

# TELEPHONE COMMUNICATION SYSTEMS

## VOLUME II CROSSBAR SYSTEMS

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CHAPTER 1

PRINCIPLES OF CROSSBAR SWITCHING

1.1 INTRODUCTION

Crossbar systems were developed in the mid 1930's to counteract some of the disadvantages of the Panel System. The panel selector switches, which introduced a high degree of noise, were eliminated from the new systems as well as their associated power driven elements. Instead, virtually noise-free talking paths were developed by using a radically new type of switch called a crossbar switch and relays with precious metal contacts. The crossbar common control units made possible more efficient operation of line and trunk network connections, derived the maximum use of intraoffice and interoffice trunk circuits and eased the overflow traffic during busy hours into alternate routes. Furthermore, the crossbar system provided the additional advantages of shorter call completing times and reduced maintenance.

1.2 THE CROSSBAR SWITCH

The basic element of any crossbar system is the crossbar switch, through which all talking connections are made. The crossbar switch is essentially a relay mechanism consisting of ten horizontal paths and ten or 20 vertical paths, depending on what size switch is needed. Any horizontal path can be connected to any vertical path by means of magnets. The points of connection are known as crosspoints. The switch with ten vertical paths has 100 crosspoints and is called a 100-point switch; the one with 20 vertical paths has 200 crosspoints and is called a 200-point switch. Figure 1-1 shows a partial perspective view of a crossbar switch.

Horizontal Paths: There are five selecting bars mounted horizontally across the face of each switch. Each selecting bar has flexible selecting fingers attached to it, one finger for each vertical path, and the bars can be rotated slightly to cause the select fingers to go either up or down.

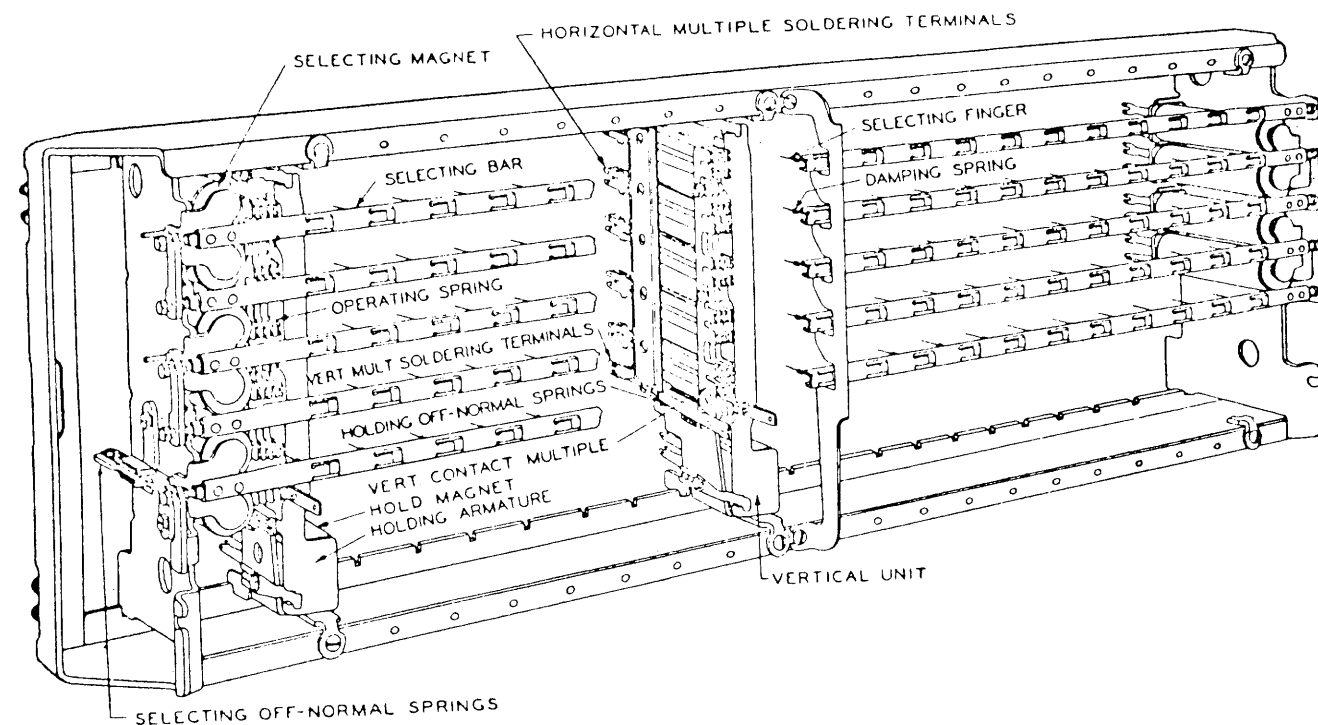


Figure 1-1 Partial Perspective View of a 200-Point Crossbar Switch - For 20 Vertical Units

Vertical Paths - Ten or 20 vertical units are mounted on the switch and each unit forms one vertical path. Each unit operates under control of a hold magnet and has ten groups of contacts (one for each horizontal path) associated with it.

3-Wire or 6-Wire - Each group of contacts may consist of three to six pairs of contact springs. A switch is classified according to the number of crosspoints and pairs of springs, for example, a 200-point, 3-wire crossbar switch or a 200-point, 6-wire crossbar switch.

Operation of the Crossbar Switch - The normal position of the selecting fingers is horizontal, lying between two groups of contacts. When a select magnet operates, the selecting bar is rotated and one of the two horizontal paths available to this bar is chosen. The selecting fingers now lie in front a group of contacts as shown in Figure 1-2.

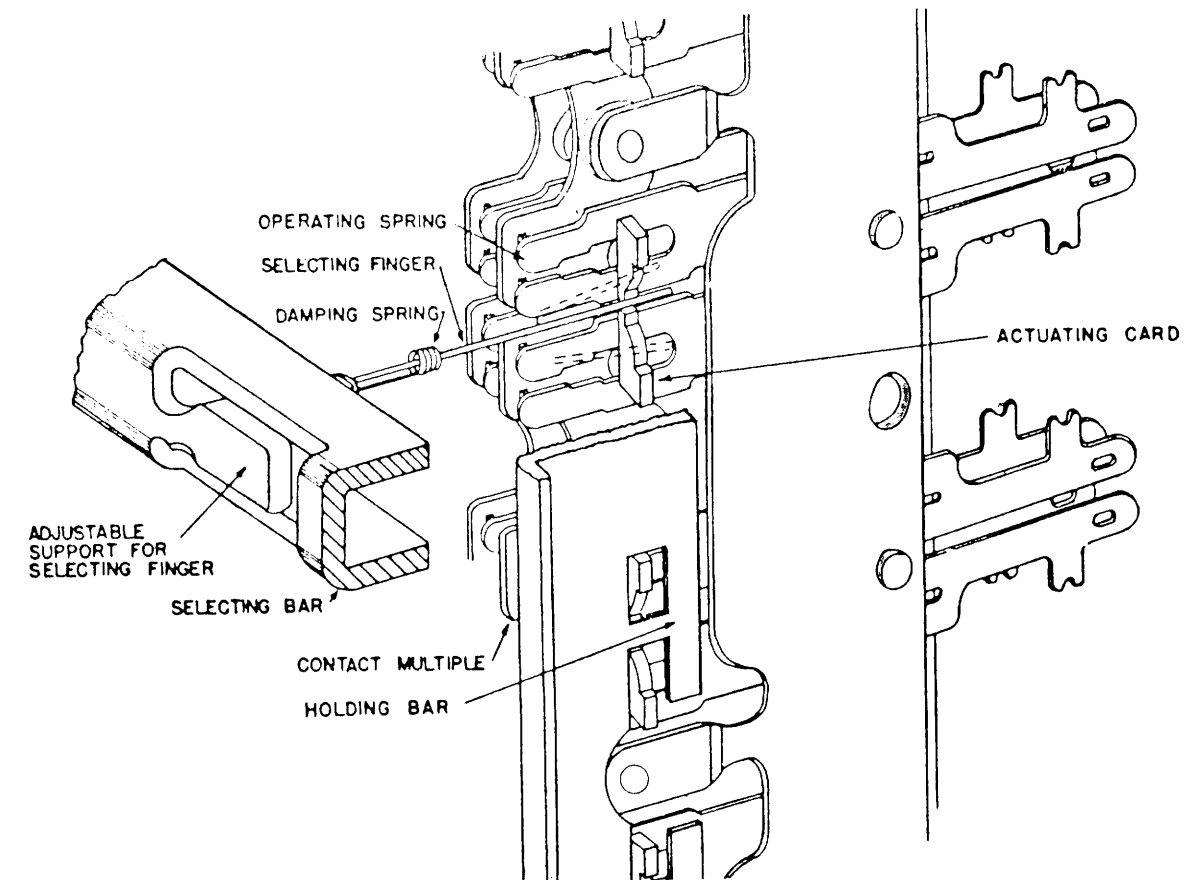


Figure 1-2 Crossbar Switch Selecting Mechanism

The hold magnet of the vertical path to be connected to this horizontal path then operates its holding bar which, using the selecting finger as a wedge, causes the group of contacts beside the selecting finger to operate, thus connecting the horizontal and vertical paths. Both the select and hold magnets must be operated in order to close a crosspoint. The other groups of contacts on this vertical unit do not operate since there is no selecting finger between them and the holding bar.

After the operation of the hold magnet, the select magnet releases returning the horizontal bar and all of the selecting fingers back to normal, except those actively held by operated hold magnets. The finger used to establish the connection, being flexible, remains wedged against the

contacts by the holding bar, and in this way, keeps the contacts operated. When the hold magnet releases, the connection is released and the selecting finger returns to normal. Since the selecting finger tends to oscillate upon being released, damping cones are provided on the hold magnet armature to act in conjunction with the damping springs to minimize these oscillations.

Only one selecting magnet on a switch may be operated at one time if the closing of more than one crosspoint on a vertical unit, with the resulting double connection, is to be avoided. More than one connection throughout a switch may exist at the same time without interference after the crosspoints for each have been closed, but those crosspoints must each be closed one at a time.

The handling of one connection at a time in a switch, later extended to handling one call at a time in a frame of switches, is a fundamental operating principle of all crossbar systems. Thus double connections are avoided and the time required by a control circuit to establish each connection is reduced to a minimum.

### 1.3 NETWORKS

Groups of interconnected and interrelated crossbar switches, structured to form a system of metallic paths used for talking and for signals such as tones and ringing, comprise a switching network. Networks and the paths of a network are selected and controlled by relay logic units. Collectively, these relay logic units in crossbar systems are known as the "markers".

In developing a switching network using crossbar switches it was possible to vary the size of each group of subscribers and trunks and still satisfy the requirement that a telephone switching network have multiple access from each subscriber to any other subscriber or trunk.

Depicted in Figure 1-3 is a typical two stage grid network. Each switch block in both stages may be considered to have ten inputs and ten outputs. Within each block the switches can connect any input to any output. The switch units within the blocks may be either forward or backward-facing without affecting the validity of the network as a

connecting means. The ten outputs of each input switch block fan out equally to the ten output switch blocks to give a total of 100 links spread uniformly between inputs and outputs. However, if each group (group size assumed to be ten) is spread equally over the ten output blocks, each individual output of a group is accessible to a separate link from a particular input group. Thus, any input can reach an output group via ten links, but a particular link and a particular output must be matched for a successful connection. This type of network then provides adequate access into an output group. Since the whole switch structure represents a coordinate grid with each intersection of horizontal and vertical forming a crosspoint with no directional motion, either side can be considered as the input.

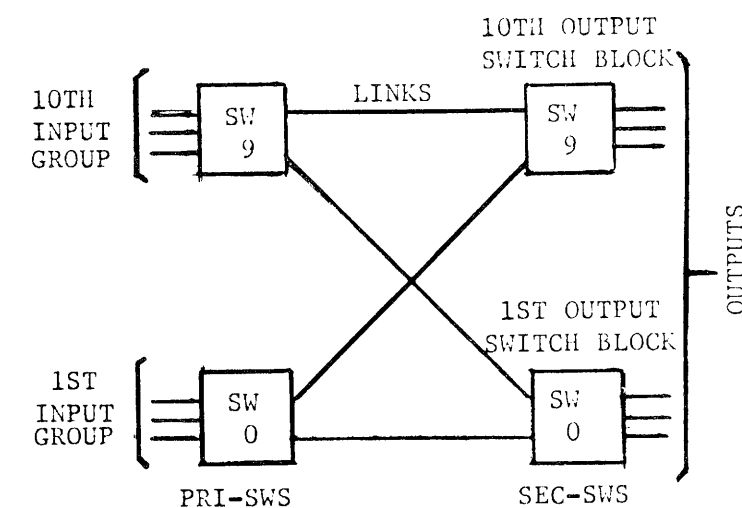


Figure 1-3 Two-Stage Grid Network

The input switches of the grid are usually designated as primary switches, and the output switches as secondary switches. The basic requirement is that each primary switch have access via at least one link to each secondary switch group. The link spread between switch groups is almost invariably laid out in an orderly fashion for ease of control and administration. For example, in Figure 1-3 note how the 0 outputs of all primary switch groups connect to the 0 secondary switch group, the 1 outputs connect to the 1 secondary switch group, and so forth. In allocating secondary terminations of links, the output terminal number on the primary switch designates the secondary switch number, and the primary switch number designates the secondary switch terminal. This is characteristic of primary-secondary grids.

With crossbar switches, a convenient size for the grid is ten switches high, both primary and secondary. There are usually ten or twenty link groups per switch, although in the latter case the links are usually considered as two groups of ten per switch. There are occasional situations in which the link spread is different from that described, but these are special cases.

When it is recognized that a two-stage grid wired as in Figure 1-3 is satisfactory for connecting any input to one of a group of outputs, it is not difficult to extend the grid to provide for connection to a particular output. It is only necessary to add a third stage, the links which will duplicate the link spread between the first two stages. This is shown symbolically in Figure 1-4 where each stage is assumed to be ten switch blocks high. Examination of this network will show that any network input can be connected to any network output over ten matching pairs of paths, usually called channels. To determine the set of ten paths which can be used, it is only necessary to know the input and output switch blocks involved. The identifying number of both links in a matching pair are the same when the numbers are assigned according to the position of the link on the switch blocks of the primary and tertiary stages.

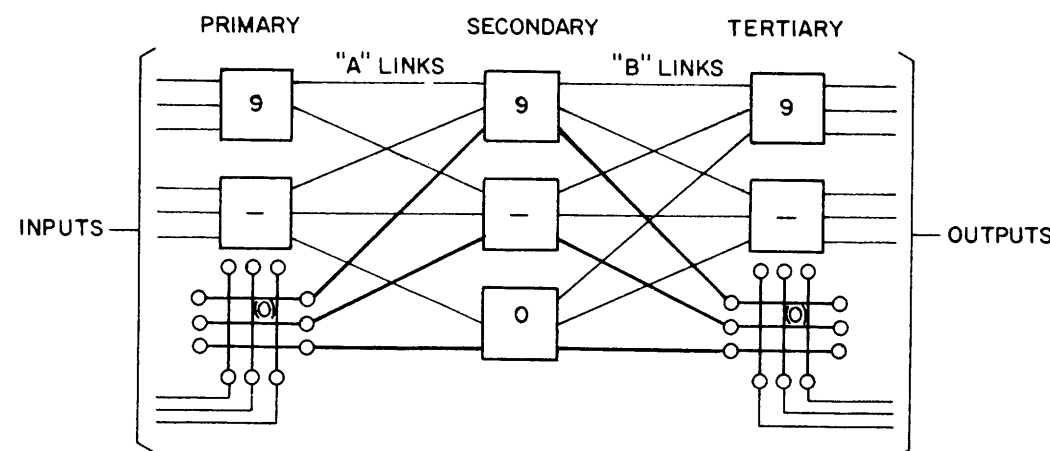


Figure 1-4 Three-Stage Switching Network

For a call between an input on primary switch block 0 and an output on tertiary switch block 0, the links which can form permissible channels are shown in heavy lines on Figure 1-4. If the input were on primary switch block 1 while the output remained unchanged, a new set of "A" links are required to match with the original set of "B" links. Since the links that make up the matching channels are available to more inputs and outputs than there are links, blocking on a particular call can occur. Since a channel can be made busy by either link in a matching pair, idle "A" and "B" links may, and frequently will, exist in the busy channel group. The hazard of blocking is reduced if the control means always assigns channels in a definite order instead of at random.

The three-stage grid is not generally suitable as an overall network because of the relatively limited number of paths it provides. However, it is useful for small switching systems. In the larger switching systems, the interconnecting paths are most frequently made up of a network of two stages of primary-secondary grids, which is, in effect, a four stage grid. A typical arrangement of these grids is shown in Figure 1-5. The fourth stage, which is actually the primary stage of the output grids, results from splitting the secondary switches on Figure 1-4. The interconnections between grids (called junctors) are not necessarily distributed in the same manner that links are within a grid. It is merely required that at least one junctor per secondary switch of each input grid connect to one primary switch of each output grid. The junctors are wired between switches of corresponding number on the opposing grids. This provides, as a minimum, one junctor to match with any pair of originating and terminating links. If the junctors are numbered in accordance with the number of the switch on which they originate or terminate, the result is a simple system of coordinating links and junctors into channels. For example, if in Figure 1-5 an input on input grid 0, primary switch 0 requires connection to an output on output grid 1 secondary switch 1, ten channels are available utilizing a particular "A" link group, a particular "B" link or junctor group, and a particular "C" link group. From input to output there exists matched A, B and C links designed to provide a pattern of fixed wired paths or channels. With this wiring scheme, previous calls equal in number to the size of the link or junctor group can block a call to an idle output, since the use of any single element in a channel makes the whole channel busy.

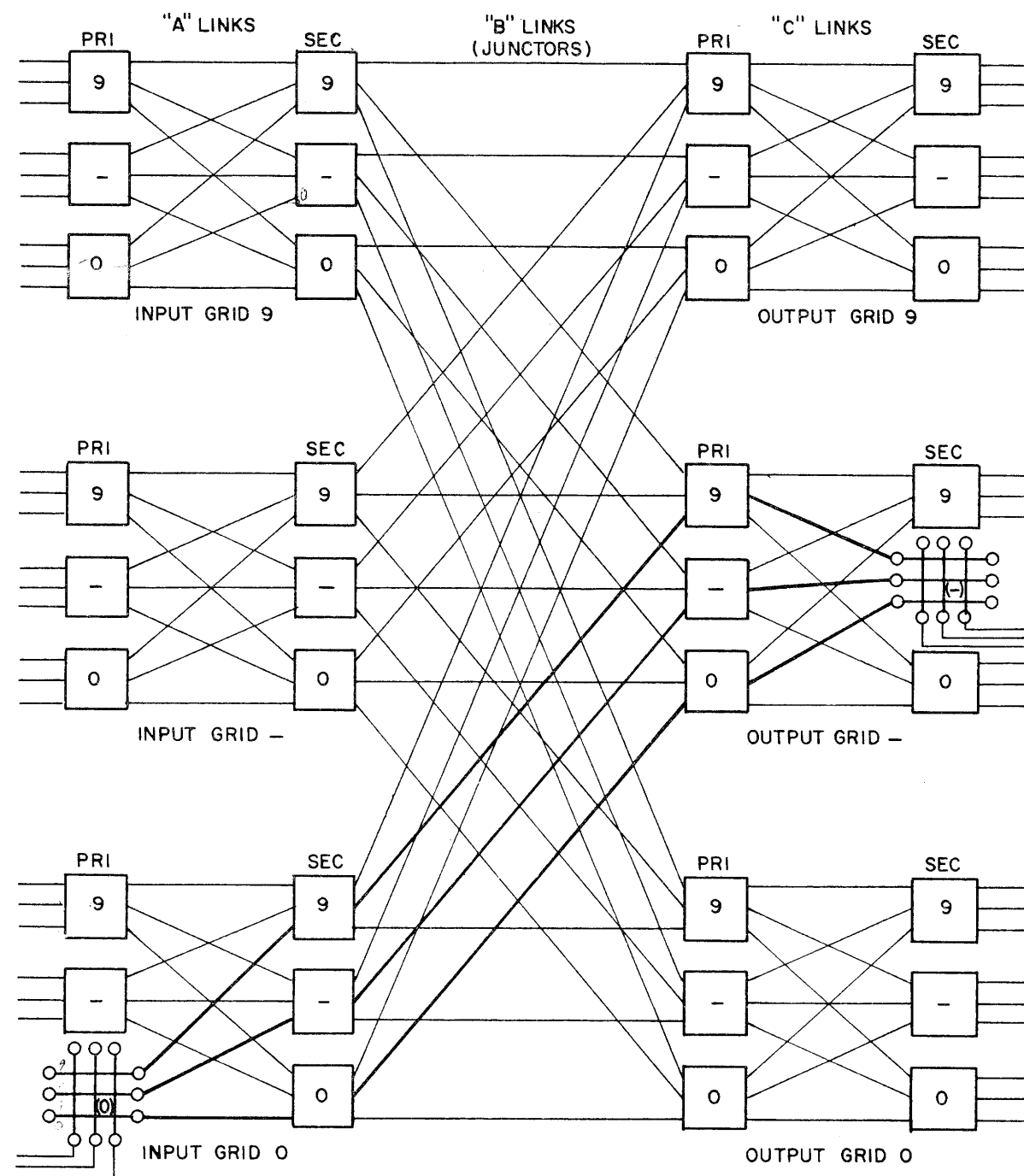


Figure 1-5 A Four-Stage Switching Network

## 1.4 NETWORK SWITCHING CONTROL

In applying the principle of the grid network to a telephone switching system we can see by inspection of Figure 1-5 that the selection of a path or channel through the grid, or switching network using crossbar switches, requires knowledge of both input and output assignments. The selection of a channel in a crossbar system is commonly called a marking function. Following this line of reasoning the marking function cannot be performed until the digit information of the telephone number has been received either in whole or part, depending upon the particular control arrangement used. It can also be reasoned that since the group of outgoing trunks to a particular destination is distributed over the secondary switches of the output group, some means is required for associating a code number and a number of widely distributed outgoing trunk locations. Besides this association there must be some means of testing these widely distributed locations and making logical decisions regarding availability and selection. It is not only possible but very probable that the digit information dialed by the subscriber is received at the central office before the marking function is completed. Therefore, in order to transmit the digit information to the next office some means of storing and regenerating digits is required.

Some of the major functions that must be accomplished by the control circuits of a marker system are:

- a. Registration: Counting and storage of the digits dialed by the customer.
- b. Translation: Conversion of code numbers into equipment locations such as office code into outgoing trunk locations, of the subscriber's number into his particular equipment location.
- c. Testing and Selection: Making busy tests of possible outgoing trunks or paths through the switching network and then selecting one to be used on each call.
- d. Outpulsing: Generation of pulses to match the stored digit information and of the proper type to be used by the next switching office.

- e. Connection: Means of temporarily interconnecting various circuits for controlling circuit action or passage of information.
- f. Various other logical decisions regarding items such as identification of calling subscribers, authorized or unauthorized calls, quantity of digits to be outpulsed, type of pulsing required and alternate action to be taken due to busy or trouble conditions.

The circuits for accomplishing the above functions are physically separated into common groups of frames or units. There is a great variation of operating time between the various functions as well as variations of circuit size for each function.

### 1.5 GENERALIZATION OF THE MARKER SYSTEM

Figure 1-6 shows a schematic representation of an interconnecting network and its associated common control or marker. For the moment, the central office network will be considered as being split into separate originating and terminating halves, and the network of Figure 6-6 may represent either half. If it is the originating half, the inputs are subscriber lines and the outputs are trunk groups. If it is the terminating half, the inputs are incoming trunks and the outputs are subscriber lines. If a tandem<sup>1</sup> operation is considered, Figure 1-6 may represent the entire office and both inputs and outputs are trunks. In any case, associated with the inputs are registers which receive the call information and which have access to the marker. Access from the inputs to the register can be achieved in a variety of ways, either through separate connectors or through the main interconnecting network.

On an originating call, the register must receive information from the subscriber before it can utilize the services of the marker. In the general case the office code is sufficient to identify the required outgoing trunk group, and as soon as it has been received, the register can request the marker to set up the connection between the subscriber's line and an outgoing trunk. When access is established between the register and marker, the register transfers the office code together with information of the location of the calling input, to the marker. Since this latter information

<sup>1</sup> Tandem Central Offices are used primarily as intermediate switching points between other central offices.

is used for control purposes, the register establishes means of determining the calling input location for use by the marker.

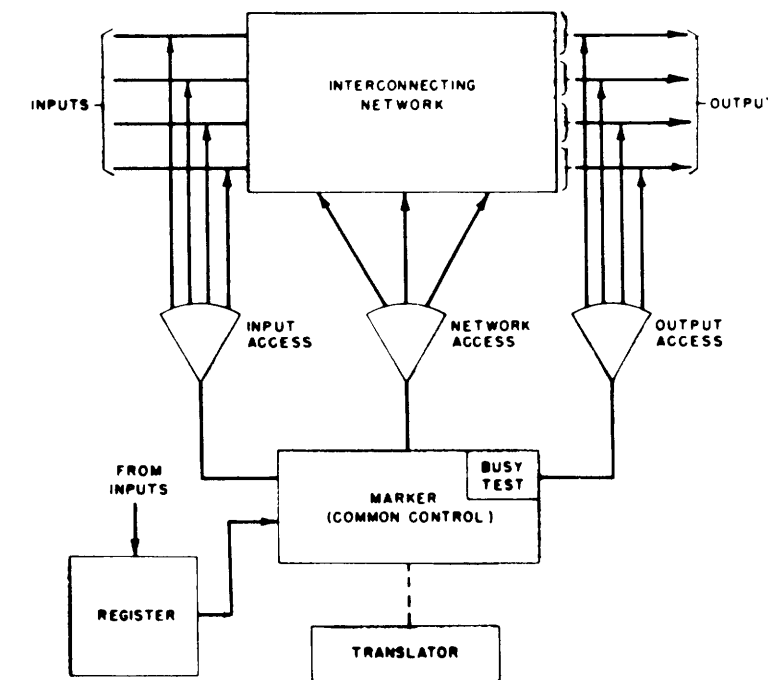


Figure 1-6 Generalization of Marker System

It is highly desirable not to have a fixed relationship between office code and trunk location on the switches. Furthermore, the nature of grid networks almost necessarily precludes such a relationship. Therefore, when the marker receives the office code from the register, it determines by translation how to gain access to the trunk group, plus any other pertinent information such as the type of trunk, pulsing required, customer charges, etc. Since it is neither practical nor desirable to establish a method of automatically hunting over adjacent terminals by the crossbar switches themselves, the individual trunks of a group can be dispersed over the whole network with considerable freedom. This, however, requires that the trunk busy test function be concentrated in the marker and that access be provided from the marker to the test leads of the trunk group. Successive individual tests of the trunks take too much time, consequently, the test leads are grouped for simultaneous testing.



There are several ways in which the marker can determine the location of a particular trunk. On Figure 6-6, a generalized access to the output groups is shown. This access may include control paths in addition to the testing paths. At the same time that the marker is locating and connecting to the output terminal of the network, it connects to the particular input terminal being served, through the input access paths.

As a result of these two actions the marker has control of the terminal points that must be connected together. The marker examines the individual network links which match to form a channel and connects together an idle set. It is desirable to examine all links simultaneously, rather than on a progressive basis, in order to save time. Within the marker, the link testing paths, are grouped to associate the "A", "B" and "C" links into matching sets so that the channel matching circuit of the marker can determine in which channels all links are idle. One is selected and the channel control circuit transmits the control signals over the access paths to establish the connection.

On Figure 1-6 only one marker is shown. This is obviously the most efficient means of control, concentrating as it does all test and control features into a single equipment unit. With relay type control circuits, the traffic volume of an average office requires the use of several markers.

As soon as more than one marker is introduced into a system, the problems multiply rapidly. Since it must be possible to place a call from any input switch to any output switch, access must be provided from each marker to every grid in the network. Each access path consists of a large number of leads which are necessary to test and establish paths on a single switch, although only a small fraction are utilized on a particular call. A simplified block schematic indicating how the access problem grows with several grids and markers is shown in Figure 1-7. When so many leads are involved, the only practicable method of handling access is to use multicontact relay connectors. The connectors can be designed so that control signals cause selection of the individual groups of frame leads applicable to a particular call. A limited number of leads then pass from markers to the connectors on the grids and the fanning out of the leads takes place within the grid frame. Furthermore, much of the connector equipment can be used in common by all control circuits.

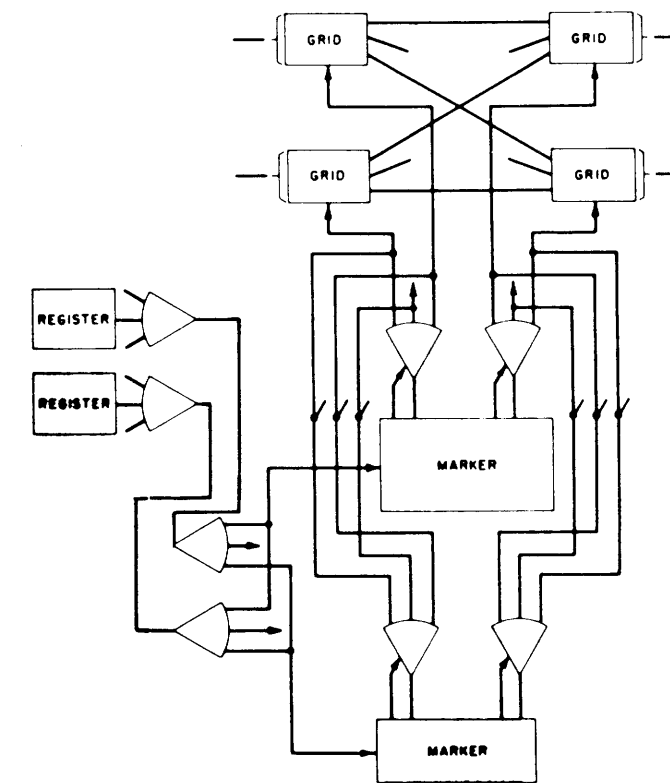


Figure 6-7 Several Markers Applied to a Network of Grids

It is inherent in most common control systems that only one control unit can work into an individual frame at a time. Otherwise there is mutual interference that may permit double connections or mutilated calls. This requires an elaborate system of lockouts in the connectors to provide exclusive access. A result of this is that the markers may block each other in the handling of calls and are subject to delays while waiting for frames to become idle. This, of course, reduces the efficiency of use of the control units. In designing systems care must be taken that such blocking cannot cause complete exclusion between control circuits. For example, if two markers simultaneously require access to the same input and output frames and each is able to seize one of the two frames, an impasse exists. This difficulty can be obviated by designing the circuits so that the grid frames must be seized in a definite order (output before input, for example). Preference assignments for each frame will also help to eliminate attempts of double seizure.

These considerations, in addition to the fact that marker units are very complex and expensive, make clear the necessity of keeping the holding time per call very low. A small holding time reduces the required number of markers, with their associated access, and increases their efficiency of use. A marker's holding time is to a large extent dependent upon the actuating time of the switches making up the interconnecting network. For this reason common control of the type discussed here is only economical when a high-speed switch mechanism is available. The necessity for speed has also imposed the use of fast-acting circuit elements in the control circuits themselves. The present result of this is that common control circuits are almost invariably all-relay devices with some utilization of electron tubes. This has a definite effect upon the complexity of control circuits since many circuit functions that are performed very simply, although slowly, by a multiterminal switch require intricate arrangements of many relays for equivalent action.

An important aspect of marker systems is that the control circuits themselves must incorporate intricate checking features to insure that they are functioning properly. When a trouble condition, serious enough to block a call is encountered by a marker, additional efforts must be made to take care of the call or it will be left hanging in the air, so to speak. Such efforts are, however, facilitated by the nature of common control which is capable of making subsequent attempts to complete a call via second trial features. In theory it is possible to make an unlimited number of additional trials to complete a call. However, each trial requires extra marker usage which reduces the availability of markers to other calls. In practice, therefore, additional trials may be restricted to two.

After the marker has picked a trunk or a called line, it may discover a channel busy condition. If there are alternate channels available, they will be tested as a second attempt. On originating calls to outgoing trunk groups, the next recourse is to choose a new trunk in the same group which will usually make available a new set of channels. When a marker encounters an all-trunks or all-channels busy condition, it also must take some alternative action. Common control is ideally suited for utilizing alternate routes, since it tests trunks early in the control-circuit cycle before paths are set up. Hence, such systems permit optimum use of direct and tandem trunking facilities. When the

control unit determines that all trunks in a particular direct group are busy, it can, with very little additional holding time, request the translator for directions to an alternate (tandem) trunk group. The control circuit then handles the call in the same fashion as though it were the original attempt. If there are additional tandem routes available, the alternate routine process can be continued as far as necessary. If all usable trunk groups are busy, the final route, in effect, is to a tone source or recorded announcement which can return a trunks busy or overflow signal to the subscriber. On terminating calls to a subscriber line, if the line is busy, a line busy signal is transmitted back to the originator.

The marker translators must provide full flexibility in furnishing information appropriate to each office code. At the present time the equipment usually consists of relay circuits plus changeable cross-connection fields on which the information for each code can be wired. Changes are relatively simple to make and the number of translator units is small. Some toll switching systems use punched cards which interrupt light beams in various patterns to provide translation information and some use electronic translators which utilize stored program control.

The information furnished by the office code translator includes the location of the trunk group for immediate use in establishing the originating connection, alternate routing directions, the type of pulsing and the number of digits to be pulsed to the terminating office. The necessary signaling information must be transferred to an outpulsing circuit. The latter circuit can be incorporated in the originating register or provided as a separate unit.

The outpulsing function is, of course, always necessary for communication with other offices and, in some systems, with the terminating end of the same office. The outpulsing function may be furnished as part of the register unit or may be furnished as separate units. If the register calls in a marker after the office code has been received, but before the rest of the called number is received, the register and outpulsing functions may be combined as shown in Figure 1-8A. This arrangement allows the outpulsing to start before registration of all digits is completed. If the register does not call in the marker until all digits are received, then separate register and outpulsing units are required as shown in Figure 1-8B.

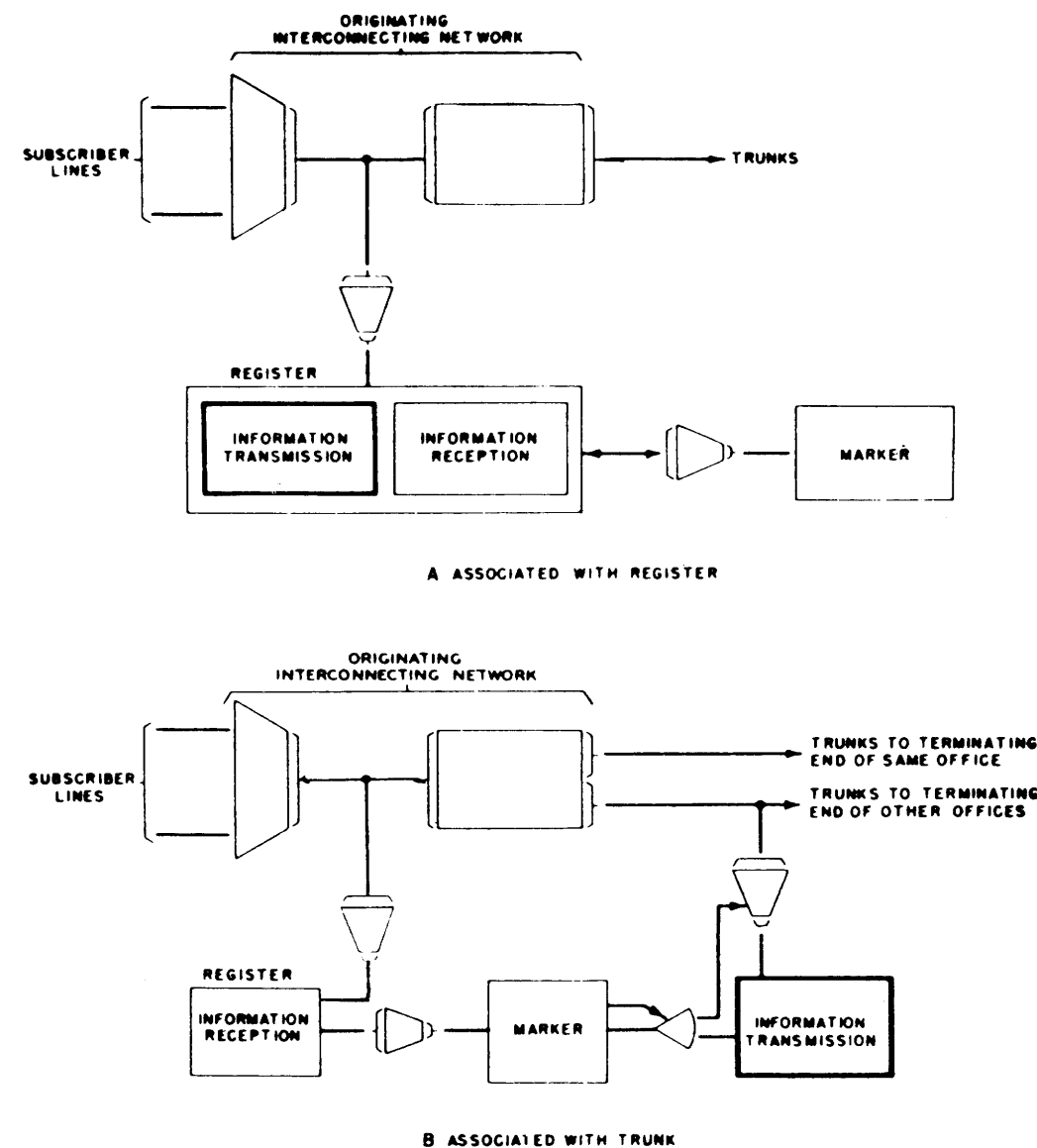


Figure 1-8 Location of Outpulsing Functions in Marker Systems

### 1.6 DIRECTORY NUMBER TO LINE NUMBER TRANSLATION

With grid type networks, line number to switch location translation, similar to office code translation, is almost invariably necessary. This comes about, not only because it is difficult to set up a logical relationship between line directory number and switch location with grid networks, but because the inherent advantages of flexibility. Therefore, line translators must be provided which enable the control circuit to determine the line location from the directory number. This implies that the overall control of terminating calls is similar to that for originating calls. The principle difference derives from the translation technique.

The considerations applying to line number translation are quite different from those obtaining for office code translation. The difference is primarily a matter of magnitude since line numbers in one central office may run up to 10,000 while office codes are well under 1,000. The resulting size and cost of the line translator is such, with present techniques, that it is uneconomical to provide one per marker. The alternative is to furnish common translators with access from all markers. Advantage can be taken of the probability that simultaneous calls will be to lines well distributed throughout the line number series. This permits breaking up one large translator into several parts, each containing the information pertinent to a grouped fraction of the lines. Each marker must have access to all subdivisions of the translator; the access must be exclusive to prevent mutual interference. This is the plan followed in present-day marker systems where the translator is known as the number group.

A sketch of this translation arrangement is shown in Figure 1-9. For convenience, each translator subdivision is shown as comprising 1,000 lines, although this number may vary from system to system depending upon traffic considerations and the particular translation method employed. It is also necessary to employ with the marker some form of pre-translation to determine the particular translator subdivision to use.

In addition to called line location and Private Branch Exchange hunting directions, the translator must also furnish information on the type of ringing required. This is later used to set up the trunk circuits to send out the correct ringing signals to the called subscriber.

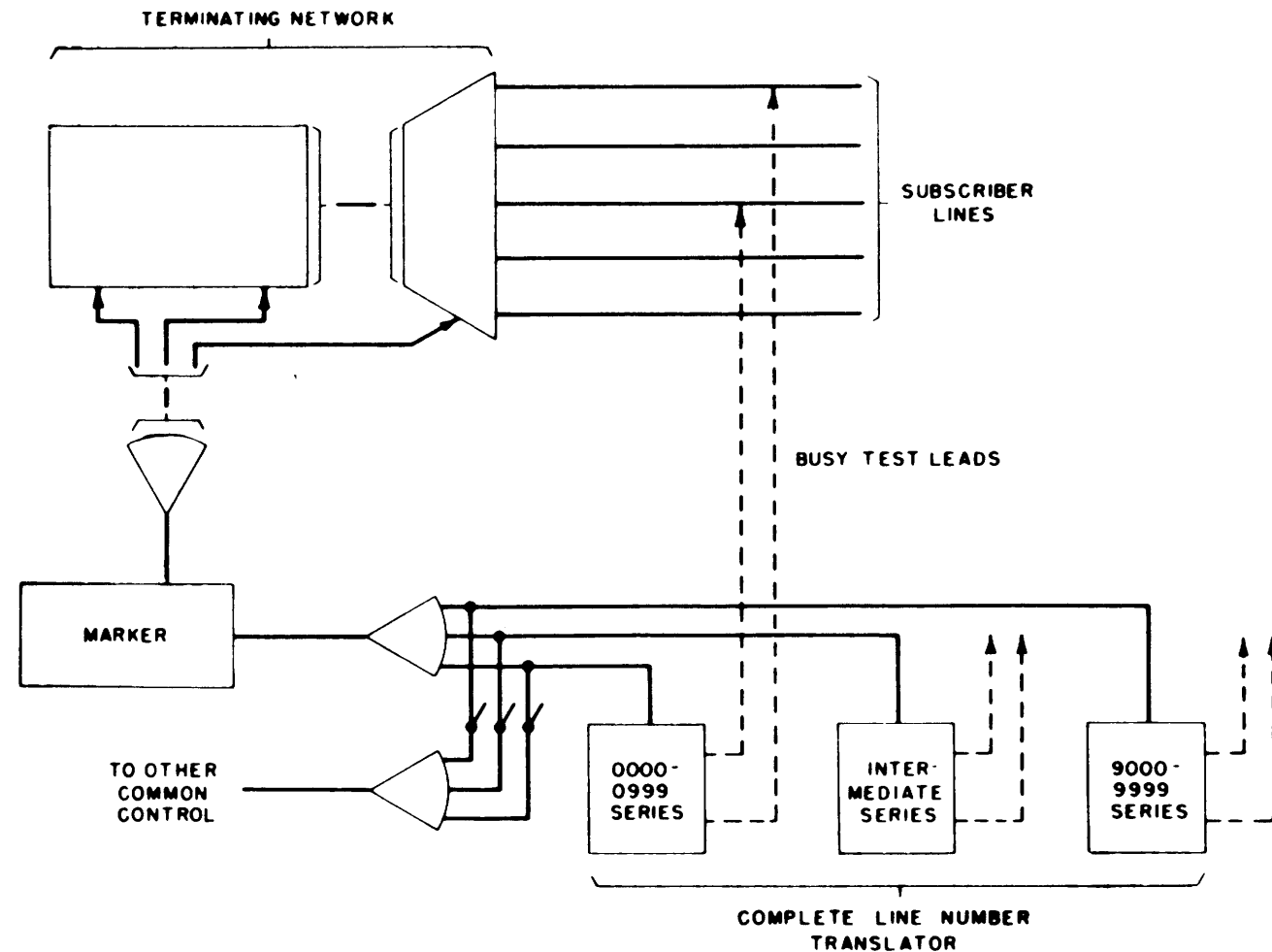


Figure 1-9 Number Translator in Marker Systems

### 1.7 PULSING LANGUAGES

Crossbar systems are designed to interpret the various types of pulsing used in other systems. Senders, for example, receive digits in the language of the calling central office and outpulse digits in a different language as required by the receiving central office. Some of the major pulsing techniques are Touch-Tone, Dial Pulsing (DP), Multifrequency (MF), Revertive Pulsing (RP), Panel Call Indicator (PCI), DC Key Pulsing (DC-KP), and Frequency Shift Pulse (FSP).

#### A. Dial Pulsing (DP)

The dial pulse is an interrupted DC signal of 10 or 20 PPS. It is the pulsing method most familiar to the average person since it is the method used for dialing on all present subscribers' lines. It is also used extensively by operators, as well subscribers, for dialing over trunks which terminate in a step-by-step system. Dial pulsing is accomplished by a dial which controls a normally closed contact directly in the line circuit. This contact remains closed as the dial is pulled around to the digit desired; but as the dial is released, the contact is opened and closed a number of times corresponding to the digit. When the digit 1 is dialed, the contact is opened and closed only once; when the digit zero is dialed, the contact is opened and closed ten times.

#### B. Multifrequency Pulsing (MF)

MF is an AC signal consisting of a combination of 2 out of 6 single frequency tones in the audible range. The frequencies are 700, 900, 1100, 1300, and 1500 and 1700 Hz. These are coded as 0, 1, 2, 4 and 7. Thus, to transmit the digit 1, we send a "0" and "1" (the 700 and 900 signals). To transmit the digit 9 we send a "2" and a "7" (the 1100 and 1500 signals).

Up to the recent introduction of the new FSP signaling technique, MF was the only AC signaling method available. Due to the obvious transmission advantages of an AC signal, MF is used in all toll operator dialing and intertoll trunks that terminate in No. 5 Crossbar, Crossbar Tandem, or ESS offices.

#### C. Touch Tone

Touch Tone is an AC signal similar to MF except that it uses 7 audible tones of uneven frequencies so that accidental triggering by the human voice on background noise is minimized. This precaution was necessary because the Touch Tone signal is originated by the subscriber in his Touch Tone set while MF is originated only by trained operators on intertoll trunks. The frequencies used in Touch Tone are 697, 770, 852, 941, 1209, 1336, and 1477 Hz.

D. Revertive Pulsing (RP)

The revertive pulse is a DC interrupted signal of 30 PPS. This pulsing technique is used only in the panel switching system.

The dial pulses from the subscriber's dial release and reoperate a line relay in the sender. This in turn operates a series of pulsing relays for each digit dialed. The information from these pulsing relays is recorded in the operation of one or more of a set of register relays for each digit.

When the incoming selector at the terminating end is seized, the elevator is started upward, and as it travels, it sends series of pulses back to the sender, which counts the pulses and stops the elevator when the proper position is reached. This is called revertive pulsing, because the pulses are transmitted back from the controlled end of the circuit to the controlling end.

E. Panel Call Indicator Pulsing (PCI)

PCI is a pulse train of 4 pulses per digit. The 4 pulses represent the 4 digits, "1", "2", "4" and "5" respectively. Thus, a positive value on the first pulse and nothing on the other 3 represents the number 1, a positive value on the second and fourth pulse represents the number 5. In actual practice the pulses are more complicated with light or heavy negative pulses indicating the presence or absence of a signal on some pulses, instead of the mere presence or absence of a positive pulse.

PCI is used on all calls routed through an electro-mechanical office and terminating in a manual office. The PCI signal activates a display panel in front of the manual switch-board operator and lights lamps corresponding to the dialed number. The operator then connects the incoming call to the indicated number with her cord. The method used to transmit these numbers was first developed for the panel system and is therefore called the panel call-indicator-PCI-system. The primary reason for developing a new system was to speed up the time required

to transmit the number, since the operator must wait during the entire transmitting period for the display on the call indicator. Numbers are transmitted by PCI pulsing at a rate of approximately 3 digits per second, which is almost twice as fast as with revertive pulsing.

F. DC Key Pulsing (DC-KP)

DC-KP is a single DC pulse per digit sent over the Tip lead, Ring lead or both. (In some cases a 3 wire positive pulse only system is utilized and the pulses may be on either or all of the 3 wires.) The pulse has 4 possible forms; high positive, low positive, high negative and low negative. The form of the pulse and the lead it is on is used for coding the digits.

DC-KP is used on calls originating in a manual office and terminating in a PANEL or No. 1 Crossbar office. The pulse is generated by an operator's 10-button keyset. This keyset is used by the manual operator to complete calls originating in her own office to the dial network. The operator plugs in the calling subscriber into a OGT dial trunk jack and keys the desired number on her DC-KP set. Actually she could have done the same thing with a simple dial, however, the DC-KP is much faster. The speed advantage of the DC-KP signal over DP was the reason for its development.

G. Frequency Shift Pulse

Frequency Shift Pulse represents an innovation in signaling. An electromechanical unit temporarily stores the binary digits to be transmitted and places mark or space signals on two sets of six leads going to a binary encoder. Continuous transmission is achieved by placing one digit (6 bits) on one of two sets of 6 leads and at the same time placing the next digit condition on the other set of 6 leads. At the terminal end these modulated frequencies are converted to signals on the two sets of leads to operate relays representing digits. FSP employs electronic computer techniques to transmit 200 bits per second over narrow band transmission facilities. The transmission consists of a synchronizing bit called a key pulse start signal followed by 6 bits representing a digit. The bits are 5 milliseconds in duration. A mark or

space condition is set for each bit position and each digit is given a code of two mark and four space bits. The bits are arbitrarily designated 0, 1, 2, 4, 7 and 10. The coding is similar to that for multifrequency where two frequencies represent the digit, except for 0 which uses 4 and 7. The 10 bit is used for the key pulse start and finish signal. Digits are transmitted by modulating 1170 Hz + 100 Hz; 1070 Hz represents a mark and 1270 Hz represents a space.

## CHAPTER 2

### NO. 1 CROSSBAR AND CROSSBAR TANDEM SYSTEMS

#### 2.1 NO. 1 CROSSBAR SYSTEM

##### A. GENERAL

The No. 1 Crossbar System was developed in the mid-1930's to overcome some of the disadvantages of the Panel System. For instance, No. 1 Crossbar offered better transmission characteristics by using precious metal contacts in talking path connections; gave one appearance to each subscriber line on the frames for both originating and terminating traffic; and PBX hunting lines could be added without number changes. No. 1 Crossbar also made possible shorter call completing times and required less system maintenance.

Since it was expected that this system would be used largely in panel areas, revertive pulsing was employed for both incoming and outgoing traffic. The No. 1 Crossbar System is also a common control system; its originating and terminating equipment each has its own senders which function with the markers to complete subscribers' connections. A simplified view of the overall equipment arrangement is shown in Figure 2-1.

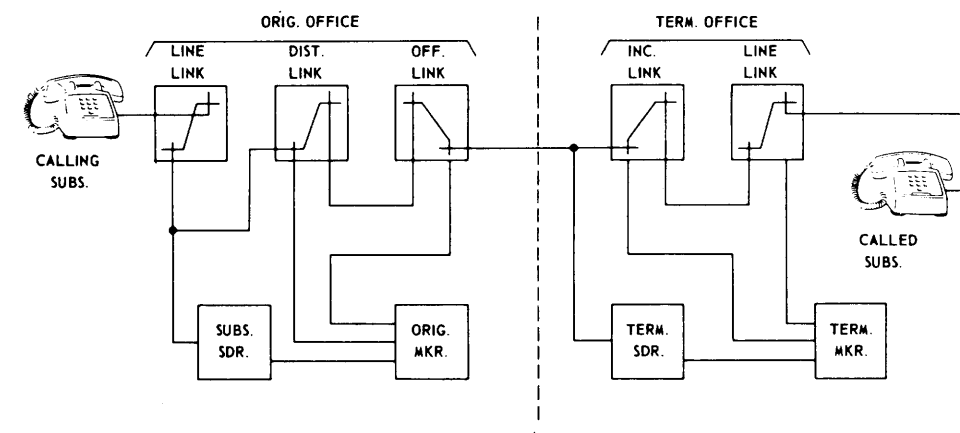


Figure 2-1 Simplified Block Diagram - No. 1 Crossbar System

From a traffic standpoint the major No. 1 Crossbar dial system frames may be divided into two general classes:

### Originating Equipment

Line Link Frame  
District Frame Group  
District Junctor Frame  
District Link Frame  
  
Subscriber Sender Link  
  
Office Link Frame  
Office Extension Frame  
Subscriber Sender Frame  
Originating Marker Connector Frame  
Originating Marker Frame

### Terminating Equipment

Incoming Frame Group  
Incoming Trunk Frame  
Incoming Link Frame  
Incoming Link Extension Frame  
Terminating Sender link Frame  
Terminating Sender Frame  
Terminating Marker Connector Frame  
Terminating Marker Frame  
Number Group Connector Frame  
Block Relay Frame  
Line Distributing Frame  
Line Choice Connector Frame  
Line Junctor Connector Frame  
Line Link Frame

Two distributing frames are also provided. The Main Distributing Frame (MDF) is used for cross-connecting the subscriber and trunk cable pairs to the crossbar frames. The Line Distributing Frame (LDF), provides a means of cross-connecting the line link frames to the terminating marker. This permits any directory number (vertical side LDF) to be assigned to any "line" circuit (Col. -Sw.-Vert. horizontal side LDF) as shown in Figure 2-2.

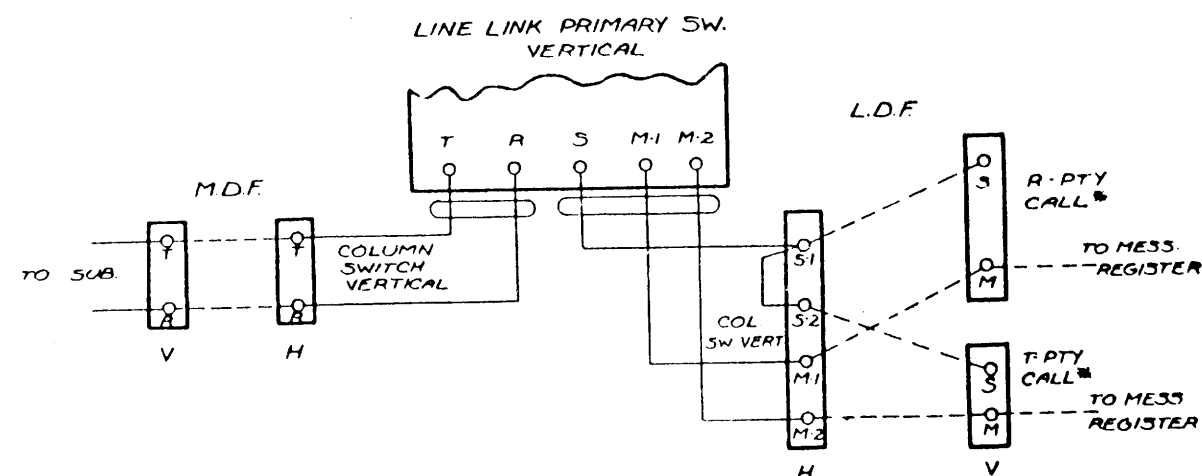


Figure 2-2 Distributing Frame Connections for No. 1 Crossbar Line Link Frames

The equipment required to complete a call and the path of a call through the No. 1 Crossbar System equipment frames is shown in Figure 2-3.

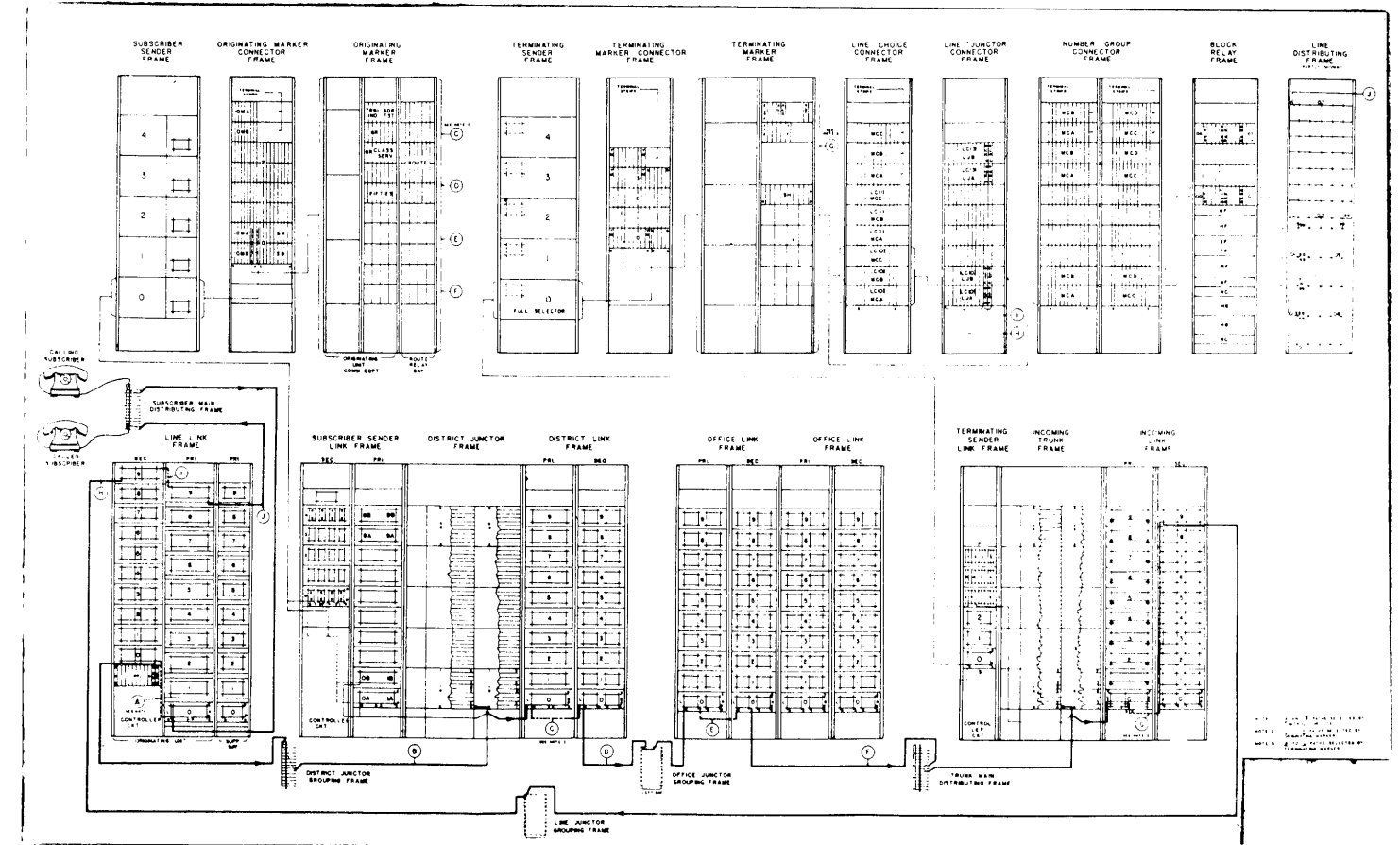


Figure 2-3 Major No. 1 Crossbar Frames

## B. FRAME EQUIPMENT

### 1. Line Link

The line link frame is used for both originating and terminating calls. It connects the customers lines, which are assigned to verticals of the



primary switches, with district junctors for outgoing calls and with line junctors for incoming calls. The assignment of lines to the line junctors for incoming calls. The assignment of lines to the line link frame is governed by load characteristics, calculated by the CCS per line for both in and out calls. CCS is an abbreviation for "Hundred Call-Second Per Hour" measurement of line load indicating the sum of the length of the time for each call on the line is one hour.

The crossbar customer's line is assigned to, and has exclusive use of a vertical of a primary crossbar switch. The primary switch has ten horizontal paths with which this vertical may connect. The ten paths handle all the traffic, both outward and inward for all the lines on a single switch. The first vertical on the first ten primary switches on each line link frame is used to obtain access to busy lines for test and verification purposes. These ten primary switches, plus the ten secondary switches are called the "basic unit." Since the traffic load for nineteen lines does not normally load the ten horizontal paths, or line links efficiently, additional switches for additional lines are added laterally to form what is known as a horizontal group shown in Figure 2-4.

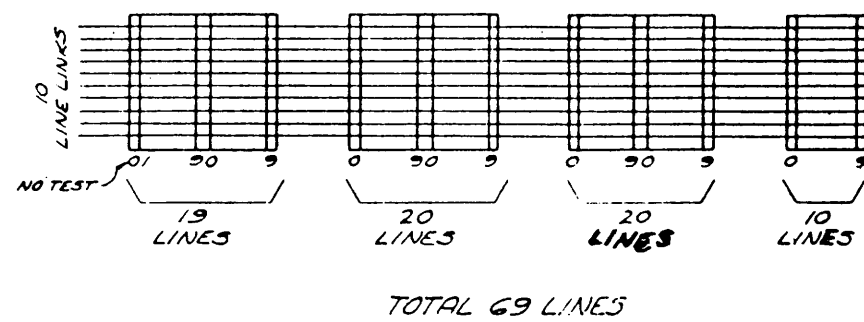


Figure 2-4 Maximum Horizontal Group

On service orders each line assignment will carry a location number for the line on the line link frame just as it does in the manual office (panel and jack), in the panel office (line group and terminal), and in the crossbar unit (column, switch, and vertical). For example, 0152 means column 01, switch 5 and vertical 2, illustrated in Figure 2-5.

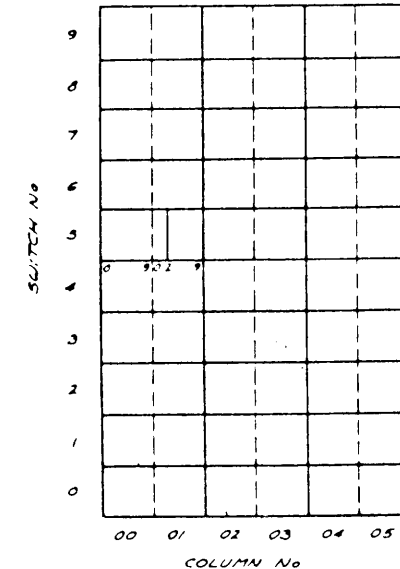


Figure 2-5 Service Order Number 0152.

Each line link frame has associated with it a "control circuit" whose function it is to recognize a calling line, choose an idle line link and assist in the selection of an idle district junctor and to operate the necessary selecting and holding magnets for connecting these paths together. On a terminating call it assists in setting up the call from the incoming trunk over a line junctor and line link to the called line.

Since a line link controller circuit may provide service to as many as 690 subscriber's lines, it is of the utmost importance that there is always a controller circuit available. As a service precaution, line link frames are arranged in pairs insofar as their controllers are concerned.



This arrangement is called a "home" and "mate" controller circuit operation. If a call is delayed in the "home" controller circuit, it will be transferred automatically to the "mate" controller circuit and handled on an "emergency" basis.

## 2. District Junctor

The district junctor frame is mounted in the center of the "District Frame Group," the subscriber sender link is on the left and the district link frame is on the right. The district junctor frame is used to mount the relay equipment which provides talking battery and supervision for the calling subscriber and controls the operation of the subscriber message register on calls dialed directly by the subscriber. Each frame will care for the 100 district junctors of the associated district link frame. The subscriber sender link frame provides access to office junctors. The district junctors are multiplied to 2, 3, 4, 5, 6, or 7 line link frames as indicated by the traffic requirements. A diagram of connections to a district junctor is shown in Figure 2-6.

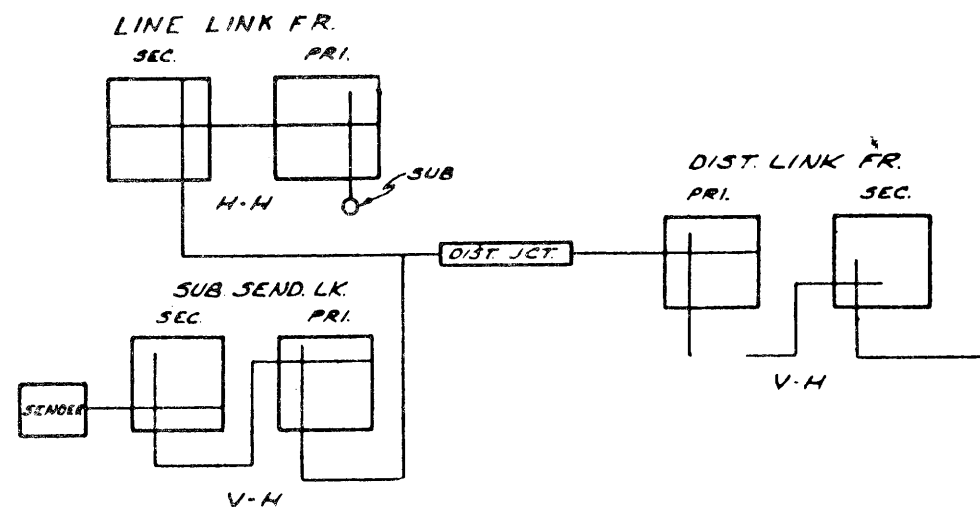


Figure 2-6 Connections Provided by a District Junctor.

The coin district junctors, in conjunction with a coin control circuit, collect or refund coins depending on whether or not the called party answers. Noncoin district junctor circuits can be arranged in conjunction with zone registration equipment to make additional charges for calls outside of the local charge zone or area.

## 3. District Link Frame

The district link frame also uses the primary - secondary arrangement of crossbar switches, each frame being equipped with ten 200 point primary switches and ten 200 point secondary switches.

The district junctors, which originate at the line link frames, terminate on the horizontals of the district link primary switches, ten junctors per switch. Further, the horizontals of the primary switches are continuous across each switch. Those on the secondary switches are cut (split) between the 10th and 11th verticals.

In addition to the primary and secondary switches, the district link frame is equipped with multicontact relays. The relays, located at the top of the district frame, are used by the originating marker to gain access to the links and junctors of the district link frames.

## 4. Subscriber Sender Link Frame

The subscriber senders are selected for each call by the subscriber sender link frame. This frame consists of primary and secondary switches whose function it is to connect an idle subscriber sender to the particular district junctor which has been selected for a given call. Since this frame must function before the subscriber begins to dial, and before the originating marker is connected, it is provided with a control circuit. The control circuit assists the line link control circuit in selecting the district junctor to be used on each outgoing call. It also determines which senders are available for use for each particular call.

An emergency control circuit is provided for use with any subscriber sender link frame. It can be connected to any one of the subscriber

sender link frames by means of manually operated switches located directly above each regular controller cabinet.

Each subscriber sender link frame can handle a maximum of 100 district junctors and 10 sub-groups (10 senders each) or 100 originating senders.

#### 5. Office Link Frame

Each office frame consists of a unit or bay of ten primary switches and ten secondary switches. All the switches are of the 200 point type.

Two hundred office junctors, originating on the secondary switch verticals of the district link frames, terminate on the vertical units of the office link frame primary switches. The two hundred links (left and right) originate on the office link frame primary switch horizontals and terminate on the secondary switch vertical units.

This arrangement makes it possible for any district junctor to obtain connection to as many as 4000 trunk locations (20 office frames with extensions times 200 trunks).

The outgoing trunks, which appear on the horizontals of the office link frame secondary switches are cabled to the main distributing frame. Here they can be cross-connected by jumpers to a local or underground trunk cable, to reach the various exchange areas.

Office frames are always used in pairs, and it is required that trunks to a given exchange be assigned to a pair of office link frames. This insures, that if a trouble condition occurs on one of the frames of the pair, a call to a given central office will be completed over a trunk available on the second office link frame.

#### 6. Office Extension Frames

When the number of office frames exceeds ten and it is desirable to operate more than 200 trunks per pair of frames, extension frames must be provided. Extension frames consist of an

additional group or bay of ten 200 point switches which are installed adjacent to the regular secondary switches of each office frame. The office link circuits are multiplied giving each trunk location access to all the links.

#### 7. Subscriber Sender

Each subscriber sender frame mounts five senders. The ten senders of two adjacent frames normally make up a subscriber sender group.

The subscriber senders of the crossbar system are similar to and perform much the same functions as those of the panel system, except that they do not control the setting up of the paths between the calling line and the outgoing trunk. On calls to panel and crossbar offices control of the incoming and final selections in the distant office will be on a revertive pulsing basis. In the case of a crossbar distant office, selections will require the use of full selector terminating senders. In panel distant offices the control remains with the originating sender for the entire operation. Calls to manual offices are handled on a call indicator or call announcer basis in the same manner as formerly handled by panel subscriber senders.

#### 8. Originating Marker Connector

Each originating marker connector frame will accommodate three connectors which connect subscriber and keypulsing senders to origination markers.

Each connector circuit will serve a maximum of ten subscriber senders, or a maximum of eight subscriber and keypulsing senders combined. These may be connected to a minimum of two or a maximum of eight markers.

#### 9. Originating Marker

The originating marker circuit receives information from the originating sender which it decodes and then returns information to the sender for controlling selections at the terminating end. The marker also selects a trunk

to the desired office and establishes a path from the district junctor to the selected trunk as well as transmitting talking selection, charge or noncharge, and party information to the district junctor.

The originating markers are arranged for a maximum of 24 subscriber classes and one operator class of service per marker group. A maximum of eight markers per group may be provided. A group of markers may be associated with a maximum of 20 district frames.

The number of markers required for traffic is based on the originating office busy hour calls plus the keypulsing calls.

A few features and limitations of the originating markers follows:

- a. The marker has a capacity for 802 possible codes including zero and permanent signal.
- b. The maximum capacity of the originating marker when trunk groups are subdivided is as follows:
  - 30 trunk groups with 2 first choice subgroups - 1 route relay.
  - 3 trunk groups with 3 first choice subgroups - 2 route relays with common subgroups.
  - 3 trunk groups with 4 first choice subgroups - 2 route relays with common subgroups.
  - 3 trunk groups with 2, 3, 4, 6 or 12 first choice subgroups - 2 route relays.

All trunk groups may or may not have a common subgroup in addition to above.
- c. Each marker is equipped with a route relay bay arranged for 100 route relays (50 multi-contact relays). Supplementary bays may be added each of which will care for 100 additional route relays.

## 10. Incoming Frame Group

The first frames encountered in handling incoming calls are known as the incoming frame group. Similar to the district frame group, they employ three frames: a terminating sender link frame which is always installed to the left of an incoming trunk frame, and an incoming link frame which is mounted to the right of the incoming trunk frames.

## 11. Incoming Trunk Frame

The incoming trunk frame provides a location for the relay equipment associated with the incoming trunk circuit. Its functions are to ring the called party's bell, to recognize removal of receiver from switchhook by the called party, to furnish talking battery, and to maintain called party supervision during conversation. In addition, it returns overflow or line busy indications to the calling subscriber in case the call cannot be completed.

Each incoming trunk frame can handle 100 trunks, (5 groups of 20) of the full selector type. Larger size trunks (more relays per circuit) will occupy more space on the frame so these extra circuits are placed on the supplementary frame.

## 12. Incoming Link

The incoming link frame differs from the district link frame in that it is provided with a different type of primary switch equipped to connect 16 trunks instead of the usual 10.

As ten primary switches are provided, each incoming link frame can therefore connect to 160 incoming trunks. Since each incoming trunk frame can mount a maximum of only 100 trunks, the extra 60 trunks are located on an additional incoming trunk frame. This frame is known as an auxiliary incoming trunk frame, and mounts a maximum of 100 incoming trunk circuits, which will connect through the primary switches of several incoming link frames.

Each primary switch has twenty, ten left and ten right links, going to the secondary switches in a vertical to horizontal spread arrangement.

Multicontact relays located above the switches on the incoming link frame assist the terminating marker in the selection of the crosspoints on the primary and secondary switches of the incoming link frame.

### 13. Terminating Sender Link

The terminating sender link frame connects an idle terminating sender, of the proper type to an incoming trunk for the handling of an incoming call.

The terminating sender link frame is arranged to mount three 100 point 6 wire primary and three 100 point 6-wire secondary crossbar switches together with the associated control equipment.

The control circuits of a pair of link frames are arranged to work on a mate frame basis to care for emergencies.

### 14. Terminating Sender

The terminating sender receives information from the originating subscriber sender, from keypulse sender or from dialing trunks. This information is converted by the sender into the called number and passed to the terminating marker.

The terminating sender frame is arranged to mount five senders. The top three positions (2, 3 and 4) will mount full selector senders only while the bottom two positions (0 and 1) will mount either full selector or "B" senders.

### 15. Terminating Marker Connector

The terminating marker connector selects an idle terminating marker and connects the sender to the marker.

Each connector frame will care for four marker connector circuits, associated control and alarm relay equipment common to these circuits, together with a location at the top of the frame for a maximum of two "B" position finder units, required when the office unit is served by a local "B" switchboard.

One connector circuit will consist of from 7 to 15 multicontact relays. The number varies with the number of terminating markers and the number of senders associated with connector.

### 16. Terminating Marker

The terminating marker frame is used to register the called number it receives from the terminating sender and from the translation of that number, locate and test the called line, and control the selection and closure of a path from the incoming trunk through the incoming link and line frames to the called line.

The number of terminating markers provided in an office will vary from two to ten, depending on the total number of terminating busy hour calls the markers will be required to handle.

When a marker is seized by a sender, it must determine, from the number that has been dialed, the correct number group connector to operate, and also the correct 100 block and 20 block relays to operate in the number group. This process is known as decoding, because the decimal directory number received, must be translated in terms designating a number group, a 500 group relay, a 100 block relay, and a 20 block relay. The marker can be arranged to test twenty lines at one time.

### 17. Number Group Connector Circuit

The 10,000 numbers in a given office are divided into "number groups." A number group consists of a series of numbers into which all the terminating markers have access, but only one at a time. The size of a number group depends upon the amount of terminating traffic

delivered to the numbers. Number groups will never be smaller than 100 numbers and are furnished in increments of 100 numbers up to a maximum of 2500 numbers.

The terminating marker obtains access to a particular number group through a number group connector circuit composed of equipment on a number group connector frame and block relay frame.

It is impractical to build a marker that is able to recognize ten thousand individual indications, and it is, therefore, arranged so that in conjunction with the number group connector and block relay frames it may locate and test the lines in blocks of twenty numbers each, selecting a block of twenty and ultimately the particular one of that block of twenty corresponding to the called number.

The possible 10,000 subscriber numbers of the office are arranged in blocks of twenty, and a 20 block relay (TB) is provided for each subgroup. There may be as many as 500 of these 20 block relays in an office, and, to simplify the selection of the desired one they are grouped into sets of five and operated through a 100 block relay (HB) also located on the block relay frame. Several of the 100 block relays are formed into a "number group" and by means of a number group connector can be temporarily connected to any one of the terminating markers.

#### 18. Block Relays

The block relay frame, besides mounting the hundred and twenty block relays associated with 800 lines, is equipped with cross-connecting fields for passing additional line information to the marker.

One field, the "NF," is used to cross-connect the subscribers number to the line choice using one of the following punchings: (a) RF punching if the line is ring party, individual line, or the last line of a PBX hunting group (b) TF punchings if the line is a tip party of a party line; (C) HF punching if it is the first or an

intermediate line of a PBX group; (d) JF punching to indicate "jump hunting;" (e) ANF punching for line overflow registrations.

The other cross-connecting field (NC) associated with each number is used for (a) quarter choice location and (b) horizontal group location for the called number.

Another cross-connection which is not associated with the block relay frame is required to give the marker complete information regarding the subscriber line. This is the NS lead which is run on the LDF. It cross-connects the subscriber's number to the column - Switch - Vertical.

#### 19. Direct Distance Dial Service

In addition to certain modifications required in existing subscriber senders and originating markers, two new equipment elements are required for providing DDD facilities in No. 1 Crossbar offices. These are the auxiliary sender and the auxiliary sender link.

#### 20. Auxiliary Sender

The auxiliary sender is a wire-spring relay unit and performs the following basic functions:

- (a) Registers two dialed digits, thus supplementing the 8-digit capacity of the subscriber sender to enable the customer to dial 10-digit foreign area calls.
- (b) Makes trunk test toward the distant office when dialing is completed, and when the remote incoming sender is attached, gives the subscriber sender an indication that it is ready to receive the digits registered in the subscriber sender.
- (c) Receives the digit stored in the subscriber sender on a PCI basis in the order dialed and outpulses each digit, after it is received, on an MF basis to the distant office.

- (d) Notifies the subscriber sender when outpulsing is completed so that both senders may release.

### 21. Auxiliary Sender Link

The auxiliary sender link provides the connecting path between any one of a maximum of 100 subscriber senders and their associated auxiliary senders. This frame may be partially equipped in individual units, each with capacity for ten subscriber senders and, when fully equipped, consists of ten auxiliary sender link units. An auxiliary sender link unit is made up of 200-point, 6-wire crossbar switch with associated relays.

### 22. Subscriber Senders

Certain modifications have been made to existing subscriber senders in order to function properly with the auxiliary sender and auxiliary sender link.

Relays have been added to these senders to enable them to perform the following functions:

- (a) Recognize calls which require an auxiliary sender either through the "0" or "1" in the second digit of the foreign numbering plan area code for 10-digit calls or on instructions from the originating marker for 7- or 8-digit calls.
- (b) Passes on to the auxiliary sender, on instructions from the originating marker, the number of digits to be deleted, if any.
- (c) Routes to overflow any 10-digit call for which an auxiliary sender is not connected in time to register the first pulse of the ninth digit.
- (d) PCI pulse its eight digits in the order dialed into the auxiliary sender instead of sending the stations digit ahead of the thousands, as is presently done when eight digits are outpulsed PCI.

### 23. Originating Markers

The originating markers have been modified to inform the subscriber sender when an auxiliary sender is required on 7-digit calls. Also, the markers will pass to the auxiliary sender via the subscriber sender, the number of digits to be deleted.

### SWITCHING A CALL THROUGH THE NO. 1 CROSSBAR SYSTEM

When a subscriber lifts the receiver, a line relay, associated with the line link frame primary switch vertical to which the line is connected, operates. The operation of the line relay notifies the line link controller that a call is being originated. The controller identifies the calling line by determining the horizontal group, vertical column, and vertical file in which the line is located. The progress of the call can be readily traced by following the heavy connecting lines shown in Figure 2-7.

The Line Link controller also connects itself to one of several sender link controllers with which the line link frame is associated. The two controllers function together to select an idle district junctor. The selection is made from one of the groups of ten district junctors which has an idle line link back to the calling line and an idle sender link to a sender subgroup which has an idle sender. District junctor groups having at least two idle junctors are preferred.

Coincident with the selection of a district junctor, the sender link controller is selecting an idle sender. This selection is made from subgroups having an idle sender link to the selected district junctors. Preference is given to those subgroups having two or more idle senders.

Following these selections, crosspoints are closed on the line link frame primary and secondary switches connecting the customer's line to a district junctor, and at the same time crosspoints are closed on the sender link primary and secondary switches to connect the

district junctor to a sender. Over these paths the tip and ring of the customer's line are now connected to a subscriber's sender. The sender sends out dial tone, indicating that it is ready to receive dial pulses. Approximately 0.6 second is required to complete this connection.

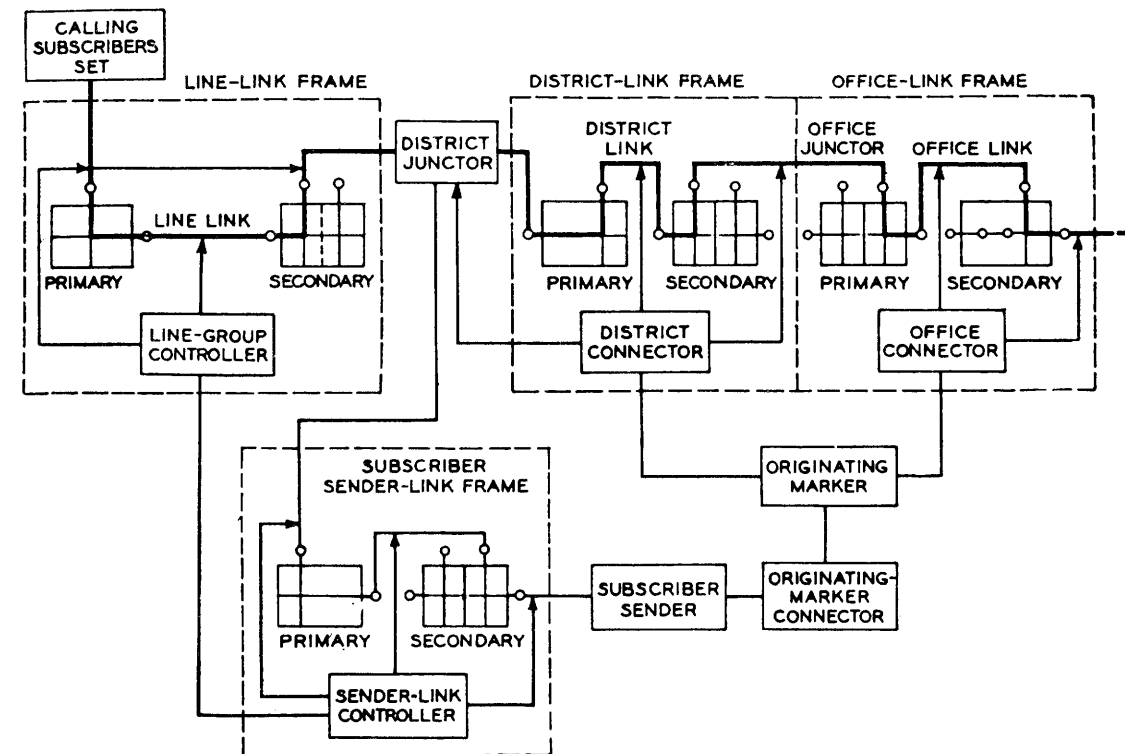


Figure 2-7 Originating Call in a No. 1 Crossbar Office

The sender also registers the number of the link frame involved, receiving this information from the sender controller.

The subscriber now dials the office code and directory number of the called subscriber. The sender counts the dial pulses and registers all digits dialed on the register switch.

As soon as the office code is registered, the sender signals the originating marker connector which connects the sender to an idle originating marker cutting through a large number of leads over which the sender and marker exchange information.

The marker receives from the sender the district frame number and the office code dialed. It decodes this information and sends back to the sender the information it needs to complete its part in handling the call.

From the route relay assigned to the office code the marker determines the pair of office frames on which the trunks to the desired office are located. The route relay also provides information as to the trunk level and the start and stop test points within that level. Through connector relays at the office frame, the marker gains access to the specified trunk locations, tests and selects an idle trunk.

The marker gains access to the office links that serve the selected trunk through connector relays at the office link frame. It also obtains access to the district link that serves the district junctor and office junctors leading to the office frame on which the selected trunk is located. Access to both the office links and office junctors is obtained through the district frame connector relays. From this combination of links and junctors the marker selects an idle district link which has access to an idle office junctor which in turn has access to an idle office link which appears before the selected trunk.

The marker now operates the select and hold magnets on the district and office link frames necessary to complete this channel from the district junctor to the selected trunk. This also provides a path from the subscriber sender to the trunk since the sender was cut through to the district junctor. The marker now has completed its functions and releases. The marker completes its function in approximately 0.5 second.



This outgoing trunk is connected to an incoming trunk in the terminating office shown in Figure 2-8.

The incoming trunk when signaled by the subscriber sender, will cause the terminating sender link controller to select an idle terminating sender and to connect it to the incoming trunk.

The two senders are now connected. The called number is transferred from the subscriber sender to the terminating sender where it is recorded on a register switch. With this information transferred the originating sender has completed its functions and releases.

The terminating sender now signals the terminating marker connector which connects an idle terminating marker to the sender cutting through the leads over which information is passed. The marker receives the called number and the incoming frame number from the sender.

The terminating marker translates this number as being in a block of 100 numbers and finally as being in one of five blocks of twenty lines in the selected block of 100 numbers. By means of cross-connections, the marker will then operate its number group connector relays in the proper number group, the proper hundreds block relay and through it the twenty block relay associated with twenty consecutively numbered lines, one of which is the called number.

The twenty block relay operates and cuts through to the marker a number of control leads which give the necessary information regarding the line and its location. The marker then tests the called line to determine whether it is busy or idle. If busy, the marker will set the incoming trunk so that the calling subscriber will receive busy tone. (The marker will then release immediately.)

If idle, the marker will determine from cross-connections on the block relay frame whether it is an individual or PBX line, whether tip or ring party ringing is required, in which line

choice, on which one of the four line link frames of the choice and in which horizontal group of the line link frame the called line is located.

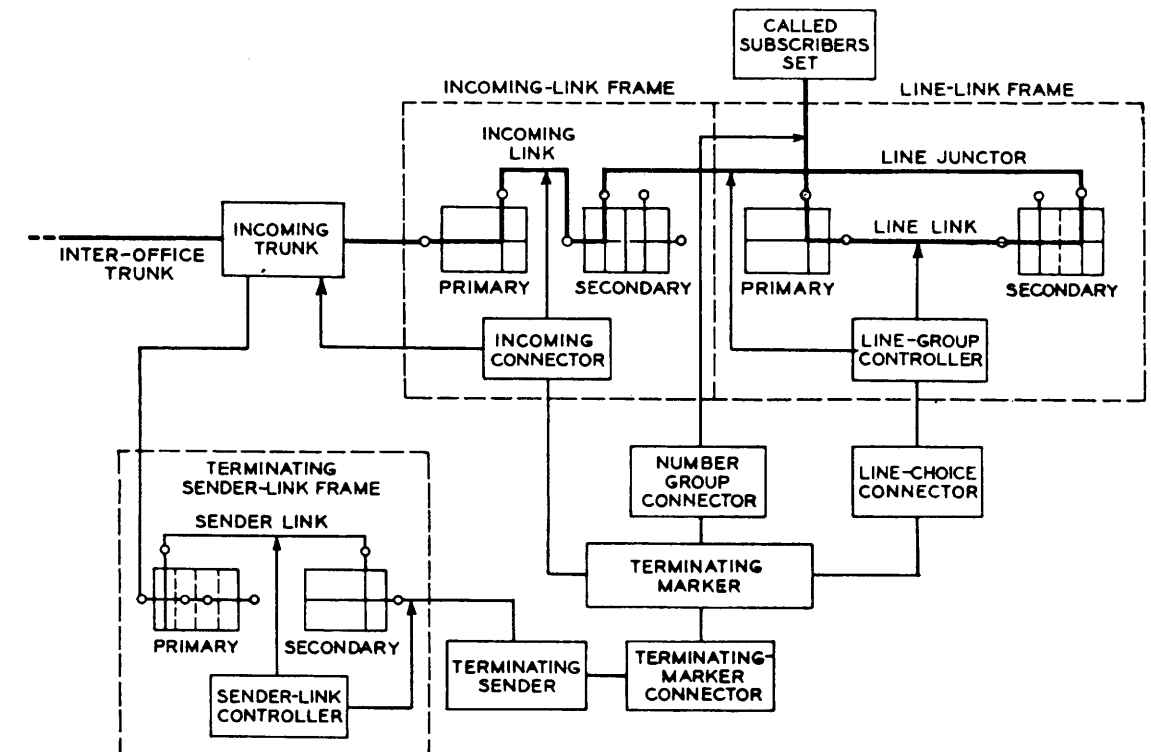


Figure 2-8 Terminating Call in a No. 1 Crossbar Office

From the line location information, the marker, by way of a line choice connector and line junctor connector, is able to test the line links that serve the horizontal group in which the called line is located. Knowing the incoming link frame to which it must connect, the marker tests the line junctors between this frame and the line link frame. At the incoming link frame, connector relays give the marker access to the links available to serve the incoming trunk. From this combination of links and junctors, the marker selects an idle incoming link with access to an idle line



junctor which in turn has access to a line link serving the horizontal group in which the called line is located. The marker will then operate the primary and secondary select and hold magnets on the line link and incoming link frames necessary to close this path between the incoming trunks and the called subscriber.

The marker also sets the incoming trunk to apply proper ringing to the called line. The marker and terminating sender now release. This marker has completed its function in about 0.5 second.

The incoming trunk applies ringing current to the called line and, when the called party answers stops the ringing and signals the district junctor that the called party has answered, so that the correct charge may be made. The calling subscriber may now talk to the called subscriber, the district junctor applying talking battery to the calling subscriber, and the incoming trunk to the called subscriber. At the end of the conversation, the two parties will hang up, and all circuits will release.

#### A DIRECT DISTANCE DIALING (DDD) CALL SWITCHED THROUGH THE NO. 1 CROSSBAR SYSTEM

It is the function of the auxiliary sender to receive the 10-digit DDD calls or the 7- or 8-digit home area calls. Figure 2-9 illustrates the function of the auxiliary sender.

#### 24. Ten-digit Call

A customer originating a call to a foreign area is connected to a subscriber sender in the usual manner and first dials the X 0/1 X foreign area code followed by the 7-digit directory number. The subscriber sender recognizes the "0" or "1" in the second digit as an indication that an auxiliary sender may be required to aid in the completion of the call. (Service codes in the X-1-1 series indicate only 3-digit calls which do not require use of the auxiliary sender.) After the third digit is dialed, the subscriber sender calls for an originating marker as at present. When one is connected, it

decodes the foreign area code in the same manner as a local office ABX code, completes a path to the outgoing CAMA tandem trunk, transmits to the subscriber sender the usual selection information, and releases.

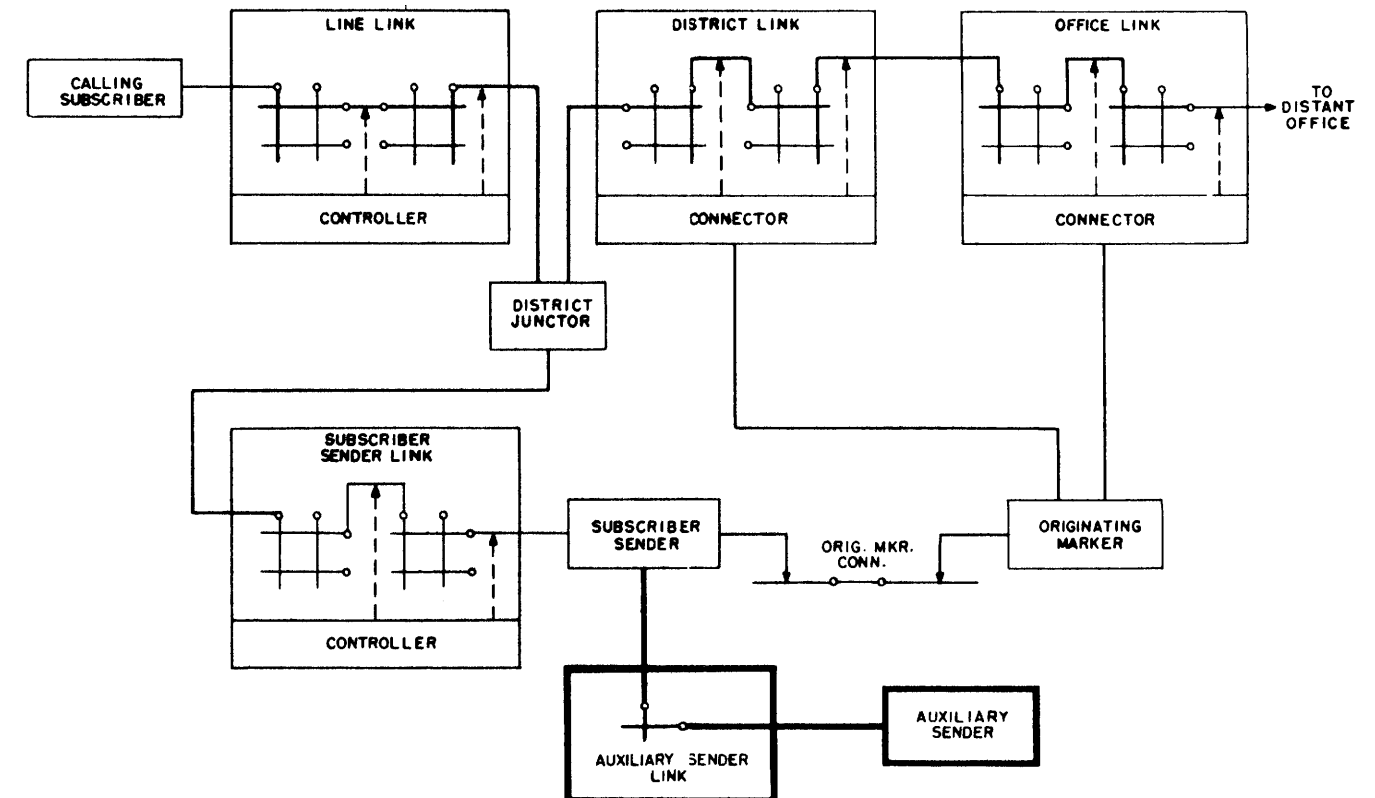


Figure 2-9 Diagram of Auxiliary Sender of the No. 1 Crossbar System.

Meanwhile, the subscriber sender continues to receive dialed digits and when the seventh digit is registered, it makes a bid for an auxiliary sender through the auxiliary sender link frame. Before the first pulse of the ninth digit, a connection is made to an auxiliary sender for registration of the ninth and tenth digits as they are dialed. If, for any reason, an auxiliary is not connected in time, the subscriber sender sends the call to overflow.

The auxiliary sender signals the subscriber sender when dialing is completed. The subscriber sender reacts by making PCI trunk test toward the auxiliary sender. The auxiliary sender then signals for a distant office sender via the subscriber sender, and when one is connected, gives the assignment signal to the subscriber sender. The eight digits in the subscriber sender are then PCI pulsed, in the order dialed, into the auxiliary sender. These digits are received in the auxiliary sender on either one of two dual function register circuits which are capable of receiving PCI digits and controlling the outputting of MF digits to the distant office. While one register circuit is receiving a PCI digit, the other register is controlling the MF outputting of the preceding digit and preparing to receive the next PCI digit. Since the MF outputting overlaps with the PCI inputting, this is referred to as the "overlap" method of operation. Therefore, the eight digits in the subscriber sender are MF outputted at the PCI rate. The two digits registered in the auxiliary sender are outputted at the regular MF rate.

After the eight digits in the subscriber sender and the ninth and tenth digits in the auxiliary are MF outputted, the auxiliary signals the subscriber sender that outputting is completed and both circuits release.

## 25. Seven-digit Call

The auxiliary sender may also be used to MF output 7- or 8-digit calls. The only difference in handling this type of call compared with a 10-digit call is that the indication that an auxiliary sender is to be used comes from the originating marker rather than from the second dialed digit. Once the auxiliary sender is connected and a distant incoming sender is attached, outputting proceeds as described above.

## 26. Digit Deletion

There is a feature in the auxiliary sender which permits it to delete the first two (skip 2) or three (skip 3) digits received from the subscriber

sender. On 7-digit calls, this feature enables the use of MF pulsing over direct trunks to No. 1 or No. 5 Crossbar offices which are equipped with MF receivers and are within the charging range of the originating office. For 10-digit traffic, the skip 3 feature may be used to delete the area code on calls going into an adjacent area through a "directional" CAMA crossbar tandem office used only for calls to that particular area.

## 2.2 CROSSBAR TANDEM SWITCHING SYSTEM

### A. GENERAL

Crossbar tandem is a relatively young switching system. It first went into service in 1941. Crossbar tandem equipment is used primarily in panel, step-by-step, and crossbar areas to switch calls among offices by means of crossbar switches in a marker common control system. Its central location provides for the application of Automatic Message Accounting (AMA) to record billing data for local and toll calls. It permits the use of AMA on calls from panel offices for which local AMA has not been developed. It provides for the application of Traffic Service Positions to the tandem office to extend customer Direct Distant Dialing (DDD) to include customer dialing of special toll calls, Coin Distance Dialing (Coin DD), and local and toll dial assistance originated as Dial Zero Calls. With proper terminating equipment it also provides for switching intertoll trunks on a 2-wire basis.

The basic need for a local tandem switching system arises in large metropolitan areas where local telephone service is furnished by many central offices as illustrated in Figure 7-10. In such areas tandem systems are used:

- a. To effect trunking economies by combining small amounts of interoffice traffic originating in the various central offices and routing this combined traffic over a common trunk group to the required destination, thus eliminating the necessity for inefficient, small, direct inter-office trunk groups.
- b. To effect central office economies by serving as a machine language interpreter" between the different types of central offices, thereby eliminating the costly necessity of equipping

every central office for direct communication with every other type of central office as illustrated in Figure 2-11.

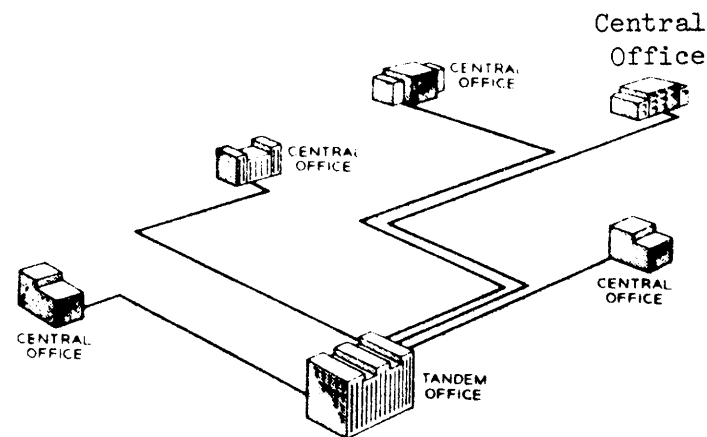


Figure 2-10 Local Tandem Switching

- c. To effect overall service economies by centralizing equipment for rendering 1-way message service (weather reports, etc.) and equipment needed as normal adjuncts of telephone service (charging equipment, etc.). Centralization results in efficient use of such equipment as compared with furnishing the same at each local central office requiring it.

## B. THE SYSTEM

The crossbar tandem is a 2-wire switching system, that is, it switches only one pair of voice transmission wires over which conversation flows in both directions. The crossbar tandem system functions in many respects like a No. 1 Crossbar office. The basic arrangement is shown in the upper portion of Figure 2-12. The lower portion of Figure 2-12 shows equipment elements required when AMA operation is provided for a crossbar tandem system. An incoming trunk is connected through a trunk link frame, office junctor grouping frame, office link frame and an outgoing trunk to another office. In operation, the incoming trunk is connected to a sender through a sender link frame. The sender registers the called number and other information required and connects to a marker

through a marker connector frame. The marker receives information from the sender and supplies the sender with information it needs to complete the call. The marker selects an outgoing trunk to the desired destination and connects the incoming trunk through the trunk and office link frames to the outgoing trunk.

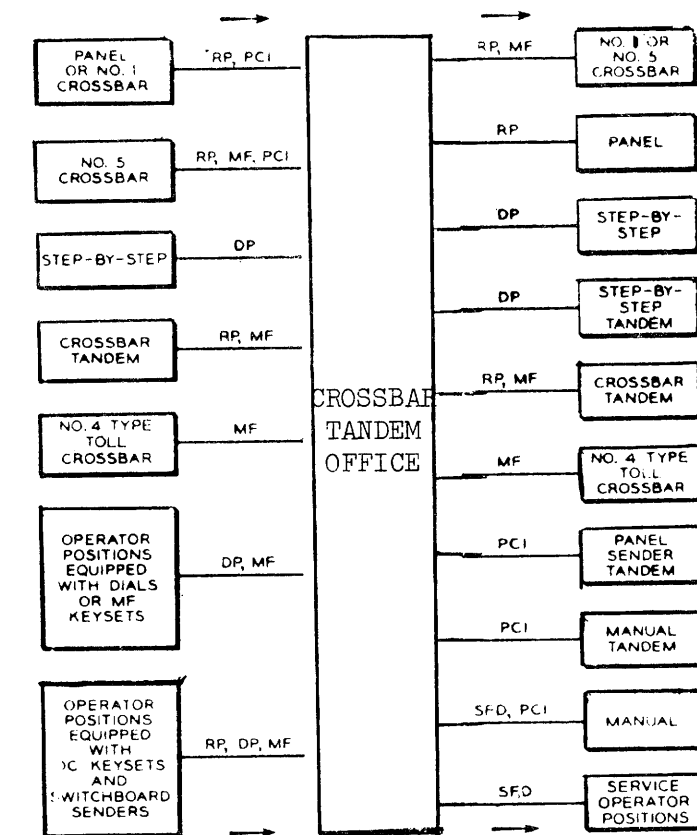


Figure 2-11. Block Diagram of Sources and Destinations of Traffic Routed through Crossbar Tandem Systems.

In the simplified block diagram of Figure 2-13 the switching network of the system consists of crossbar link frames. Incoming trunks from the calling central offices appear on trunk link frames and outgoing trunks to the called central offices appear on office link frames. Through a system of links and junctors, which interconnect the crossbar switches on these frames, any incoming trunk can be connected to any outgoing trunk. For each connec-



Figure 2-12 Block Diagram With and Without AMA

The diagram illustrates a TDM-based trunking system architecture. It shows the flow of data from an incoming trunk through various switching and control components to an outgoing trunk. The components include a Tandem Trunk, Trunk Link Frame, Office Link Frame, Sender Link, Sender, Marker Connector, and Marker. The flow is indicated by arrows, showing the path from the incoming trunk through the Tandem Trunk, then through the Trunk Link Frame and Office Link Frame, and finally through the Sender Link, Sender, Marker Connector, and Marker to the outgoing trunk.

Figure 2-13 Simplified block diagram of crossbar tandem

To establish a path, the incoming trunk calls for the services of the common control equipment. This equipment consists of a small number of elements (senders, markers, etc.), each of which is called into service for a relatively short time, performs its functions, releases, and is free to serve another call. The basic functions of these common control elements are:

1. Store the digits as they are received (sender function).
2. Translate these digits into switching control information (marker function).
3. Test for and select an idle outgoing trunk (marker function).
4. Test for and select a matching set of connecting links between the incoming trunk and the outgoing trunk (marker function).

### 5. Outpulse as required (sender function).

Over the years, this original switching plan of the crossbar tandem has proved to be highly satisfactory for meeting the first fundamental tandem system objective of enabling trunking economies to be effected in large metropolitan areas. Its switching speed, traffic capacity, and trunking flexibility are all adequate, since its control circuits are fast, and it can accommodate a maximum of about 3,000 incoming trunks and 4,000 outgoing trunks assignable in a wide range of group sizes.

### 1. Frames and Framework

Since it is not practical in this text to illustrate each type of switching frame used in crossbar tandem, nevertheless a few illustrations are provided to aid in visualizing how circuit elements such as relays, resistors, inductors, capacitors, electron tubes, etc. are first mounted in position on precisely drilled mounting bars which in turn are assembled into various units and finally are mounted on metal frame uprights. In crossbar tandem, frames measure 11 feet 6 inches high with sheet metal bases 10 inches wide and are of varying lengths. Most frames have their own fuse panels which are mounted on the top. Nomenclature is important. The name given to a type of equipment performing a specialized function in the system often reveals its purpose or use in that system. For example, Figure 2-14 shows a Trunk Link and Trunk Link Extension Frames while Figure 2-19 depicts the Marker Frame. It is worthwhile to note from these figures and Figure 2-12 that link frame types contain crossbar switches primarily; while frames housing control equipment such as controllers, senders, markers, trunks, etc., contain circuit elements other than crossbar switches.

### 2. Trunk Link

The trunk link frame shown in Figure 2-14 consists of primary and secondary bays of switches and relay equipment comprising 200 links used for interconnection of incoming trunks and office junctors. The primary ends of the links are arranged to serve 160 incoming trunks (basic

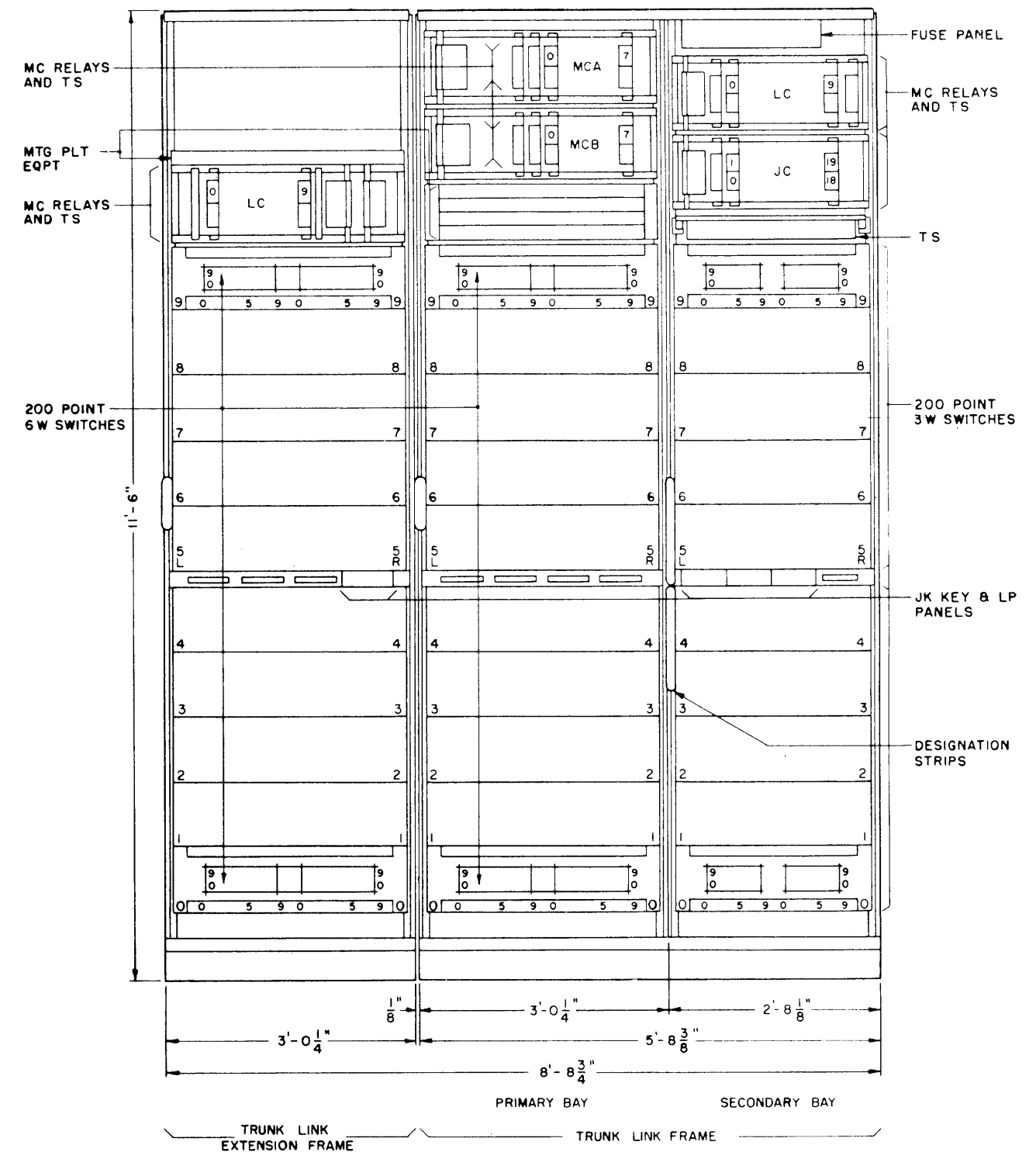


Figure 2-14 - Trunk Link and Trunk Link Extension Frames

frame) or 320 trunks (with trunk link extension frame). The secondary ends of the links serve 200 office junctors. The trunk link frame is arranged to operate with a maximum of eight markers and 20 office link frames and will serve any combination of AMA and non-AMA trunks, limited only by the decade requirements and cabling considerations.

The trunk link extension frame provides for a maximum of 160 trunks to which the trunk links are given access by a multiple between the primary and primary extension switches.

The trunk link arrangement is symbolically represented in Figure 2-15.

### 3. Office Link

This 2-bay frame and one-bay office extension frame are the same as the corresponding frames used in No. 1 local crossbar offices. A second extension frame may also be furnished in tandem offices to provide increased trunk capacity.

The office link frame has a capacity of 200 links, the primary switches of which serve 200 office junctors. The secondary switches provide for 100 outgoing trunks if the switches are not split and a maximum of 200 or 300 outgoing trunks if the horizontal multiples of all switches are split. The extension frame has a capacity of 100 outgoing trunks.

On the basis of 200 or 300 trunks per frame and a maximum of 20 office link frames (as limited by the marker), the physical maximum number of outgoing trunks per marker group is 4000 with one extension frame and 6000 with two extension frames. To insure uninterrupted service, a test group of trunks is divided between two office link or extension frames, and the frames are furnished and operated in pairs.

The office link arrangement is symbolically represented in Figure 2-16.

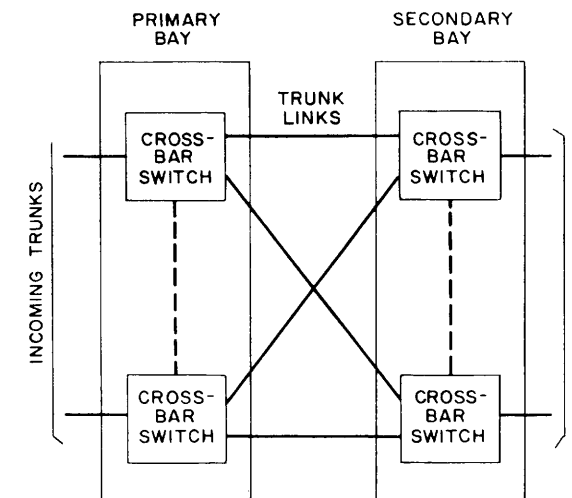


Figure 2-15 Trunk Link Frame - Primary and Secondary Bays Connected by Trunk Links

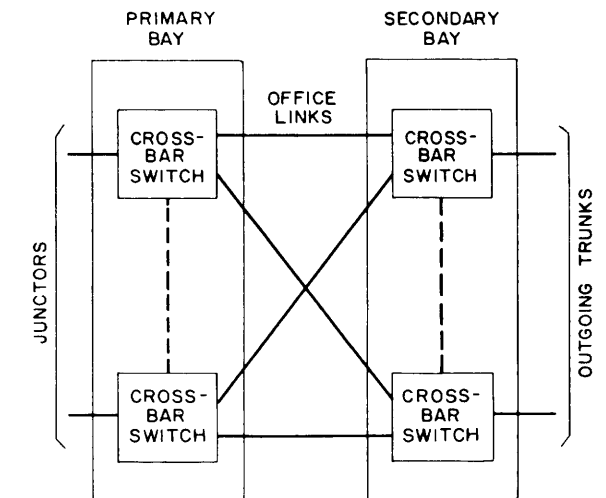


Figure 2-16 Office Link Frame - Primary and Secondary Bays Connected by Office Links

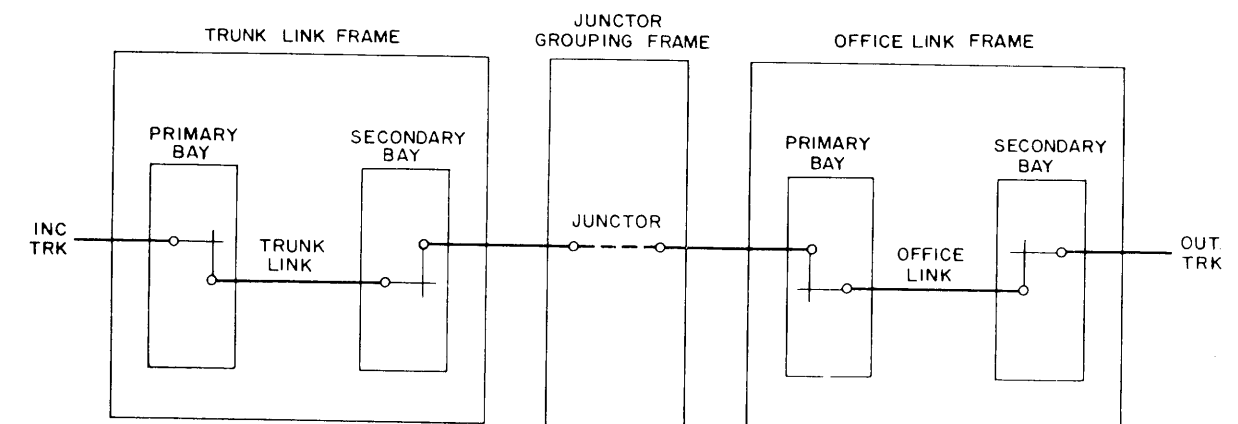


Figure 2-17 A Complete TJO Channel

#### 4. Office Junctor Grouping Frame

This is a 2-bay frame on which are mounted terminal strips and jumper distributing rings used to interconnect the secondary of the trunk link frames with the primary of the office link frames in such a way as to obtain complete access of incoming trunks to outgoing trunks. In addition to this, the grouping frame is arranged so that as the size of the office increases, the effort required to change the junctor distribution is kept to a minimum. Figures 2-18a and 2-18b illustrate an initial and a growth distribution arrangement.

The junctor channel between the trunk link frames and the office link frames is referred to as a TJO channel. A channel consists of a trunk link, a junctor, and an office link connecting an incoming trunk to an outgoing trunk as represented in Figure 2-17.

#### 5. Sender Link

This frame is a 2-bay structure. Four 200-point, 5-wire primary switches and four 200-point, 5-wire secondary switches, together with the sender subgroup connector multicontact relays and terminal strips, are mounted in one bay. The other bay contains a fuse panel, trunk group connector multicontact relays, and two controller circuits enclosed in a front casing and a rear enclosure.

The sender link frame is provided with ten groups of four primary-secondary links, each group having access on the primary switches to ten trunks and on the secondary switches to a total of 40 senders of either of two kinds. The frame serves a maximum of 100 trunks and has access to a maximum of 80 senders.

Each of the two controller circuits, A and B, serves half of the 40 links interconnecting the primary switch verticals with the secondary switch verticals. Each group of four links serving ten trunks is made up of two A and two B links.

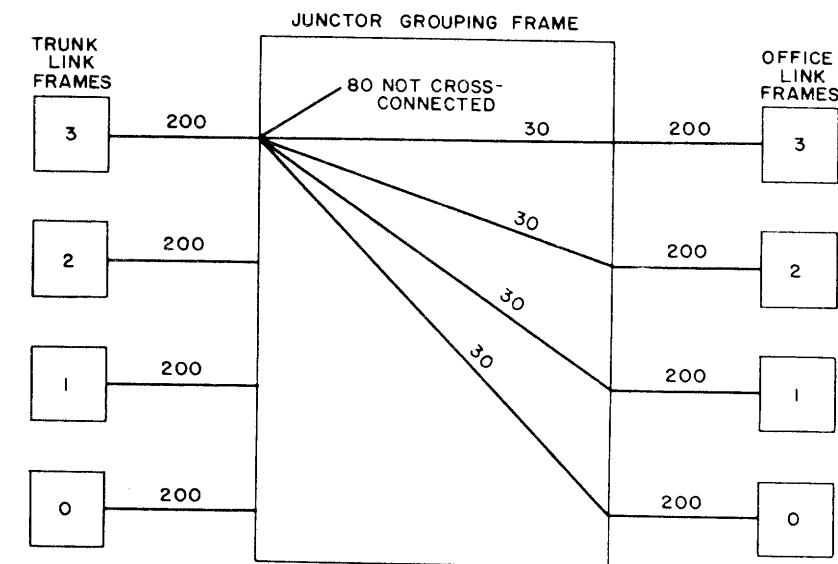


Figure 2-18a Junctor Groups - 4-4 Size Office

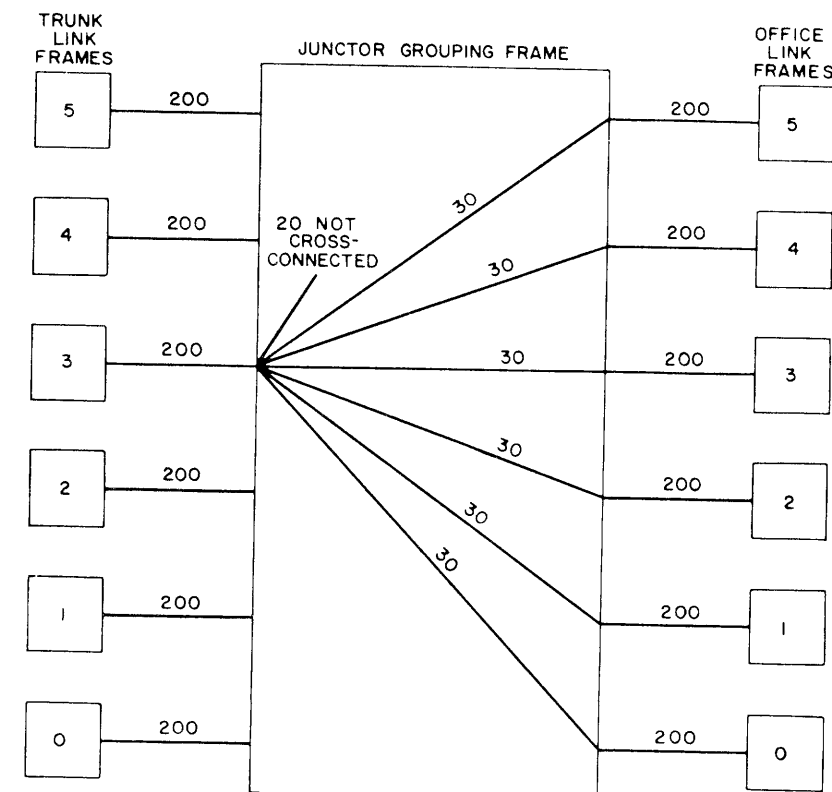


Figure 2-18b Junctor Groups - 6-6 Size Office (Initially 4-4 Size)

The ten horizontals of each secondary switch are cabled to ten senders of one kind or to ten senders of each of two kinds. These two kinds of senders may be revertive and dial pulse, revertive and multifrequency, dial pulse and multifrequency, or PCI arranged for AMA and multifrequency, etc. When there are two kinds of senders, the horizontal multiple strapping is cut at the point corresponding to the division between the links serving trunks requiring one kind of senders and those serving trunks requiring the other kind. Senders are treated in switch subgroups of five. Each switch subgroup of senders appears at secondary switch horizontals 0 to 4 or 5 to 9. Each group of four links has access to senders of one kind only. The multiples for the different kinds of senders are entirely independent of each other and each may appear on some frames to the exclusion of the other kind. The sender multiple for each kind of sender is arranged so that all sender subgroups have approximately the same number of appearances and are extended through the greatest possible number of frames.

#### 6. Senders

A sender is used to assist in the completion of a call through the tandem office. The sender receives and stores information required by other circuits and controls the selection in the tandem office of a trunk to the desired terminating office.

The sender receives from the originating office the called number and the calling number (when the tandem office is arranged for automatic number identification (ANI) operation).

The sender receives and registers from the sender link frame, the trunk link frame number which serves the trunk, the trunk class mark, trunk data group number, rate class, if any, and other information required to complete the call.

After the sender registers the office or area and office codes, it connects through a marker connector to the marker. It transmits information to the marker and receives from the marker information that is required to complete the call.

There are four types of senders and sender frames available, namely: revertive, PCI, dial, and multifrequency pulse. The pulsing used in transmitting the called number from the originating office to the tandem sender indicates the type of sender.

The revertive pulse sender frame has a capacity of five revertive senders. This sender functions with trunks incoming from panel or crossbar offices that control the routing of the call partly or wholly on a revertive pulsing basis. It is used to complete calls to panel, crossbar, step-by-step, and manual offices.

The revertive sender is arranged to register seven digits and to complete calls by revertive pulsing, dial pulsing (4, 5 or 6 digits), and on a straightforward basis. PCI calls are completed by closing a circuit for the direct transmission of PCI pulses from the originating office over the tandem completing trunk.

The PCI, dial, and multifrequency pulse senders are arranged for AMA, but will also handle non-AMA calls. They are able to register and out-pulse a greater number of digits than the revertive sender and to complete calls by revertive, PCI, dial, and multifrequency pulsing and on a straightforward basis.

The PCI sender frame has a capacity of three PCI senders. This sender is used in the completion through tandem of calls dialed by subscribers in panel and crossbar offices. PCI pulsing into the tandem office is used to obtain greater code capacity (640 as compared to 300 for revertive) and to permit outpulsing of party letters from the local office. It is arranged to register eight digits and to outpulse four to eight digits on a dial or multifrequency basis. The digits may be four or five numerals or four numerals and a party letter preceded, if desired, by 1-, 2-, or 3-code digits. The code digits may be transmitted as registered or converted to any other values by translation from the marker.



The dial pulse sender frame and the multifrequency pulse sender frame have a capacity of four dial pulse senders and four multifrequency pulse senders respectively. The dial pulse sender is used in the completion through tandem of calls from step-by-step subscribers, from manual, DSA and toll switchboards equipped with dials, from other senders arranged for dial pulsing. The multifrequency pulse sender is used in the completion through tandem of calls from senders arranged to transmit multifrequency pulses and from manual, DSA, and toll switchboards equipped for multifrequency keypulsing. These senders will accept three to eleven digits and will output one to eleven digits. The outputted digits may be as registered, 1, 2, or 3 digits prefixed to the registered digits to be outputted, the first three digits changed and on area calls, the first three registered digits may be deleted and the next three digits code converted.

The dial pulse sender is arranged for bylink operation to avoid second dial tone to step-by-step subscribers. With this feature, the first three digits following the directing code are registered in an incoming register which is connected to the tandem incoming trunk by the incoming register link. Subsequent digits are dialed directly into the sender. The digits in the register are transferred to the sender through a sender register connector.

The association of trunk, trunk link, and sender link frames is by direct cabling. The 160-trunk capacity of the basic trunk link frame is accommodated on ten primary switches. The added 160 trunk capacity of the trunk link extension frame is accommodated on ten primary switches. Each switch accommodates 16 trunks in pairs on eight levels. The other two levels are used for discriminating purposes to serve the proper one of a pair of trunks involved in a given call. A group of ten trunks is considered to be of one type from the standpoint of sender requirements and code grouping as well as circuit features. It is cabled to appear as a primary switch group of ten trunks on the sender link frame. It is served, therefore, by that one type of sender to which

it can give but one indication as to the associated trunk link frame number and code group. Because of this, trunks may have traffic characteristics differing in general between decades or groups of a maximum of ten trunks. These groups are cabled to the trunk link frames in such quantities that each frame serves trunks of varying characteristics in approximately the same proportion. To carry this plan of load distribution still further, the ten trunks of each group are terminated one in each of ten primary switches of the trunk link frame. Since the trunk link frame gives the marker indication by primary switch levels of certain characteristics of the associated trunks, it is necessary that both trunks on each level be of the same type in this regard.

#### 7. Multifrequency Current Supply

When senders are arranged for multifrequency outputting, multifrequency current supply equipment is required. This frame consists of two 6-frequency oscillator units, an alarm and transfer unit, distributing resistance panels, and miscellaneous equipment.

#### 8. Marker Connector

The function of a marker connector is to connect a sender to an idle marker for the selection of a trunk to the proper destination and for information necessary for completing the call.

The dial pulse and multifrequency senders transmit to the marker on certain leads on a two-out-of-five digits basis. The revertive and PCI senders transmit to the marker on certain leads on a two-out-of-seven digits basis. These different systems of transmitting to the marker result in these leads in the marker multiple differing in designation and use at the marker. Multifrequency senders, for example, when not arranged for foreign area translation, transmit to the marker on certain leads on a two-out-of-seven basis and on a two-out-of-five basis when arranged for foreign area translation.

### 9. Marker

In completing a call through a crossbar tandem office the marker is used to decode the office or area code, to select and test the corresponding outgoing trunk group and channels thereto, to set up information in the sender for handling the call, and to operate the proper select and hold magnets on the trunk and office link frames to connect the incoming trunk to the selected outgoing trunk. Calls may originate in step-by-step, crossbar, and panel offices, private branch exchanges, and at dialing and keypulsing switchboards. They may be completed to panel, crossbar, step-by-step, and manual call indicator offices, to private branch exchanges, and to official codes; they may be extended to panel sender, crossbar, step-by-step, and manual call indicator tandem offices, and to panel distant office equipment. Operator calls may be extended to manual straightforward positions.

In processing a call involving an area code or PBX indialing, the marker receives six digits. The first three digits are decoded and used to cause a translator to be connected to the marker. The translator registers and decodes the second three digits and causes an FAC code point in the marker to be grounded.

Routing information is obtained from two wires threaded through rings in a ring field consisting of nine horizontal rows of rings, each row containing from three to seven rings. Part of the routing information is stored by threading a wire connected to a code point through one or two rings in each row, as required, to a first string firing circuit terminal. The remainder of the routing information is stored by threading a second wire from a related second string terminal through one of two rings in each row, as required, to a second string firing circuit terminal. When the code point is grounded, a surge is sent through the first wire; a voltage is induced in every coil through which the wire is threaded, firing associated tubes which operate associated relays. The output of these relays are registered and the tubes and associated relays released. The

related second string terminal is then grounded and the second string firing circuit sends a surge through the second wire which induces a voltage in every coil through which the wire is threaded, firing associated tubes which operate associated relays. The output of these relays is registered and completes the route information for the particular code point.

The marker frame consists of a single-bay marker control unit and a double-bay marker route unit shown in Figure 2-19.

### 10. Translator

The translator frame, is a single-bay frame used in conjunction with the marker to provide for 6-digit translation for a maximum of five foreign areas with 60 routes for each area. Its use provides for selecting the best route to a particular office in a foreign area where there are several routes by which the tandem office can reach the foreign area. It is also used for selecting a particular PBX when several share a 3-digit code.

### 11. Trunks

The trunk frames accommodate the numerous trunks used to provide incoming calls access to crossbar tandem switching equipment elements. The trunk frames are single-bay structures accommodating either 23-inch mounting plate units or 30-1/2 inch mounting plate units. The frames have capacities of 10, 20, 30, 40 or 60 trunks depending on the apparatus involved. Trunks are grouped in decades of one to ten trunks numbered 00 to 09, 10 to 19, etc. or 50 to 59 on the trunk frames. The trunks in a decade have certain common requirements and are handled on a decade basis at the various trunk appearances. At the trunk link frame, each trunk decade (00 to 09, 10 to 19) is connected at the trunk link frame so as to contribute one trunk to each of the ten primary switches on the frame. Each primary switch accommodates a maximum of sixteen trunks, two on each level from 2 to 9. Trunks 00 to 09 will normally appear as the first of the trunks on a level and

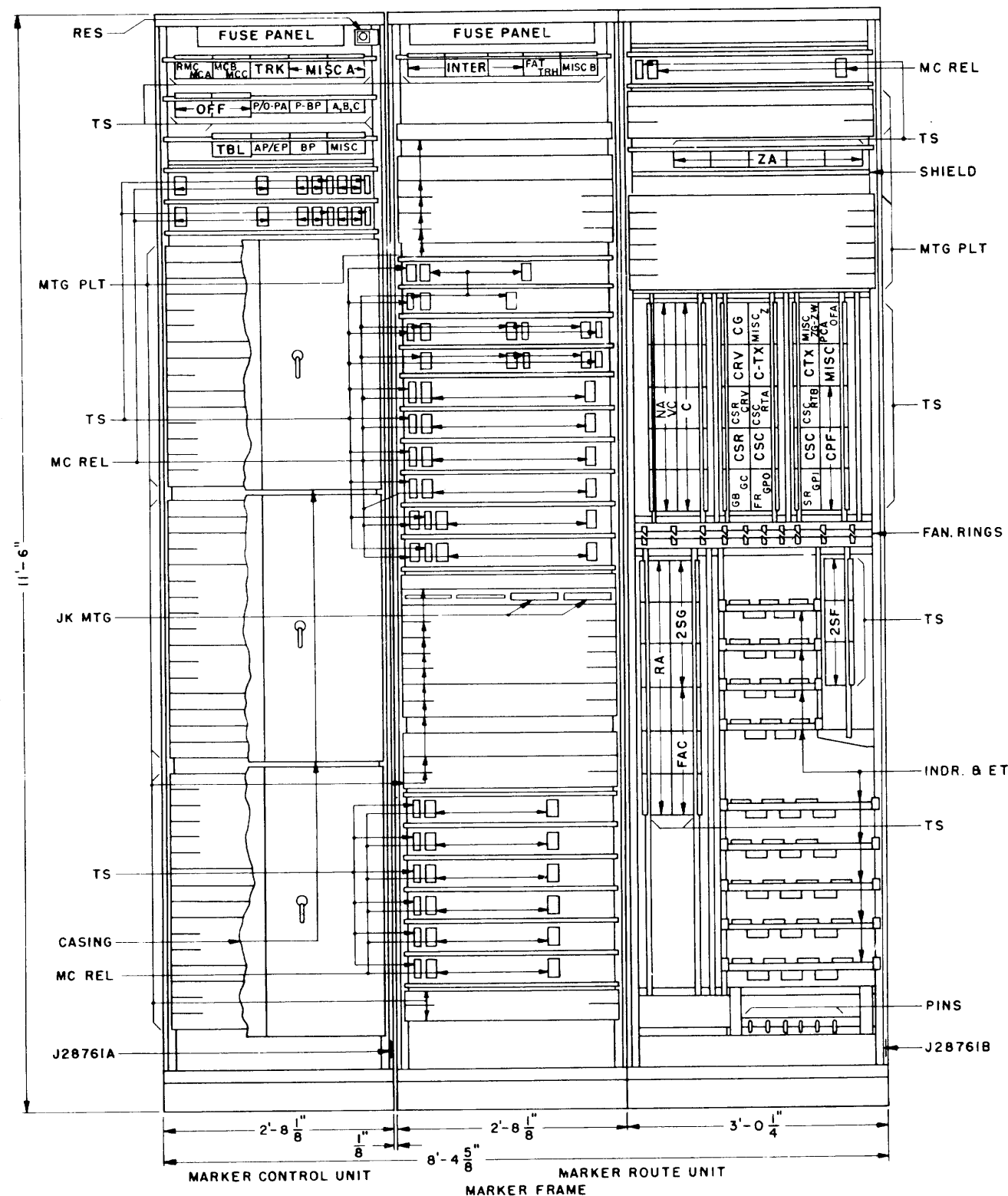


Figure 2-19 - Marker Frame

trunks 10 to 19 as the second. The trunk numbering consequently indicates by the units digit, 0 to 9, the trunk link primary switch on which it appears and by the tens digit, even or odd, the position on the level.

Trunk frames fall into four general categories, Non-AMA, AMA, 100B TSPS, and 2-way.

## 12. Non-AMA Trunks

The non-AMA trunk frames are remote-control zone registration, through supervision, repeater supervision, simplex or composite supervision, PCI pulsing, MF pulsing, and Extended Area Service, Loop or E&M.

Remote-control zone registration trunks are used for calls from panel offices arranged for remote-control zone registration. Charge pulses are sent to the originating office according to the rate cross connections in the trunk and the duration of the call. In the case of 2-rate trunks, the marker determines whether the lower or higher rate is effective.

Reserve trunks are provided to handle calls for remote-control zone registration trunks which are under routine test. They are automatically substituted for any associated service trunk under test and are arranged to assume, automatically, the particular rate schedule of the trunk for which they may be substituted at the time.

The through supervision trunks are used in completing calls from No. 1 Crossbar or panel offices.

The repeated supervision trunks are used on calls involving revertive, dial or multifrequency pulsing from crossbar, panel, step-by-step, and No. 4 type offices, and from operators.

The simplex or composite supervision trunks are used on dial pulsing or multifrequency pulsing calls from local or toll offices and may be arranged to rering forward with a simplex ringing signal.

The PCI pulsing trunks are used with PCI senders in completing calls from panel, No. 1, and No. 5 Crossbar offices on a non-AMA basis.

The MF pulsing trunks are used on calls from a toll switchboard in the same or adjacent building.

The Extended Area Service (EAS) trunk accommodates E&M or loop lead supervision trunks, arranged for dial pulsing and convertible to MF pulsing.

### 13. AMA Trunks

The AMA trunk frames are of three types PCI, dial pulsing, and multifrequency pulsing accommodating 30, 20 and 20 incoming trunks, respectively, and the common relay interrupter and miscellaneous equipment. These trunks are used on calls from subscribers in panel, step-by-step, and crossbar offices and control the recording of the call by the associated AMA equipment.

An AMA trunk functions the same as a non-AMA trunk in establishing a connection through the trunk and office link frames to an outgoing trunk. On seizure, a sender arranged for AMA is attached through a sender link. In processing the call, the trunk identified itself to the recorder through the call identity indexer causing the trunk number to be perforated as part of the initial entry. After the call is answered, the trunk again calls in the recorder to perforate the trunk number with the answer time entry. By means of the trunk number the separated elements of the call are brought together in the accounting center for billing purposes.

When a call originates in a step-by-step office, a DP trunk is seized after a directing code is dialed by the subscriber. In the interdigital time between this directing code and the area or office code, the trunk causes a register link to seek an idle register and a sender link a sender. It is intended that a register be connected in the interdigital time and record

the three digits of the area or office code. The sender must be connected before these three digits are recorded in the register. When the register has recorded three digits, it signals the sender to record the remaining digits. Subsequently the area or office digits are transmitted to the sender through a sender register connector and the register disconnects. As soon as these digits are recorded in the sender, a marker is called in and the call is processed as for other trunks.

Special toll trunks cover the handling of calls such as person-to-person, reverse-charge, charge to third party, or credit card charge. The customer dials a directing digit followed by the called number. The directing digit directs the call to the tandem office over trunks associated with the traffic service position. On seizure, the trunk is connected to a tandem sender by way of its associated sender link and controller circuit. After the calling and called numbers are received by the sender, it signals the trunk circuit to connect to an idle operator's position through its associated switchboard link and connector circuit. The position requests the services of a data transfer circuit which connects to the trunk and sender circuits and transfers the call data to registers at the selected position. The operator is then connected to the transmission circuit for talking to the calling customer, while the sender calls a marker to set up a channel to the desired outgoing trunk. The trunk circuit assists in setting up this connection by identifying itself to the marker, closing the first crosspoints in the trunk link frame, and supplying means for maintaining the connection through the trunk and office links for duration of the call.

Recording-completing trunks provide service for customers who desire operator assistance. The customer dials an operator code and is routed to the tandem office over a recording completing trunk associated with the 100B traffic service position.

When a customer dials the operator code, a recording completing trunk in the tandem office is seized which causes a tandem sender to be connected. After ANI (Automatic Number Identification) information is recorded, the sender passes a position request signal to the trunk. After receiving the call details, the position enables conversation to take place between the calling customer and the operator.

The customer informs the operator of the called number and whether the call is person to person, station to station, station paid, collect, or special, and she then keys this information into her position register. When the position is reattached, the position calls in the data transfer circuit and the called number is passed from the position register through the data transfer circuit.

There are a few types of calls which the traffic service position operator will not complete. They are: overseas calls, marine operator calls, conference calls, mobile telephone calls, and sequence calls. In these cases, the operator initiates a transfer of the call. The trunk starts a trunk finder which causes a cord-type tollboard operator to take up the call. The 100B TSPS operator will be bridged on the transfer connection and will pass the call details. After this she releases her position, leaving the transfer connection under joint control of the calling customer and the cord-type toll switchboard operator.

Centralized dial coin trunks are furnished in a tandem office to permit the handling of calls dialed by coin subscribers. When the incoming coin trunk is seized at the tandem office, it connects to a sender through the sender link frame. From the sender link, the sender receives information identifying the trunk class and its data group number. The sender receives and registers the called number followed by the station paid start pulse consisting of 1500 and 1700 Hz. After this the sender requests ANI from the originating office. Following receipt of the ANI information, the sender signals the trunk to bid for a position which in turn bids

for a data transfer circuit. The data transfer circuit, when seized, closes through a number of transmitting and receiving leads between the sender, the trunk, the rater, and the position. The sender passes the called and calling number information as well as the station (1+) mark to the position. The sender passes to the rater the first six digits of the called number, a 7- or 10-digit mark, class of service, recorder number and the station mark. The rater also receives the office index from the trunk and combines this with the recorder number to determine the originating rate center from which the call came. From the above data, the rater determines the rate treatment number which is used by the computer to indicate the charges for the duration of the initial and overtime periods. In addition, the rater determines the duration of the initial period to set the trunk timer for the initial period. Should the call be to a vacant code, the sender requests the marker to set up the call to a VACANT CODE announcement. Should the call be to a point which cannot be rated automatically, it must be manually rated by the operator.

#### 14. Traffic Usage Recorder

The traffic usage recorder frame is used to measure usage of various circuits by scanning on a 100-second cycle and recording busies on traffic registers. The crossbar switches are divided into scan and register switches which provide for scanning a maximum of 3600 circuits and provide access to a maximum of 1200 traffic usage registers. Circuits having holding times over 10 seconds are given one scan switch appearance and the 100-second scanning rate provides accurate hourly measurements in terms of hundred call seconds (CCS). Circuits having holding times of 10 seconds or less are given ten equally spaced appearances on the switches and are scanned at a 10-second rate to obtain the desired accuracy.

The traffic usage recorder equipment also controls the cameras used to photograph traffic usage registers or regular traffic registers. The traffic register equipment provides for

obtaining traffic data, such as overflow, group busy, peg count, load and usage. A single-sided distributing frame is furnished adjacent to the traffic registers for terminating the many leads from the connecting circuits and for flexibility of cross connections between the traffic registers and the connecting circuits.

#### 15. Service Observing

Multiline service observing equipment for incoming trunks provide for service observing at a No. 12 service observing desk in the same or another building. This equipment consists of small surface-wired units and patching facilities mounted in relay rack bays. Each multiline service observing circuit has a maximum of 50 loop connectors arranged for patching to the relay-rack appearance of the trunks to be observed.

#### 16. Floor Alarms

The floor alarm unit accommodates the alarm relay equipment for a variable number of frames and aisles of equipment distributed over a maximum of two floors. It provides audible and visual signals under trouble conditions and supplements the alarms appearing on the individual frames. The audible signals by means of distinctive tones indicate the type of alarm. The visual signals in the form of floor and aisle pilots using differently colored lamps indicate the general nature and location of the trouble. The alarms may be transmitted to an alarm receiving center by means of alarm sending and transfer equipment when unattended operation of the tandem office is required.

#### 17. Power

The power requirements for crossbar tandem offices are similar to local No. 1 Crossbar offices and the same power plants may be used if available. For a new office a 302A plant for 24 and 48 volts is used. For zone registration trunk timers or master timers, a source of 22 volts ac is required. This is supplied from a relay rack mounted 506A power plant unit. A

504B plant is required to furnish 115-volt, 60-cycle current from the office battery during commercial power failure or low voltage to the 506A power plant and to the perforator cabinet output reel motors. For zone registration charging pulses a 170-volt supply, tapped at 135 volts, is required. Various circuits require + 130 volts. This voltage is supplied by 405A or 410B power plants. Low tone and ringing are taken from an existing local office ringing plant. The 48-volt talking battery required for some trunks is obtained through filters.

For a comprehensive look at the power plants mentioned above refer to "Telephone Power Plants," Chapter 18.

### C. SYSTEM MAINTENANCE

As in all switching systems a variety of test equipment form an integral and indispensable part of the system. Test frames detect and localize malfunctions and other circuit deficiencies in the system. Corrective action is then applied by the maintenance personnel.

#### 1. Incoming Trunk Test

The incoming trunk test frame, is a single bay of equipment used for testing the incoming trunks in the terminating office. It is associated with these trunks through the incoming trunk test connector frame and makes its tests automatically or repeatedly as desired. One frame has a basic capacity of 4000 trunks but may be arranged for an additional 4000 if required. A supplementary teletypewriter frame may also be provided for automatically printing records of transmission tests.

#### 2. Sender Test

The sender test frame, associated connector frame, the supplementary test frame, and the register test connector frame, provide for testing PCI, revertive pulse, multifrequency pulse and dial pulse senders, local CAMA operator positions, trunks to toll or DSA switchboards equipped for CAMA operation, incoming registers, and

transverters. Remote multifrequency pulsing positions are not tested by this test frame. The testing of outgoing trunks to remote positions and the operation of these positions is done at the manual outgoing trunk test frame.

### 3. Trouble Recorder and Connector Frames

The trouble recorder frame, the associated trouble recorder connector frame, are used to record automatically troubles encountered during the establishment of service and test calls. A record is made by punching holes in a card by means of a perforator. The record card is printed so that the information recorded can be read directly by a maintenance man.

### 4. Sender Make-busy

The sender make-busy frame, is a single-bay frame accommodating a jack field, registers, and relay equipment. The primary function of the sender make-busy frame is to provide sender make-busy jacks for use in removing any sender from service. Associated with these MB jacks are SS lamps which light to indicate as well as to identify stuck senders; SC lamps which light to indicate as well as to identify stuck senders involved in delayed assignments of PC1 calls and CP keys affording means of canceling the automatic priming feature of any stuck sender when it is desired to trace the trouble. There are sender subgroup make-busy jacks, jacks to reduce the timing intervals of the senders, a load register lamp per group of senders, and an alarm which operates when a predetermined number of sender subgroups become busy.

## D. CROSSBAR TANDEM SWITCHING TELEPHONE CALLS

The path of an ordinary telephone call requiring a 3-digit translation is illustrated in Figure 2-20. The sequence of connections are numbered to aid in tracing the path.

The call arrives in the tandem office over an incoming trunk and leaves over an outgoing trunk. The incoming trunk may be selected by an operator, a local office, a tandem office, or a dial toll office. The procedure in the tandem office is the same in any case.

As shown in Figure 2-20, each incoming trunk has two major appearances in a crossbar tandem office; one on the trunk link frame (used for the talking connection) and one on the sender link frame (used for passing information to the common control equipment). The trunks are arranged in decades on the sender link frame to permit the sender link to provide to the sender information which is common to ten trunks.

The sender link frame is the first of the trunk appearances to be used. It consists of two sets of crossbar switches, primary and secondary. The incoming trunks appear on the primary switches and the senders on the secondary.

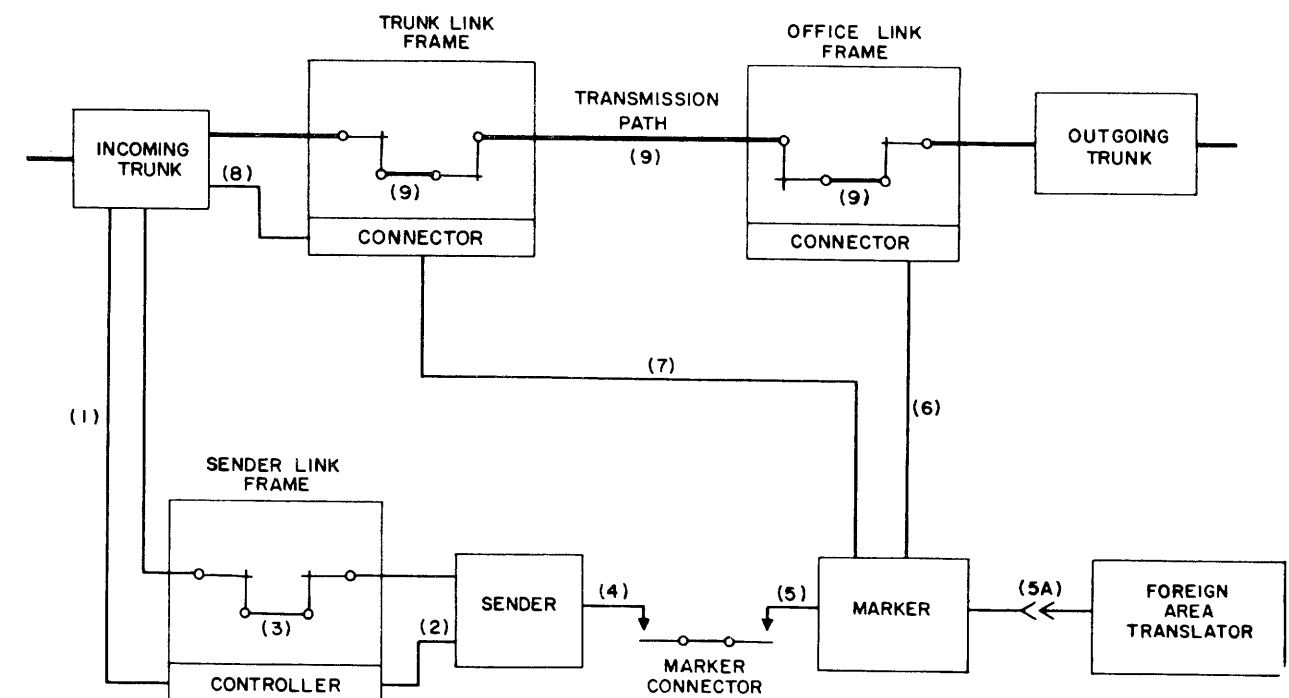


Figure 2-20 Path of a Call Through a Crossbar Tandem Office



As soon as an incoming trunk is seized, it signals a sender link controller (connection 1) to connect an idle sender for registering the incoming pulses. The sender link controller tests for and selects an idle sender (connection 2). The controller then sets up the connection through the crossbar switches of the sender link (connection 3). This completes the function of the sender link controller which releases from the connection and is free to serve other calls.

As soon as the sender is attached, it signals the originating operator or preceding office sender to begin pulsing. When three digits have been received, the sender signals the marker connector (connection 4) to seize an idle marker (connection 5).

The sender passes the first three digits (the code) to the marker along with the information derived from the decade arrangement on the sender link frame. The marker (1) decodes the information received from the sender, (2) operates one of its route relays from which it derives the information required for routing the call, and (3) passes the outputting instructions to the sender.

The marker then seizes the office link connector that has access to the pair of office link frames on which the outgoing trunk group is terminated (connection 6). As soon as it is connected to the pair of office link frames, the marker does two things simultaneously; (1) it seizes the trunk link connector that serves the trunk link frame on which the incoming trunk is terminated (connection 7) and (2) it starts testing for an idle outgoing trunk. (The marker knows the number of the trunk link frame from information stored in the sender which was obtained from cross-connections associated with the sender link decade arrangement.) The marker then instructs the incoming trunk through the sender to connect to the trunk link connector (connection 8), which in turn cuts through to the marker the test leads associated with the trunk links that serve the switch on which the incoming trunk is terminated.

When the pair of office link frames was seized, the marker also started testing for an idle outgoing trunk, as mentioned above. At this point, the marker signals the sender to release the marker connector which in turn releases the marker. This completes the first or decoding stage of the marker operation. The marker connection is now free to serve other calls. The marker may also serv

another call but only up to the point where the outputting instructions are passed to the sender. For the call in progress, the marker maintains a path to the sender via the trunk link connector, the incoming trunk, and the sender link (connections 7, 8 and 3).

When the outgoing trunk is seized and made busy, the trunk selection relay in the marker indicates whether the trunk is located on the even or odd office link frame. The marker then causes the trunk link frame to cut through the test leads associated with the junctors to that office link frame.

The office link frame cuts through to the marker the test leads associated with the office links serving the selected outgoing trunk.

The marker now has access to the test leads for the trunk links, junctors, and office links, and it proceeds to set up the connection from the incoming trunk to the outgoing trunk. It makes the channel test by testing groups of three leads simultaneously, selects one group, and then closes the crosspoints to establish the selected channel (connection 9). The marker signals the sender that the path has been established and then releases from the trunk link and office link frames.

The sender then sends a signal forward and upon receipt of a go signal it output pulses as it had been directed by the marker. After outputting is completed, the talking path is cut through. The sender and sender link then release and the call is under control of the incoming trunk.

When the incoming trunk receives a release signal from the calling end, it releases the switches through the office.

#### 1. Call Requiring 6-digit Translation

A call requiring 6-digit translation follows the same method of operation as described above for a call requiring 3-digit translation up to the point of marker seizure. Since this sender is arranged for 6-digit translation and the first



three digits of this call are of the form NOX/N1X<sup>1</sup>, the sender waits for six digits before calling in a marker.

The marker decodes the first three digits and operates an area relay rather than a route relay. The operation of this area relay causes the associated foreign area translator to be called in (connection 5A).

The fourth, fifth, and sixth digits are sent to the foreign area translator which translates them to one of 60 route indications. The marker uses this information to operate a route relay and the call is completed as described above.

## 2. Remote Control Zone Registration

The calls thus far described have involved no charging functions at the crossbar tandem. All charging was handled at the originating offices. Crossbar tandem can also handle calls where the message registers at the local office are controlled by signals from the crossbar tandem equipment. This is known as remote control zone registration.

Calls using remote control zone registration are handled by revertive pulsing trunks and senders. The trunks have options for various initial and overtime intervals and for various numbers of registrations for the initial and overtime periods. A trunk may be arranged for one or two rates. To indicate more than two rates, separate trunk groups to tandem must be used. Where a trunk is arranged for two rates, the marker examines the called code and determines which rate is to be applied.

## 3. Coin Zone Dialing with Local Office Operator Assistance

Crossbar tandem can also handle coin zone calls with the assistance operators located at the local originating office or in a near-by building.

<sup>1</sup>NOX/N1X Where area codes take this form

N = Any number from 2 to 9

X = Any number from 0 to 9

This type of call is dialed by a customer at a coin station and is routed to crossbar tandem by the local office. An operator is called in to request and monitor the initial deposit and to time the overtime on calls which exceed the initial period. The operator must also compute, request, and monitor overtime charges.

This arrangement is limited to a maximum of four charges per trunk group, and only traffic originating in panel and No. 1 Crossbar offices can be served.

This traffic is handled at crossbar tandem by PCI trunks and senders. The sender is arranged to delay outpulsing on these calls until it has received a go ahead signal from the operator.

## 4. Centrex Features

### a. Inward Dialing

The association of crossbar tandem and PBX's (Private Branch Exchange) is shown in Figure 2-21. It is possible to employ crossbar tandem to dial direct to PBX extensions where a central office code is shared by more than one PBX. This is accomplished by assigning to the PBX a number series within a central office code used for PBX purposes at the crossbar tandem, with each extension assigned a standard seven digit number. As many as sixty P.B.X.'s can share one central office code. The marker will recognize the shared office code and arrange for six-digit translation using the office code and first three digits of the extension number. This permits reservation of numbers in groups of ten, so that the entire number series is used most efficiently.

For P.B.X. indialing, six digit translation is required for local type codes that are assigned to more than one P.B.X. and on a non-shared basis when the number of digits to be outpulsed to that P.B.X. varies on different calls. For example, six-digit translation is required on nonshared codes when the tandem office does not outpulse any digits to reach

the P.B.X. attendant (access to the attendant is on a separate trunk group) and does out-pulse one to four digits to reach the extension. Two marker seizures are required on indialled calls requiring six-digit translation.

If a home area code plus an office code that is shared by several P.B.X.'s is received in the tandem, the marker sets up a connection to an appearance on the office link frame which is connected back through the office to the incoming trunk. This "loop around" operation causes the home area code to be deleted during the first connection through the office so that the call can be completed to the P.B.X. in the usual manner during the second connection. Three marker seizures are generally required for this type of call.

#### 5. Other Features of Crossbar Tandem

In addition to the major adjuncts to basic crossbar tandem, toll, CAMA and the Traffic Service Position, there are a number of other features or changes of significance, many of which have been added recently to the tandem switching system. Most do not involve extensive new equipment as such, but rather changes or additions to already existing equipment. Of note is the following, with some mention of the equipment area affected:

##### a. PBX In and Out Dialing

This feature promotes means for dialing to and from PBX extensions without calling in the PBX attendant. For indialing each extension is assigned a 7-digit number which may be dialed by any authorized customer on either a local or toll basis. The first three digits make use of an unused office code in the area and several PBX's can share these digits by assigning each a block in the 10,000 numbers.

For outdialing the extension will dial an exit code (usually "9"), receive second dial tone from crossbar tandem and then proceed with dialing on local, toll or assistance calls in the usual way. Charging is by message register on one message unit nonovertime calls and by CAMA on all others.

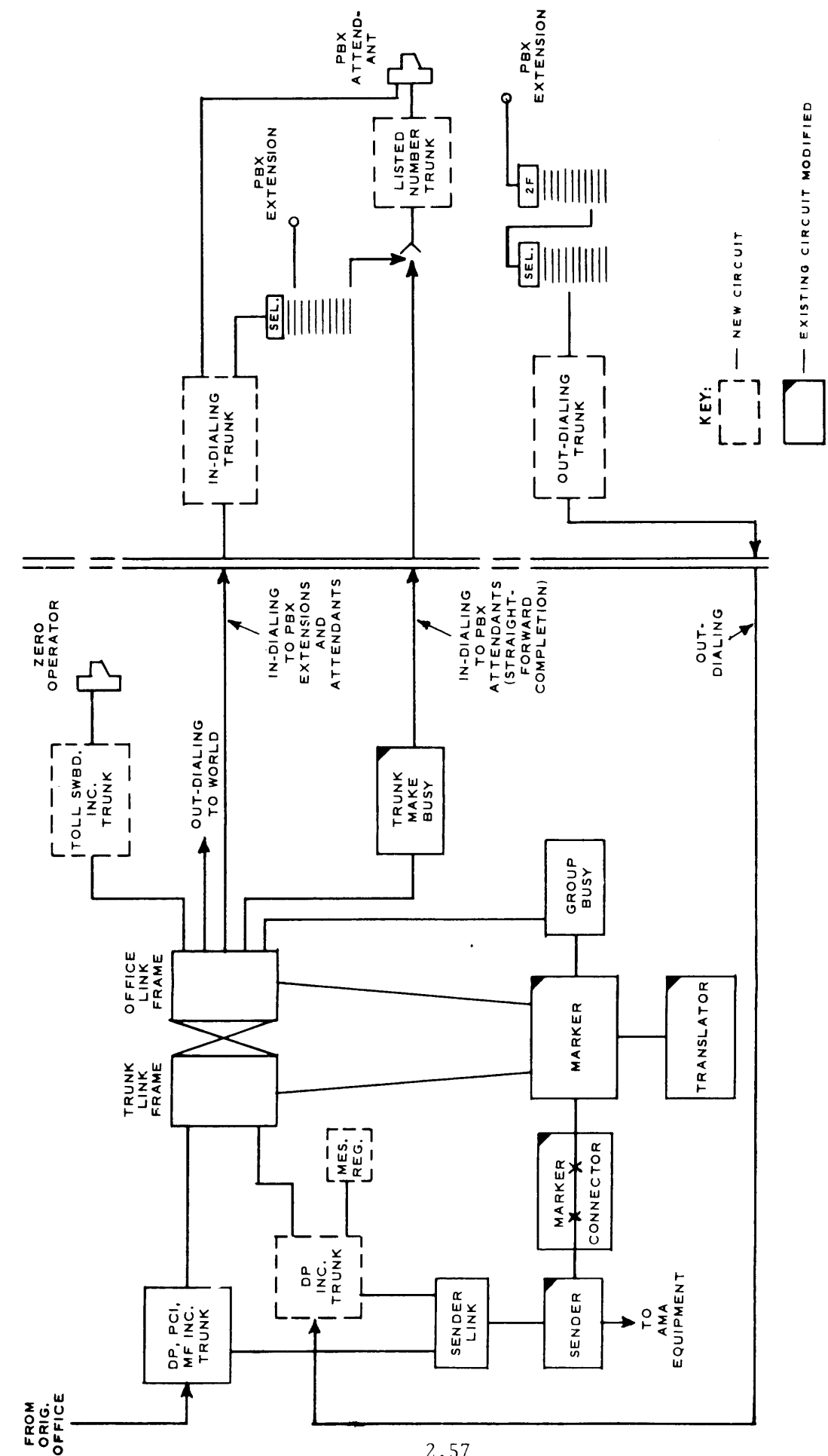


Figure 2-21 PBX In- and Out-Dialing Through Crossbar Tandem

E. CENTRALIZED AUTOMATIC MESSAGE ACCOUNTING

Centralized Automatic Message Accounting (CAMA) features have been introduced into the crossbar tandem system making it possible to provide the centralized facilities of AMA to all offices using the tandem office. Figure 2-22 depicts crossbar tandem with the first version of CAMA. A broader and more detailed description of CAMA is given in Vol. IV, Ch. 4. However, in a limited manner, it would be appropriate to add that when a crossbar tandem office is arranged for AMA, additional functions and frames are required to record data for billing purposes and to complete special calls with the aid of a traffic service position operator. Billing data is recorded as perforations on paper tape as are local offices arranged for AMA. The tapes are processed in accounting centers on the same machines used in processing local AMA tapes.

The elements of an AMA call recorded for billing purposes include the called and calling subscriber numbers, the time of answer, the time of disconnect, the called area, message billing index, and the trunk number.

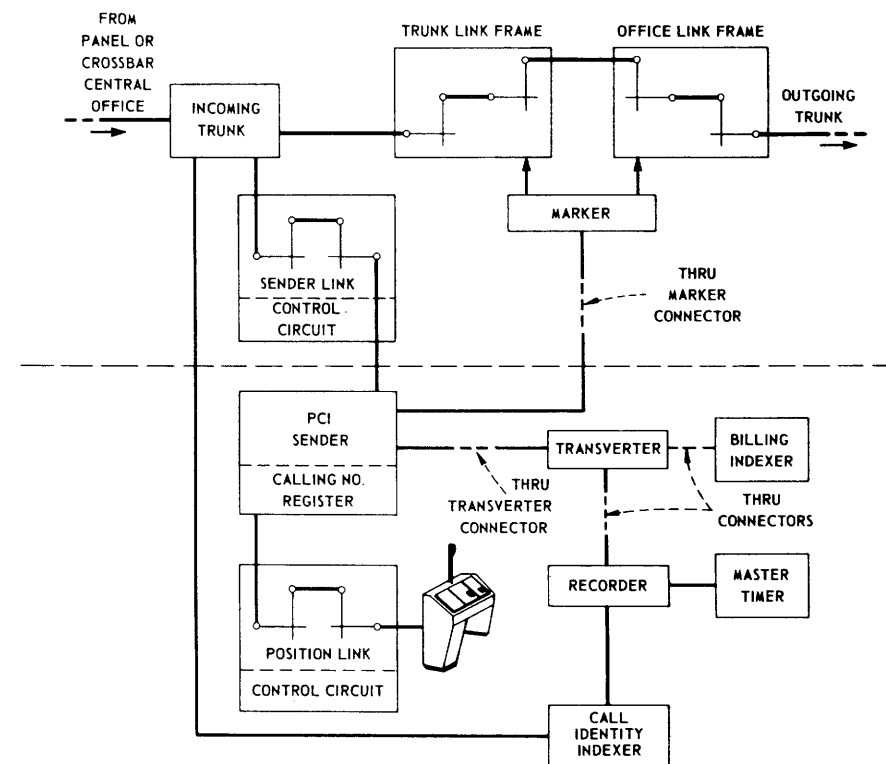


Figure 2-22 Functional block diagram of crossbar tandem with the first version of CAMA

On AMA calls, the calling number may be registered by an operator or by multifrequency pulsing from an originating local office arranged for automatic number identification. For operator identified calls, the sender causes the position link to connect the subscriber to an operator at the CAMA switchboard.

The AMA equipment consists primarily of a switchboard, perforators, position links, transverters, master timer, transverter connector, billing indexer, recorder, call identity indexer, 3-digit incoming register and link, sender register connector, 10-digit incoming register and link, data transfer, rater, timer link, and charge computer frames. The three digit incoming register and link (3-digit register) and its associated sender register connector are used in step-by-step areas to avoid second dial tone. The 10-digit incoming register and link equipment is also used in step-by-step areas; however, all digits are registered in the register and upon completion of dialing, this information is transmitted to the MF sender by way of the data transfer circuit.