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TELETYPE

PRINTING TELEGRAPH SYSTEMS

PROPOSAL

TELETYPEWRITER SWITCHING SYSTEM FOR SHIPBOARD INSTALLATION

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Abstract

A study has been made of the feasibility of using a teletypewriter switching system for communication between U.S. Navy ships. Several solutions were examined in the light of presently known requirements.

A high speed (750 words per minute) selective calling system was found to have most promise from an operating and technical standpoint. It is recommended that, should active Navy interest in such a system develop, a formal study be undertaken.

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1. Introduction

The purpose of this paper is to present the results of an investigation undertaken by the Teletype Corporation into the feasibility of improving Navy ship to ship communications through the use of a teletypewriter switching network. A proposal will be made for a switching system which, it is hoped, will adequately meet the requirements of the Navy. Since teletypewriter equipment would form an integral part of any such system, the Teletype Corporation is submitting this engineering proposal as a service to the Navy, and as a guide in planning such a system. While general system requirements are known, many of the necessary detailed requirements are presently unknown. Where required, assumptions have been made in order to establish a yardstick against which to measure performance of any considered system. These assumptions are, of course, subject to modification in the light of future experience.

2. System Requirements

A. General Requirements

The Navy's communication problems have been growing in recent years due to a need for a greater volume of traffic between ships and between shore and the fleet.
Present day fleet communicating methods are becoming increasingly inadequate.

The Navy is considering the use of teletypewriter equipment in shipboard application, in combination with newly available radio terminal equipment, in order to improve ship-to-ship communications. A network was described by the

Navy personnel as consisting of up to 20 ships which are interconnected by radio channels via one ship designated as a relay point. A teletypewriter system is required to provide automatic interconnection between stations on these ships.

B. Specific System Requirements

Navy personnel indicate that any proposed teletypewriter switching system shall meet the following requirements: (Refer to Fig. 1)

(1) It shall interconnect up to 20 ships each having up to 5 stations (transmit-receive terminals).

(2) It shall be possible to communicate from a station at one ship to a station at a second ship. Internal station-station communication will not be required.

(3) One ship shall be designated a relay point. This relay point shall perform the switching center function of receiving the transmissions from other ships and retransmitting the information on the appropriate carrier subchannel(s) to the addressee.

(4) The system shall be operable with terminal equipment operating at the standard speeds of 60, 75, or 100 wpm.

(5) The system shall be operable over a minimum number of narrow band radio channels not to exceed 40.

(6) Consideration shall be given in system design to the problems of propagation, radio frequency noise and other interference commonly found on radio circuits.

(7) Message storage at the switching center, if required, shall be provided by magnetic tape or other reusable storage medium.

(8) Consideration shall be given to the problem of size, since such a system must be practical for installation aboard Navy ships where space is limited.

(9) The switching center equipment shall be of such size and cost that it is practical for installation aboard several ships in the net. As many ships as practicable shall be equipped with standby switching center equipment to be capable of assuming system control should the original center be disabled.

(10) The system shall be designed so that minimum operator attendance is required at the switching center. A completely automatic system shall be considered a design objective.

(11) Consideration shall be given to elimination of the conventional 60 and 20 milliampere keying loops in the terminal equipment and at the switching center insofar as practical. A keyed tone signal shall be considered as a possible substitute.

C. Operating Requirements

The type of traffic transmitted over the system will be both tactical and administrative in nature. There will be no facsimile, voice or computing data transmitted over the switching system.

(1) Two levels of priority shall be provided in the system.

(2) Two way conversation circuits are not required. Two way communications shall be provided only if required for circuit assurance or error control.

(3) Means shall be provided to prevent loss of messages by the system due to improper addresses, garbled transmission, mechanical and electrical failures, etc. The following features will be provided as and if necessary.

(a) Answer back - A means for the station receiving a message to so inform the transmitting station.

(b) Message numbering - A means for automatically numbering messages.

(c) Equipment failure alarms - Automatic means for informing operators at the switching center, and at sending and receiving stations, that an equipment failure has taken place. These alarms should be both audible and visual.

(d) Error control - Means for automatically detecting transmitted errors, and for informing the transmitting station of such errors, and for controlling retransmission of the traffic. Use of a redundant error correcting code shall be considered.

(e) Retransmission - Provision for rerun of messages at the sending stations.

(5) It shall be possible to address a message to two or more stations at one or more ships in the system. It shall be possible to address a message to all stations or groups of stations on selected ships.

(6) It shall be possible to easily add or subtract stations to the net. This shall be accomplished by the operation of a switch, through a line jack arrangement, or other simplified devices

D. Traffic Requirements

(1) Introduction

One of the first steps to be taken when designing a switching system is to determine traffic requirements. These requirements should be determined as accurately as possible, in order that the performance of any system may be effectively evaluated. In order to evaluate system performance, parameters which should be known or accurately established include the following:

(a) Number of stations to be serviced.

(b) Speed of operation.

(c) Total message load to be handled in the busiest hour.

(d) Percentage of the load handled by each station in the system.

(e) Average message length in words, including heading. Shortest and longest message length.

(f) Message format, preamble, length of time necessary to act on preamble, message numbering, priority level, etc.

It is, of course, realized that it is not always possible to obtain accurate estimates for all of the above parameters, especially where an operating system does not presently exist which is similar in nature to the simulated model. It is sometimes possible, however, to obtain the analog of the required data by monitoring communications which are in other forms such as dispatches, voice messages, etc. Much of this traffic would pass through the switching system if one were available for use. Analysis of message parameters can thus be made by study of this information, and in light of the analysis, a system proposed.

It is not enough, however, to design a switching system capable of handling today's traffic loads. Experience has shown that whenever new communications facilities are made available, the customer discovers more uses for it than are apparent at the time of the traffic study. Planning for increased traffic is therefore an important factor in system design since capacity for growth is a measure of time to obsolescence.

(2) Traffic Parameters

In the absence of known requirements, the following message and system traffic parameters have been used to study various approaches to the Navy communications problem. Some are admittedly arbitrary assumptions, but nevertheless are assumptions which must be made since actual data is not presently available.

(a) Number of stations - 20 ships x 5 stations per ship = 100 stations.

(b) Speed of operation - System shall operate with terminal equipment operating at a standard speed of 100 wpm.

(c) Percentage of work load handled by each station - assumed to be equal.

(d) Total message load to be handled in busiest hour - assumed to be 1,200 messages per hour, or 20 per minute.*

(e) Average message length - assumed to be 20 words for tactical messages,* including address (routing information) and preamble.

* It is assumed that the maximum message load will occur during tactical situations. It is further assumed that tactical messages are very short messages. Administrative messages will generally be longer, but will be transmitted during periods when the system is lightly loaded.

(f) Message format, preamble, message numbering - no assumptions; length of time necessary to act on address - no assumptions;.

(g) Priority assumptions - No system delay requirements are assumed for administrative traffic; however, it is assumed that tactical traffic must be processed by the system in less than one minute.

3. Transmission Facilities

Any communication system is of course only as reliable as its weakest link. A switching center having perfect reliability will be useless if circuits connecting outlying stations are marginal. This is especially important where line control and switching information must be transmitted along with the intelligence. A garbled address can cause misdelivery or loss of an entire message. Importance of reliable transmission techniques cannot be overstressed. Recommendations in this report are being made under the assumption that reliable radio channels either exist or will exist at the time a switching center is made available for shipboard use.

One proposed system which the Navy is considering, makes efficient use of the radio frequency spectrum by the use of Collins Kineplex equipment to subdivide a 3 KC voice band into 40 independent 100 wpm telegraph channels. Each ship in the net would be assigned certain of these channels and their transmissions be kept in these channels. (See Fig. 1) A centrally located relay point would receive and retransmit the forty channels at a second frequency. Consequently, a message originating at a distant location would be received by the relay point on one carrier frequency, routed and then retransmitted via a second carrier on a channel serving the addresses. Each location must therefore be equipped with a send-receive Kineplex terminal for duplex operation.

A second method under consideration makes use of an FCC-16 16 channel frequency shift keyer. This equipment would sub-divide a 3 KC bandwidth into 16 independent 100 wpm channels, and would operate in a similar fashion to the system previously described.

In both systems it is extremely important that means be provided for closely controlling transmitted carrier frequencies and power at all ships other than the relay point, since their transmissions must be received and detected by a single receiving set at the relay point.

4. Switching System Types

A. General

Switching equipment functions basically as a connecting link between two stations. Switching systems are of two general types, message relaying and line switching

(1) Message Relaying Message relaying systems may be either single or multiple line systems, or both. In a single line (selective calling) switching system, all stations are connected in series forming a party line. Each station is connected to respond only to traffic which is addressed to it. Each station may also transmit, in turn, under control of the master station.

In multiple line systems, single or multiple party lines are joined at a hub designated as the switching center. Messages are received at the switching center on one line, routed and then retransmitted on a second line serving the addressee. Messages may be routed manually (torn tape) or automatically at the switching center. Switching systems such as the Bell 81D1 and Western Union Plan 51 , which are installed in many locations throughout the country, are examples of automatic message handling systems.

(2) Line Switching A line switching system provides interconnecting means between a line serving one outlying point, and a second line serving another outlying point, in response to directing signals received at the switching center. A telephone exchange or the teletypewriter TWX System are examples of line switching systems. Point to point contact is made between message originator and addressee. Once connection is made, all traffic is received by the addressee at the same instant it is transmitted. Line

switching systems usually employ full or half duplex circuits.

Three switching systems will now be evaluated as possible solutions to the Navy problem. They are, multiple line message relaying, line switching and single line message relaying (selective calling).

B. Multiple Line Message Relaying

(1) Types A manual torn tape switching system is the least complicated approach to a multiple line message relaying switching system. All of the incoming lines are terminated in an office. Incoming messages are read by operators and routed manually to the line serving the destinations for which the messages are intended. A further development of this system provides equipment for automatically reading, routing, and handling incoming traffic, through the use of standard Teletype terminal equipment and electromechanical devices. A further extension applies magnetic tape, ferrite and solid state devices to the storage, message routing, and handling functions.

(2) System Features

Line Capacity Multiple line message handling switching systems are characterized by maximum usage of incoming line capacity. All incoming lines may be carrying traffic simultaneously, since the switching center is equipped to store messages for retransmission when outgoing line time is available. It is not unusual for input lines on such systems to be operating at as high as 80 per cent of capacity. Outgoing lines then operate at higher rates because of the existence of multiple address messages.

System Capacity The absolute capacity of a message handling system is limited by the number of available lines or channels, and the speed of operation of terminal and switching equipment. Assuming 40 input and outgoing lines, as would be the case providing Kineplex is employed in the system, and 100 words per minute terminal equipment, approximately 100 x 40 x .8 or 3,200 words per minute can be handled by the system. The estimated requirement is 400 wpm.* Assuming tactical messages have an average length of 20 words, 160 messages per minute or 9,600 messages per hour can be processed. Providing there are twenty ships in the system, each ship, on the average, can originate 480 such messages per hour.

Priority Facilities Maximum use of available channel capacity is accomplished through the use of message storage facilities at the relay center. Incoming traffic, for example, is stored at the relay center until the outgoing line for which it is intended is

* The system shall be capable of handling twenty twenty word messages per minute (See Paragraph 2D (2) d and e) or 400 words per minute.

free. It is characteristic that, as message handling systems approach capacity occupancy, message delays become longer and longer.

The longer a message is delayed by the system, the greater a need for levels of priority, in order that high precedence messages are not delayed. A message handling system of this type may include priority features, but at considerable expense. It becomes necessary to handle priority traffic separately from routine or low precedence material, in order to route high priority material first.

<u>Multiple Address Provision</u> All switching systems must include facilities for handling messages intended for more than one customer. In a multiple line message relaying system, additional equipment is required at the switching center to provide the special handling required to process such traffic.

<u>Message Assurance</u> Because of the problems of radio frequency propagation, and interference, means must be provided for informing the transmitting station that its message has been properly delivered to the intended receiving location. Since message delivery systems are characteristically one way systems, this creates additional problems. An automatic message delivery assurance feature adds appreciably to the complexity.

(3) System Application to Problem

System Description Figure 2 shows a possible system block diagram of a multiple line message relaying switching center. At the left and at the right two of the twenty ships are drawn. The relay point is shown at the center. Up to five stations may be connected at each ship. These may be arranged in a selective calling loop. Alternately, they may be wired to a line concentrator for outgoing traffic, and to a selector which handles incoming material. This latter arrangement is shown in Figure 2. A message originating at one of the stations at the location on the left first passes through the line concentrator, which makes one of the two outgoing radio channels available. It is received at the relay point where it is read, routed and retransmitted to the destination. It is received on one of the channels by the selector at the right, where it is routed to the intended station.

System Evaluation A multiple line message handling system achieves very high capacity through maximum usage of available channels. However, a large volume of terminal and switching apparatus is required at the relay point in order to read, route, store and retransmit traffic. Even more equipment would be required to provide the desirable features of priority, multiple address and answer back. The weight, size and first cost per station of such a system are very high. In view of the additional requirement that several stations in the net are to be equipped to operate as relay points, the weight and cost become even more prohibitive.

(4) Conclusion

While the system offers traffic capacity well in excess of that assumed to be required, this capacity must be obtained through the use of an undesirably large amount of terminal and switching equipment. Therefore, it is concluded that a multiple line message relaying switching center should not be used for the Navy application.

C. Line (Circuit) Switching Approach

(1) Types Line switching is a second possible approach to the Navy problem. At the relay point, lines are switched rather than messages. No provision is made for traffic storage. All traffic immediately passes through the relay point to its destination. Line switching may be accomplished manually or automatically. Manual switching requires the attendance of an operator who connects incoming to outgoing lines at the request of the message originator. Line interconnection may

be accomplished automatically through the use of a PBX type automatic switchboard. Both manual and automatic systems require duplex circuits, at least initially, so that "busy" conditions can be made known to the calling station.

(2) <u>System Features</u>

<u>Line Capacity</u> Practical line capacity is much less in a line switching system than in the message handling system previously discussed. Before a message may be delivered, both the outgoing channel at the sending point and the incoming circuit at the receiving point must be free. Providing either is "busy", traffic may not be transmitted. Consequently, as system occupancy approaches capacity, longer and longer waiting times will be encountered, with a resulting decrease in line efficiency.

<u>System Capacity</u> Maximum system capacity is a function of the number of available channels serving each station. Assuming Kineplex is used, 40 duplex channels are available for distribution among the 100 stations at twenty ships. Two transmitting channels and two receiving channels could therefore be allotted to each ship, the five stations at each location sharing these channels. Traffic in or out of a ship therefore requires both an incoming and outgoing channel.

A maximum of twenty messages may thus be transmitted simultaneously (each message requires one incoming and one outgoing channel at both the transmitting and receiving ship.) Using terminal equipment operating at 100 words per minute, the absolute maximum capacity of this system is 2,000 words per minute.

This capacity would seldom, if ever, be reached. It is unreasonable to assume that, of the twenty stations trying to transmit, none would have traffic for the same point as another. Message destination distribution, and other variables, (priority and multiple address) would limit practical maximum loading of the switching center to 50 per cent or less of absolute capacity. It is therefore assumed that a practical maximum message capacity for this system would not be over 1,000 words per minute. (400 wpm estimated requirement).

Since traffic is primarily unidirectional, a method may be found to increase system capacity through more efficient utilization of the return leg of the duplex circuit. After the transmitting circuit has been established, the return circuit may possibly be disconnected for other uses. This feature is possible however, only by increasing the size and complexity of the system. For practical purposes duplex circuits should be employed exclusively.

Priority Facilities A line switching system must also include a "break in" feature to enable messages of high precedence to interrupt long messages of lower precedence. Care should be taken to prevent a high priority message from interrupting a message of equal or more importance. Inclusion of a priority feature adds to the complexity of the system.

Multiple Address Provisions Multiple address messages create a formidable problem in automatic line switching systems. It is apparent that, in order to transmit a multiple address message, all addresses must be available for traffic simultaneously. Otherwise the message must be transmitted to each station separately. Provision for connecting an incoming channel to more than one outgoing channel adds appreciably to the complexity of the system. If multiple address messages are a large percentage of total system traffic, the entire system message capacity will be greatly decreased.

Message Assurance The line switching system suggested here employs duplex circuits. Therefore, a message may be acknowledged immediately upon its receipt.

(3) System Application to Problem

System Description A proposed line switching system is shown in Figure 3. At the left and at the right two of the twenty remote ships are drawn. In block diagram form, these ships are identical to those shown on the message relaying system diagram of Figure 2. At the relay point in the center, however, a PBX line switching terminal is installed. Channels from the originating station at the left are switched at the relay point to connect with lines serving the desired destination at the right. The PBX switching terminal shown is much smaller and less complex than the message relaying system discussed previously. PBX switching devices now exist for telephone application which can be modified and adapted for teletypewriter signals. In order to achieve maximum reliability and minimum size, however, solid state devices should be incorporated.

System Evaluation A line switching system, operating at standard teletypewriter speeds, has several attractive features. The size, cost and capabilities of such a system appear practical for shipboard installation. The system has sufficient potential capacity to easily handle the estimated traffic requirements, with additional capacity for increased load. The system also provides full duplex circuits, a reliable message assurance and answer back feature. Two functions must be provided, however, which add to the complexity and cost of an automatic PBX system.

These are priority and multiple address. It is difficult to include the priority feature and apparently extremely difficult to include the multiple address feature. The multiple address function could be handled on a manual basis, supplementing the automatic system.

(4) Conclusion

While this system seems to fulfill most of the necessary engineering requirements of the Navy problem, and deserves serious consideration, it does have shortcomings which appear to have solutions only by using supplementary manual switching. A further examination of switching system types should be made for a more adaptable system.

D. Single Line Message Relaying (Selective Calling)

(1) Types A single line message relaying (selective calling) system is a third approach to the Navy problem. As mentioned, a selective calling system provides for series connection of all stations on one party line. Each station transmits, in turn, under control of the master scanning station.

Each receiver is coded to respond only to traffic intended for it. Speed of operation of such a system is limited to speed capabilities of terminal equipment, and characteristics of the transmission media. Since the minimum system capacity requirement is 400 words per minute, a selective calling system must operate at least at this rate in order to merit consideration. Low speed systems may therefore be eliminated. A possible satisfactory approach is a high speed (750 w.p.m.) tape to tape system. At 750 words per minute, the bit pulse duration is less than two milliseconds, (assuming serial transmission of a 7.0 unit code) which is far too short to be transmitted reliably over high frequency radio circuits. Through the use of parallel channels, bit length may be made equal to character length. Since the bit length of a standard 100 word per minute start-stop signal is 13.5 milliseconds, parallel transmission would permit a speed increase to 750 words per minute with no reduction in reliability. A 750 words per minute parallel channel selective calling system will therefore be described.

(2) System Features

Line Capacity The line capacity of a selective calling system is identical to system capacity, since a selective calling system is essentially a single line system. A selective calling system, however, requires line time for control purposes. Transmitters must be told when to transmit and receivers must be given time to act on directing signals. Line control functions will not, however, exceed twenty per cent of total system capacity. Effective capacity of a 750 w.p.m. system will therefore not be less than 600 words per minute. (400 words per minute required)

Priority Facilities Transmission of priority traffic ahead of routine traffic may be easily provided in a selective calling system. After each message transmission, the high speed scan searches all transmitters for priority messages. Those transmitters having priority traffic transmit first. Those with routine traffic must wait. Should a backlog of traffic occur at any one ship, it is of course, the responsibility of the ship to transmit its priority traffic ahead of its routine traffic.

It is questionable whether a priority arrangement is necessary, however, in a high speed system such as the one proposed. At 600 words per minute, assuming the average tactical message is 20 words long, 30 messages per minute will pass through the system. It is normally possible, therefore to deliver any tactical message from one location to another in substantially less than one minute from the time the material is ready for transmission, regardless of priority. A priority facility may therefore not be required in a high speed selective calling network.

Multiple Address Provisions A multiple address message is easily handled by a selective calling system. Each receiver may be programmed to receive any or all traffic on the line. A message may be addressed to more than one station by simply adding addresses to the message preamble. Certain address codes may be reserved for broadcast type traffic, where all, or a selected number of receivers respond.

Message Assurance A selective calling system is essentially a message delivery system. No provision is made for conversation type circuits. Message assurance is not as positive, therefore, as it is in the line switching system previously discussed. A message assurance technique is available, however, which seems entirely satisfactory. A transmitter, called in by the high speed scan, automatically transmits the address and directing symbols of the message, and halts. The addressee, in response to these symbols, inserts an answer back symbol onto the line, which retriggers the transmitting station, and the message is sent.

This message assurance method appears quite satisfactory, in that the transmitting location is always certain that his message will be received, if not by the intended receiver, by some receiver in the net. He is reasonably certain that the correct station will receive his message, providing the message is addressed properly. It would be the responsibility of any station receiving incorrectly addressed material to relay it to the intended customer.

(3) System Application to Problem

System Description A simplified block diagram of a selective calling system is shown in Figure 4. At the left and right two of the twenty ships are drawn as before. Up to five stations are connected at each ship. Terminal equipment at each station consists of a standard speed printer, typing keyboard perforator, and a high speed tape reader. There is an additional quantity of control equipment at each ship, which is shown at the top. A selector performs line monitoring and control functions. A high speed punch records all incoming traffic on paper tape, and a standard speed tape reader routes the material to the proper station via a 100 wpm selective calling loop. The system functions in the following manner:

The master scan automatically generates call directing codes, polling each ship in turn. Should any station on the ship have traffic, it responds to a poll by transmitting its message. Should two or more stations on a ship have traffic when that ship is polled, the traffic having highest priority will automatically be transmitted. If a ship does not have traffic when it is polled, a "no traffic" symbol is automatically returned to the master scan. The master scan then polls the next ship in the net until one is found where traffic is present.

The relay point receives all transmissions from the outlying ships. These transmissions are on six channels of a multiple channel transmission facility. All ships time share the same six channels, and transmit on the same carrier frequency. The relay point instantaneously retransmits all incoming traffic on six channels of a second carrier frequency. The traffic is recorded by the receivers at the various ships. Receiving stations may be programmed to receive specific traffic, group, or broadcast messages.

System Evaluation The selective calling system, as proposed, is probably about the same size and as complex as the line switching approach discussed previously. It is therefore much smaller and less complex than the multi-line message handling switching system.

The system capacity is 600 words per minute, which is above the minimum requirement of 400, but probably less than the line switching approach. On a capacity per channel basis, however, this system has much higher capabilities, since only six channels are required, as compared to 40 for both the line switching and multiple line message handling systems. It is recognized that six hundred words per minute system capacity may prove to be inadequate to handle actual traffic loads. Should this prove the case, the system capacity can be increased through the use of additional parallel channels. On the other hand, should 600 w.p.m. prove adequate, certain economies can probably be achieved through the use of lower capacity transmission facilities. Additional channels, if available, may also be used for functions such as error control, and supplementary low speed circuits.

This system readily adapts to handling multiple address and priority traffic. An acceptable and practical message assurance feature can also be easily provided.

(4) Conclusion

The selective calling switching system appears to offer most promise of meeting the requirements of the Navy problem. Of all the systems considered for shipboard application, this approach best meets the requirements of size, growth potential, and provision for possible future inclusion of additional features.

5. The Proposed System

The system proposed is a 750 w.p.m. selective calling system. Some of the features of this system will now be discussed:

A. Description of Components on A Ship

Each ship has up to five stations. Terminal equipment at each station consists of a page printer, associated with the incoming line, and a typing keyboard perforator and high speed reader associated with the outgoing line. (See Fig. 5) The printer and typing keyboard perforator may be standard Teletype Model 28 equipment. The tape reader is a Teletype 750 w.p.m. reader. Each station therefore consists of standard Teletype equipment, all of which may be enclosed in the equivalent of a Model 28 console.

In addition to station equipment, each ship has a control and distribution point to govern the receiving and transmitting functions of the various stations. (See Fig. 6) The high speed selector at this control point performs the following functions:

(1) It controls transmission of high speed readers at each station in response to directing signals from the relay point.

(2) It controls operation of a high speed punch (located at the control and distribution point) in response to directing signals from the relay point.

(3) It inserts the "no traffic" symbol as required.

The high speed selector performs all of its switching and control functions through the use of transistors and solid state circuitry.

The high speed tape punch, controlled by the selector, is a standard Teletype 750 wpm reperforator. Selected incoming traffic is routed to the punch, which records the material on paper tape. The tape is then fed automatically to a standard speed tape reader which transmits the material serially, at 100 wpm, to the printers at the various stations. The printers on each ship are connected in a selective calling loop.

All of the control equipment, including the high speed punch, and the 100 wpm transmitter distributor, may be installed in a relay rack type enclosure which need not be more than 36 inches high.

B. Description of Components at The Relay Point

At the relay point, line control functions are performed. Functions of the master scan may be summarized as follows: (See Fig. 7)

(1) The master scan, which constantly rides the line, generates call directing codes allowing each ship in turn, to transmit material.

(2) The unit automatically inserts control symbols such as "no traffic" and "end of message" responses whenever required.

(3) The unit provides alarm devices which warn operating personnel of possible equipment or system failures.

In addition, facilities are provided at the relay point for adding and subtracting stations from the net, and for relaying all traffic in the system. This unit can probably be packaged in a standard 19 inch cabinet thirty six inches high. A ship which is equipped to function as a relay point would have one 36" cabinet for master scan control, plus one 36" cabinet for its control and distribution equipment.

C. Future Magnetic Recording Devices

The system, as described, employs paper tape recording and reading devices. Should the use of paper tape prove impractical because of paper supply, or other problems, magnetic devices may be employed. However, the volume of any one ship should not present a difficult paper tape supply problem. In any event, standard paper tape equipment should be used in any field trial because of its ready availability.

D. System Growth Features

Additional system capacity may be required, if not initially, at some future time. This capacity may be obtained through utilization of more than six subchannels. Providing 16 radio subchannels are available, and only six are used by the basic system, ten become available for other uses.

A second group of six subchannels may possibly be employed, where traffic load warrants, to form a second high speed system, which would provide about twice the capacity of the one system alone. In this type of operation, one or more of the ships must operate as the tie-point between loops. All traffic between stations on one loop and those of the other must pass through the tie-point, which is common to both loops. Care should be taken to minimize traffic between loops to avoid a possible "bottleneck." This possibility may be minimized by assigning those stations to the loop on which they have a majority of business.

System capacity may also be increased by increasing the speed of operation. As mentioned, the system speed of operation is limited by the speed capabilities of terminal equipment, and characteristics of the transmission media. High speed tape readers and punches capable of operation at fifteen hundred words per minute, can be developed. Signals from this equipment could be transmitted over twelve parallel channels; alternate characters are applied to each of the two groups of six channels. System capacity is therefore doubled, with no reduction in transmitting margin.

E. Error Control

There are a number of techniques available for error control of transmitted data. The degree to which error control is required is usually determined by the type of traffic which is to be transmitted. Since the type of traffic which this system will carry is presently unknown, the degree to which error control is required cannot now be determined.

In order to correct errors they must first be detected. An error, having been detected, may or may not need correcting, however, depending upon the message content. Should error correction prove desirable, the simplest method by which it may be accomplished is by transmitting a service message to the traffic originator requesting retransmission. Such a technique may prove entirely satisfactory, since, as mentioned, not all errors need correcting. One or two errors occurring in the text of the average kind of message will not ordinarily destroy the intelligence of the message. A technique can be devised, if required, for automatic retransmission of material on detection of an error. However, this would add to complexity of the system. Furthermore, system capacity would be significantly reduced where circuit conditions call for frequent retransmission.

Errors may be detected and corrected through multiple transmission of all messages. At the receiver, copy is examined and compared automatically or manually for errors. This method obviously reduces system capacity directly as the multiple of retransmission.

Since commonly used error control devices add redundancy to a system, speed of transmission is sacrificed for accuracy. It may be possible however, to achieve error control in the proposed system without significant loss of speed, but at the cost of growth potential. This may be accomplished through the use of the ten available parallel radio channels for multiple transmission of material. Each retransmission should be delayed, however, in order to obtain time diversity since noise ordinarily effects all channels simultaneously.

In view of the foregoing, while no predictions are being made as to whether error control is required, some form can be supplied if necessary.

F. Radio Silence

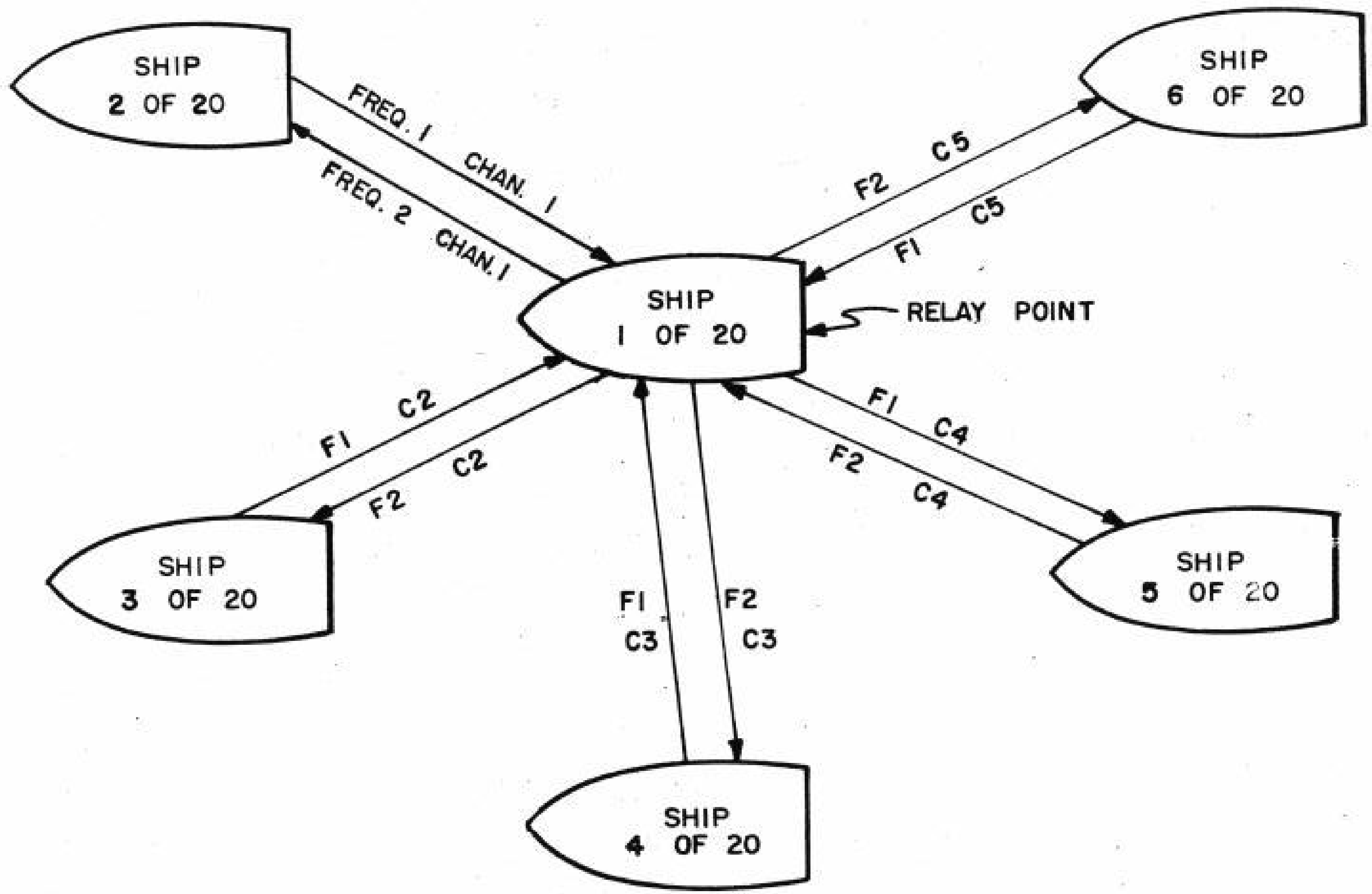
Radio silence requirements may conceivably be imposed on the system. Transmission through the system may be limited to short bursts at specified intervals. A high speed system, such as the one recommended, is highly adaptable to this potential requirement. At 750 words per minute, a message will obviously require only one seventh as much time for transmission, as a message transmitted at 100 words per minute. The switching system may therefore be operated for periods as short as one or two minutes, during which time a message 750 or 1,500 words in length may be transmitted. The system proposed is an asynchronous system, which adapts very readily to the radio silence requirements. Since phase relationship between transmitting and receiving terminals in an asynchronous system is maintained on a character by character basis, and the time of adjacent characters may be completely random, an asynchronous system can commence operation immediately each time the system restarts operation.

6. Conclusion

Three switching system types have been examined as possible solutions to the Navy problem. Of the three, two appear practical in the light of presently known requirements. These are line switching and high speed selective calling. Of the two, selective calling has features which recommend it for adoption, subject to one consideration.

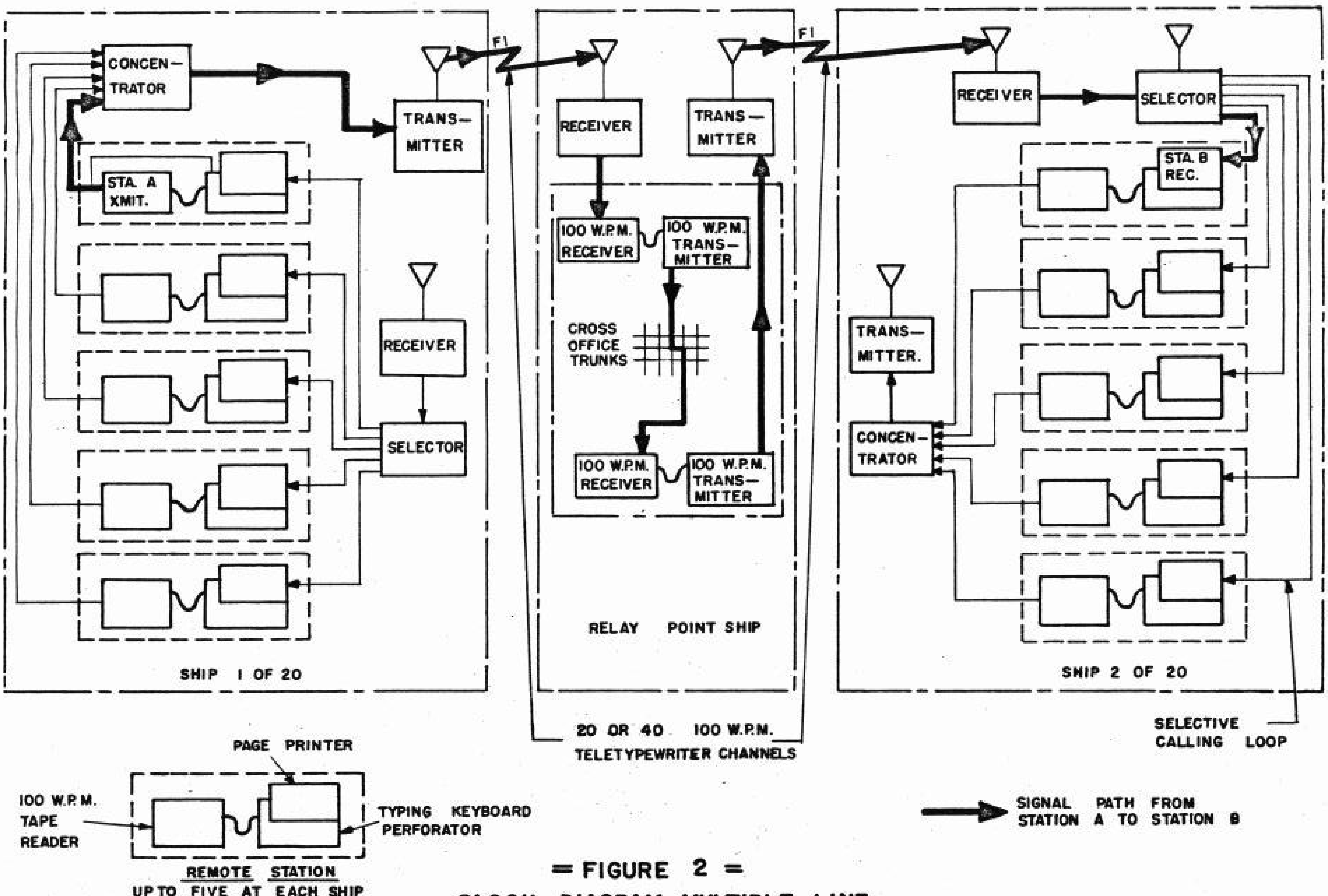
The first two systems discussed employ transmission equipment wherein 19 of the 20 ships transmit on assigned subchannels of a common carrier frequency. Each subchannel is assigned to only one ship. The selective calling system which is proposed, on the other hand, utilizes transmission equipment wherein 19 of the 20 ships time share six subchannels of a common carrier frequency. Since subchannels are time shared, additional demands may be placed on transmitting and receiving equipment. It is believed that subchannel time sharing can be accomplished, although transmitter frequency control problems may arise.

It is recommended that, should active Navy interest in a high speed selective calling system develop, a program be undertaken to determine requirements and to estimate the cost of field trial equipment. Field trial models may then be engineered, constructed and installed aboard ships for test. Only through actual operating experience can the true usefulness of any completely new system be determined, and requirements for future operating systems established.



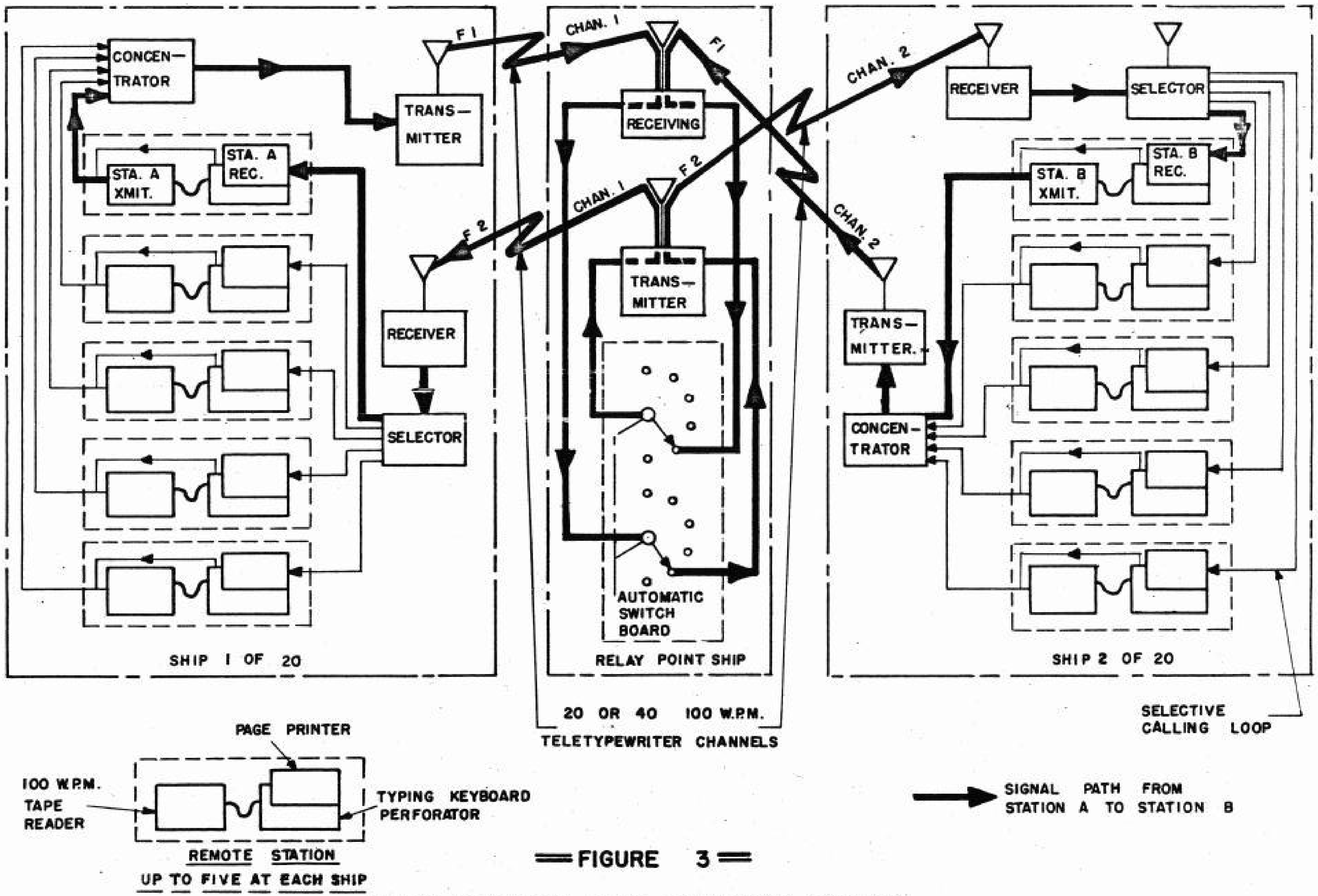
= FIGURE 1 =

PROPOSED TELETYPEWRITER SWITCHING SYSTEM



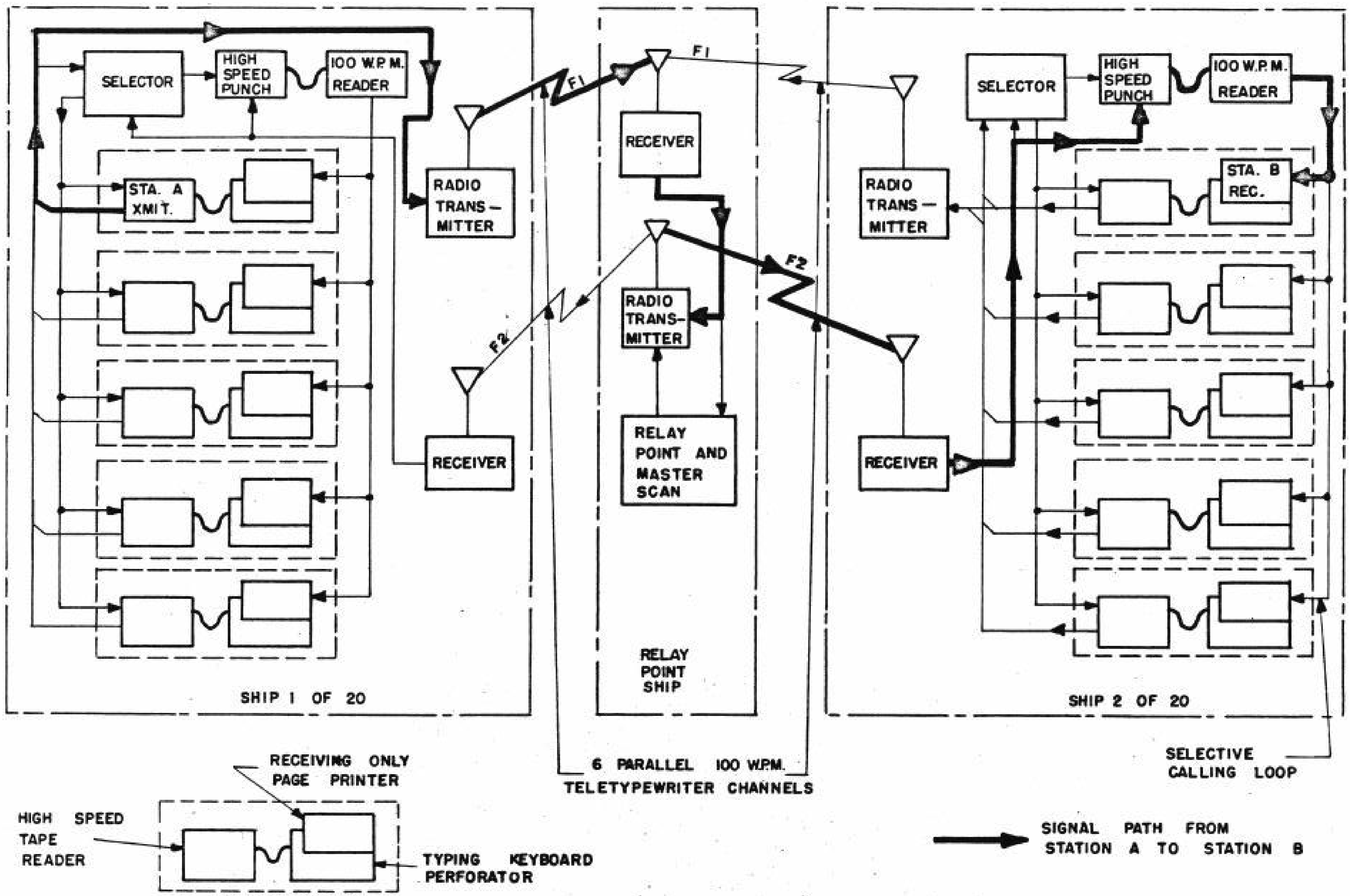
= FIGURE 2 =

BLOCK DIAGRAM MULTIPLE LINE
MESSAGE HANDLING SWITCHING SYSTEM



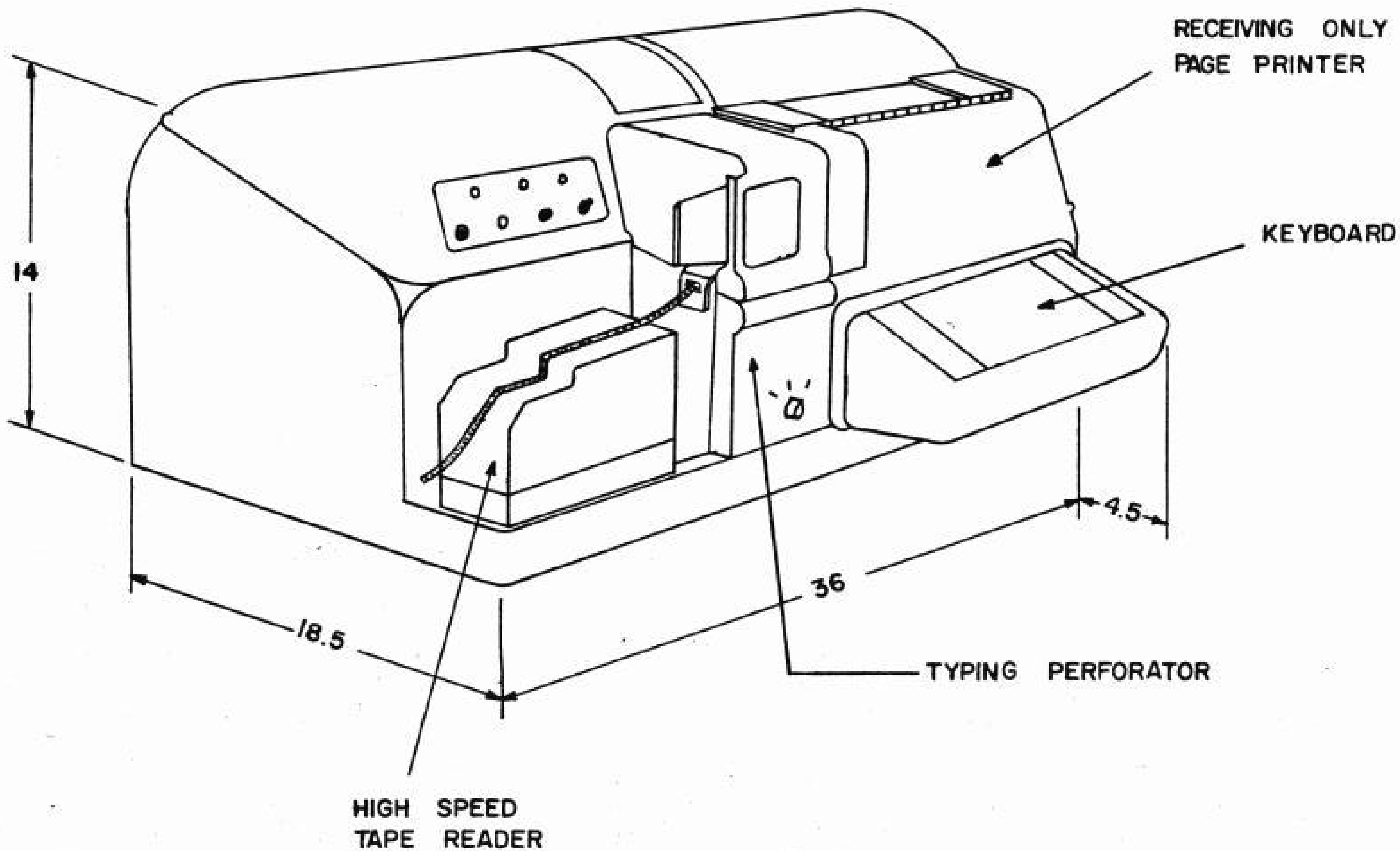
══ FIGURE 3 ══

BLOCK DIAGRAM, LINE SWITCHING SYSTEM



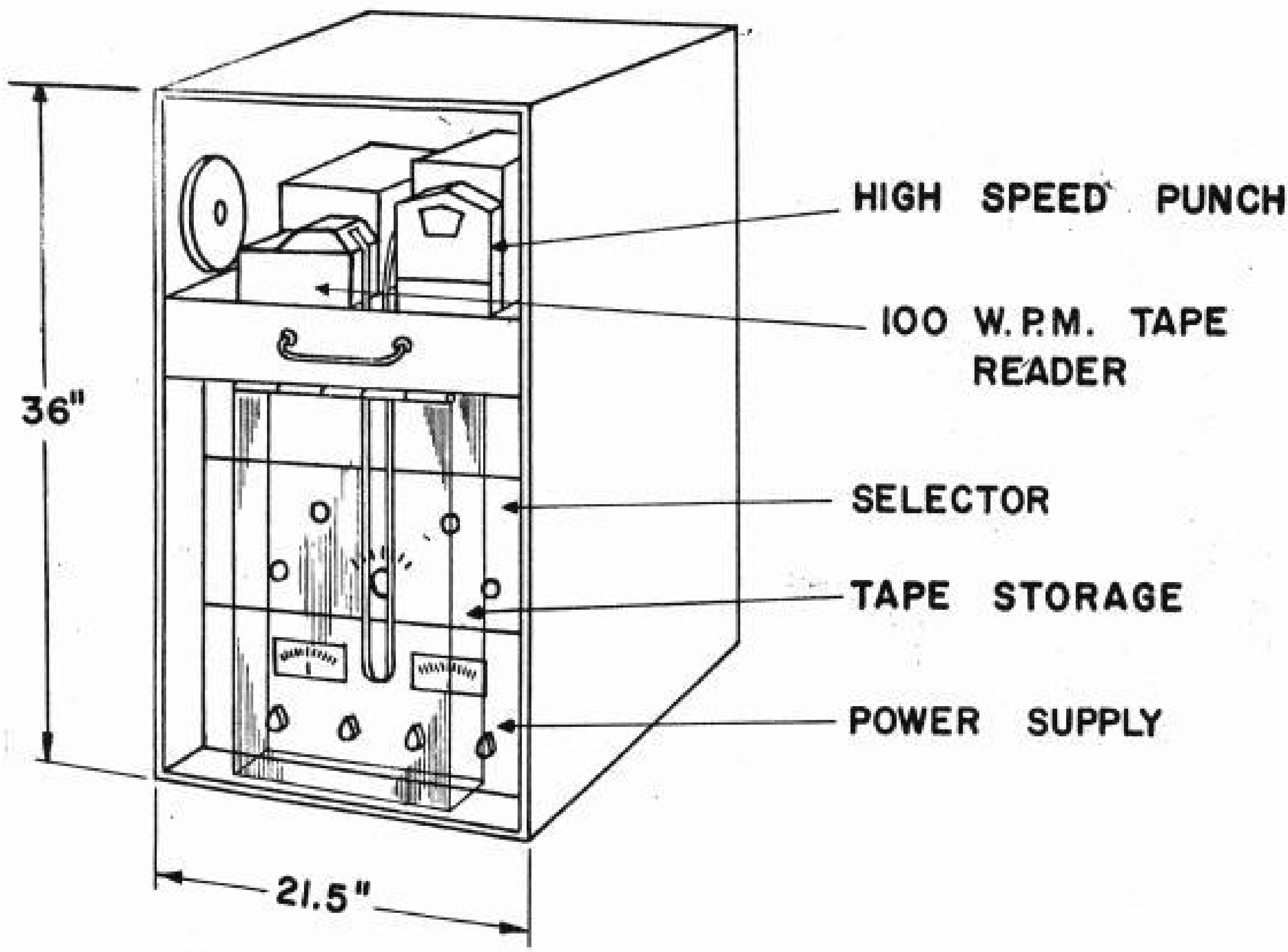
— FIGURE 4 —

BLOCK DIAGRAM, SELECTIVE CALLING SYSTEM



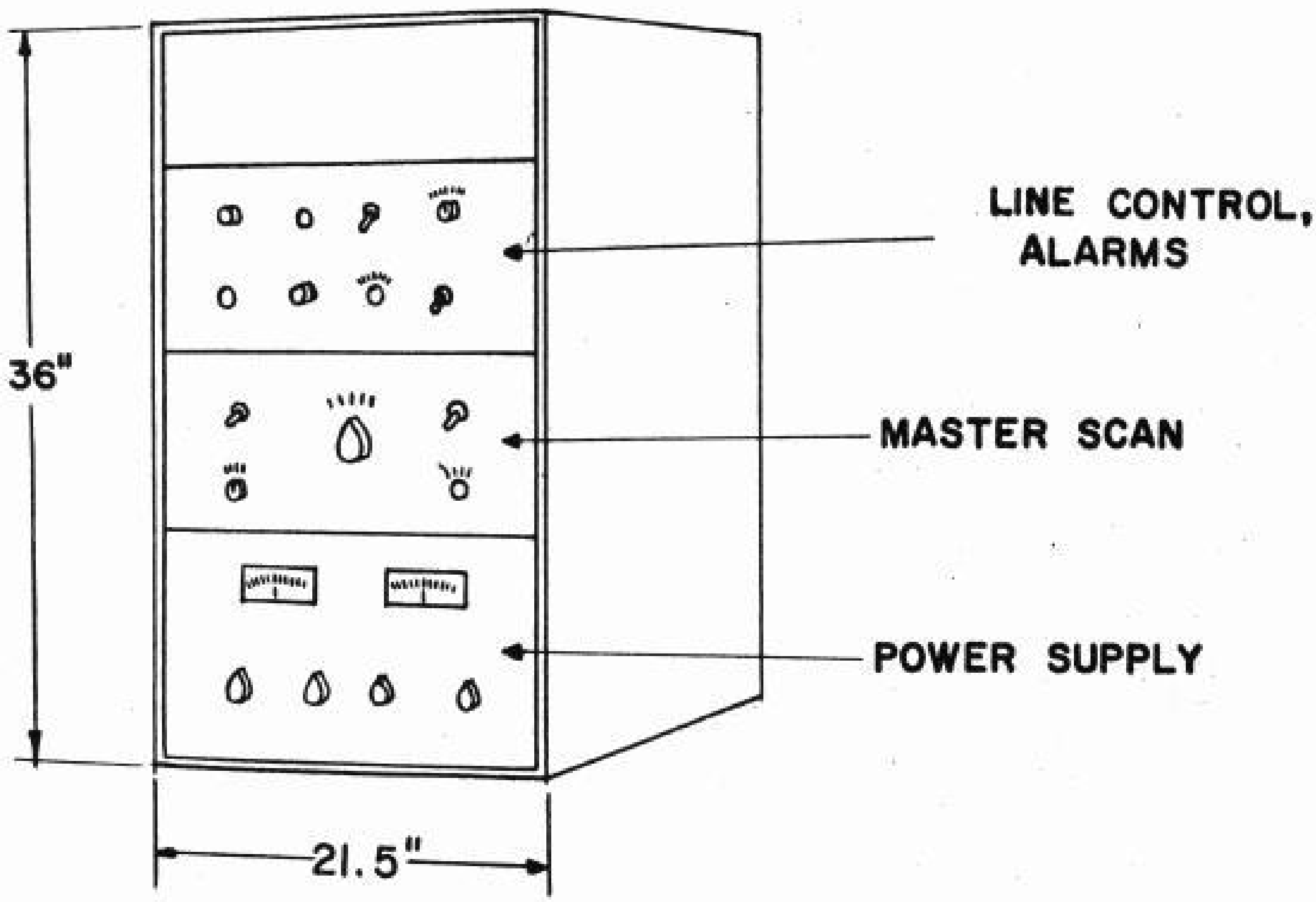
═ FIGURE 5 ═

SHIPBOARD STATION



=FIGURE 6=

CONTROL AND DISTRIBUTION POINT



= FIGURE 7 =

RELAY POINT

LINE CONTROL AND MASTER SCAN EQUIPMENT