Traffic distribution in the No. 5 crossbar marker

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In any automatic telephone switching system, an even distribution of traffic is a desirable objective, and is always sought where other and conflicting objectives are not controlling. In the higher usage circuits, such as senders and registers, for example, relay wear and contact erosion are critical factors in determining the life of the equipment. Hence it is desirable to distribute the traffic evenly over these circuits so that their relays tend to wear at a fairly uniform rate, thus giving the maximum period of service before corrective maintenance is required. For interoffice trunks, a uniform load among the trunks of a group reduces the assignment and balancing effort in both the originating and the terminating offices. Closely related to the equalization of load among switching paths, and accomplished in No. 5 crossbar offices by the same control circuits, is the preferential assignment of the common equipment to various groups of subscriber lines. This serves to prevent undue delays to the higher numbered line groups which may occur in periods of heavy traffic.

The simplest ways of selecting switching paths give far from uniform distribution. If, in choosing an idle trunk in a group, for example, the selection process always started at the same point, the later trunks would carry materially less traffic than the earlier ones even at times of full load, and during hours of light load might carry none at all.

In step-by-step and panel systems, where the selectors hunt over their terminals in this manner, more favorable distribution can be obtained only by such mechanical means as slipped or reversed multiple,* and the improvement that can be gained is limited. Common control systems in which both selection and hunting features are centrally controlled offer better opportunities for obtaining good distribution. In the No. 1 crossbar system, four major types of control circuits are employed: the line link and sender link control circuits, and the originating and terminating marker circuits. To secure adequate control of distribution the necessary features have to be provided in each of these four circuits. In the No. 5 crossbar system, however, all the major selection and hunting features are concentrated in a single type of circuit, the marker. Thus, more complete control of distribution becomes feasible, since more elaborate distributing circuits can be justified economically in a single type of marker.

In the latter system, the trunks of each group and the originating registers are distributed as evenly as possible over all trunk link frames. In placing a call to a trunk or an originating register, the marker remembers the trunk link frame to which it placed the last previous call, and attempts to place the present call to the next higher numbered trunk link frame.

Except the arrangement for selecting a trunk link frame, the largest group from which a selection must be made is the block of twenty trunks on the trunk link frame.* Since this group besides being the largest, presents the most difficult problem, its requirements determine the design of the common preference control circuit, and it may most satisfactorily be used to illustrate the principles involved in many of the selections.

In choosing an idle trunk out of the group, the selecting circuit, in effect, tests the trunks one after the other and seizes the first idle one of the desired route it encounters. Which particular idle trunk will be seized thus depends on two factors: the trunk at which the circuit begins to test, and the order in which the testing proceeds.

* Record, *September*, 1944, *page* 514.

* See page 45.

In the actual circuit this testing of the trunks is done simultaneously, but the arrangement of the circuit is such that the same two factors of point of start and order of search determine which trunk is to be selected. To secure uniform use of the trunks, the point at which testing begins should be changed after each operation of the marker to break up any tendency to select some particular trunks more often than others. Where any trunk of the group is equally suitable for use, this rotation of the starting point is sufficient in itself to give uniform distribution over a period of time, bearing in mind that a marker ordinarily does not serve the same route on successive operations. These simple conditions do not apply to the trunk blocks in the trunk link frames however.

These blocks may include a number of groups of trunks, the various groups occupying successive positions of the twenty in the block. To illustrate the inadequacy of a rotation of the starting point, assume, for example, that a particular group of four trunks occupies positions 8 to 11, inclusive. On twenty successive searches for an idle trunk in this group the marker would test the trunk occupying position 8 first in seventeen out of the twenty times, on the average, since it would be tested first when the starting point was anywhere from positions 12 to 19 or from 0 to 8, both inclusive. Each of the other three trunks of the group would be tested first only once. Beside rotating the starting point of test, therefore, it is necessary also to break up the order of test in some situations to avoid conditions of this type.

To do this, distribution control in the marker is divided into two processes: one establishes a beginning point that is changed after each operation of the marker, and the other determines the order of search. The first process is represented in the No. 5 crossbar marker by a common sequence circuit that establishes a beginning point for the search in all groups, and changes this point after each seizure of the marker. The other is a preference circuit that establishes the order in which the search is carried out. The sequence circuit changes the beginning point at each marker seizure, while the preference circuit, beginning at a point indicated by the sequence circuit, will test in an order that will give the most uniform distribution.

The major selections requiring distribu-

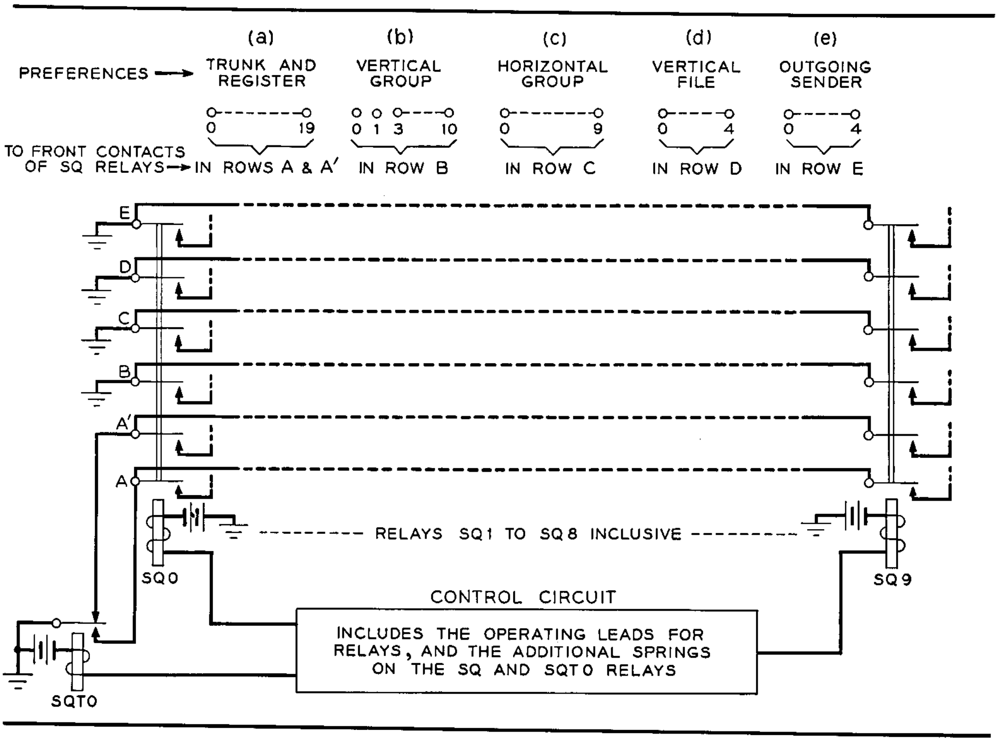

Fig. 1 — Simplified diagram of the sequence circuit of the marker.

tion control in the No. 5 crossbar marker are (1) vertical-group identification; (2) horizontal-group identification; (3) vertical-file identification; (4) trunk and originating register selection; and (5) outgoing sender selection. The first three of these together identify a calling line on a line link frame. Preference control is needed here to determine which of several simultaneous calls on a line link frame shall be served first. The fourth determines which trunk marker seizures. Thus if relay SQ0 is operated on the first seizure, SQ1 will be operated on the second, SQ2 on the third and so on. For the eleventh seizure SQ0 will be operated again, and the cycle will repeat. Sets of leads representing the five functions for which a preference selection is required are connected to the front contacts of each relay, and when the relay is operated, ground is placed on these leads as shown in Figure 1. The ten leads used for horizontal group

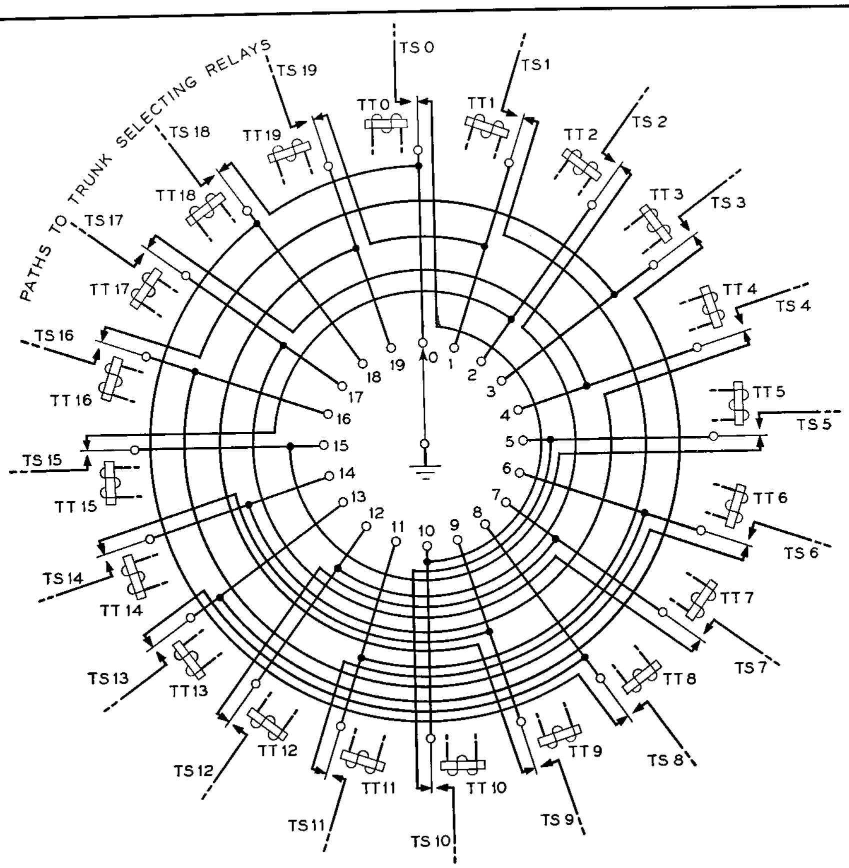

Fig. 2—Diagrammatic representation of the preference circuit for a trunk block of 20 trunks.

of the desired route or which originating register of those available in the preferred trunk link frame should be employed. The outgoing sender selection determines which sender of the desired type shall be selected from the preferred subgroup.

The basic sequence circuit of the marker is indicated in simplified form in Figure 1. Ten SQ relays, numbered 0 to 9, are operated one at a time by a group of six control relays in a control circuit. The SQ relays are operated in numerical order on successive selection, for example, are connected to the front contacts of the C row of springs of the SQ relays, and thus for each seizure of the marker ground will appear on one of these leads. Since the vertical files and outgoing senders are selected in groups of five, each lead is connected to contacts on two SQ relays. The first lead will be connected to the 0 and 5 SQ relays, the NO. 1 lead to the 1 and 6 SQ relays and so on. For ten seizures of the marker, therefore, these groups are run over twice. With respect to vertical group selection, lines which should have preference in times of emergency, such as fire, police, and ambulance lines, are assigned in vertical group 2, which is always given first preference regardless of the position of the sequence circuit. Therefore the ten leads from the sequence circuit are connected to vertical groups 0, 1 and 3 through 10, and they become effective only if there is no demand on vertical group 2. Vertical group 11, where used, is given second preference at one step of the sequence circuit.

To provide for the twenty leads for the blocks on the trunk link frames, two contacts on each SQ relay are employed. Leads 0 to 9 are connected to the front contacts of the springs of row A and leads 10 to 19 to contacts on the springs of row A′. Through a front and back contact on the SQTO control relay, ground is placed on the A row of the SQ relay for the first ten seizures of the marker and to the springs of the A′ row for the next ten seizures. In this way ground is applied to the twenty leads of the trunk and register group, one after another, on twenty consecutive seizures of the marker.

The groups of leads at the top of Figure 1 run to the preference circuits for the various selections. Although the basic principle is the same in the design of all preference circuits, the larger size for that of the trunk blocks and its greater complexity make it the best to serve as an illustration. Since the originating registers are associated with one of the trunk blocks of each trunk link frame, and since these, because of their high use, require particular care in equalizing the distribution, the distribution for the registers has been the controlling factor in arranging the preference circuit for the trunk blocks. There may be from four to eight registers on a trunk link frame and their location is such as to group them all at the beginning of one of the trunk blocks. More offices are expected to have five registers per trunk link frame than any other number, and thus this number was assumed in designing the preference circuit. This circuit for the trunk blocks is indicated in Figure 2. The twenty leads from the sequence circuit are connected to the points on the inner circle, where the arm from the central ground, rotating clockwise, represents the advancing action of the sequence circuit. The TT relays, to the springs of which the leads from the sequence circuit connect, are operated for all idle trunks of the desired group, and are released for all busy trunks and for all trunks of groups other than the desired one. The order in which trunks are tested is thus determined by the connections from the back contacts of the TT relays.

By following through these connections, it will be seen that the testing order instead of being 0, 1, 2 to 19 and back to 0 is that given by the middle ring of numbers in

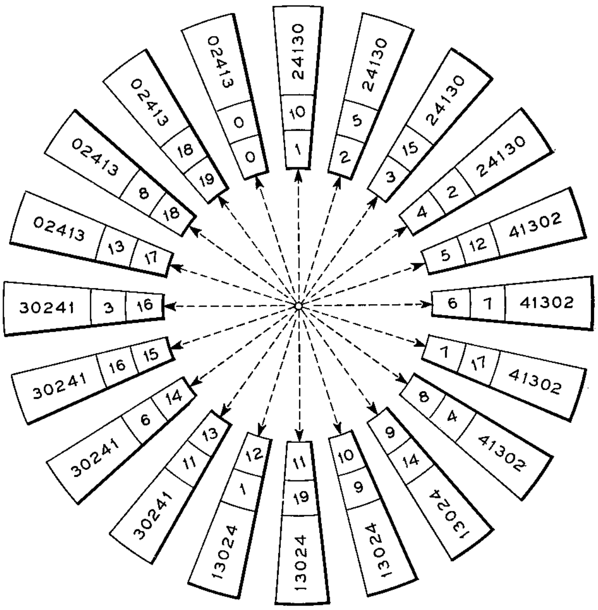

Fig. 3—Diagram representing testing order of trunks and registers.

Figure 3 reading in the clockwise direction. The inner ring of numbers here corresponds to the numbering of the TT relays and of the leads from the sequence circuit in Figure 2. If the sequence circuit had started at 0, the order of testing would thus be 0, 10, 5 and so forth as shown in the middle ring. Had the point of start been other than 0, say 12, the order of testing would be found by rotating the middle ring until 12 was opposite 12 on the inner ring and the order would then be 12, 7, 17, and so on. The order in which the five registers would be tested for the twenty starting positions is given in the outer ring of Figure 3. In position 0 of the sequence circuit, for example, five registers in positions 0 through 4 of the trunk block

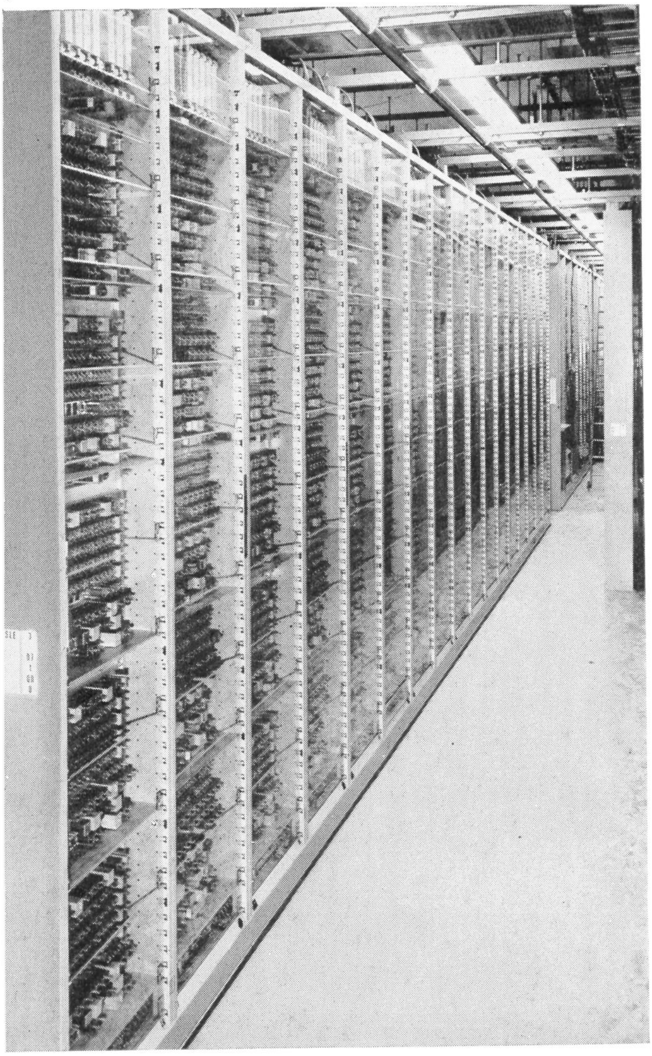

Fig. 4—A line of originating register bays in the Towson office. The distribution of calls to these registers is under control of the circuits in the marker that is described in this article.

are tested in the order 0, 2, 4, 1, 3, as shown in the outer ring. It will be noticed that each of the register appearances is first preference in four positions of the sequence circuit, second preference in four positions, third preference in four positions, fourth preference in four positions and fifth preference in four positions. Since different markers, each with its independent sequence circuit, are placing calls, and since each marker normally places different types of calls and prefers different trunk link frames on successive usages, the over-all effect is to randomize the selection of originating registers. Over a sufficient period of time, the tendency is to load the registers uniformly.

The performance of this feature was observed during two half-hour periods at the Media central office. The observations were made under rather light traffic conditions, which would tend to emphasize any maldistribution of calls among the registers. The results indicate that, with five registers per trunk link frame in service, the least used register carried about twenty per cent less traffic than the average register, and the most used register carried about twenty per cent more traffic than the average register. With higher traffic density, these deviations from average would tend to be reduced. Also, it is probable that observations over a longer period of time would show less deviation from average. Even disregarding these last considerations, the deviations indicated above represent a material improvement over the performance of comparable features in previous switching systems.

In securing optimum distribution for five registers, it is not possible to secure equally good distribution for all other groups of various sizes and positions. The order established gives the best over-all results that could readily be obtained while at the same time securing the optimum distribution for five registers.

A somewhat similar problem occurs in the vertical-group identification function, and in the sender selection function, and they are handled in a similar manner. There may be anywhere from six to twelve vertical groups on each line link frame of an office and thus a staggered preference chain is provided to give equitable service to each vertical group for any number within these limits. Similarly there may be from one to five senders of a type in a sender subgroup, and a staggered chain is used to distribute the calls uniformly among them. There are always two subgroups of each type of sender, with the preference being alternated between the two subgroups by a simple two relay circuit.

Another traffic distribution feature of the marker is that of channel selection. A channel is a path through the line link and trunk link crossbar switches from the subscriber's line to the trunk or originating register. The function of channel selection is divided into two parts, junctor group selection and selection of a channel within the junctor group. A junctor is a path from a line link frame to a trunk link frame. Junctors are arranged so that, for any size office, there are at least ten junctors from each line link frame to each trunk link frame. For the smaller sizes of office, there are correspondingly more junctors from each line link frame to each trunk link frame. For selection purposes, the junctors are divided into groups of ten or less, and calls are distributed among the junctor groups by means of a six-step sequence circuit, similar in operation to the multi-purpose sequence circuit described above. After a junctor group has been selected, the individual channel is selected in the same manner as in No 1 crossbar, the lowest numbered idle channel being selected first. This procedure represents an exception to the "even distribution" technique, in attempting to obtain the most efficient use of the channels. Provision is made, by a simple wiring change, for changing the starting point of the channel selection to equalize the wear on the switches during the life of the office.

The marker also provides flexible alternate routing arrangements for outgoing calls, so that, if the direct trunks to the desired destination are all busy, as many as three different alternate routes may be tried. This feature is of particular value in areas having a high volume of interoffice traffic. It allows a relatively efficient use of the small direct trunk groups, since the alternate routes are engineered to carry the calls which fail to find direct trunks.

There are many other subsidiary features which could be included in the discussion of traffic distribution arrangements. However, the major features that have been mentioned in this article illustrate the versatility which is made possible by concentrating the selecting arrangements in one type of common-control circuit.