THE MARKER PRINCIPLE
in Telephone Switching Systems

By FRANK H. WIEGAND

THE two basic requirements of any telephone system are, first that the equipment and circuits permit satisfactory conversations between users, and second that the equipment quickly connect any subscriber's line with that of any other subscriber. Among telephone engineers, the first requirement is referred to as transmission, while the second requirement is referred to as the switching system.

In a broad sense the switching system might be defined as including the circuit from the central office to the telephone instrument on the subscriber's premises; however, this is generally termed the "outside plant." The switching system concerns itself primarily with that portion of the subscriber's telephone instrument which is used to transmit electrical signals to the central office, and the equipment in the central office which responds to these signals and selects the desired customer's line.

SUBSCRIBER'S SIGNALING DEVICES

The oldest of all telephone switching systems is, of course, the manual system, where an operator connects the calling party with the called party by means of a cord circuit or by means of switching keys. The customer's signaling device in this system is the movable hook upon which the receiver hangs, and in the case of magneto instruments, the crank of the magneto type ringing generator. The signal in this case is used only to notify the operator that a connection is desired, the actual number being transmitted verbally.

Practically all of the automatic switching systems used in the United States have been of the "step-by-step" or "panel" types. Both of these systems include a dial on the subscriber's telephone by means of which he transmits electrical signals to the central office apparatus and thereby controls its operation in selecting the desired telephone line. In fact the dial has become almost universal as the subscriber's signaling device because of its compactness, ruggedness and low cost; and it is generally used on central office switchboards where operators have occasion to complete calls through automatic equipment.

In certain of the central offices, however, a device called a "Key Pulsing Set" is used in place of a dial. With this device the operator sets up the desired number by depressing keys in the same manner that a number is set up in an adding machine, and because of the faster operation she is able to complete more calls per hour. The cost and size of the present key-pulsing set probably will confine its use to operators in the central office; however, the laboratories are exploring the possibility of simplified key-type dialing equipment for use by subscribers.

NEW SYSTEM ANNOUNCED

One of the major development projects which were announced by the Bell Laboratories just prior to the war was a new system of dial telephone switching. This new system is called the "Crossbar System," since the new crossbar type of switch is used to make many of the required connections; however, a more descriptive name of the system would have been "The Marker System," since some other type of switch could have been used in place of the crossbar switch while still retaining the "marker" principle. Inasmuch as a detailed description of the crossbar switch is not essential to an overall picture of the marker principle, the crossbar switch as such will be brought into the discussion only as it performs its functions under control of the marker, which is the "brain" of the new system.

ANALOGY OF MARKER PRINCIPLE

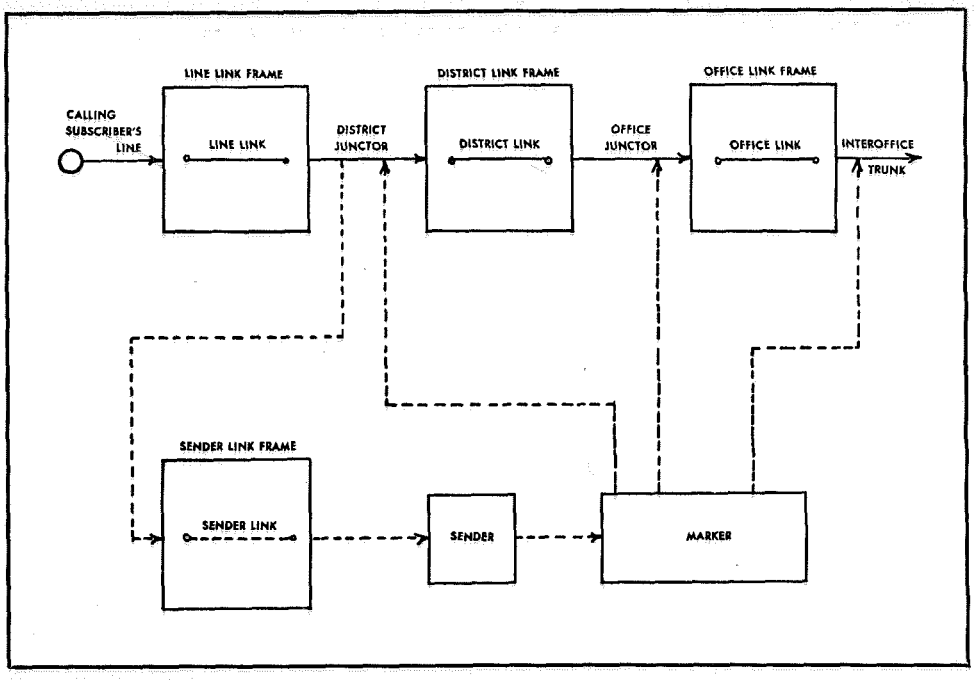
Perhaps the best way to point out the difference between the marker principle and the step-by-step principle which is now in use in southern California is by means of an analogy. If you were going to make a railroad trip from Los Angeles to Chicago, using the step-by-step principle, you would go to the station in Los Angeles and take the first train out of Los Angeles which was going in the general direction of Chicago. Let us assume that this train terminated its run at El Paso. At this point you would then take the first train headed east, which, let us assume, went as far as St. Louis, still with no assurance that you could get passage from there to Chicago. But if, at St. Louis, you were unable to obtain a reservation to Chicago, your trip would have to be abandoned and the train space consumed in taking you as far as St. Louis would have been wasted, and could have been utilized by some one else who wanted to go somewhere other than to Chicago.

Now, if you were to make this trip, using the marker principle, your ticket agent would communicate ahead to each junction point to be sure that a clear channel was available through each link of the journey, and if St. Louis reported no passage available to Chicago, he would try an alternate route through La Junta and Kansas City to Chicago. In case he was unable to make connections for you over the alternate route, he would give you a "busy signal" and you would "hang up," thereby leaving your seating space on the trains available for some other person whose trip could be completed. The ticket agent in the above analogy corresponds to the marker in the crossbar system, since each has the duty of locating a clear channel through all links of the trip (or call), trying an alternate route if the first attempt is unsuccessful, and preventing you from tying up train space (or telephone circuits) in case no clear channel is available.

EQUIPMENT INVOLVED IN OUTGOING CALL

Now that we have become acquainted with the marker principle through the medium of an analogy, let us see how it is applied in telephony by following the progress of a call through the crossbar system. In *Fig. 1* is shown a block diagram of that portion of the equipment between the calling subscriber's line originating end and the interoffice trunk circuit.

Each subscriber's line terminates on a frame, known as a "line-link-frame." It will be noted that the name of each of these frames includes the word "link." The links are the talking circuits between those crossbar type



AT LEFT:

FIG. 1. Equipment involved in a call outgoing from a crossbar type central office. Talking paths are shown by solid lines and control circuits are shown by dotted lines.

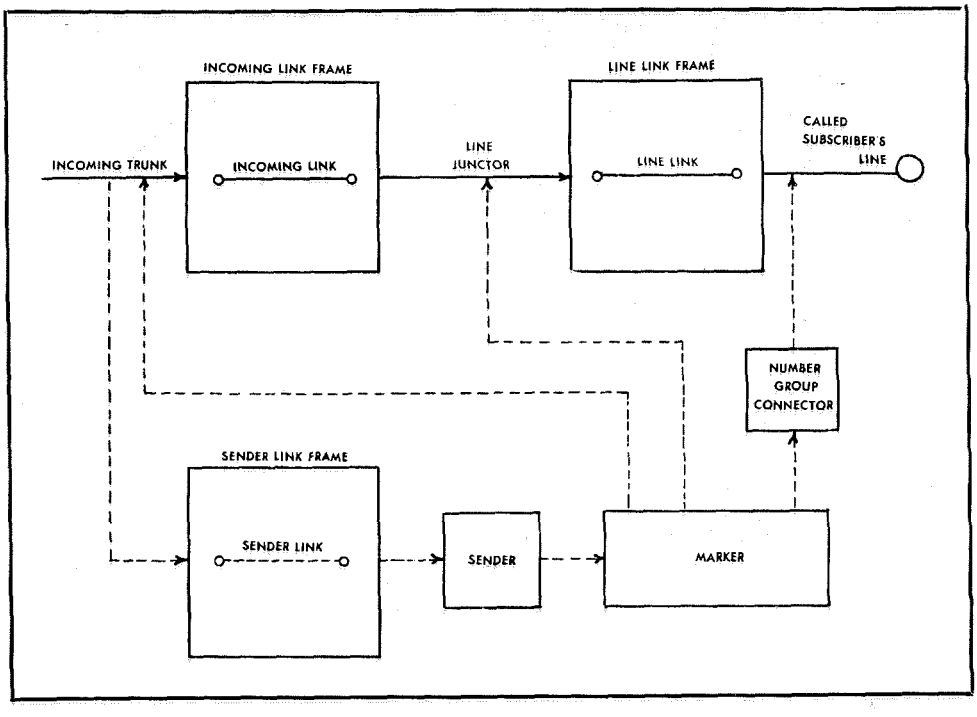
switches which are mounted on any frame, this name being used to distinguish them from the talking circuits between the frames, which are called "junctors."

When the calling party lifted his receiver the control equipment associated with the particular line-link frame on which his line appears noted his desire to make a call, scanned the district junctor circuits to be sure that an idle one was available, scanned the links between the primary crossbar switch on which his line appears and the secondary crossbar switch on which the idle junctor appears, and then simultaneously operated the mechanism of the proper crossbar switches, thereby connecting him through to a district junctor. At the same time a clear channel was located between the district junctor and an idle sender. This entire process of selection and connection requires only two-thirds of a second, after which dial tone is sent to the calling subscriber, and the control circuits are free to serve another call.

MARKER DIRECTS OUTGOING CALL

The calling subscriber now dials the letters and numbers of the telephone number he desires and the sender receives these and registers them within itself by the operation of appropriate relays. A marker is now called into the circuit to analyze the call and schedule a clear channel through the equipment to an outgoing trunk leading to the office whose prefix was dialed. Typical of the questions which must be answered by the equipment in order to handle properly each call are the following:

1. Is the calling party entitled to dial a call to the prefix he has dialed, or should this call have been handled as a toll call?
2. Is this call from a coin-box telephone, thus requiring that another piece of equipment called a "coin supervisory circuit" be brought into the connection to collect or return coins at the proper time?
3. If zone registration is included in the tariff structure, how many zones will this call pass through, and how many regis-



AT RIGHT:

FIG. 2. Equipment involved in a call incoming to a crossbar type central office. Talking paths are shown by solid lines and control circuits are shown by dotted lines.

trations on the calling party's message register should be made?
4. Is this a party line, and which party on the line should be charged for the call?
5. What is the location on the district link frame of the particular district junctor being used on this call?
6. Which idle trunk on which office link frame will carry the call to the distant office?
7. Which links and which office junctor can be used to build the circuit between the district junctor and the outgoing trunk?
8. Can the distant office be reached through a tandem office in case all direct trunks to the office are in use?

One of the interesting by-products of the system is that the marker provides cross-connecting facilities which permit the location of the trunks on the office frames to be independent of the office code dialed. Each marker can handle as many as 800 office prefixes, which is more than enough to handle even the largest system.

OVERLAP FEATURE

The call handling capacity of each marker is increased by incorporating what is known as the "overlap feature." This feature permits a marker to be working on two calls at the same time; that is, it can start decoding the office code which is being dialed on the next call, while still marking a clear channel for the previous call.

Before a marker leaves the connection it is working on, it makes a check to see that all of the contact points of the crossbar switches are properly closed, thus insuring that the circuit is complete to the distant office. Having completed all of its functions in approximately one-half second, the marker disconnects and signals to the group of senders that it is ready to handle another call. The markers which handle the originating end of the call are called originating markers, and a group of five or six originating markers is generally sufficient to handle a central office of 10,000 subscriber terminals.

CALL INCOMING TO CROSSBAR OFFICE

In the distant office, a terminating marker performs a similar function in locating a clear channel between the incoming trunk and the called subscriber's line shown in *Fig. 2*. Here the problem is somewhat different, in that the originating marker can locate any idle trunk to the desired office, whereas the terminating marker must locate one particular line out of all the subscriber lines in the distant office. It will be noted, however, from a comparison of *Figs. 1 and 2* that the general layout of the terminating equipment is similar to that in the originating office.

When the call whose progress we are following is extended to the distant office, it becomes an incoming call with respect to that office, and a terminating sender is connected to the incoming trunk by means of crossbar switches which are mounted on the terminating sender-link frame. The originating sender now transmits to the terminating sender the called telephone number, each digit of which it had previously recorded. Here again, the overlap feature is incorporated, since the originating sender may start transmitting the first digit of the called telephone number before the calling party has finished dialing the last digit.

TERMINATING MARKER FUNCTIONS

Having received the called telephone number, the terminating sender calls in a terminating marker, which

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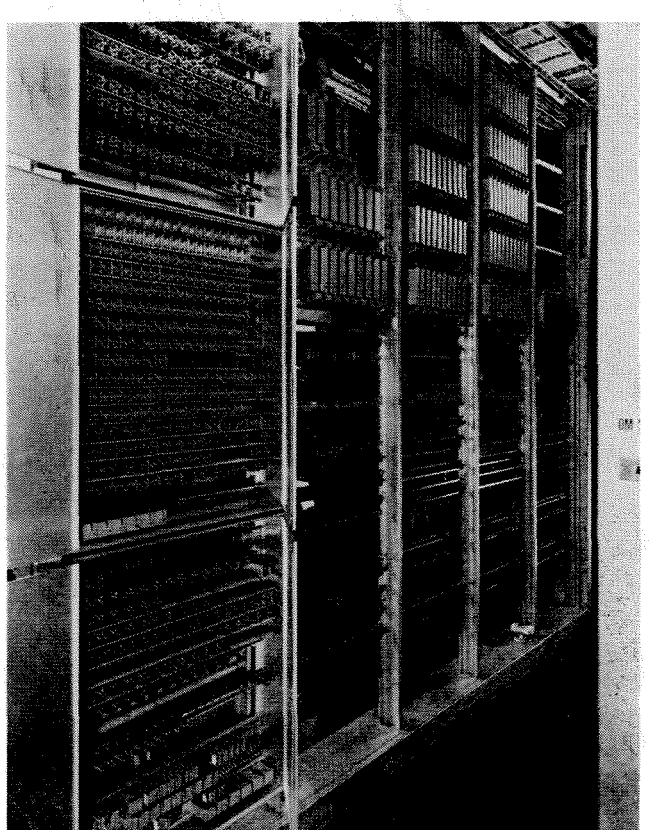
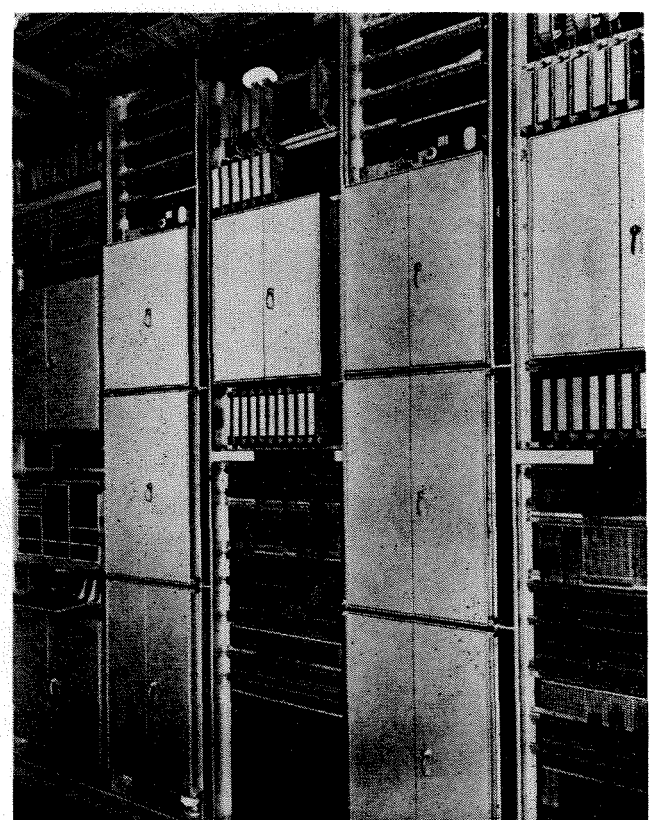


An originating marker, with relay cabinet at the left, route relays at the upper right, and cross-connecting terminals at the lower right.



Each terminating marker consists of two bays, one consisting chiefly of three cabinets of relays, and the other of one relay cabinet and the cross-connecting terminals.

to solve a problem by completely passive resistance, by utter resignation.

These experiments of Maier and others extend our frontiers for two reasons: They substantiate the theory that some nervous breakdowns, at least, result from psychological frustration rather than from purely physical illness. Moreover, they throw some light on the practical problems of heredity and environment by determining whether the children of neurotic rat parents are more easily disturbed than are the children of "Horatio Alger" parents. To control the environment, it is, of course, necessary to have both neurotic and normal young rats raised by neutral foster parents.

THE FUTURE OF PSYCHOLOGY

All of these studies present certain foci of emphasis which give us clues to the future development of the science of psychology. They show us the psychosomatic principle—that mind and body are a unity, that there are no mental phenomena divorced from physiological or chemical influences, and conversely that there are no body changes which are uninfluenced by mental phenomena. They give us more understanding of what the psychologist calls readjustive behavior. They show us that, whereas we bring into the world an innate pattern of reflexes and of hungers, it is possible to modify these inherited mechanisms to an enormous degree. That means that it is possible to produce either the civilized man or the criminal, the sane or the insane, the selfish or the altruistic, by varying the kinds of conditions under which the child is reared. We know now enough to prevent a considerable percentage of all the insanity and of the crime which bedevils the world, if the public is willing to apply to these problems the techniques which modern science has developed. It is not over-optomistic to state that we also know enough to prevent future wars as we learn to feed properly the fundamental hungers of individual men. Psychologists are emerging from the ivory tower of the early years of experimentation and are taking an increasing interest in problems of social control and progress. The research which they are carrying on will yield better ways of living.

The Marker Principle

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performs the following tasks in a time interval of about one-half second.

1. The marker locates the test terminals of the called line, using a "number-group-connector" circuit to accomplish this mission.
2. The called line is then tested to see if it is idle or busy, and if found to be busy, the marker orders the trunk circuit equipment to return a busy signal to the calling subscriber. This test also indicates what type of ringing current should be applied in order to signal the proper party on the line.
3. From the test terminals the marker then determines the location of the called line on the line-link frame.
4. The marker then selects a clear channel for a talking circuit from incoming trunk to the called subscriber's line, in the same manner that the originating marker set up a channel from the calling subscriber to the outgoing trunk.
5. Under control of the marker, the relay equipment in the incoming trunk circuit applies the proper type of ringing current to the called line and sends an audible ringing signal back to the calling party.
6. If the called number is that of a P.B.X. (private branch exchange) or a subscriber having more than one line, the marker will recognize this arrangement and test all of the lines associated with this subscriber's listed telephone number, testing as many as 20 simultaneously, and will select an idle one. A point of special interest here is that whereas all previous telephone switching systems required that all the lines to one subscriber be numbered consecutively to permit this "trunk hunting" feature, the crossbar system with its marker operation permits scattering the trunks of a P.B.X. group, or they may even be assigned in certain instances to a special group of numbers outside the regular 10,000 series. This scattering of trunks which have high incoming calling rates is of particular interest to the traffic engineer since it permits better balancing of the load carried through the various channels of the equipment.
7. If the number which has been called is an unassigned line, or one which has been disconnected, the marker recognizes this condition, and routes the call to a special intercepting operator.

TROUBLE INDICATOR CIRCUIT

With a system as intricate and complicated as the crossbar system, the location of the source of trouble would be a very involved process, and would cause equipment which should be working at a high call fill to be held out of service a considerable length of time unless some automatic trouble-indicating feature were included. When a marker encounters circuit trouble, it routes the call over an alternate channel and calls in a trouble indicator circuit which locates the trouble and sounds an alarm, thus permitting the repairman to get the faulty equipment back in service in a minimum length of time.

NEW TYPE RELAY

One item of equipment which has not been mentioned thus far but which contributes in a large measure to marker operation, is a new type of relay which is called the "multi-contact relay." This relay employs two magnets and two armatures, each of which operates half of the contacts. With both halves functioning together, the relay will close 60 contacts simultaneously; however, the halves may be operated separately with a maximum of 30 contacts each. Each contact is double, the end of each moving contact spring being forked with a contact on each tine of the fork. With a single contact the number of failures per thousand operations is very small, but with two contacts in parallel, the probability of failure is negligible. With this type of relay, the large number of circuits in the marker can be extended to the associated equipment almost instantaneously, permitting a high call handling capacity for each marker.

CONCLUSION

Present indications are that the marker principle is here to stay, and new applications of this type of circuit continually are being discovered. That this is not just a laboratory model, but is a commercially-proved system is evidenced by the initial installation which has been functioning in New York for several years, and other installations scattered across the United States, including two or three in the East Bay district of San Francisco. To date none has been introduced in southern California, the step-by-step system being used exclusively in this area thus far. As far as the telephone user is concerned, he places a call through a crossbar system in exactly the same way that he does through a step-by-step system, but to the telephone engineer the introduction of the marker principle represents an entirely new approach to the problem of telephone switching.

Flash of Genius Doctrine

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Patent Office then the Patent Office must institute a new type of prosecution in which each inventor-applicant is required to show his personal prior art. The ramifications of such a requirement in cases of research organizations of any size constitute a tremendous burden. A