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An Experimental Electronic Telephone Exchange

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IN 1956 THE POST OFFICE AND THE FIVE PRINCIPAL manufacturers of telephone equipment in this country set up the Joint Electronic Research Committee (J.E.R.C.) to co-operate on the joint research and development of electronic telecommunications exchange switching systems. The manufacturers are the Automatic Telephone & Electric Company Ltd., Ericsson Telephones Ltd., The General Electric Company, Siemens-Edison-Swan Ltd. and Standard Telephones and Cables Ltd. Since 1956 the six parties have pooled their research and development efforts with the object of producing an experimental electronic exchange for field trial at Highgate Wood in the London network.

Potentially, the use of electronic devices for telephone exchange switching offers advantages in space saving, lowering of maintenance costs because of the absence of mechanical moving parts, and economies in apparatus due to the high speeds of operation. Time in electronic systems is reckoned in microseconds as opposed to milliseconds in mechanical systems and this leads to new concepts, particularly in the design of the control equipment; it also offers potential service advantages in respect of rapid connexions on long distance calls.

Of the several possible technical solutions to the problem the "Switched Highways" time-division-multiplex system was chosen for the first experiment.

Apparatus

The equipment uses valves, diodes and transistors in large numbers and many of the basic "bricks" from which the system is built are similar to those used in electronic computers. The essential bricks are "gates" and "stores". The gate is the electronic equivalent of a relay and its contact; when operated it closes a path between two terminals. Such gates can be made to operate and release in less than a microsecond.

For storage purposes magnetostrictive delay lines (described below) and a magnetic drum are employed.

Permanent information relating to the subscribers' lines—for example, their type, class of service and meter records—is stored on a magnetic drum, each line being allocated a small section of the drum surface for this purpose. The magnetic drum is similar in appearance to that described in the Winter 1958 *Journal.* Delay line stores are used for the storage of information which is required only temporarily—for example, for digits dialled by the callers or to retain the memory of the paths over which a particular connexion has been established.

The delay line consist of a thin wire of magnetic material threaded through two coils, one at each

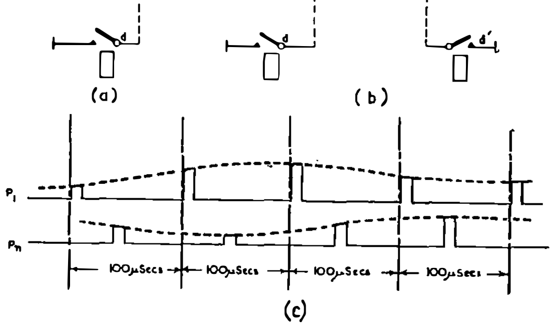

Fig. 1 (a), (b), (c): Principle of time-division-multiplex

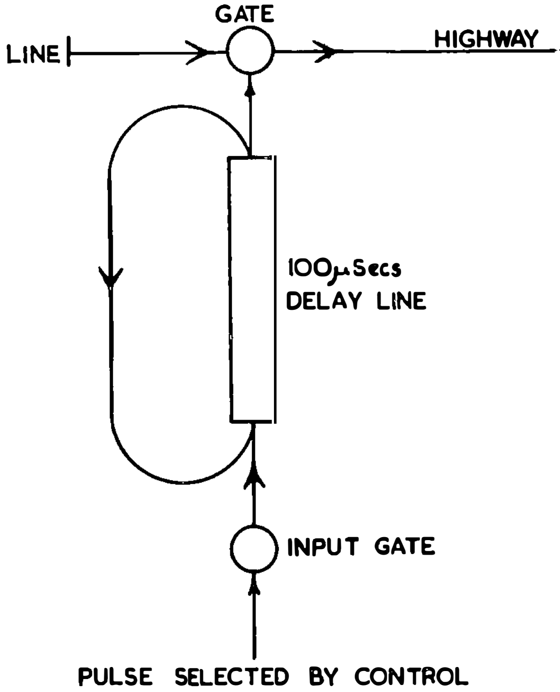

Fig. 2: Principle of delay line store

end. If a current pulse is applied to one of these coils a slight deformation takes place of the wire within the coil and a mechanical wave is transmitted along the wire, the time taken for the wave to reach the distant end depending on the nature and length of the wire—about 5 microseconds per inch for the wire used on the model. This wave is detected by the second coil, and the resulting electrical signal is amplified and re-applied to the input coil.

Thus, a number of pulses suitably displaced in time may be injected into and allowed to circulate indefinitely in the wire storage system. The delay line thus acts as a "memory" device since once in the system each pulse will be found re-entering the wire at an exact multiple of the time it was originally injected. Any pulse can be erased from the system by inhibiting its re-entry at any of these times. The delay lines used in the experiment are either 100 and 900 microseconds long, the 100 microsecond lines being commonly used in the connexion path memories and the longer lines for the storage of other information relating to the calls.

The transmission system uses the principle of Time–Division–Multiplex that is, no call has the exclusive use of any path through the exchange but, instead, each path is shared by a number of calls each of which is allocated the use of the path for a brief fixed period in a time cycle. Fig. 1 (a) illustrates the principle. A number of subscribers, four of which are shown, are connected via relay contacts to a common wire or highway H. (The relays shown are individual to the lines). To connect *a* to *c*, relays *a* and *c* must be operated at the same time, and clearly no other independent conversation is possible while this condition obtains. If, however, the relays *a* and *c* are operated and released at regularly repeated intervals which allow time for another pair of relays to operate when *a* and *c* are released, samples of two conversations will appear alternately on the highway. Each listener will hear fragments of the conversation of his correspondent but there will be no connexion between the two calls.

Further, if the relay sequence operates fast enough subscribers will not notice the discontinuities in the speech. If more than one group of lines is fitted the same principles could be applied but in considering calls between groups such as calls from *a* to c^1 (Fig. 1 (b)) care must be taken to ensure that the time period allocated for the call is not already in use in either of the groups: that is, that relay *IH* (the inter-highway connecting gate) closes only during the times allocated to the inter-group calls. On the other hand there is nothing to prevent any call which terminates within its own group from using a time period identical to one already in use on a call in another group, always providing the groups are not interconnected at that instant.

By using ultra high speed relays (electronic gates) 100 conversations can be carried on each highway. Each call is then allocated one of 100 one microsecond periods or pulse channels in a repeating cycle 100 microseconds long.

Fig. 1 (c) shows two conversations, one allotted pulse channel P_1 the other channel P_n. Both calls are carried on the same wire. At time P_1 the gates appropriate to the first call open to switch a pulse on to the highway. The amplitude of the pulse is modulated by the level of the wave form of the speech at the instant of sampling, as shown by the dotted line, which indicates the envelope of the wave form. The second conversation is sampled similarly at time P_n. Each conversation is therefore sampled for a period of one microsecond at intervals of 100 microseconds; that is, 10,000 times a second. The original wave form is reconstituted in the receiving portion of the line circuits, but in any case the discontinuities would be too short to be noticed by the callers.

The switching of the gates is controlled by delay line stores. Fig. 2 indicates the principle. A selected pulse appropriate to the channel to be used is applied to the input gate of the delay line and is detected at the output 100 microseconds later at which time it momentarily closes the gate joining the line to the highway. The pulse re-enters the delay line and reappears at the output 100 microseconds later, the process continuing despite the removal of the original pulse from the input gate. Hence once a connexion has been established in this manner the delay line will retain a "memory" of the pulse channel used on the connexion and continue to control the gate until such time as the circulating path is broken to release the call.

The circuits are arranged so that as long as the subscriber's line is looped a train of pulses will flow out on to the highway at the time indicated by the delay line. During dialling these pulse trains will be interrupted but the connexion will remain held, both the set-up and release of connexions being controlled by common apparatus.

The block schematic diagram of a two group system is shown in Fig. 3. The traffic carrying capacity of each group is about 60 erlangs so that the number of lines (subscribers' plus junctions) in a group may vary considerably. At Highgate Wood it will be 800.

The exchange divides into two parts, the switching network and the controls. The switching network contains the highways and their interconnecting gates, with similar gates by which any highway can be connected to the register. In contrast to step by step systems the network does not include means of selection, the paths to be used for any call being selected by the common control. The high speeds of electronic apparatus enable one selector to serve even for the largest exchanges; they also enable calls to be set up on a "one at a time" basis because at any instant only one call, either incoming or outgoing, can be in process of being connected.

When a call is originated the selector chooses a pulse channel to connect the caller with the register, the appropriate gates being operated as previously described with reference to Fig. 2. If a number of calls arrive simultaneously they are connected by the control in a particular sequence, the time of connexion of each call to the register being so short that there is no apparent delay. The final

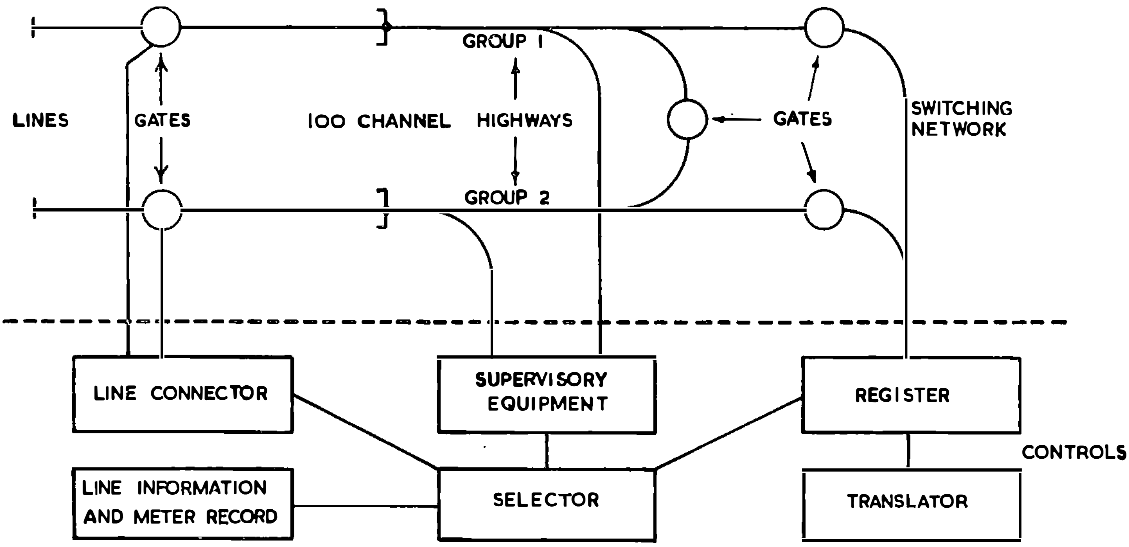

Fig. 3: Diagram of experimental electronic exchange

Fig. 4: General view of equipment racks

connexions to the called lines are set up in a similar manner, only one call being dealt with at one time.

The equipment provides all the normal facilities of a director exchange and allows for developments such as Subscriber Trunk Dialling. Register and supervisory equipments give standard facilities but are arranged on a common basis, the application of time sharing principles enabling one set of storage equipments to deal with a large number of connexions. Up to 100 registers can be made common in this manner and the common supervisory apparatus can monitor and control all the calls in the exchange.

The system provides full flexibility. Any type of line can be given any position in the exchange. P.B.X. lines and junctions can be selected sequentially even when not wired to adjacent equipment positions.

A view of a section of the model is shown in Fig. 4.

Conclusion

Highgate Wood will not be opened for public service until the equipment has been subject to the most stringent tests. Although every care will be taken to minimize the risk of breakdown some risk must always remain when an experiment of this magnitude is undertaken. Hence the present electro-mechanical installation will be arranged to serve as an emergency reserve for the electronic exchange. One effect of this decision is that the electronic system has to use the existing subscribers' apparatus, including the standard dial and bell set. Since electronic switches cannot readily handle the high power necessary to ring the bells each line circuit is equipped with a relay for this purpose. Indeed, in respect of connexions to the outside world the electronic system is in the same position as the earliest automatic exchanges and conversion equipment has to be fitted on all external circuits to ensure compatibility between the new system and the old.

The design and development of the system has meant considerable effort from each of the parties to the J.E.R.C. Agreement. Although detailed design work and manufacture has been apportioned between the parties the close co-operation between them has ensured the development of a fully integrated system.