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VOLUME II
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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.

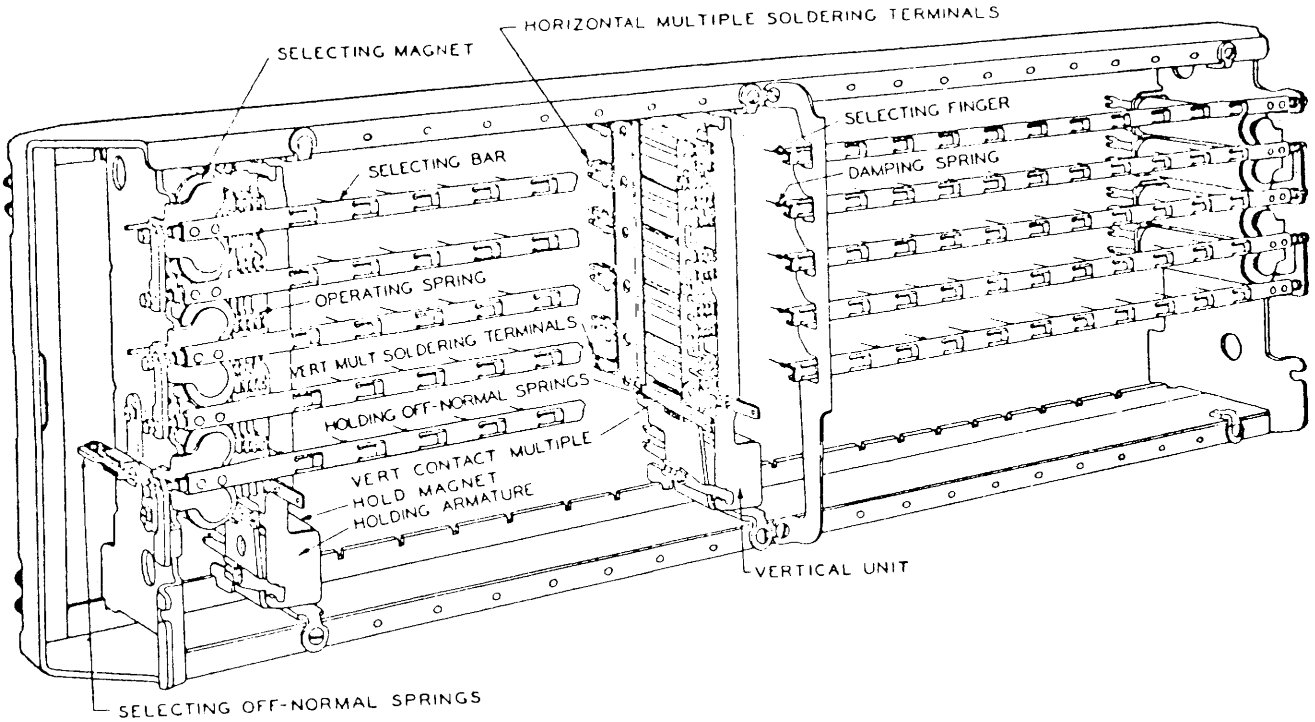

Figure 1-1 Partial Perspective View of a 200-Point Crossbar Switch - For 20 Vertical Units

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.

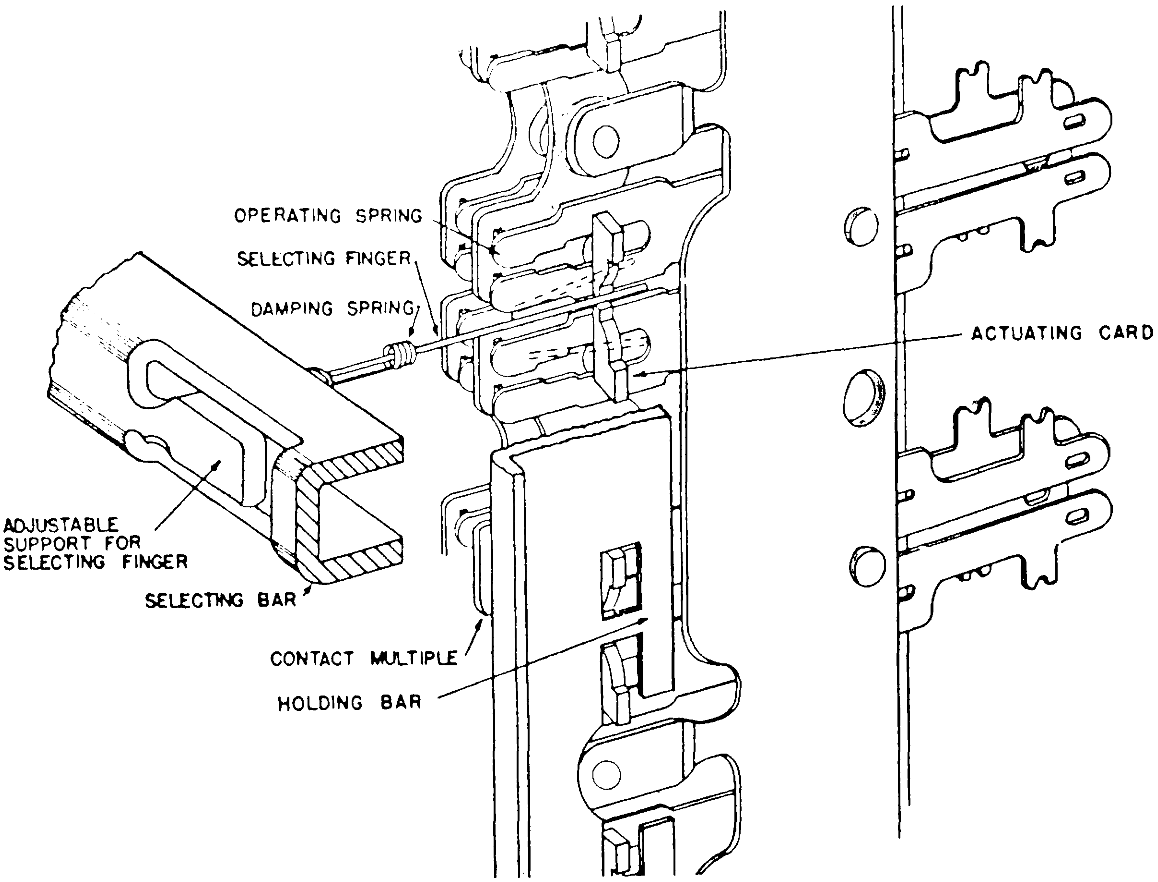

Figure 1-2 Crossbar Switch Selecting Mechanism

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.

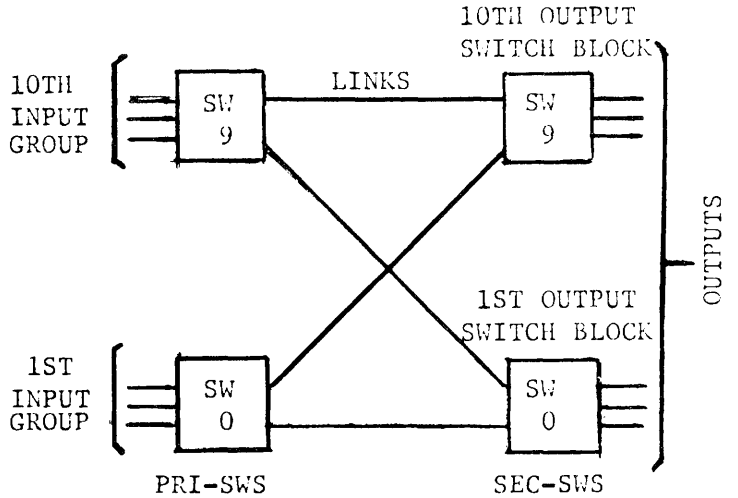

Figure 1-3 Two-Stage Grid Network

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.

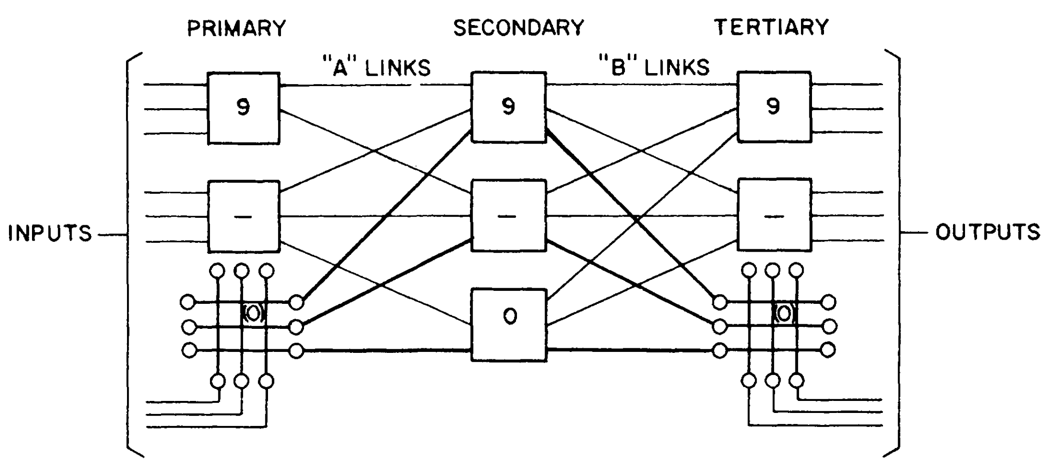

Figure 1-4 Three-Stage Switching Network

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.

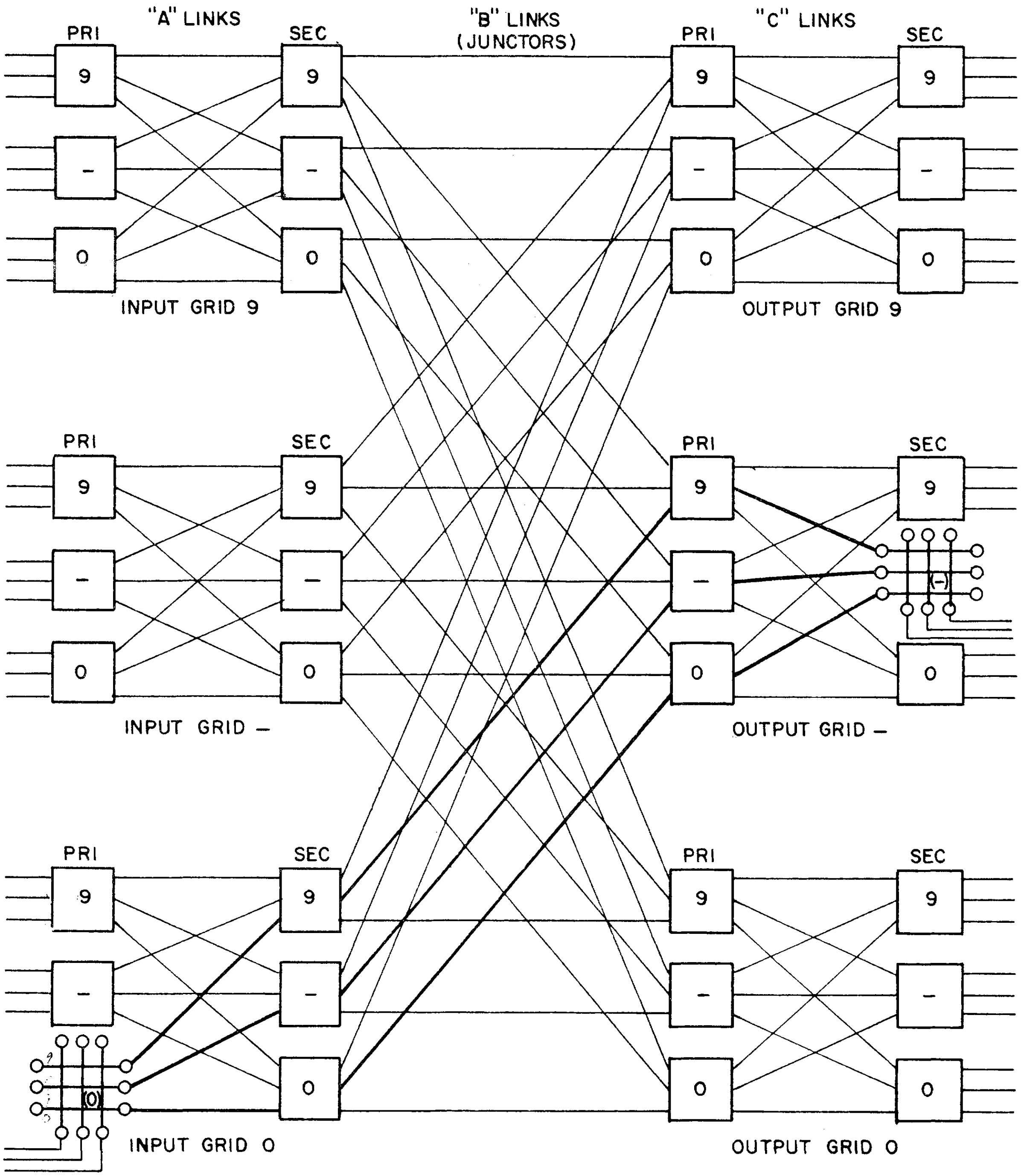

Figure 1-5 A Four-Stage Switching Network

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[1] 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

[1] 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.

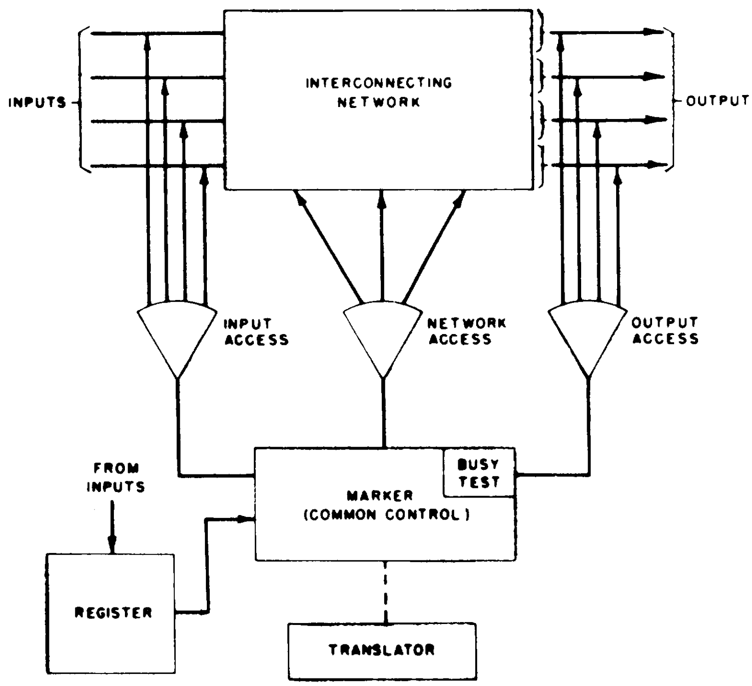

Figure 1-6 Generalization of Marker System

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.

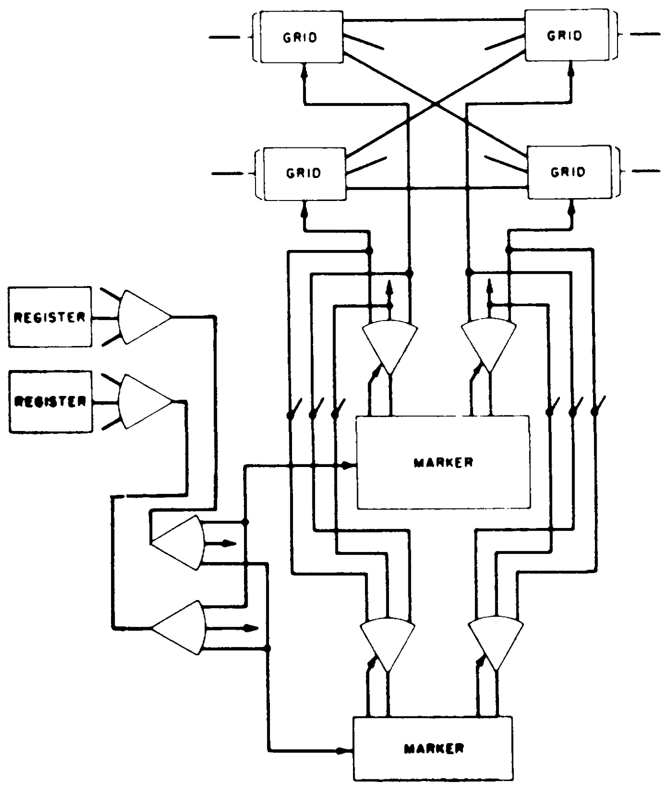

Figure 6-7 Several Markers Applied to a Network of Grids

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.

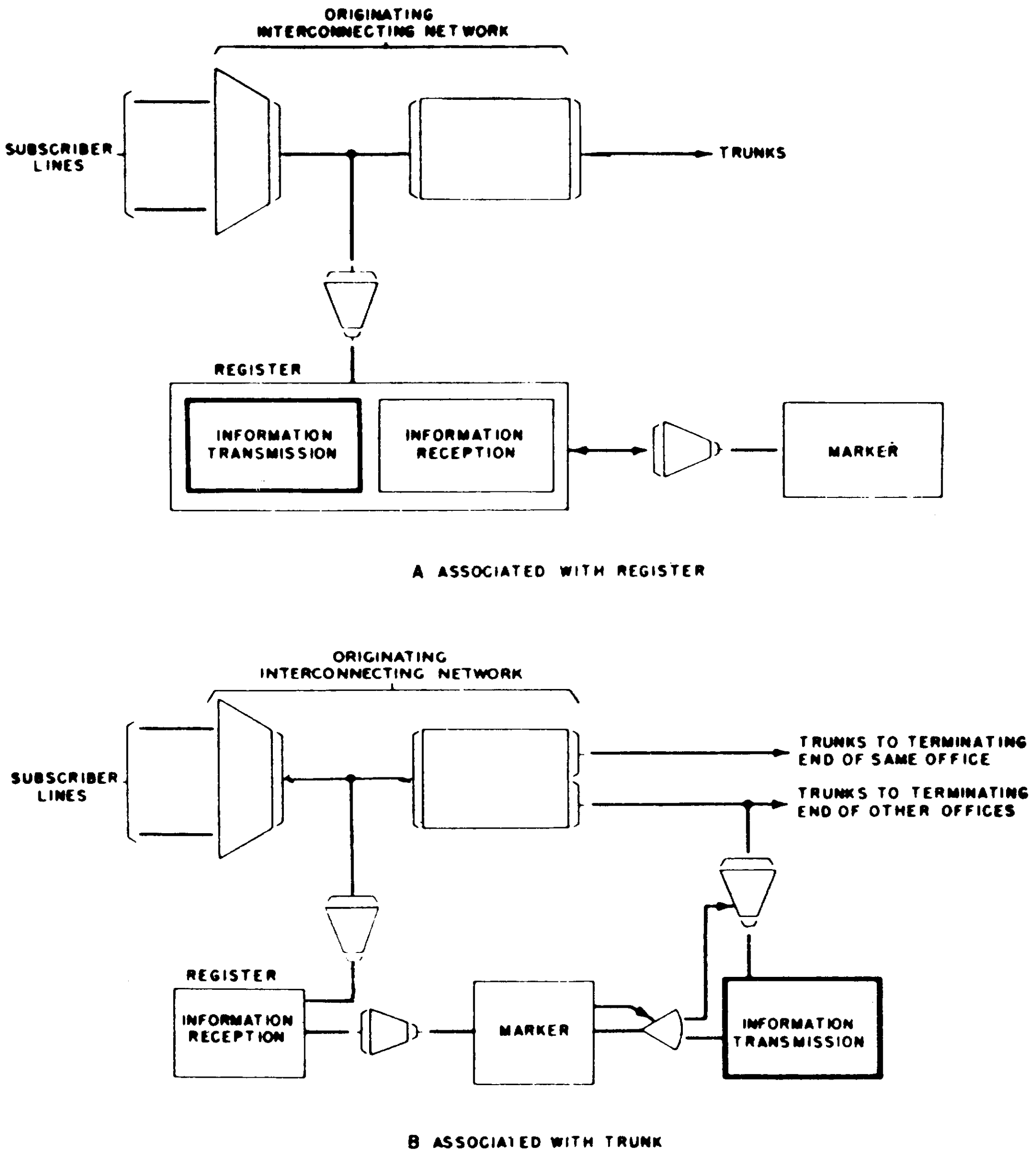

Figure 1-8 Location of Outpulsing Functions in Marker Systems

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.

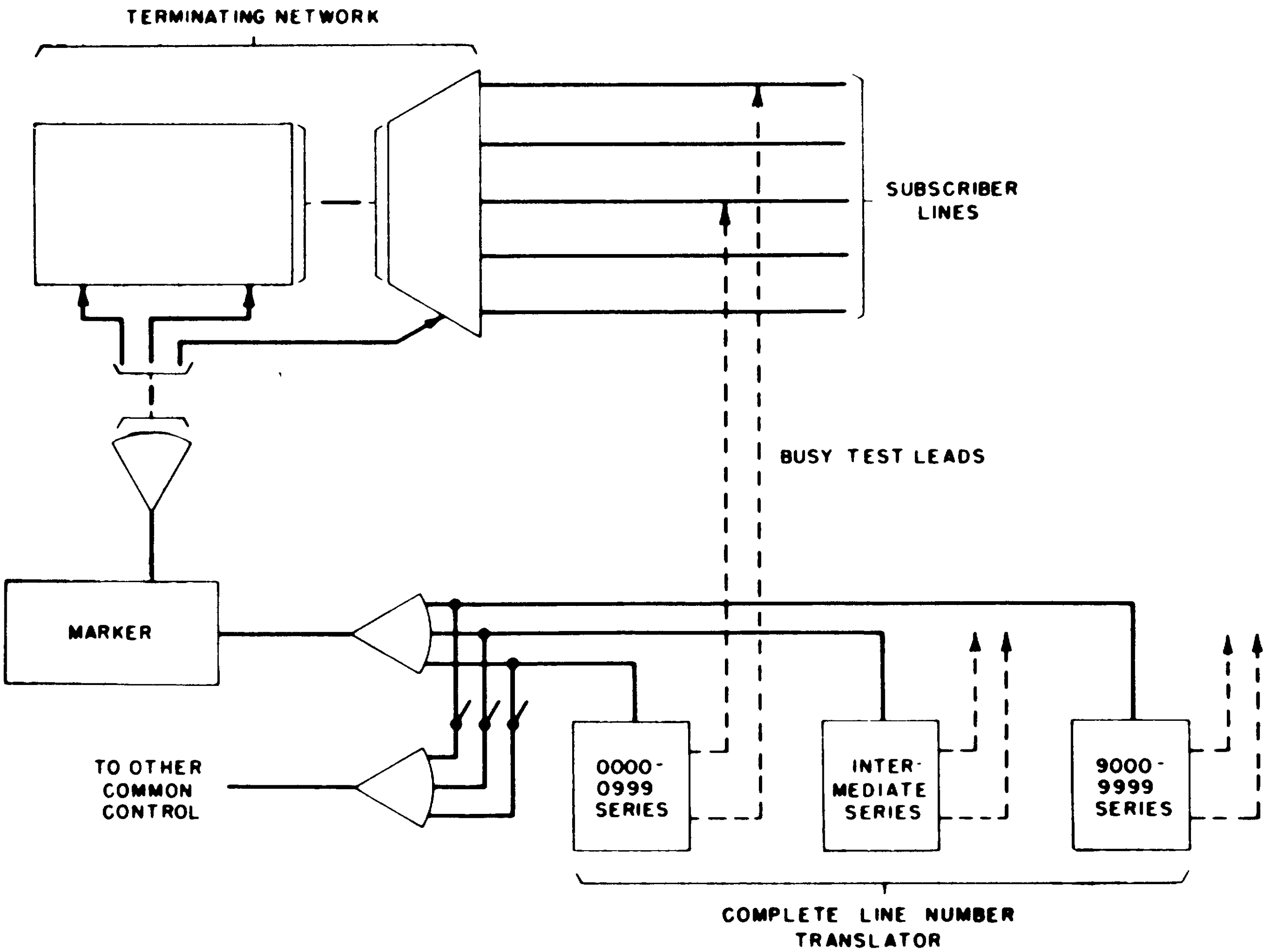

Figure 1-9 Number Translator in Marker Systems

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 familar 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.