Crossbar Tandem as a Long Distance Switching System

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Major toll switching features are being added to the crossbar tandem switching system for use at many of the important long distance switching centers of the nationwide network. These include automatic selection of one of several alternate routes to a particular destination, storing and sending forward digits as required, highly flexible code conversion for transmitting digits different from those received, and a translating arrangement to select the most direct route to a destination. The system is designed to serve both operator and customer dialed long distance traffic.

INTRODUCTION

The crossbar tandem switching system,[1] originally designed for switching between local dial offices, will now play an important role in nationwide dialing. New features are now available or are being developed that will permit this system to switch all types of traffic. As a result, crossbar tandem offices will have widespread use at many of the important switching centers of the nationwide switching network.

This paper briefly reviews the crossbar tandem switching system and its application for local switching, followed by discussion of the general aspects of the nationwide switching plan and of the major new features required to adapt crossbar tandem to this plan.

CROSSBAR TANDEM OFFICES USED FOR LOCAL SWITCHING

Crossbar tandem offices are now used in many of the large metropolitan areas throughout the country for interconnecting all types of local dial offices. In these applications they perform three major functions. Basically, they permit economies in trunking by combining small amounts of

traffic to and from the local offices into larger amounts for routing over common trunk groups to gain increased efficiency resulting in fewer over-all trunks.

A second important function is to permit handling calls economically between different types of local offices which are not compatible from the standpoint of intercommunication by direct pulsing. Crossbar tandem offices serve to connect these offices and to supply the conversion from one type of pulsing to another where such incompatibilities exist.

The third major function is that of centralization of equipment or services. For example, centralization of expensive charging equipment at a crossbar tandem office results in efficient use of such equipment and over-all lower cost as compared with furnishing this equipment at each local office requiring it. Examples of such equipment are remote control of zone registration and centralized automatic message accounting.[2] Centralization of other services such as weather bureau, time-of-day and similar services can be furnished.

The first crossbar tandem offices were installed in 1941 in New York, Detroit and San Francisco. These offices were equipped to interconnect local panel and No. 1 crossbar central offices in the metropolitan areas, and to complete calls to manual central offices in the same areas. The war years slowed both development and production and it was not until the late 40's that many features now in use were placed in service. These later features enable customers in step-by-step local central offices on the fringes of the metropolitan areas to interconnect on a direct dialing basis with metropolitan area customers in panel, crossbar, manual and step-by-step central offices. This same development also permitted central offices in strictly step-by-step areas to be interconnected by a crossbar tandem office where direct interconnecting was not economical. Facilities were also made available in the crossbar tandem system for completing calls from switchboards where operators use dials or multifrequency key pulsing sets.

Since a crossbar tandem office usually has access to all of the local offices in the area in which it is installed, it is attractive for handling short and long haul terminating traffic. The addition of toll terminal equipment at Gotham Tandem in New York City in 1947 permitted operators in New York State and northern New Jersey as well as distant operators to dial or key pulse directly into the tandem equipment for completion of calls to approximately 350 central offices in the New York metropolitan area. This method of completing these calls without the aid of the inward operators was a major advance in using tandem switching equipment for speeding completion of out-of-town calls.

CROSSBAR TANDEM SWITCHING ARRANGEMENT

The connections in a crossbar tandem office are established through crossbar switches mounted on incoming trunk link and outgoing office link frames shown on Fig. 1. The connections set up through these switches are controlled by equipment common to the crossbar tandem office which is held only long enough to set up each individual connection. Senders and markers are the major common control circuits.

The sender's function is to register the digits of the called number, transmit the called office code to the marker and then, as subsequently directed by the marker, control the outpulsing to the next office.

The marker's function is to receive the code digits from the sender for translation, return information to the sender concerning the details of the call, select an idle outgoing trunk to the called destination and close the transmission path through the crossbar switches from the incoming to the outgoing trunk.

GENERAL ASPECTS OF NATIONWIDE DIALING

Operator distance dialing, now used extensively throughout the country, as well as customer direct distance dialing are based on the division of the United States and Canada into numbering plan areas, interconnected by a national network through some 225 Control Switching Points (CSP's) equipped with automatic toll switching systems.

An essential element of the nationwide dialing program is a universal numbering plan[3] wherein each customer will have a distinctive number which does not conflict with the number of any other customer. The method employed is to divide the United States and Canada geographi-

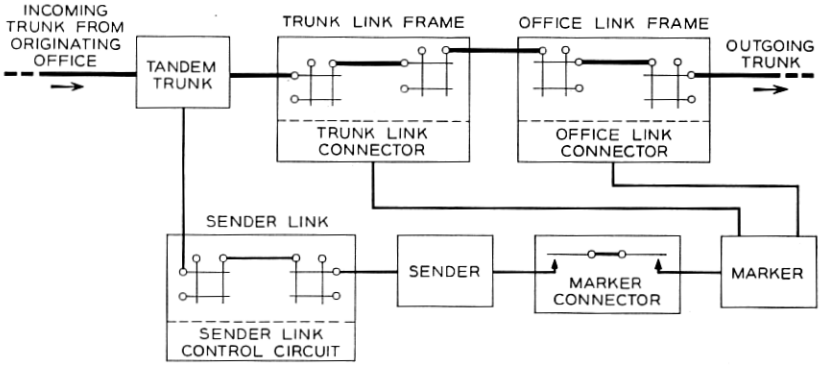

Fig. 1 — Crossbar tandem switching arrangement.

cally into more than 100 numbering plan areas and to give each of these a distinctive three digit code with either a 1 or 0 as the middle digit. Each numbering plan area will contain 500 or fewer local central offices each of which will be assigned a distinctive three-digit office code. Thus each of the telephones in the United States and Canada will have, for distance dialing purposes, a distinct identity consisting of a three digit area code, an office code of two letters and a numeral, and a station number of four digits. Under this plan, a customer will dial 7 digits to reach another customer in the same numbering area and 10 digits to reach a customer in a different numbering area.

A further requirement for nationwide dialing of long distance calls is a fundamental plan[4] for automatic toll switching. The plan provides a systematic method of interconnecting all the local central offices and toll switching centers in the United States and Canada. As shown on Fig. 2, several local central offices or "end offices" are served by a single toll center or toll point that has trunks to a "home" primary center which serves a group of toll centers. Each primary center, has trunks to a "home" sectional center which serves a larger area of the country. Similarly, the entire toll dialing territory is divided into eleven very large areas called regions, each having a regional center to serve all the sectional centers in the region. One of the regional centers, probably St. Louis, Missouri, will be designated the national center. The homing arrangements are such that it is not necessary for end offices, toll centers, toll points and primary centers to home on the next higher ranking office since the complete final route chain is not necessary. For example, end offices may be served directly from any of the higher ranking switching centers also shown in Fig. 2.

Collectively, the national center, the regional centers, the sectional centers and the primary centers will constitute the control switching points for nationwide dialing. The basic switching centers and homing arrangements are illustrated in Fig. 3.

TANDEM CROSSBAR FEATURES FOR NATIONWIDE DIALING

The broad objective in developing new features for crossbar tandem is to provide a toll switching system that can be used in cities where the large capacity and the full versatility of the No. 4 toll crossbar switching system[5] may not be economical.

The application of crossbar tandem two-wire switching systems at primary and sectional centers has been made possible by the extended use of high speed carrier systems. The echoes at the 2-wire crossbar tandem switching offices can be effectively reduced by providing a high

office balance and by the use of impedance compensators and fixed pads. A well balanced two-wire switching system, proper assignment of intertoll trunk losses, and the use of carrier circuits with high speed of propagation will permit through switching with little or no impairment from an echo standpoint.

The new features for crossbar tandem will provide arrangements necessary for operation at control switching points (CSP's). These include automatic alternate routing, the ability to store and send forward

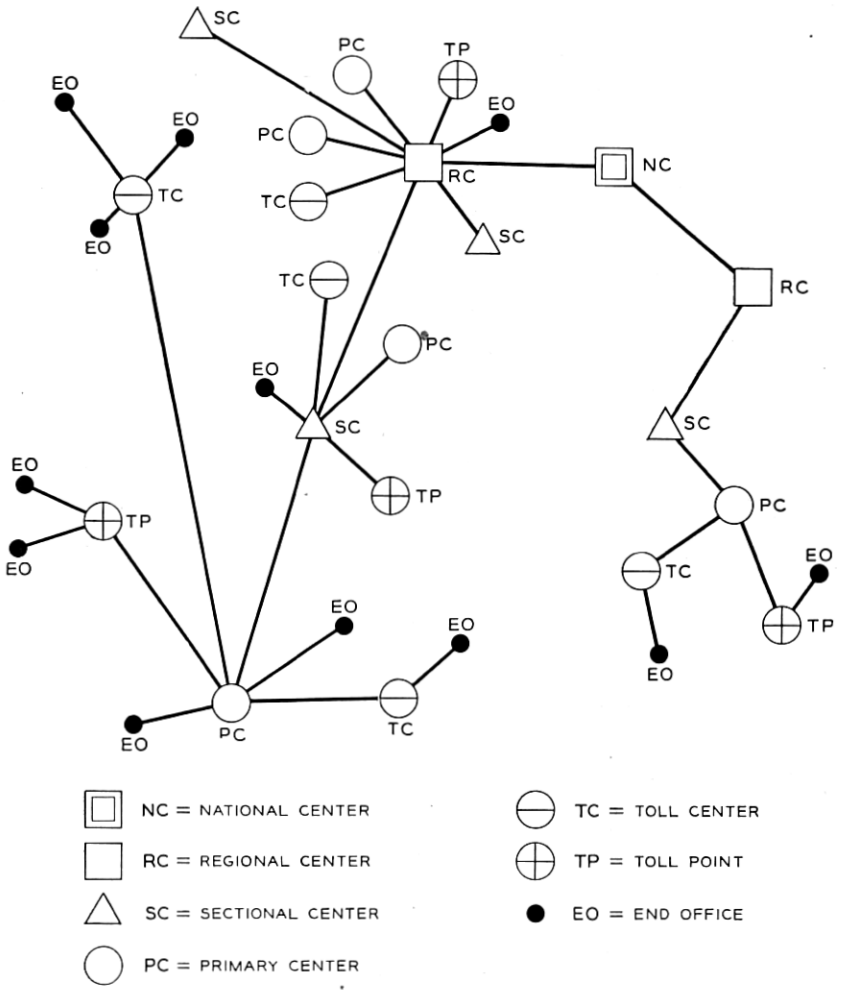

Fig. 2 — Homing arrangement for local central offices and toll centers.

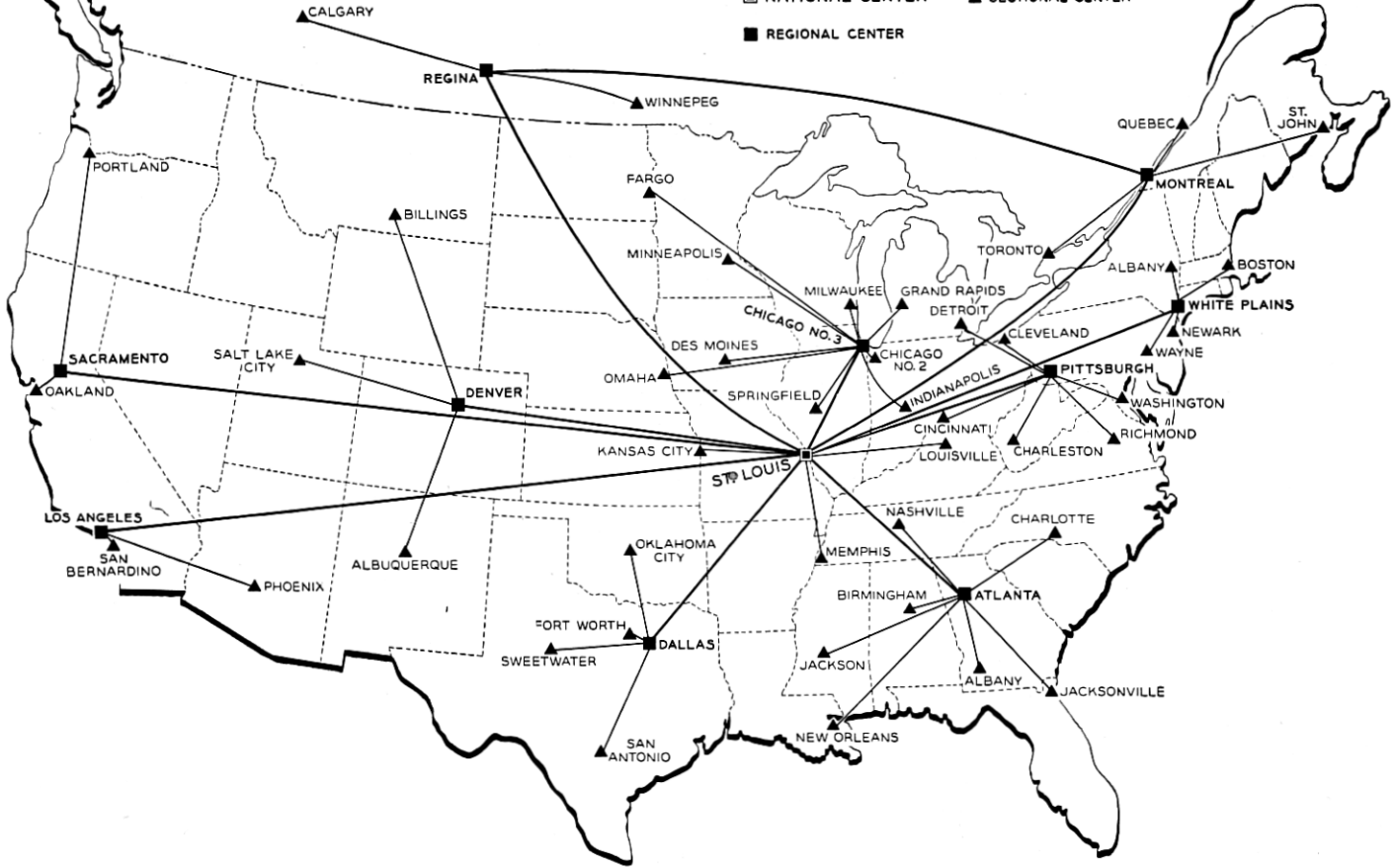

Fig. 3 — Today's vi[illegible] of the basic digital switching network in 1965.

digits as required, highly flexible code conversion (transmitting forward different digits for the area or office code instead of the dialed digits), prefixing digits ahead of the called office code, and six-digit translation.

ALTERNATE ROUTING

The control switching points will be interconnected by a final or "backbone" network of intertoll trunks engineered so that very few calls will be delayed. In addition, direct circuits between individual switching offices of all classes will be provided as warranted by the traffic density. These are called "high-usage" groups and are not engineered to handle all the traffic offered to them during the busy hour. Traffic offered to a high-usage group which finds all trunks busy will be automatically rerouted to alternate routes[6,7] consisting of other high-usage groups or to the final trunk group. The ability of the crossbar tandem equipment at the control switching point to select one of several alternate routes automatically, when all choices in the first route are busy, contributes to the economy of the plant and provides additional protection against complete interruption of service when all circuits on a particular route are out of service.

Fig. 4 shows a hypothetical example of alternate routing when a crossbar tandem office at South Bend, Indiana, receives a call destined for Youngstown, Ohio. To select an idle path, using this plan, the switching equipment at South Bend first tests the direct trunks to Youngstown. If these are all busy, it tests the direct trunks to Cleveland where the call would be completed over the final group to Youngstown. If the group to Cleveland is also busy, South Bend would test the group

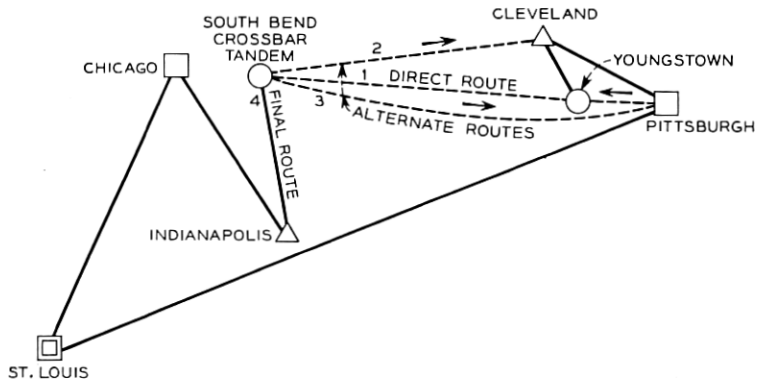

Fig. 4 — Toll network — alternate routing.

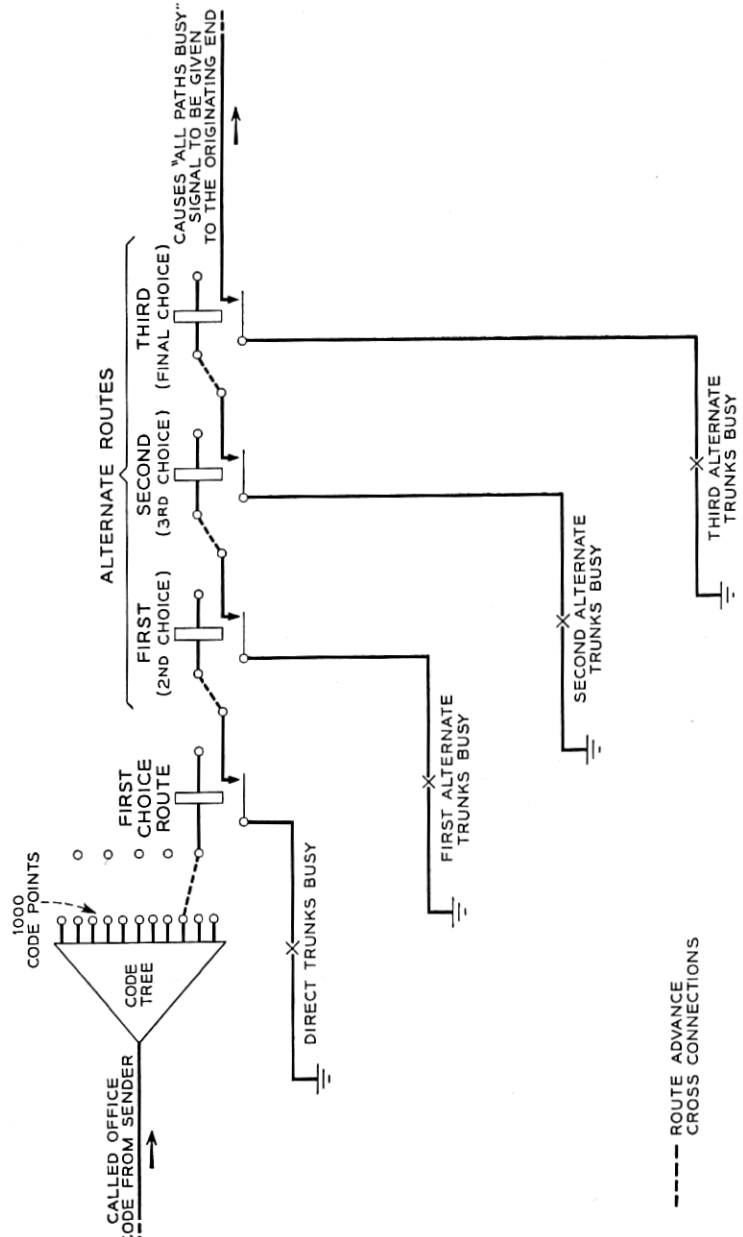

Fig. 5 — Method used for alternate routing.

to Pittsburgh and on its last attempt it would test the final group to Indianapolis. If the call were routed to Pittsburgh or Indianapolis, the switching equipment at these points would attempt by first choice and alternate routes to reach Youngstown. The final choice backbone route would be via Indianapolis, Chicago, St. Louis, Pittsburgh, Cleveland to Youngstown. Should all the trunks in any of the final groups tested be busy no further attempt to complete the call is made. It is unlikely that so many alternate routes would be provided in actual practice since crossbar tandem can test only a maximum of 240 trunks on each call and, in the case illustrated, the final trunk group to Indianapolis may be quite large.

The method employed by the crossbar tandem marker in selecting the direct route and subsequent alternate routes is shown in simplified form on Fig. 5. As a result of the translating operation, the marker selects the first choice route relay, corresponding to the called destination. Each route relay has a number of contacts which are connected to supply all the information required for proper routing of the call. Several of these contacts are used to indicate the equipment location of the trunks and the number of trunks to be tested. The marker tests all of the trunks in the direct route and if they are busy, the search for an idle trunk continues in the first alternate route which is brought into play from the "route advance" cross-connection shown on the sketch. As many as three alternate routes in addition to the first choice route can be tested in this manner.

STORING AND SENDING FORWARD DIGITS AS REQUIRED

The crossbar tandem equipment at control switching points must store all the digits received and send forward as many as are required to complete the call.

The called number recorded at a switching point is in the form of ABX-XXXX if the call is to be completed in the same numbering plan area. If the called destination is in another area, the area code XOX or XIX precedes the 7 digit number. The area codes XOX or XIX and the local office code ABX are the digits used for routing purposes and are sufficient to complete the call regardless of the number of switching points involved. Each control switching point is arranged to advance the call towards its destination when these codes are received. If the next switching point is not in the numbering area of the called telephone, the complete ten-digit number is needed to advance the call toward its destination. If the next switching point is in the num-

bering area of the called telephone the area code is not needed and seven digits will suffice for completing the call.

For example, suppose a call is originated by a customer in South Bend, Indiana, destined for customer NAtional 4-1234 in Washington, D.C. If it is assumed that the route to Washington is via a switching center in Pittsburgh, then the crossbar tandem equipment at South Bend pulses forward to Pittsburgh 202-NA4-1234, 202 being the area code for the District of Columbia. Pittsburgh in turn will delete the area code and send NA4-1234 to the District of Columbia terminating area.

As another example, suppose the crossbar tandem office at South Bend receives a call from some foreign area destined to a nearby step-by-step end office in Michigan. The crossbar tandem equipment receives and stores a ten-digit number comprising the area code and the seven digits for the office code and station number. Assuming that direct trunks to the step-by-step end office in Michigan are available, the area code and office code are deleted and the line number only is pulsed forward. To meet all conditions, the equipment is arranged to permit deletion of either the first three, four, five or six digits of a ten-digit number.

CODE CONVERSION

At the present time, some step-by-step primary centers reach other offices by the use of routing codes that are different from those assigned under the national numbering plan. This arrangement is used to obtain economies in switching equipment of the step-by-step plant and is accetpable with operator originated calls. However, with the introduction of customer direct distance dialing, it is essential that the codes used by customers be in accordance with the national numbering plan. The crossbar tandem control switching point must then automatically provide the routing codes needed by the intermediate step-by-step primary centers. This is accomplished by the code conversion feature which substitutes the arbitrary digits required to reach the called office through the step-by-step systems. Fig. 6 illustrates an application of this feature. It shows a crossbar tandem office arranged for completing calls through a step-by-step toll center to a local central office, GArden 8, in an adjacent area. A call reaching the crossbar tandem office for a customer in this office arrives with the national number, 218-GA8-1234. To complete this call, the crossbar tandem equipment deletes the area code 218 and pulses forward the local office code and number. If the

call is switched to an alternate route via the step-by-step primary center, it will be necessary for the crossbar tandem equipment to delete the area code 218 and substitute the arbitrary digits 062 to direct the call through the switches at the primary center, since the toll center requires the full seven digit number for completing the call.

PREFIXING DIGITS

It may be necessary to route a call from one area to another and back to the original area for completion. Such a situation arises on a call from Amarillo to Lubbock, Texas, both in area 915 when the crossbar tandem switching equipment finds all of the direct paths from Amarillo to Lubbock busy as illustrated on Fig. 7. The call could be routed to Lubbock via Oklahoma City which is in area 405. A seven-digit number for example, MAin 2-1234, is received in the crossbar tandem office at Amarillo. Assuming that the call is to be switched out of the 915 area through the 405 area and back to the 915 area for completion, it is necessary for the crossbar tandem office in Amarillo to prefix 915 to the MAin 2-1234 number so that the switching equipment in Oklahoma City will know that the call is for the 915 area and not for the 405 area.

Prefixing digits may also be needed at crossbar tandem offices to route calls through step-by-step primary centers. The crossbar tandem office in Fig. 8 receives the seven digit number MA2-1234 for a call to a

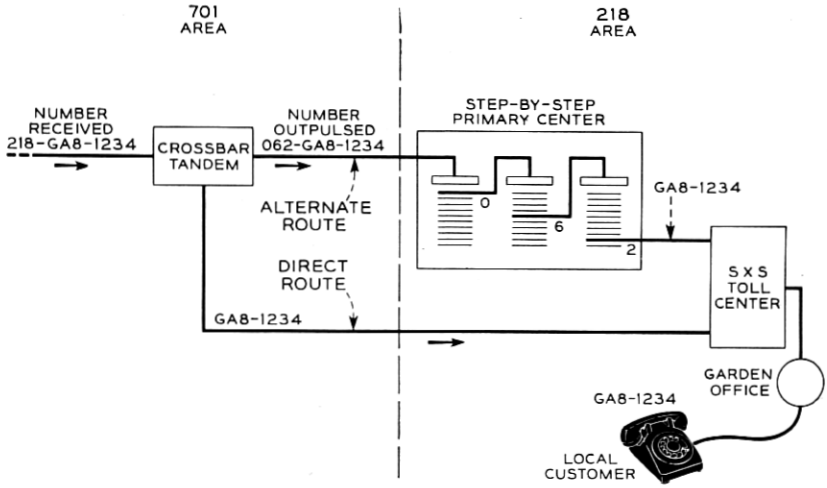

Fig. 6 — Code conversion.

customer in the Madison office in the same area. However, since the toll center needs the full seven digit number for completing the call and since the step-by-step switches at the primary center "use up" two digits (04) for its switching, the crossbar tandem equipment must prefix 04 to the seven digit number.

METHOD OF DETERMINING DIGITS TO BE TRANSMITTED

The circuitry involved for transmitting digits as received, prefixing, code conversion and for deletion involves both marker and sender functions. The senders have ten registers (1 to 10) for storing incoming digits and three registers (AA, AB, AC) for storing the arbitrary digits that are used for prefixing and code conversion.

On a ten-digit call into a crossbar tandem switching center the area code XOX, the office code ABX and the station number XXXX are stored in the inpulsing or receiving registers of the sender. The code digits XOX-ABX are sent to the marker which translates them to determine which of the digits received by the sender should be outpulsed. It also determines whether arbitrary digits should be transmitted ahead of the digits received and, if so, the value of the arbitrary digits to be stored in the sender registers AA, AB and AC. Case 1 of Fig. 9 assumes that a ten-digit number has been stored in the sender registers 1 to 10

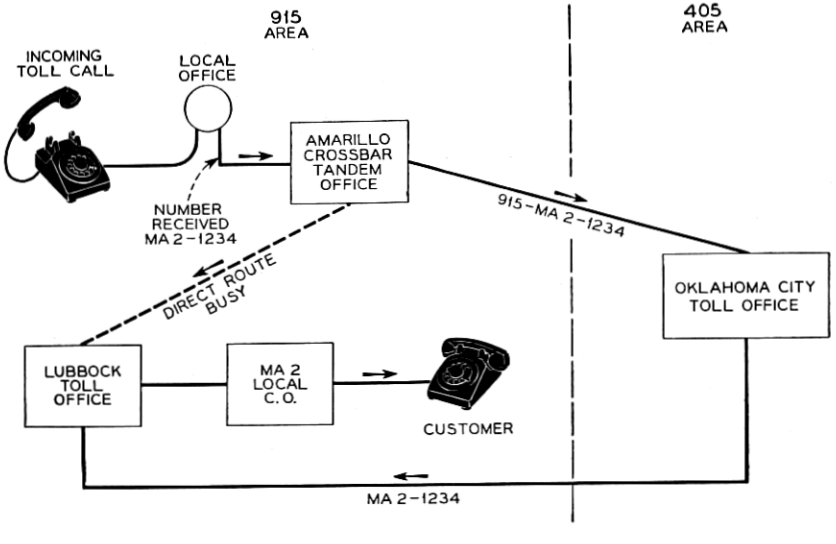

Fig. 7 — Prefixing.

and that the marker has informed the sender the called number is to be sent as received. The outpulsing control circuit is connected to each register in turn through the steering circuit S1, S2, etc. and sends the digits stored.

Case 2 illustrates a situation where the sender has stored ten digits in registers 1 to 10 and received information from the marker to delete the digits in registers 1 to 3 inclusive and to substitute the arbitrary digits stored in registers AA, AB and AC. The outpulsing circuit is first connected to register AA through steering circuit PS1, then to AB through PS2, continuing in a left to right sequence until all digits are outpulsed.

Case 3 covers a condition where the sender has stored seven digits and has obtained information from the marker to prefix the two digits stored in registers AB and AC. Outpulsing begins at the AB register through steering circuit PS2 and then advances through steering circuit PS3 to the AC register, continuing in a left to right sequence until all digits have been transmitted.

These are only a few of the many combinations that are used to give the crossbar tandem control switching equipment complete pulsing flexibility.

SIX-DIGIT TRANSLATION

Six-digit translation will be another feature added to the crossbar tandem system. When only three digits are translated, it is necessary to direct all calls to a foreign area over a single route. The ability to translate six digits permits the establishment of two or more routes from the switching center to or towards the foreign area. This is shown in Fig.

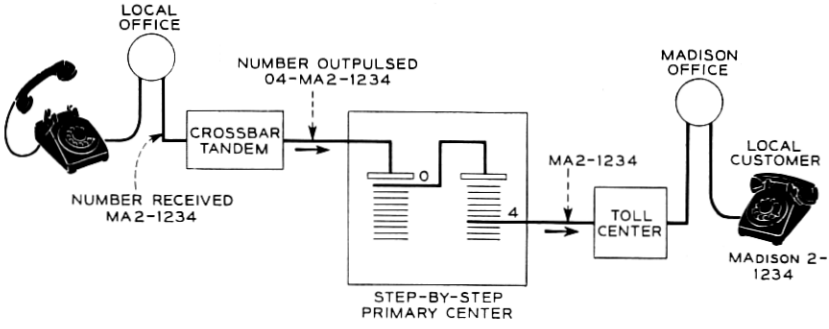

Fig. 8 — Prefixing.

10 with Madison and Milwaukee, Wisconsin, in area 414 and Belle Plaine Crossbar Tandem in Chicago, Illinois, in area 312. An economical trunking plan may provide for direct circuits from Chicago to each place. If only three-digit translation were provided in the Chicago switching equipment, the route to both places would be selected as a result of the translation of the 414 area code alone and, therefore, calls to central offices reached through Madison, would need to be routed via Milwaukee. This involves not only the extra trunk mileage, but also the use of an extra switching point. With six-digit translation, both the area code and the central office code are analyzed, making it possible to select the direct route to either city.

Six-digit translation in crossbar tandem will involve primarily the use of a foreign area translator and a marker. The translator will have a capacity for translation of five foreign areas and for 60 routes to each area. Since the translator holding time is very short, one translator is sufficient to handle all of the calls requiring six-digit translation, but two are always provided for hazard and maintenance reasons.

On a call requiring six-digit translation the first three digits are

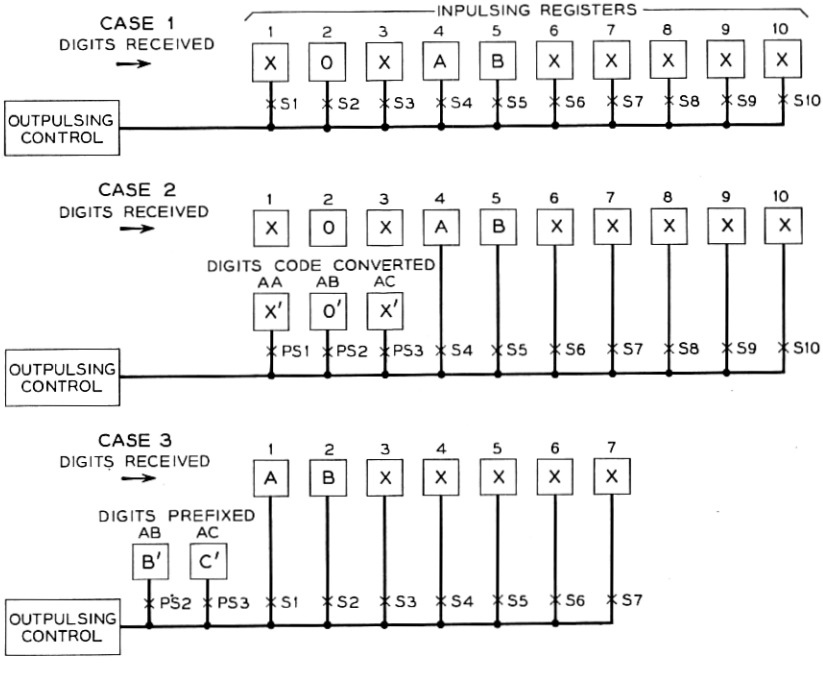

Fig. 9 — Method used for outpulsing digits.

translated in the marker and the second three digits in a foreign area translator which is associated with the marker. Fig. 11 shows, in simplified form, how this translation is accomplished.

The first three digits, corresponding to the area code, are received by a relay code tree in the marker which translates it into one of a thousand code points. This code point is cross-connected to the particular relay of the five area relays A0–A4 which has been assigned to the called area. A foreign area translator is now connected to the marker and a corresponding area relay is operated in it. The translator also receives the called office code from the sender via the marker and by means of a relay code tree similar to that in the marker translates the office code to one of a thousand code points. This code point plus the area relay is sufficient to determine the actual route to be used. As shown on the sketch, wires from each of the code points are threaded through transformers, two for each area. When the marker is ready to receive the route information, a surge of current is sent through one of these threaded wires which produces a voltage in the output winding to ionize the T- and U- tubes. Only the tubes associated with the area involved in the translation pass current to operate one each of the eight T- and U-relays. This information is passed to the marker and registered on corresponding tens and units relays. These operate a route relay which

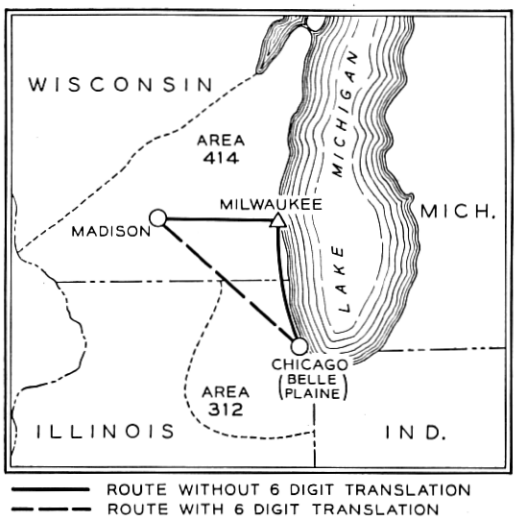

Fig. 10 — Six-digit translation.

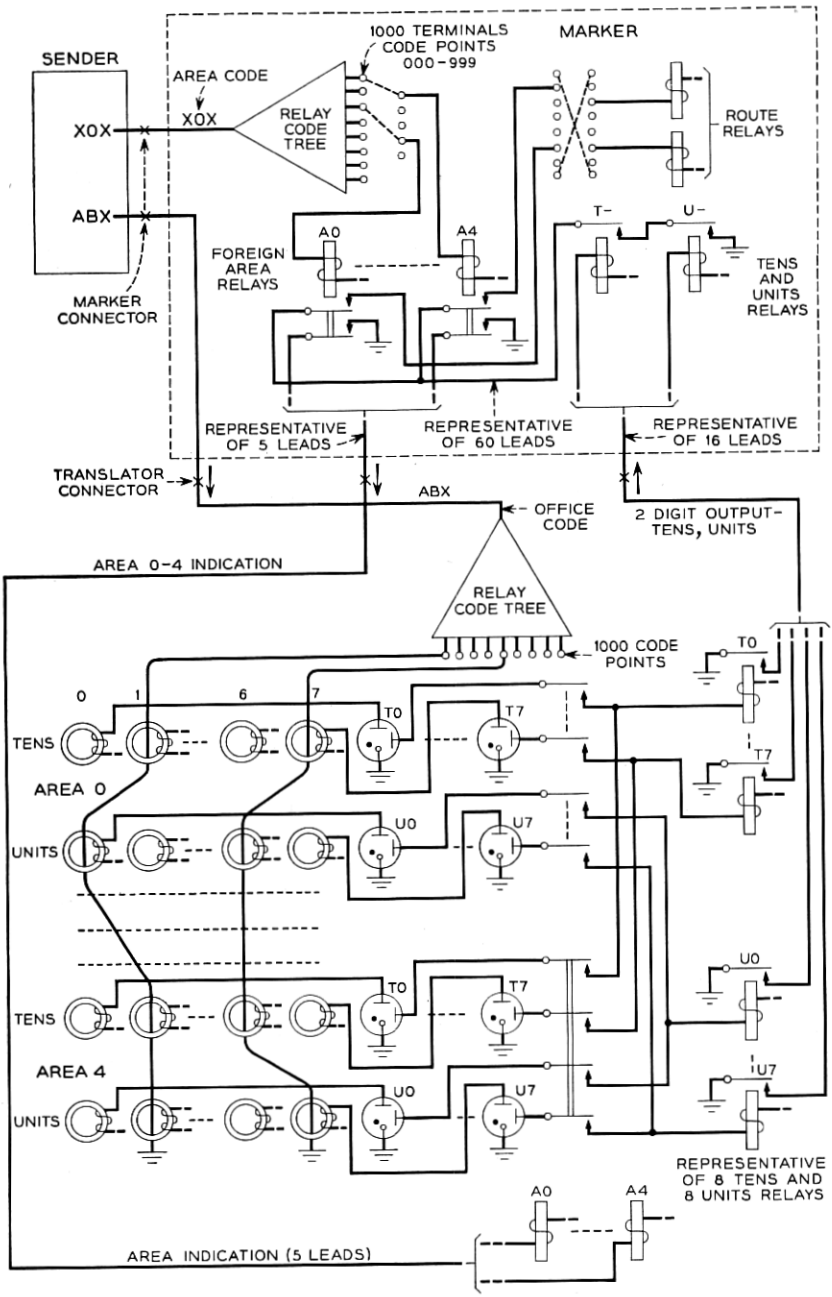

Fig. 11 — Method used for foreign area translation.

provides all the information necessary for routing the call to the central office involved.

CUSTOMER DIRECT DISTANCE DIALING

Crossbar tandem will provide arrangements permitting customers in step-by-step offices to dial their own calls anywhere in the country. Centralized automatic message accounting previously mentioned will be used for charging purposes. While the basic plan for direct distance dialing provides for the dialing of either seven or ten digits, it will be necessary for the customer in step-by-step areas to prefix a three-digit directing code, such as 112, to the called number. This directing code is required to direct the call through the step-by-step switches to the crossbar tandem office so that the seven or ten digit number can be registered in the crossbar tandem office.

When a customer in a step-by-step office originates a call to a distant customer whose national number is 915-CH3-1234, he first dials the directing code 112 and then the ten-digit number. The dialing of 112 causes the selectors in the step-by-step office to select an outgoing trunk to the crossbar tandem office. The incoming trunk in the crossbar tandem office has quick access to a three-digit register. The register must be connected during the interval between the last digit of the directing code and the first digit of the national number to insure registration of this number. This arrangement is used to permit the customer to dial all digits without delay and avoids the use of a second dial tone. If this arrangement were not used, the customer would be required to wait after dialing the 112 until the trunk in the tandem crossbar office could gain access to a sender through the sender link circuit which would then signal the customer to resume dialing by returning dial tone.

After recording the 915 area code digits in the case assumed, the CH3-1234 portion of the number is registered directly in the tandem sender which has been connected to the trunk while the customer was dialing 915. When the sender is attached to the trunk, it signals the three-digit register to transfer the 915 area code digits to it via a connector circuit. Thus when dialing is complete, the entire number 915-CH3-1234 is registered in the sender.

Crossbar tandem is being arranged to serve customers of panel and No. 1 crossbar offices for direct distance dialing. At the present time, ten digit direct distance dialing is not available to these customers because the digit storing equipments in these offices are limited to eight digits. Developments now under way, will provide arrangements for expanding the digit capacity in the local offices so that ultimately

calls from customers in panel and No. 1 crossbar offices may be routed through crossbar tandem or other equivalent offices to telephones anywhere in the country.

CONCLUSION

The new features developed for crossbar tandem will adapt it to switching all types of traffic at many important switching centers of the nationwide toll network. Of the 225 important toll switching centers now contemplated, it is expected that about 80 of these will be equipped with crossbar tandem.

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