, finally terminates in Barbados, B. W. I.

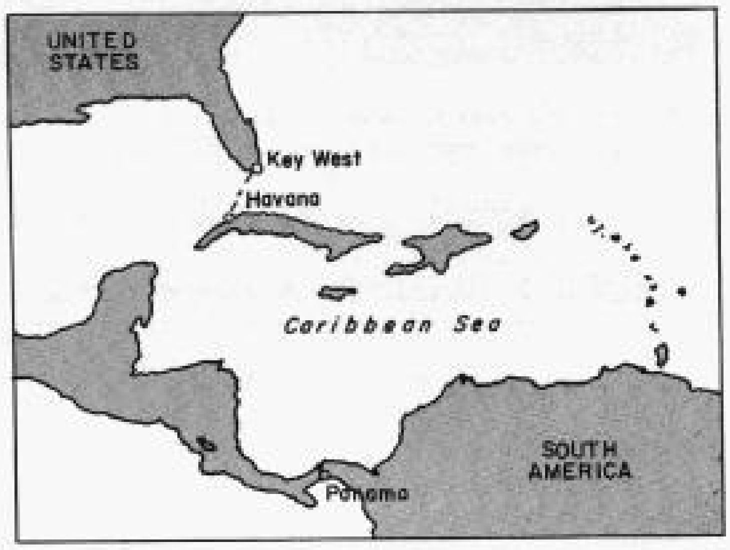
Another early requirement supplied by the Company was the transmission to brokerage houses in Havana of the quotations of the New York Stock Exchange. This service was extended from the mainland in 1930 by superposing on one of the three physical circuits a unidirectional single-channel amplitude-modulated carrier system.

Here, then, was a further indication of the tide of specialized traffic demands arising from the operation of mercantile houses trading in sugar, the staple product of the island, coffee, tobacco, fruit and chocolate, and the international airlines. To provide these leased facilities a second carrier system was designed and put in operation in 1949.[2] Each of the two additional frequency-modulated duplex channels so derived is capable of carrying either a teleprinter circuit or a triple-channel multiplex. And in 1950, the older multiplexes were replaced by similar equipment capable, however, of accepting and delivering teleprinter start-stop code signals from and to the customer extensions.

Signal-Shaping Amplifiers

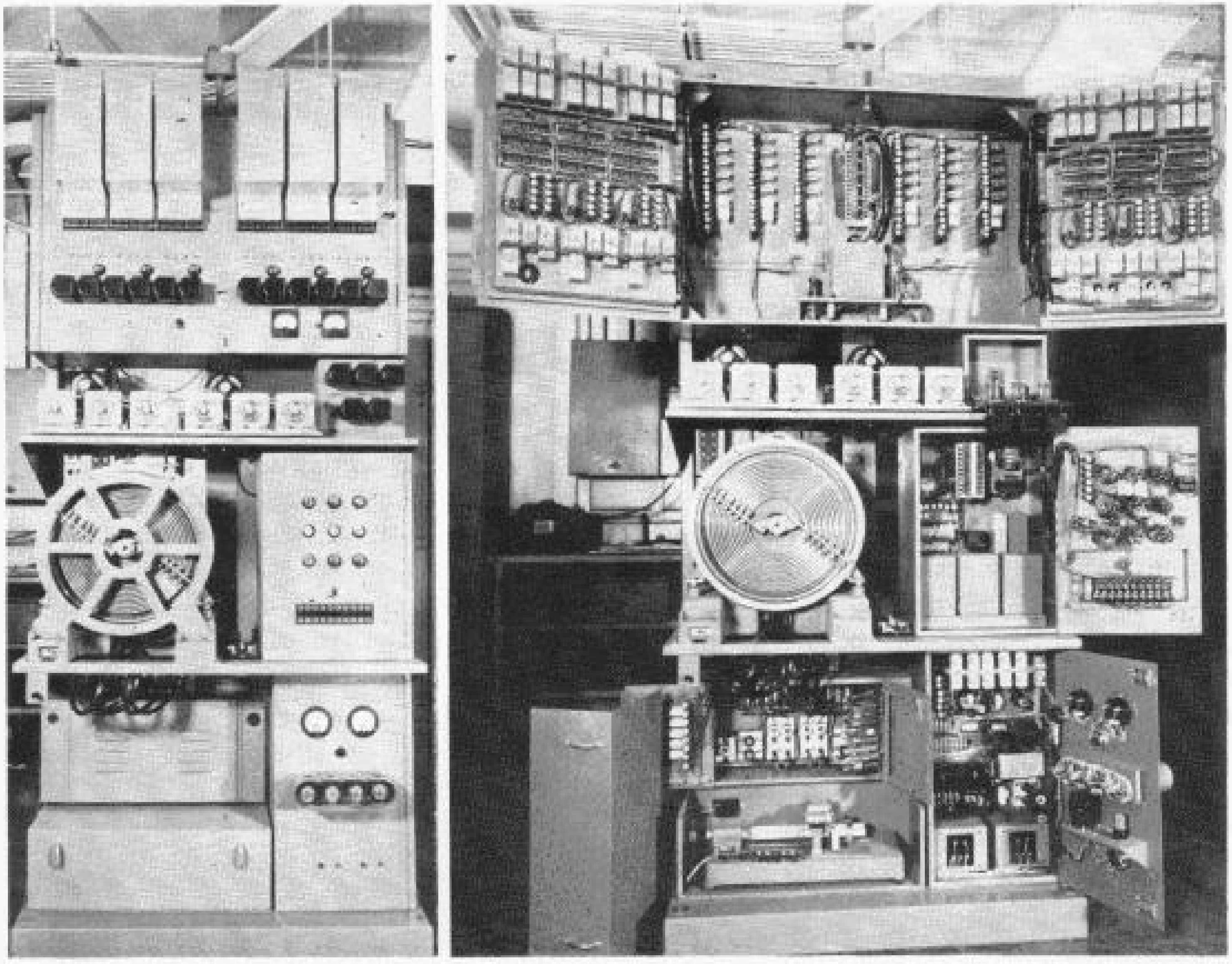
The somewhat higher signalling speed of the new multiplexes highlighted the need for a cable receiving device of greater sensitivity and stability than the unaided polar differential relay. Consequently, in 1955 all the Havana cables, together with the Tricore cable between Key West and Miami Beach, were equipped with signal-shaping vacuum-tube amplifiers.

These amplifiers are in widespread use throughout the submarine cable network of the Company to equalize the transmission distortion and to amplify the signals on cables from 50 to 500 miles in length. The output relays are driven by a vacuum-tube amplifier and while earth current potentials and corresponding low-frequency components in the residual duplex unbalance are prohibited from influencing the output because of the discrimination inherent in the equalizing networks, low-frequency signal components equivalent to the suppressed disturbing currents are restored to the signal by a self-energized correction circuit.



High-Speed Signalling

At the time the amplifiers were installed, tests were made to determine the feasibility of higher signalling speeds, for again the pressure for additional channels to Havana was being felt and it was thought that the new amplifiers might be the key to a full exploitation of the latent signalling spectrum of these low-attenuation cables. For the investigation of higher speeds, magnetic tapes were prepared in the laboratory. These contained



Photos R-10,839 & R-10,840

Figure 1. The sending six-channel multiplex terminal (left); with doors open (right)

the signal combinations that would produce the same transmission distortion and attenuation that would be encountered at the speed of signalling of a six-channel multiplex, at 100 cycles per second compared to the usual 50 cycles, and these tapes were then inserted in a magnetic tape recorded signal transmitter at Key West for observation at Havana.[3] A signal of good quality was obtained at the higher speed by readjustment of the signal-shaping network in the terminal amplifier and the duplex balance was easily improved to a workable accuracy. Despite the greater amplification, disturbance from natural sources and transmission on other cables was still negligible, and when the frequency-modulated carrier was superposed on the test cable without mutual interference practical operation of a six-channel duplex multiplex circuit on any one of the three cables seemed assured.

The success attending these tests represented a real breakthrough in the previous restriction on channels to Havana. The higher signal capacity of six-channel multiplexes and their compatibility with the frequency-modulated carrier meant that the number of multiplex channels could be doubled simply by the provision of new terminal equipment, a step comparable to the doubling of transatlantic facilities that had been effected by the insertion of submerged repeaters.

Multiplex Design

Design of the six-channel multiplex terminals to use the wider signal spectrum now known to be available was soon initiated. Aside from designing for operational stability and the use of well-tried features familiar to the operating personnel, several fundamental decisions were made. In view of the large number of channels ultimately possible, it was thought desirable to avoid use of tape reperforation to couple incoming teleprinter signals to the cable time-division channels. The untidy tape loops and the maintenance of tape continuity were eliminated by the incorporation of a channel repeater between each teleprinter signal receiving start-stop distributor and the five corresponding sending segments of the multiplex distributor. Correlated with the decision to use channel repeaters was the limitation of the teleprinter extensions to a speed of 368 operations per minute, nominally referred to as 60-word operation. To have designed for 65 words or 390 opm would have meant the transmission into the domestic telegraph system of teleprinter signals containing rest or stop pulses only 86 percent of unit length, and this would have precluded regeneration at repeater points thus rendering the longer teleprinter signal extensions much more susceptible to distortion and bias.

The Sending Terminal

The sending terminal is shown in Figure 1 and the flow of intelligence through this equipment can be seen in Figure 2. Each sending rack provides means for coupling six incoming teleprinter lines to their respective five-unit code multiplex channels. The individual relay banks housing the channel repeaters are mounted at the top of the rack with the teleprinter circuit line and selector relays beneath them. A new start-stop distributor was designed to receive the incoming teleprinter signals from each extension and to deliver the five intelligence impulses to one of two capacitor storing banks in the associated channel repeater.

A group of three units is driven by a common motor geared to produce the correct brush speed, the engagement of the brush shaft being effected by a dry metallic clutch of recent design significantly free of variation in take-up lag. The brushes are shown at rest on the stop segments of the faceplate in the photograph of Figure 3. Upon the reception of a teleprinter character the clutch magnet circuit is energized by the start impulse of spacing polarity preceding the five intelligence impulses. The brush then rotates for a single revolution, returning to the rest segment coincident with the arrival of the stop impulse of marking polarity at the end of the character. Here it remains until the start impulse of the next character occurs. During its revolution the brush passes over five short-length scanning or pickup segments at intervals of 22 milliseconds. The successive impulse polarities of the five intelligence impulses thus selected are momentarily stored on a relay. The longer segment following each selection is used to deliver a charge from the armature of the relay to an associated capacitor in one or the other of the two capacitor storing banks in the channel repeater. The stored charges are subsequently commutated by segments on the multiplex faceplate to the coils of five storing relays. After positioning, the armatures of these relays are given time to settle firmly on their contacts before

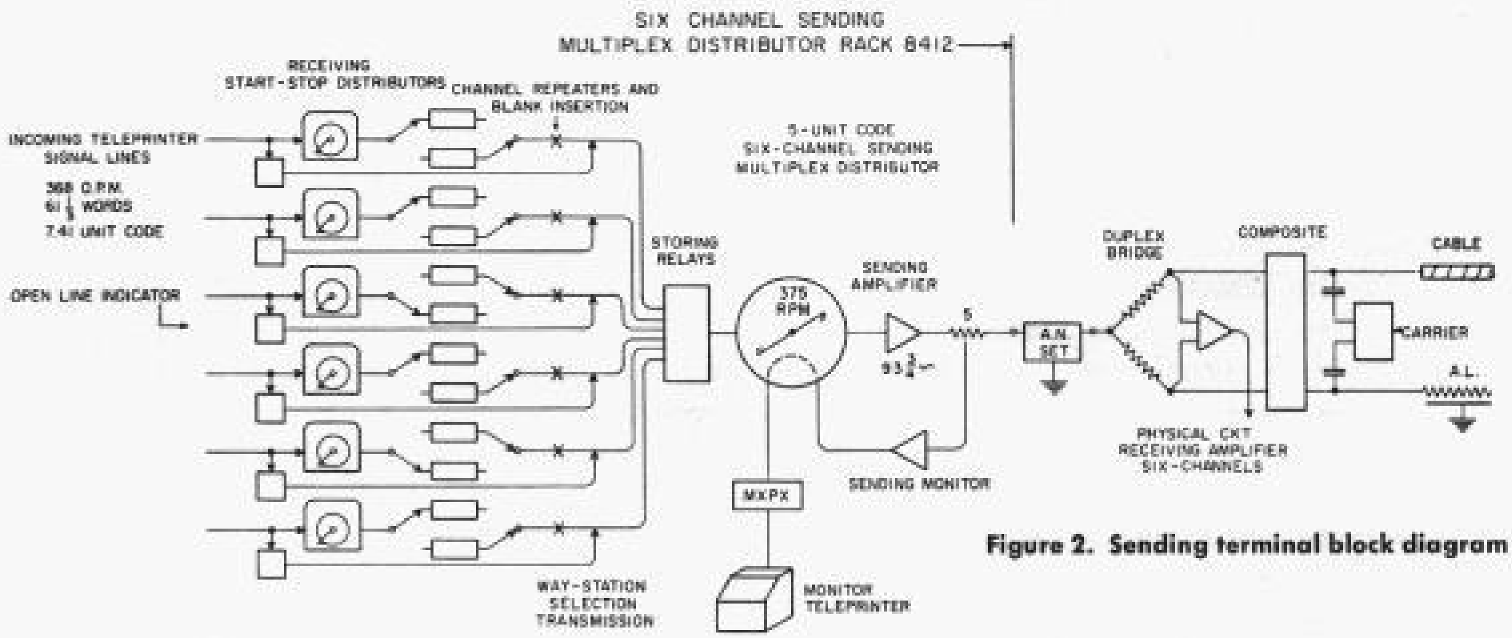


Figure 2. Sending terminal block diagram

delivery of the signals to the sending amplifier.

In order to obtain the sixth pulse segment for operation of the transfer relay in the channel repeater, it was necessary to shorten the fifth delivery segment. Closure of the sixth pulse segment shifts the delivery of the next character received to the alternate bank. Both the sixth and stop segments are isolated by short segments. By means of an indicator knob, the faceplate can be shifted to measure the quality of the incoming teleprinter signal and to center the selection point midway between the minimum limits of variation in signal impulse arrival time.

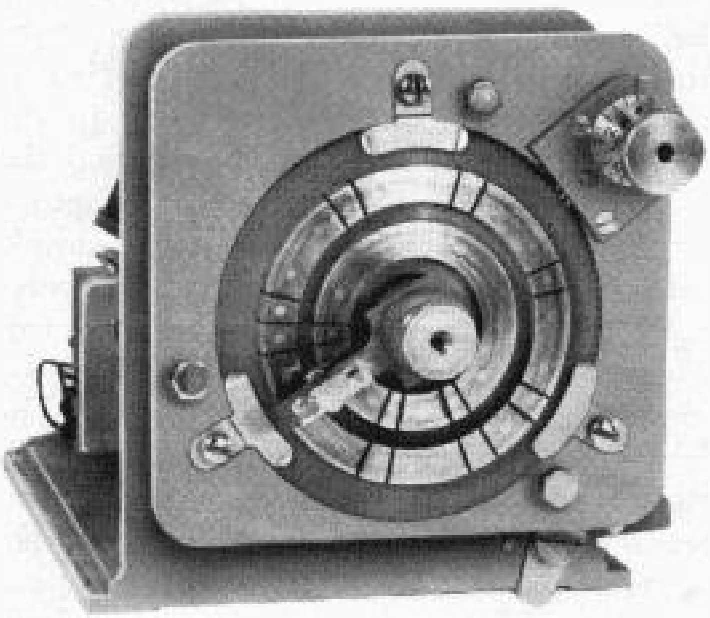


Photo R-10,844

Figure 3. Faceplate of receiving start-stop distributor

The large multiplex distributor shown directly below the shelf of six start-stop distributors is already in widespread use as a time division commutator on the North Atlantic system. For use on the Key West to Havana cables, the distributor was equipped with a faceplate possessing on one commutator all the segmented rings necessary to both sending and receiving functions, an interchangeability that reduced the number of units that had to be manufactured and held in reserve at each station. One ring is segmented to provide 22-millisecond timing intervals for each one of the six channels either when translating the multiplex signals to teleprinter signals at a receiving terminal or when monitoring the signal transmitted to the apex of the cable duplex bridge at the sending terminal. The other rings are segmented in the conventional manner for selection, correcting, transmission of unit length impulses, and local functions.

Channel Repeating

The distributor brushes must rotate slightly faster than the maximum rate of transmission of the incoming teleprinter signals so that regardless of the normally encountered power frequency changes in the supply to teleprinter keyboard and transmitter-distributor motors, the distributor will never fall behind in phase but will from time to time "catch-up" with the signal input. To stabilize the speed at 375 rpm or seven rpm above the maximum teleprinter character rate, the usual sliding weights were removed from the distributor driving fork and the fork inclosed in a draft and sunlightproof cabinet located on the plinth of the rack. With this slight speed differential, the signal attenuation is not appreciably increased and the rest or stop pulse duration of each translated teleprinter character issuing from the receiving rack is still well in excess of unit length. At 375 rpm the length of this pulse is 28 milliseconds or 27 percent greater than a unit length impulse of 22 milliseconds. One might say that the code retransmitted is of 7.27 units instead of the 7.41-unit code signals originally incoming to the sending rack. Regeneration of the 7.27-unit code signal characters can be effected at one or more repeater points without "clipping" the rest pulse.

About every eight or nine seconds, the slight amount of excess mulitplex speed causes the brush extracting intelligence stored in one bank of capacitors to approach the segments associated with the alternative bank. Before a scramble can occur, however, an auxiliary or auto-stop circuit continuously searching for this condition stops the alternation of the transfer relay feeding information to the multiplex for a single character and substitutes a blank for transmission. Thus a new lag, equivalent to the time duration of a character, is introduced and the cycle repeats. If the power frequency at the sending extension increases, the rate of blank insertion decreases; it increases if the frequency drops below 60 cycles per second. Should the teleprinter extension send sporadically as from a keyboard, more than one blank may be transmitted between characters and in the limit where sending ceases the blank is transmitted continuously.

Way-Station Selection

Leased circuits frequently contain one or more drops or way stations in addition to the terminals and are then provided with way-station selecting apparatus enabling one station to call any other. Station selections are preceded by an open-line condition lasting a few seconds, a signal serving to start all teleprinter motors in anticipation of the transmission of the selection character group itself. Ordinarily, a continuous spacing signal would be sent over a channel of a five-unit code multiplex as a series of BLANKS equivalent to the idling condition and the significance of the preselection open-line interval would be lost. The fact that the upper-case shift function or LETTERS character is sent but once in traffic operations presented an opportunity to translate the open-line interval to a form acceptable to the multiplex. Accordingly, whenever a multiplex channel is assigned to the support of a leased circuit operative with way-station selection, the usual OPEN-LINE alarm circuit is arranged to send a succession of LTRS functions (all five impulses of marking polarity) for the three- to five-second preselection interval.

At the receiving terminal, the reception of a succession of shift functions, quite in excess of traffic need, is recognized as the preselection open and in response the terminal apparatus opens the outgoing customer extension to activate all teleprinter motors for the call soon to be received. Both sending and receiving sensing circuits return to normal immediately upon the reclosing of the incoming teleprinter circuit extension.[4]

Sending Amplifier

Transmission to a submarine cable at speeds in excess of 50 cycles is usually effected by brushes traveling over accurately segmented rings. It was known, however, that on the three Havana cables, a highly inductive multisection antinoise set designed to suppress all frequency components above 300 cycles lay in the apices of the duplex bridges to prevent physical transmission from interfering with operation of the carrier systems. Since previous experience had demonstrated the impossibility of transmitting from segments to an inductive sending end impedance because of segment gap flashover, it was decided to transmit to the duplex apex from a vacuum-tube power amplifier. This amplifier is mounted at the base of the rack to the right of the switch compartment and the sending fork box. To obtain a satisfactory signal shape with the relatively simple networks available in the distant receiving terminal amplifier, however, all frequency components, including the d-c component, must be transmitted to the cable by the sending apparatus. Accordingly, the amplifier was designed to impress only the higher frequency components of the signal upon the duplex apex; the d-c component and the very low-frequency components are still supplied from the sending segments through a resistive-capacitive network.

Figure 4 shows the circuit theory of the sending amplifier. Segments of the transmitting ring are protected by unusually large battery tap resistors of 500 ohms so that "bridging" by a worn brush is of no importance. The resistor R of about 1000 ohms in the LOW path limits the d-c cable current to 40 or 50 milliamperes and the 40-microfarad capacitor C suppresses all high-frequency components while simultaneously providing a low-impedance path to ground for the high-frequency components generated by the vacuum-tube amplifier in the HIGH path. The latter is a push-pull power amplifier transformer coupled to the cable duplex bridge and is driven by a flip-flop vacuum-tube relay that "squares-up" the otherwise rounded off waveform from the ring caused by the high-battery tap resistors. An inspection of the voltage loci shows that the sum of the high- and low-path voltages reproduces at the cable bridge apex a produced across this resistor by the charging currents to the cable apex after amplification drives a high-speed monitor relay. The multichannel multiplex signal output of the relay is then returned to a

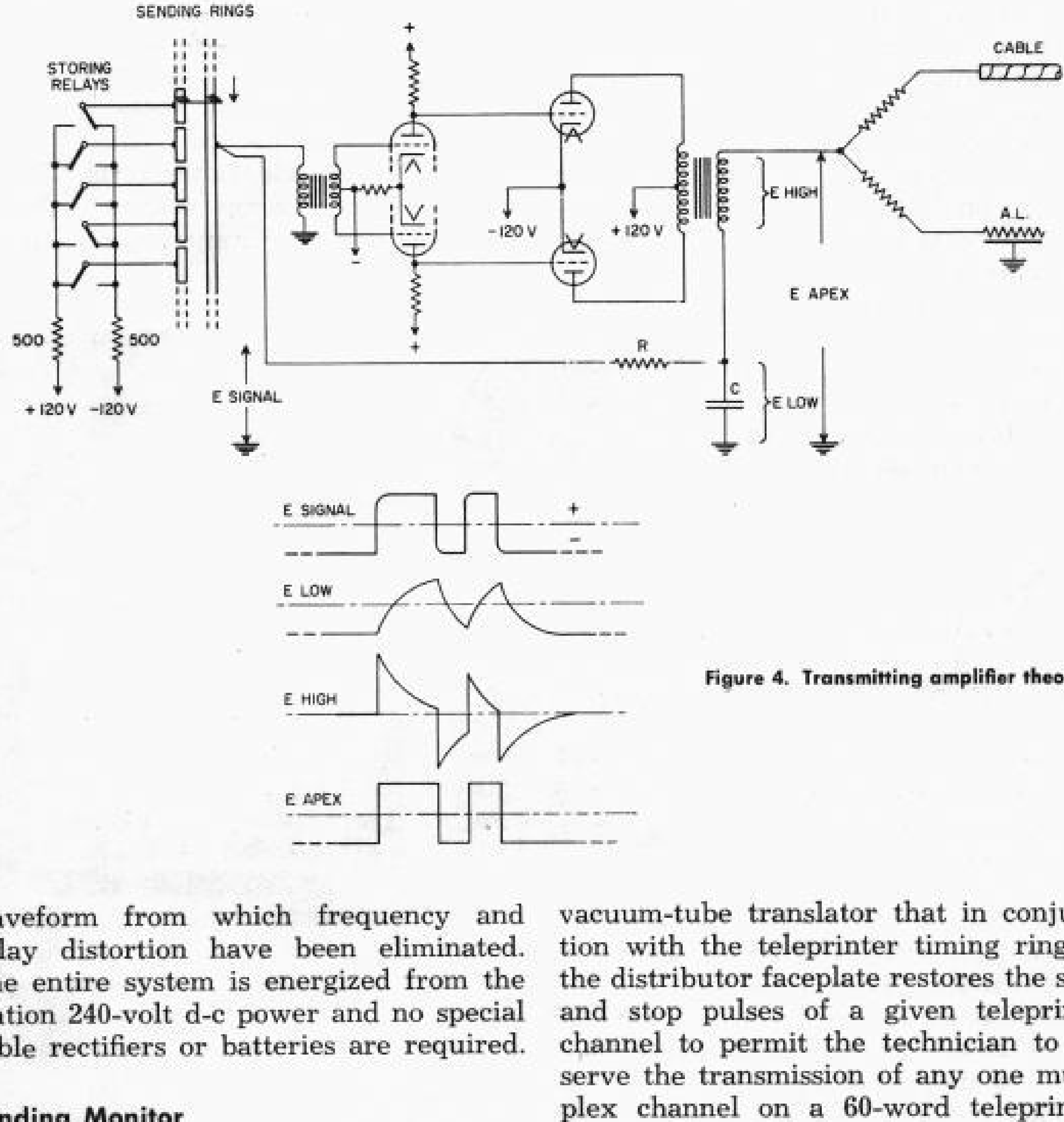


Figure 4. Transmitting amplifier theory

waveform from which frequency and delay distortion have been eliminated. The entire system is energized from the station 240-volt d-c power and no special cable rectifiers or batteries are required.

Sending Monitor

Experience has shown that it is imperative that the technician be provided with means to monitor the transmitted signals and that the only reliable method is to drive the monitoring device by the current actually entering the apex of the duplex bridge, for then an interruption of the cable or artificial line currents will announce failure in circuit continuity. At the sending terminal, a 5-ohm resistor is placed in series with the output of the sending amplifier and the voltage drop vacuum-tube translator that in conjunction with the teleprinter timing ring on the distributor faceplate restores the start and stop pulses of a given teleprinter channel to permit the technician to observe the transmission of any one multiplex channel on a 60-word teleprinter. The monitor cabinet and channel selector switch are contained in a cabinet adjacent to the multiplex distributor.

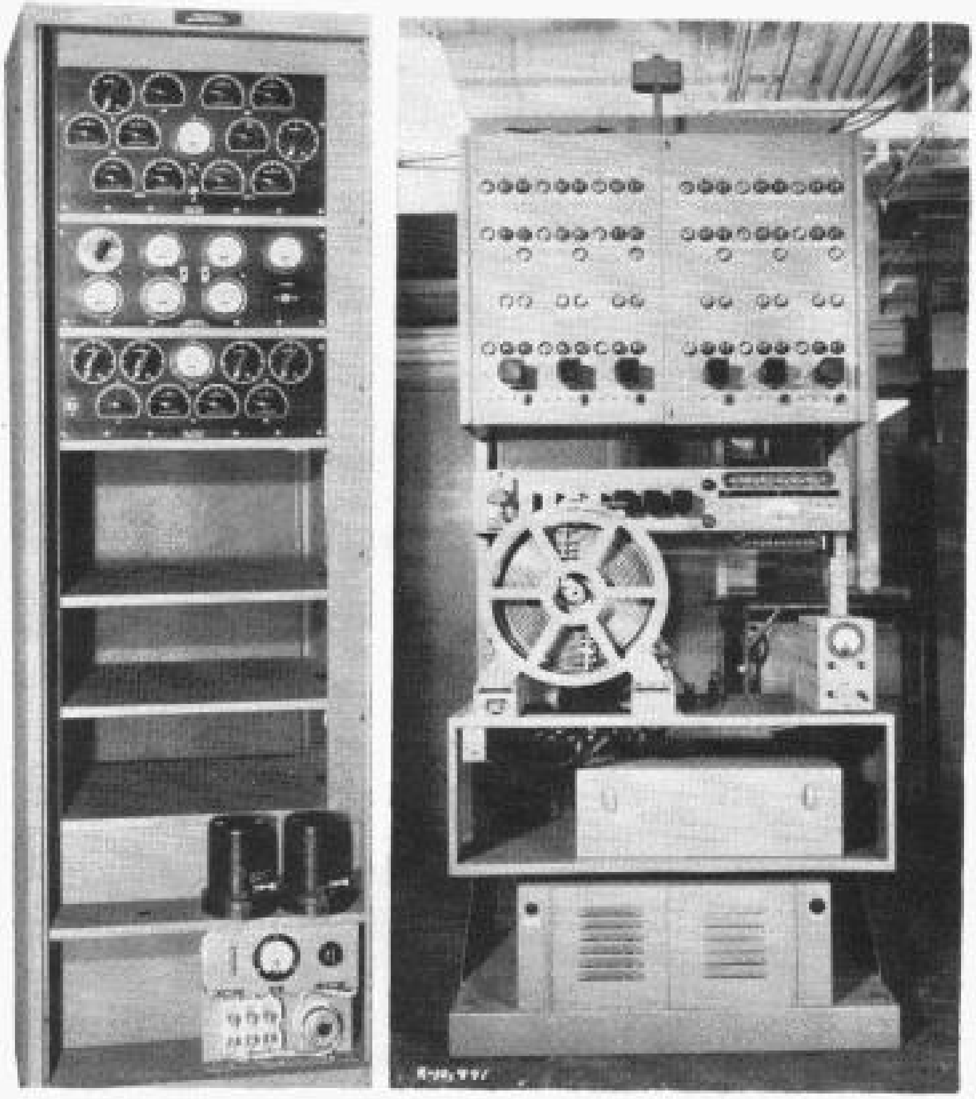
At the request of the distant station received over either the International Talk-Channel or on the Morse facilities provided on these racks, the sending terminal technician can transmit the "all idle channel" pattern for phasing of the receiving distributor, or a recurrent pattern which is devoid of characteristic distortion thus enabling the receiving station technician to range and center the signal pickup without requiring the transmission of a test tape.

The Receiving Terminal

In their propagation from the sending to the receiving terminal, the form of the signals is degraded by the effects of frequency and delay distortion. On cables of this electrical length, the former effect may reduce the amplitude of the highest frequency reversals to one twenty-fifth of their original size while the delay distortion retards the time of arrival of the lower frequency components relative to the attenuated highs. The form of the received signal is quite unintelligible. To equalize these distortion effects, a signal-shaping amplifier is used on the Key West-Havana and other cables of the same order of attenuation. Two such amplifiers are generally mounted in a single cabinet although but one is shown in Figure 5. For speeds of operation above 50 cycles high-speed relays whose upper limit of operation is several hundred cycles per second are substituted for those shown in the photograph.

Adjustable filter sections located in the upper compartment shape the received signals and suppress the very low-frequency earth current and residual unbalance potentials, and the electrical noise frequencies lying outside the upper end of the signal spectrum. The shaped signal waveform, minus the zero-frequency component, is then amplified by a two-stage transformer coupled amplifier driving one or two output relays. The output relay drives the receiving relay loop in the multiplex set and a low-pass filter or local correction network which restores the d-c signal component.

The six-channel receiving terminal is shown in the photograph of Figure 5, and a block diagram of this equipment is shown in Figure 6. A single receiving rack complementary to the sending rack previously described is required at each cable terminal. A cabinet at the top of the rack contains six identical sets of vacuum-tube circuitry, each set having three distinct functions. Of first importance is the circuit translating the received multiplex signals to the teleprinter form. This is accomplished by a new vacuum-tube circuit operating in conjunction with its associated group of the six sets of 22-millisecond teleprinter timing segments on the distributor faceplate. The five intelligence impulses received by the multiplex are a little over five milliseconds in duration. These are first stored on five capacitors. Each capacitor is then discharged by its respective segment on the



Photos R-7,888 & R-10,841

Figure 5. The receiving signal-shaping amplifier (left); the receiving six-channel multiplex terminal (right)

teleprinter timing ring through one winding of a transformer having seven primary windings. Of the seven timing segments for each channel the first segment discharges a positively charged capacitor through the number one winding of the transformer to prefix the start impulse to the teleprinter character being developed. Similarly, a seventh but negatively charged capacitor is provided to produce the stop impulse.

The voltage transients induced in the transformer secondary drive a vacuum-tube bistable amplifier that in turn positions a relay controlling the outgoing teleprinter line. Auxiliary circuitry holds the line closed whenever traffic ceases.

The way-station selection repeater has been previously described. When not in use, it is switched to sense an open teleprinter line and to bring such an abnormal condition to the attention of the technician.

A channel-failure alarm is the third feature provided. This circuit senses, for a greater than normal time interval, the absence of time differential blanks, caused perhaps by a failure in the channel repeater circuitry or by loss in phase of the receiving distributor. The basis of the circuit is a capacitor charged through a high resistance. If during traffic transmission the time differential blanks do not appear at the usual rate of seven or so per minute the voltage on the capacitor rises excessively and triggers an alarm. Should the distributor drop behind in phase by one or more segments all idle channels will develop a repetitive character and again the absence of an occasional blank will trip the alarm.

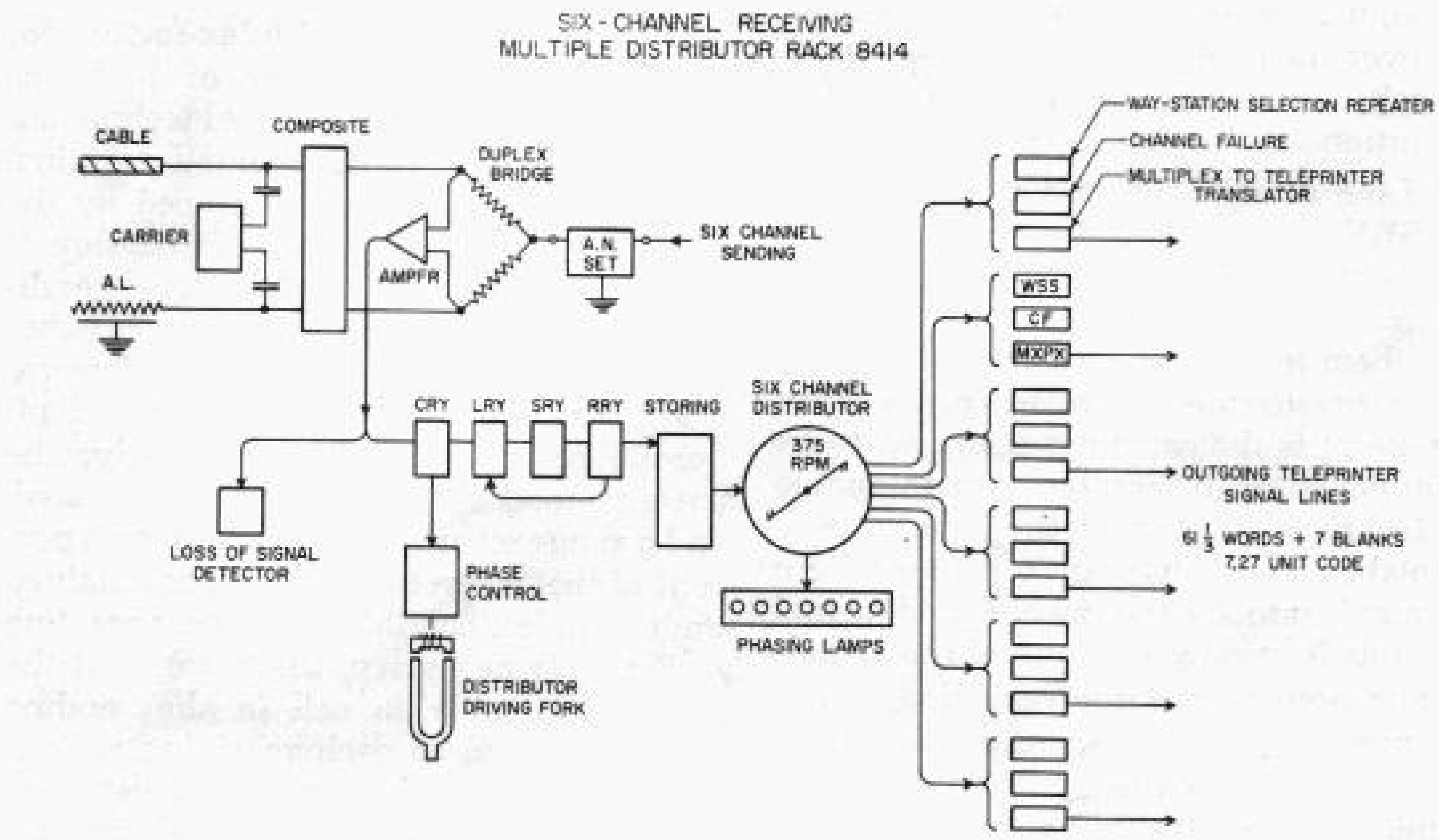


Figure 6. Receiving terminal block diagram

The lower portion of the rack supports apparatus for the regeneration of the cable multiplex signals, and the distribution of the impulses to the translating circuits. The circuitry is conventional and a duplication of that used on transatlantic multiplexes. As the block diagram implies, one relay, Corrector Relay CRY, driven by the incoming signals continuously scans the phase of the multiplex brushes. Should the driving fork tend to speed up slightly, due to a reduction in ambient temperature or a decrease in d-c power voltage, the phase of an alternating current voltage generated by the brushes will begin to lead the instant of signal crossover and a series of corrective electrical charges will be fed to the fork control bank. As a result the current flowing in a damping coil at the extremities of the fork tines will be decreased, thereby lessening the stiffness of the fork and causing it to slow the speed of brush rotation. Conversely the magnetic flux is increased by the same corrective circuits should the fork slow down. Thus, the receiving brushes rotate continuously at precisely the same speed as the sending brushes and in channel phase with them, although because of the time of propagation over the cable, there will be an angular lag equivalent to a fraction of a revolution.

A Line Relay LRY and a Selector Relay SRY operating in conjunction with 30 scanning segments of the faceplate regenerate the signal impulses and deliver them to three storing relays. Storage of the regenerated impulses for a short time permits the scanning segments to be mounted on an orientable ring to enable the technician to center the range.

On the long transatlantic cables where the amplitude of the most rapid signal reversals is greatly attenuated the signal-shaping networks of the receiving amplifier are tuned to emphasize the next lowest reversal frequency whose impulses contain two transmitted impulses rather than one. These "doubles" reversals are very much larger than the "singles" and are not degraded by electrical noise. Although under conditions of suppressed singles operation any singly transmitted impulse does not appear in the amplifier output, the missing impulse can be interpolated by the use of appropriate circuitry within the multiplex equipment. On the six-channel terminal a Reversing Relay RRY is provided for this purpose. This relay is positioned by each regenerated signal impulse and returns to the line relay a current of half-value and opposite in direction to the signal impulse last seen. If the next impulse is a suppressed impulse the line relay will be free to reverse its position in response to the reversing current alone and thus the impulse will be synchronously "filled-in".[3]

On the actual Havana cables it was found that the signal-to-noise ratio was sufficiently great to make the use of this circuit unnecessary. The "singles" impulses are amplified to equal the size of all other frequencies and only a single relay is necessary in the output circuit of the amplifier. Consequently circuit operating maintenance is somewhat less demanding.

Regulating

When preparing a multiplex facility for traffic use, the attendance of both the sending and receiving terminal technicians is required. First the sending terminal must be made aware of the need by the receiving terminal for the transmission of the "all channel idle" or "spacing" condition in order that the receiving brushes can be wheeled around until, by observation of the neon phasing lamp bank, channel phase is established. Secondly, the pattern combination must be requested, and a range excursion not less than 50 percent of the theoretical maximum obtained under duplex conditions before accepting traffic. It is necessary, therefore, that the receiver be able to call in the sending technician, and so each receiving rack is equipped with a loss of signal detector. When the need arises, the receiving station simply stops transmission in the opposite direction thereby immediately alerting the distant sending technician.

Successful Operation

The six-channel equipment was placed in service early in April 1957. Its immediately successful operation not only provided three additional duplex teleprinter channels to Havana but permitted the three-channel multiplex then in the old Miami office to be abandoned just prior to the establishment in the new office of more up-to-date operations through Atlanta. A duplicate set of six-channel equipment is now under construction and other plans are afoot to increase the channels potentially available from the three cables. In Figure 7 the author has, with some indulgence, sketched the application of the new six-channel equipments, and the projected carrier channel terminals and recorder code combining apparatus to this communication network. As the need arises, the ultimate realization of a total of some 27 odd duplex and commercial news circuits to Cuba is thus seen in the offing.

A second frequency-modulated carrier shown superposed on the Number 4 cable division apparatus to combine over a single physical or carrier channel the two duplex recorder code circuits interconnecting with the Cable and Wireless system in the West Indies will further increase the efficiency of use of the existing three-channel multiplexes to New York. The bidirectional recorder code to teleprinter signal translators associated with this mode of cable code operation are in the process of development. This apparatus will not only translate the alphanumerical characters of one code to the electrical impulses of another code but will substi-

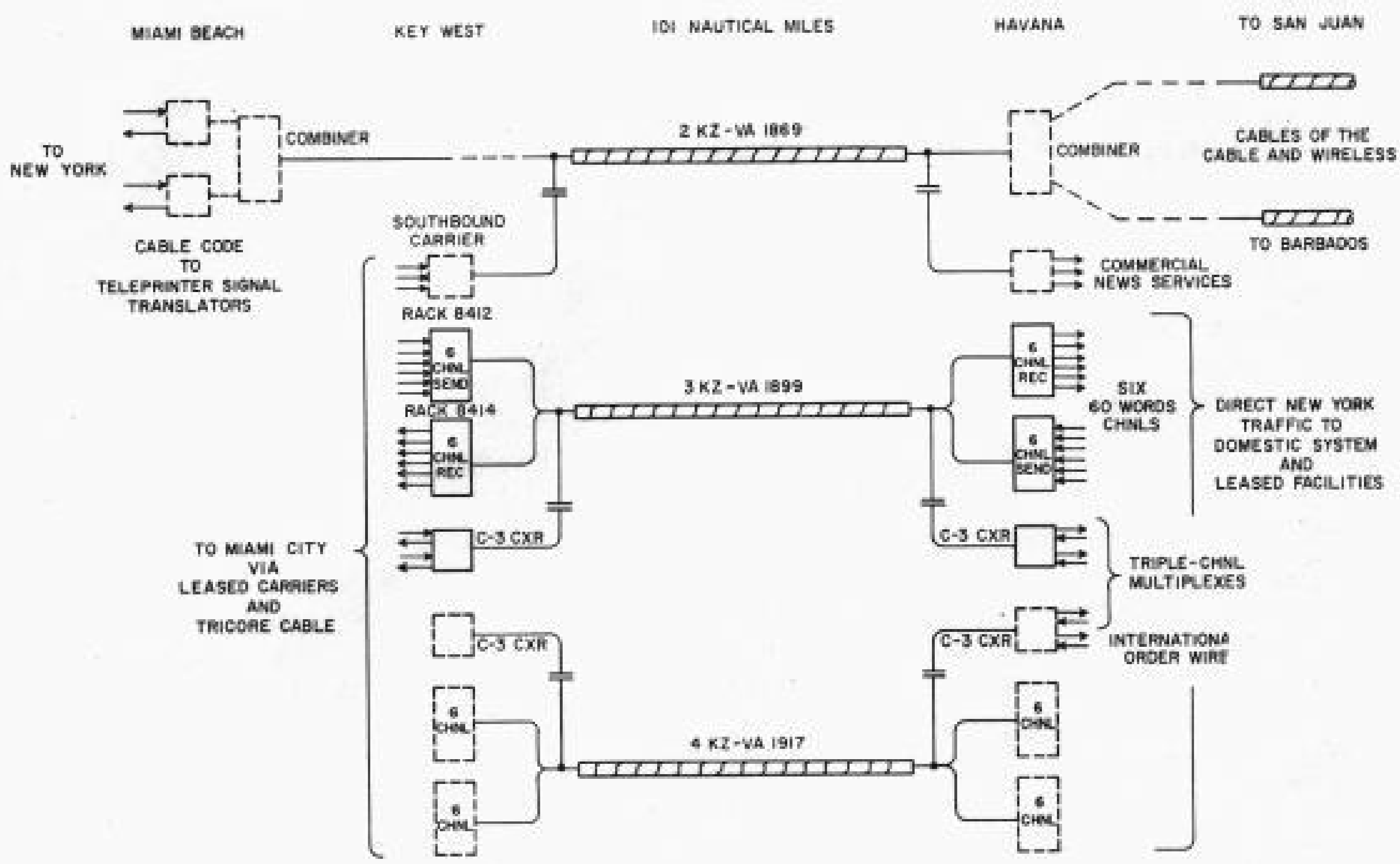


Figure 7. Ultimate facilities

will be a duplicate of the original; the performance of the latter could scarcely be improved upon, while the replacement of the old work-horse, the amplitude-modulated carrier, by a three-channel unidirectional carrier transmitting commercial news service will relieve the existing triple multiplex of the inefficient use of their otherwise duplex operative channels. Similarly, the completion of the design and the installation of special time tute for the special designations almost traditional in recorder code the equivalent function characters common to reperforation switching systems. And southbound, other special apparatus adjunct to the translators will automatically inject the correct "attack" or way-station call of the many stations along the island chains.

The author wishes to recognize the contributions of the several engineers whose special efforts made the six-channel idea realizable. S. A. Kirkowski designed the new start-stop distributors and W. J. Ramhorst, as a continuation of previous submarine cable equipment design, furnished the physical layouts of the racks. Synthesis of the basic circuitry and the carrying of the project to an operative conclusion was done by G. T. Fontaine.

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3. A Magnetic Tape Signal Transmitter for Ocean Cables, E. T. FINNEGAN, *Western Union Technical Review*, Vol. 10, No. 3, July 1956.
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A biographical sketch of the author appears in the January 1957 issue of Technical Review.

Patents Recently Issued to Western Union

Facsimile Recorders

F. G. Hallden, D. M. Zabriskie

2,816,001—December 10, 1957

An automatic facsimile recorder which forms a message blank into cylindrical form by feeding recording paper around two circular flanges to form the ends and then holds it firmly during recording by wrapping therearound a thin flexible sheet from which the central portion has been removed. An inside stylus is used. Upon completion of recording the wrapper is opened and the paper is fed out, sheared off and ejected into a receptacle.

Telegraph Transmitter

H. W. Glaser, T. E. Melick

2,816,161—December 10, 1957

A perforated tape transmitter useful, for example, in switching systems where it is desired first to transmit the selection characters preceding a message and then to resend these characters along with the message for use in a subsequent selection. At a point several characters beyond the sensing pins, the movement of the sent tape is blocked so that the tape tends to pile upward in a loop passing through a rectangular aperture in a sliding member. When the desired characters have been sent, the slide is released to carry the loop back over the pins and resending of the looped tape is initiated. Any number of characters may be resent any number of times.

Means to Facilitate the Handling of Telegraph Storage Tape

F. J. Haupt, W. J. Ramhorst

2,818,468—December 31, 1957

In telegraph switching applications the storage tape after being perforated passes through a chute into a storage bin and is subsequently withdrawn through the same chute. When the chute is long, the tape, now rendered relatively flexible by the perforations, tends to jam. The jamming is remedied through stiffening the tape by means of a device attached to the perforator which creases the tape between the two outer rows of perforations to impart a truncated "V" configuration. The tape is again flattened upon withdrawal from the bin.