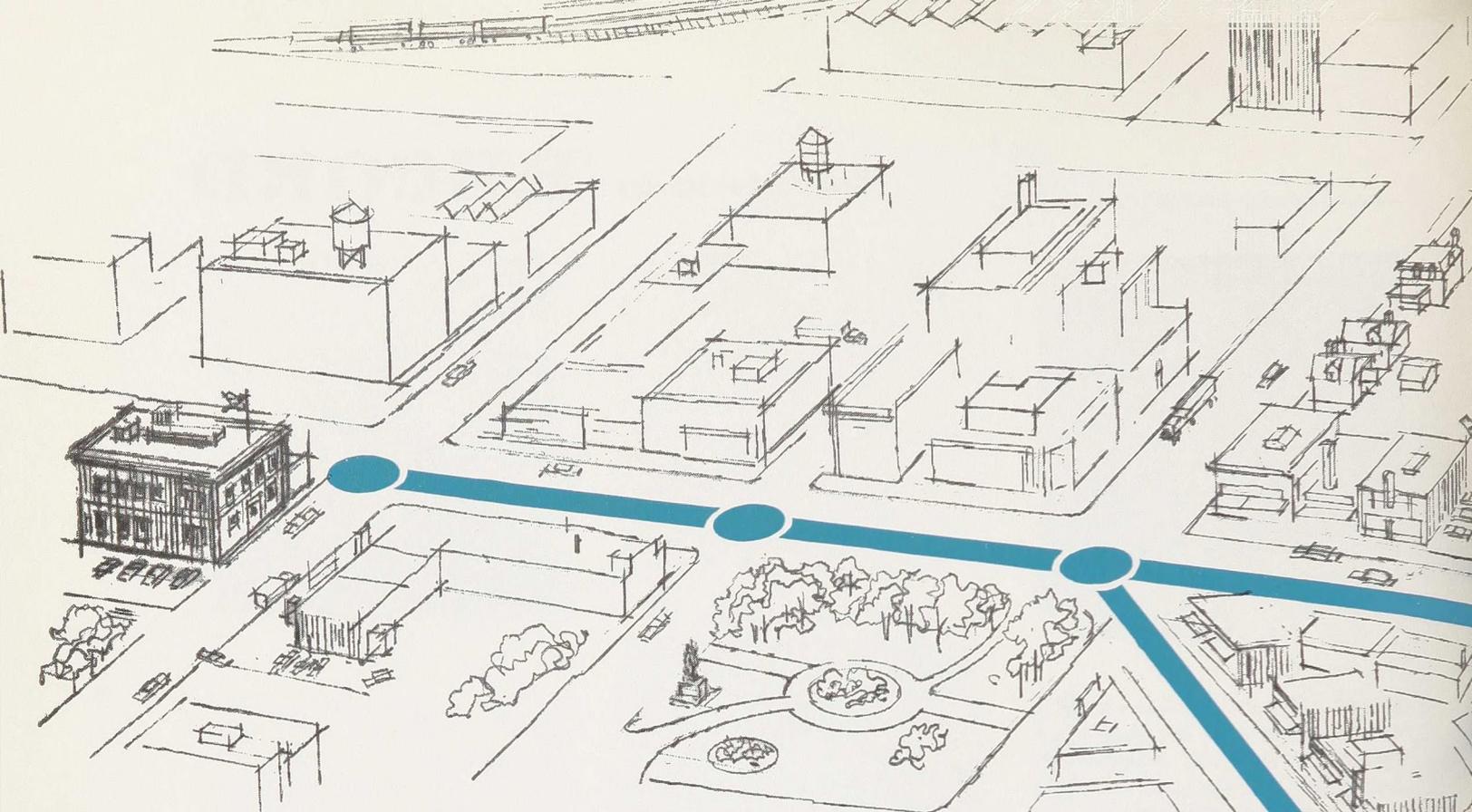


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**Cover** *Illinois Bell engineers run transmission tests on T1 carrier system installed at Skokie, Ill. office (See story on page 281).*



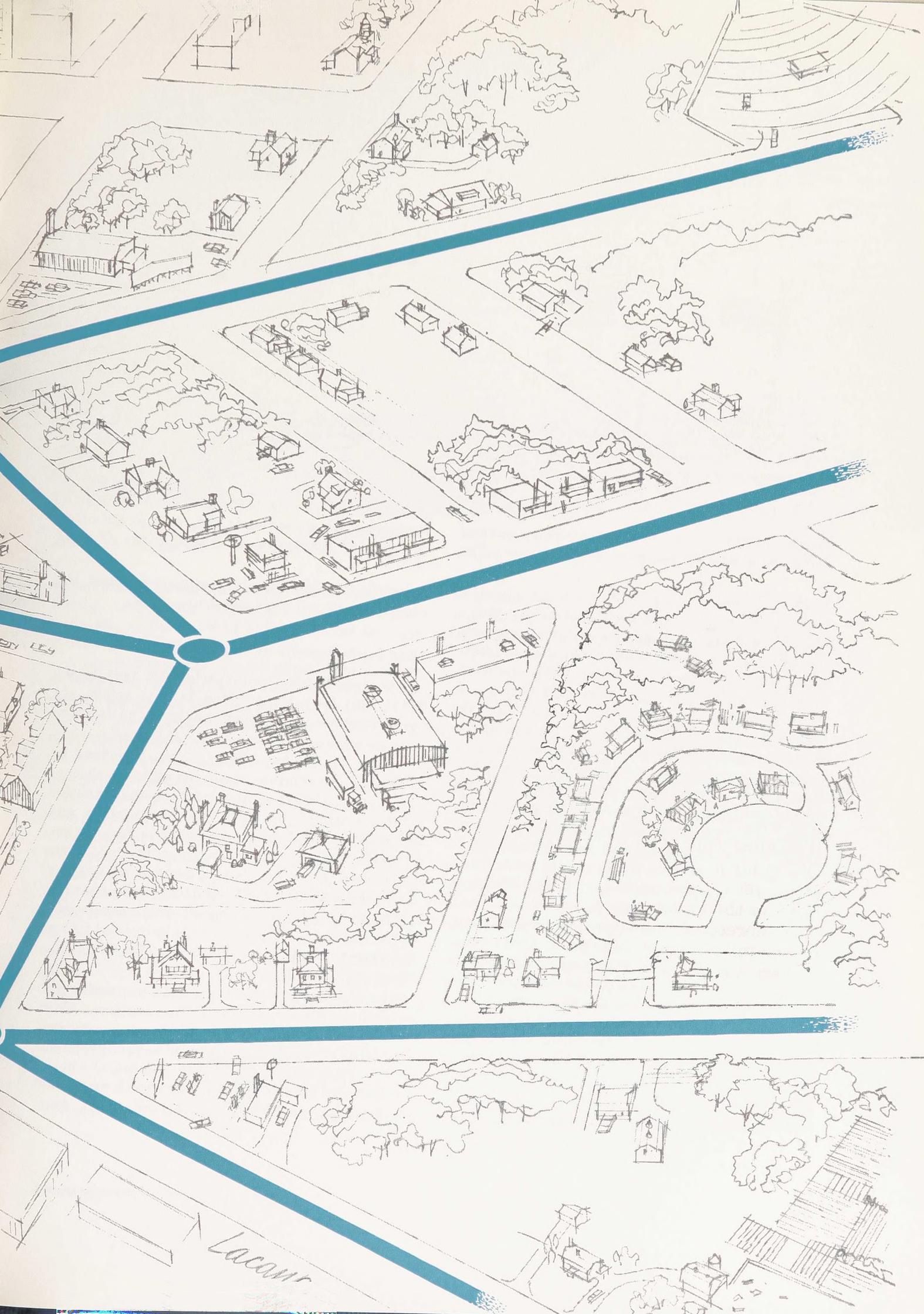
# Engineering Outside Plant With Computers

R. W. Amory

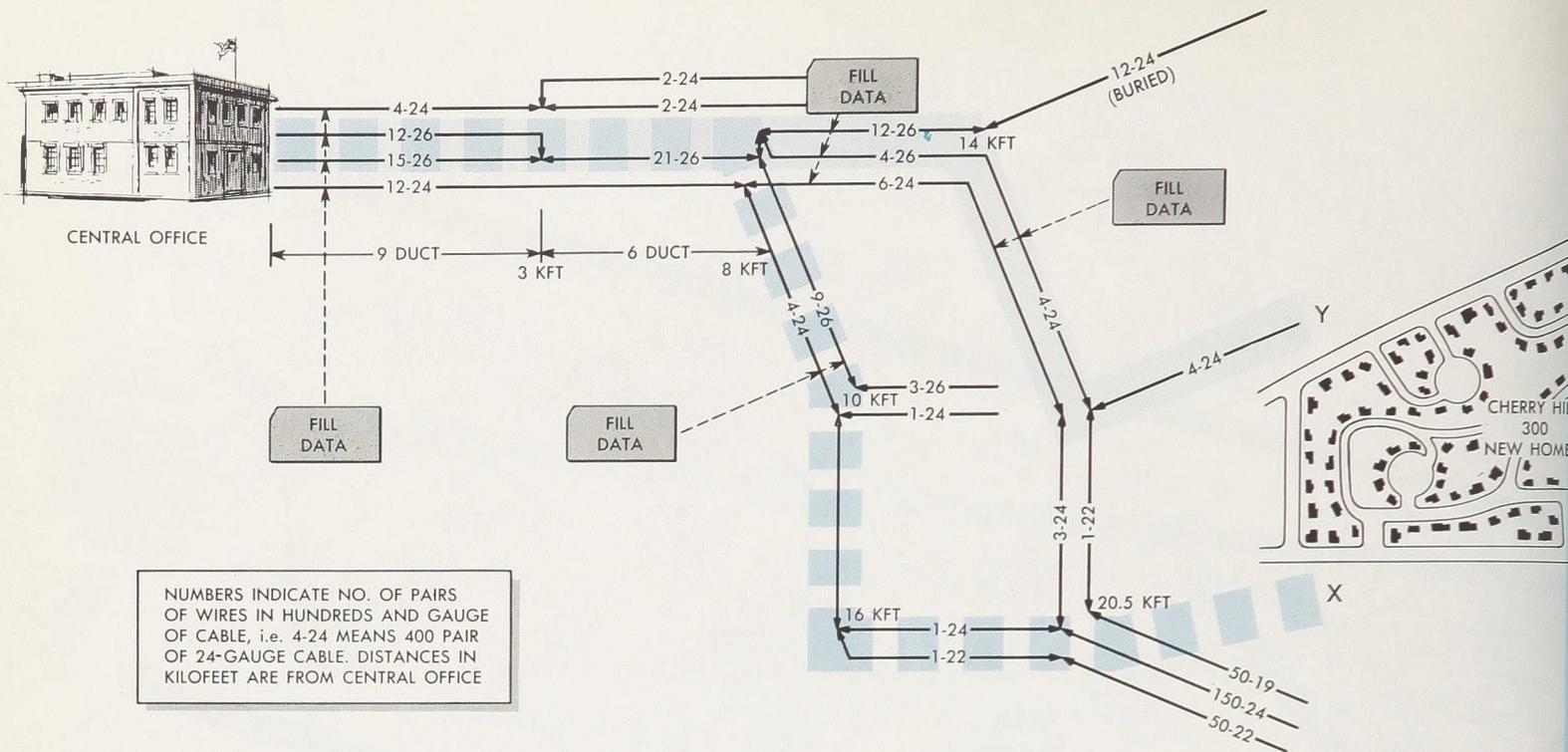
**E**XCHANGE OUTSIDE-PLANT ENGINEERING encompasses the design and administration of the telephone facilities connecting the customer to the central office. To satisfy the increasing demand for new telephone service, the Bell System spends over \$500 million annually for additions to the exchange outside plant. About 10 per cent of this represents the cost of engineering this construction program.

Because of the many technological improvements that have been made since World War II, the outside plant has been in a period of transition. Fifteen years ago, the outside plant was a network of paper-insulated cables, limited access terminals, and an appreciable amount of open wire. Today, there are PIC (polyethylene insulated conductor) cables, full access terminals and new systems,

*Highly-stylized drawing exemplifies the problems inherent in selecting best route to provide service from central office (left) to new housing development (right).*



Lacour



Schematic diagram of routing between a central office and a new development of 300 homes. The

capacity of each section of the route is indicated in terms of number of pairs and gauge of cable

such as concentrators, which permit multiple use of cable pairs (RECORD, September, 1962). Tomorrow holds promise of even more intricate multiplexing systems. As innovations create alternative means for solving cable network problems, outside plant engineering becomes a more complex, time consuming and costly task.

networks be individually designed to meet the characteristics of each particular area.

To cope with this problem, the Outside Plant Engineering Department at the Laboratories, in cooperation with the Outside Plant Facilities Group at AT&T undertook studies concerning the use of computers in engineering the exchange plant. The computer programs and associated methods that were developed have been successfully tested in several telephone operating companies and are now operational in the Michigan Bell Telephone Company.

#### Four Basic Aspects of Engineering

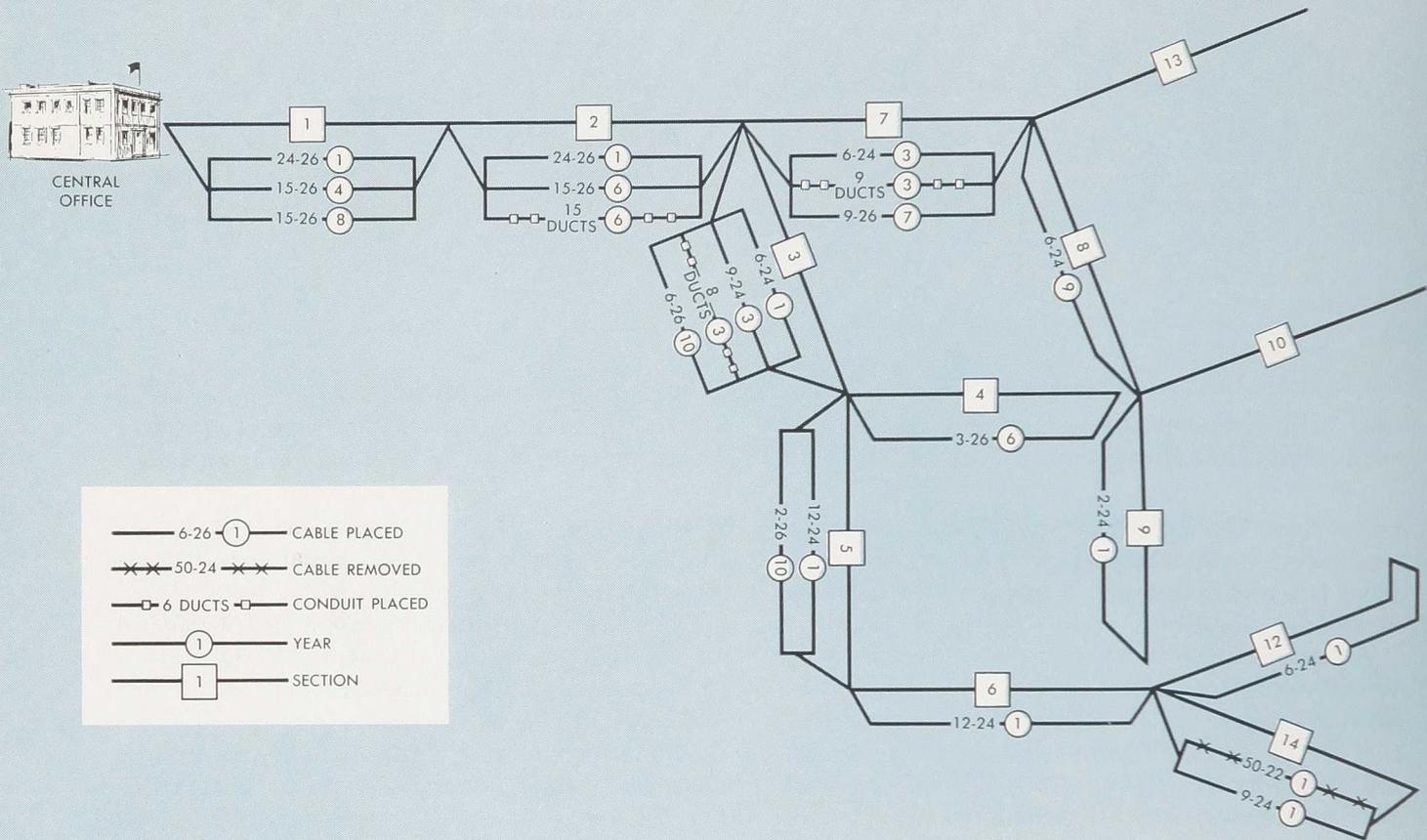
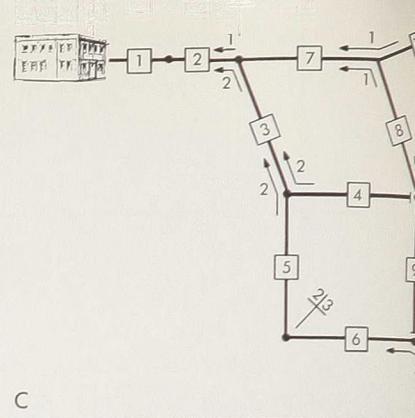
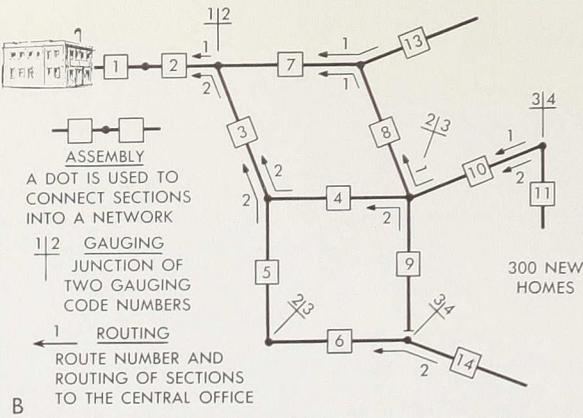
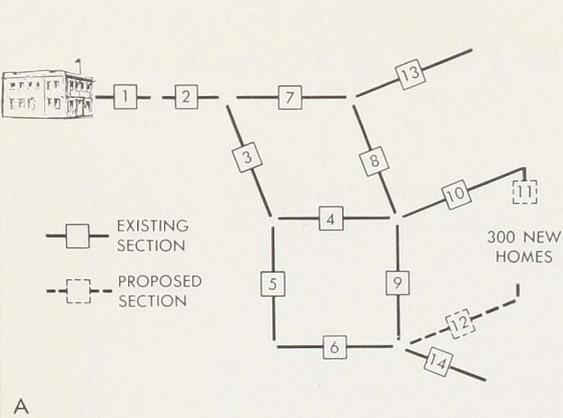
The outside-plant engineering job may be divided into four parts which in this article are called *problem*, *alternatives*, *analysis* and *decision*.

Before discussing these new engineering methods, let us consider the three major factors that influence the design of the exchange plant: (1) the geography of the area served (the location of streets, rivers, lakes and so forth), (2) the present and future needs of the telephone customers and their location in the area, and (3) the engineering of present and new facilities. Variations in these factors from one central office to another over a period of years result in a large number of different conditions which require that outside-plant

A *problem* occurs when additional outside-plant facilities are needed. The problem is defined by collecting information about the physical characteristics of the area, the location and quantity of the existing cable facilities and structure, and the present and future requirements for service. In general, the engineer works with some form of a schematic of the route, such as that shown above. Each box marked "fill data" in the drawing contains data in chronological order concerning the available facilities and the existing and future requirements of the cross section with which the box is associated.

The *alternatives* are determined to provide for several possible solutions to the problem. This usually takes the form of tentatively selecting several alternate routes to serve the problem area. In the layout shown on the frontispiece, the basic problem is to provide facilities to a proposed development of 300 homes located about four





In diagrams above, proposed routes are divided into nonconnected sections. As shown in A, sections 11 and 12 are alternative means for connecting the present network to the development. Rout-

ing criteria for each alternative are shown in figures B and C. The lower drawing indicates the ten year requirements for cable and conduit as recommended by computer for alternative in C.

materials, cost, and timing involved for each alternative solution may be obtained for periods ranging from one to thirty years. The print-out provides the engineer with the information necessary to make the final decision and prepare construction work orders.

and the cost of materials that apply in the area under study.

The input data to the program is divided into four parts:

(2) PROBLEM DATA — constitutes the bulk of the information describing the *problem*, and includes available facilities, requirements and type of supporting structure. These data are recorded by section, which is defined as a length of feeder route that can be engineered as a unit. A complex feeder route consists of many sections.

(1) ECONOMIC DATA—includes economic tables

This section concept is illustrated in A above. It shows the cable route introduced on the frontispiece as a section schematic. The program can handle a maximum of 99 sections.

(3) ASSEMBLY DATA — directs the program in assembling the section data into a complete feeder route network. The section assemblies for alternatives X and Y are shown on page 262 (B and C). Because only a small amount of data is required to assemble a complete network, alternatives can easily be investigated. As part of the strategy, the facility requirements in each section can be divided over several paths to the central office. This division of load can be changed as a function of time, thus permitting the shifting of a load from one path to another.

(4) RUN DATA — consists of two optional types of instructions for obtaining an analysis of all or selected sections of the problem with modifications of the economic data and/or problem data. Among other things, the effects of variations in the growth forecast, changes in structure or cable fills can be evaluated.

### **Computer Program**

The computer program consists of a main routine and thirteen subroutines. The main routine contains the logic for reading and storing the input data, determines the sections that have facility shortages and directs them to the proper subroutines for detailed analysis. In addition, it summarizes and stores the resulting data for future printing.

Subroutines are groups of sequential logic instructions that operate on the input data and do specific analyses. A major subroutine called Data Assembly is organized to accept the detailed problem data by sections, assemble it into a feeder route network, and determine the cumulative present and future requirements by gauge.

In today's exchange plant design, transmission requirements are satisfied if the resistance limits assigned to a central office are not exceeded. Therefore, the gauge requirement for a cable pair is a linear function of the central-office resistance limit and the distance between the customer and the office. These requirements are incorporated into the computer program by the assignment of a Gauge Code Number (GCN) to each section of the network. The program contains the logic for interpreting the GCN and determining the gauge requirements for each section along the entire route to the central office.

The output of the Data Assembly Subroutine is the cumulative present and future requirements by gauge for each section of the network, ready for detailed analysis. The remaining subroutines of the program do the detailed analysis and most of the designing of the feeder route.

The Main Subroutine analyzes the growth problem, section-by-section, year-by-year, for the entire study period. For each year and at each section it compares by gauge the facilities available to the requirements. Coarse gauge facilities, if available, are used to solve a fine gauge problem. Should the facilities exceed the requirements, the next section is examined. Should a shortage of facilities exist, the program flow is directed to the proper subroutine to analyze this in detail. The appropriate subroutine is determined by the type of support structure involved, that is, aerial, underground, or buried plant.

The type of support structure, in turn, determines the extent of the problem and directs the specific analysis by calling in the appropriate subroutine. There are three theoretical cable sizing subroutines, one each for sizing aerial, underground, and buried cables.

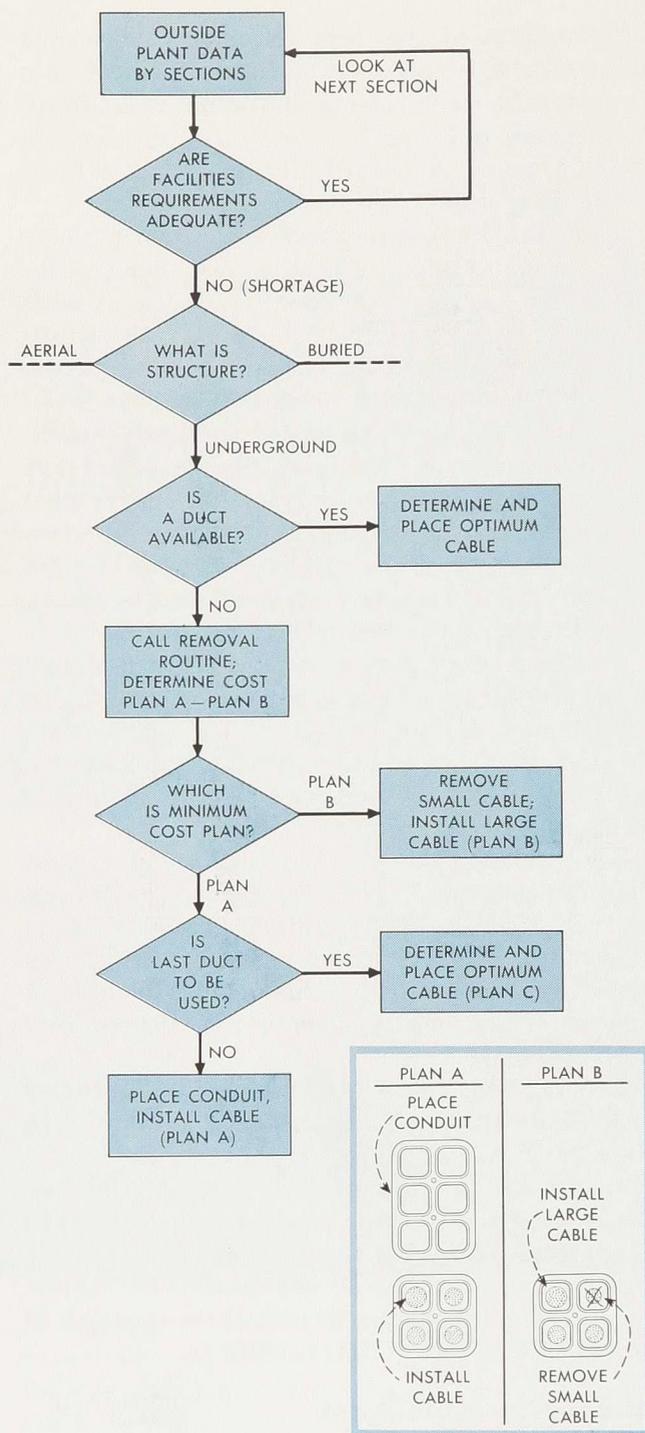
An optimum cable size is a function of growth requirements and local costs. Because cables are manufactured in discrete sizes, the optimum is determined by an iterative process in which the size resulting in the minimum over-all cost is selected. The choice is made by the Discrete Sizing Subroutine.

In designing pole lines, cost per unit distance is used as the basis for analysis. However, in the case of conduit, the subroutine determines the optimum size (number of ducts) required to meet the estimated future demand. Because the type of paving, trenching conditions and vehicular traffic volume significantly change the cost factors, the program is designed to permit the engineer to adjust costs to reflect field conditions.

### **Alternative Subroutines For Structure Congestion**

A Removal Subroutine is used when the structure—pole line or conduit—is congested; for example, where a four-duct conduit run has three cables and a new cable is needed. The subroutine investigates and evaluates two alternative solutions to this problem.

Plan A — Place new structure and new cable as determined by growth requirements.



Flow diagram showing major questions and answers which the computer program follows in determining the various outside plant installation possibilities.

Plan B — Place a new large cable, remove a small cable and defer placing the new structure.

Plan A is straightforward in that an optimum

size cable and conduit system can be determined independently by calling in the proper sub-routines.

Plan B requires programming logic to scan the existing cables and determine which cable would incur the least penalty if it were removed. In this process, the worth of each cable is measured by the present and future needs of the particular section. Once it is decided which cable is to be removed, the size of the new cable is determined. This size must provide replacement pairs for the cable being removed. The choice between Plan A and Plan B is based on economic factors. The capital required to reinforce the conduit system in Plan A is calculated. The number of years this conduit system would be deferred under Plan B is determined and Plan B is credited with a saving for having deferred these conduit expenditures for that length of time. From these savings, the economic penalties incurred in Plan B are subtracted. These penalties are generally the cost of removing the existing cable and the replacement of the pairs removed. If the saving is positive, Plan B is considered the best solution. A simplified flow diagram of a typical removal routine problem and the decisions involved is shown at the left.

Plan C may be investigated at the discretion of the engineer. For instance, the engineer has the option of coding the input data for a section to cause the program to place a cable in the last available duct. As the risk involved with such a choice cannot be evaluated by economics, this plan is not compared to Plan A or B. Should the engineer decide that the last duct is to be used, the program logic is as follows. When a cable is to be placed and only one duct is available, a Plan A vs. Plan B economic comparison is made to determine the proper action. If Plan B is the economic choice, it will be followed. Should Plan A be selected, this decision is set aside and a cable is placed in the last duct (Plan C). The cable size and gauge placed in the last duct reflects the optimum economic condition established between the size of cable placed and the value of the deferred conduit investment.

Selected parts of computer printout sheets summarize data, and present results of possible solutions to specific problems. The optimum economic solution is recommended; however, the ultimate decision is the engineer's.

OUTSIDE PLANT FEEDER ROUTE ANALYSIS

PROBLEM 999 ASSEMBLY PLAN Y RUN 1 SOUTHWOOD EAST BAY DISTRICT EASTERN BELL  
 SECTIONS NUMBERED 1 THROUGH 14 STUDY PERIOD IN YEARS = 10  
 MAX. NO. OF CABLES ON POLE LINE = 3 MAX. NO. OF PAIRS ON POLE LINE = 1800.  
 CABLE SIZING FACTOR = 1.00 BURIED PLACING COST = \$ 1.00  
 CONDUIT PAVING COST = \$ 4.00

CUMULATIVE DATA SUMMARY

SECTION	1	2	3	4	5	6	7	8	9	10	11	12
SECTION LENGTH	3000.	5000.	2000.	6000.	6000.	4500.	6000.	2000.	4500.	4000.	3000.	4000.
AVAILABLE FACILITIES												
19 GAUGE PAIRS	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
22 GAUGE PAIRS	-0.	-0.	-0.	-0.	-0.	100.	-0.	-0.	100.	-0.	-0.	-0.
24 GAUGE PAIRS	1600.	1600.	400.	100.	400.	100.	600.	600.	-0.	400.	-0.	-0.
26 GAUGE PAIRS	2700.	2100.	900.	300.	-0.	-0.	1600.	400.	-0.	-0.	-0.	-0.
CABLE LIST												
CABLE SIZE 1	400.	200.	400.	100.	400.	100.	400.	400.	100.	400.	-0.	-0.
CABLE SIZE 2	1200.	200.	900.	300.	-0.	100.	600.	600.	-0.	-0.	-0.	-0.
CABLE SIZE 3	1200.	1200.	-0.	-0.	-0.	-0.	1200.	-0.	-0.	-0.	-0.	-0.
CABLE SIZE 4	1500.	2100.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
CABLE SIZE 5	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
CABLE GAUGE(1,2,3,4,5)	33440	33340	34000	34000	30000	32000	43400	43000	20000	30000	00000	-00000
STRUCTURE												
EXISTING-PROPOSED	2 2	2 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	0 1	0 1
NO. CABLES-NO. DUCTS	4 9	4 6	2 0	2 0	1 0	2 0	3 0	2 0	1 0	1 0	0 0	0 0
FILL AT RELIEF	0.85	0.85	0.85	0.85	0.90	0.90	0.85	0.85	0.90	0.90	0.85	0.85
WORKING FACILITIES												
19 GAUGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22 GAUGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24 GAUGE	470.	470.	545.	0.	545.	545.	250.	250.	60.	190.	0.	300.
26 GAUGE	4105.	3205.	860.	285.	185.	0.	1260.	170.	0.	0.	0.	0.
GROWTH REQUIREMENTS												
YEAR 1												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	20.0	20.0	25.0	0.	25.0	25.0	50.0	50.0	40.0	10.0	0.	10.0
GAUGE 26	390.0	290.0	40.0	15.0	15.0	0.	155.0	30.0	0.	0.	0.	0.
YEAR 2												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	20.0	20.0	24.0	0.	24.0	24.0	45.0	45.0	40.0	5.0	0.	10.0
GAUGE 26	294.0	234.0	50.0	10.0	30.0	0.	95.0	20.0	0.	0.	0.	0.
YEAR 3												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	30.0	30.0	35.0	0.	35.0	35.0	25.0	25.0	20.0	5.0	0.	10.0
GAUGE 26	255.0	215.0	50.0	10.0	30.0	0.	95.0	20.0	0.	0.	0.	0.
YEAR 4												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	30.0	30.0	35.0	0.	35.0	35.0	25.0	25.0	20.0	5.0	0.	10.0
GAUGE 26	255.0	215.0	50.0	10.0	30.0	0.	95.0	20.0	0.	0.	0.	0.
YEAR 5												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	35.0	35.0	40.0	0.	40.0	40.0	25.0	25.0	20.0	5.0	0.	10.0
GAUGE 26	235.0	195.0	30.0	10.0	10.0	0.	95.0	20.0	0.	0.	0.	0.
YEAR 6-10												
GAUGE 19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
GAUGE 24	35.0	35.0	40.0	0.	40.0	40.0	25.0	25.0	20.0	5.0	0.	10.0
GAUGE 26	235.0	205.0	30.0	10.0	10.0	0.	115.0	20.0	0.	0.	0.	0.

ALL FINAL DECISIONS ARE PRECEDED BY THREE ASTERISKS \*\*\*

YEAR 1

SECTION 1

OPTIMUM CABLE SIZING ROUTINE AVERAGE PAIRS SHORT IN PAIRS SHORT IN  
 GROWTH CROSS-SECTION GAUGE  
 PLAN I OPTIMUM SIZE BASED ON PROBLEM GAUGE  
 YEAR 1 PLACE 2400. PAIRS OF 26 GAUGE 2 CABLE 260. -1330. -1410.  
 WILL CONSIDER PLANS I, II AND III  
 CANNOT OVERSIZE PLAN 1 CABLE, THEREFORE PLAN II IS OMITTED.  
 WILL CONSIDER PLANS I AND III  
 YEAR 4 NEXT SHORTAGE NOT IN COARSER GAUGE, PLAN III OMITTED

\*\*\*PLACE 3000. FEET OF 2400. PAIR 26 GAUGE U.G. CABLE PAIRS SHORT(26 GA)=-1330. AC = 4901. IFC = 32688.

SECTION 2

OPTIMUM CABLE SIZING ROUTINE AVERAGE PAIRS SHORT IN PAIRS SHORT IN  
 GROWTH CROSS-SECTION GAUGE  
 PLAN I OPTIMUM SIZE BASED ON PROBLEM GAUGE  
 YEAR 1 PLACE 2100. PAIRS OF 26 GAUGE 2 CABLE 215. -840. -920.  
 WILL CONSIDER PLANS I, II AND III  
 YEAR 5 NEXT SHORTAGE NOT IN COARSER GAUGE, PLAN III OMITTED  
 YEAR 5 CABLE RELIEF REQUIRED IN 26 GAUGE  
 YEAR 5 PLACE 12 DUCT CONDUIT  
 YEAR 5 PLACE 1200. PAIRS OF 26 GAUGE 2 CABLE 205. -29. -134.

PLAN II-1 OVERSIZING CABLE  
 YEAR 1 PLACE 2400. PAIRS OF 26 GAUGE 2 CABLE  
 YEAR 6 CABLE RELIEF REQUIRED IN 26 GAUGE  
 YEAR 6 PLACE 12 DUCT CONDUIT  
 YEAR 6 PLACE 1200. PAIRS OF 26 GAUGE 2 CABLE 205. -14. -119.  
 SAVINGS FOR DEFERRING CABLE 1 YEARS = 3318.54 SAVINGS FOR DEFERRING STRUCTURE 1 YEARS = 8803.80  
 PENALTY FOR OVERSIZING = 669.88  
 SUMMARY \*\*\* PLAN II-1 NET SAVINGS OVER PLAN I = \$ 11452.47

\*\*\*PLACE 5000. FEET OF 2400. PAIR 26 GAUGE U.G. CABLE PAIRS SHORT(26 GA)=-840. AC = 8168. IFC = 54479.

PROBLEM 999 ASSEMBLY PLAN Y RUN 1 SOUTHWOOD EAST BAY DISTRICT EASTERN BELL

SUMMARY END OF YEAR 1

	IFC	AC	CUM AC	PLANT PLACED			
AER. CABLE	67250.	11293.	11293.	MCF	19 GA	22 GA	24 GA
UND. CABLE	87167.	13069.	13069.		0.	0.	30.600
BUR. CABLE	0.	0.	0.		0.	0.	38.400
CONDUIT	0.	0.	0.	TRENCH FT. =	0.	DUCT FT. =	0.
POLE LINE	1492.	266.	266.	POLE LINE FT. =	4000.		
TOTALS	155909.	24628.	24628.				

CUM PWAC = 24628.

The cable-sizing routines optimize a cable size as a function of the anticipated growth in the particular gauge in which the shortage has occurred. The Oversizing-Overgauging Subroutine concerns optimizing both the cable size and gauge as a function of the present and future requirements for all gauges and the need for new structures in the section to be analyzed. Any cross section of an exchange network may require several of the four basic gauges of conductors. Because a cable usually contains only one gauge of conductors, heavy gauge conductors are sometimes used to serve customers having fine gauge requirements. The use of an overgauge cable may economically defer the placing of a fine gauge cable and/or structure. Also the oversizing of a cable may do likewise. Therefore, this routine investigates the following three alternative plans:

Plan I—assumes that the size and gauge of cable selected by the Discrete Sizing subroutine has been placed. It then determines future needs for other cables and new structures over a significant study period and calculates the cost of these materials.

Plan II—follows the procedure described in Plan I except that the initial cable selected by the Discrete Sizing subroutine is oversized. The economic penalty for oversizing is compared with the possible savings derived by deferring a Plan I finer gauge cable and/or a new structure. Should Plan II indicate a saving, the oversizing procedure is continued until the maximum savings are achieved.

Plan III—is used when a coarse gauge cable is required in Plan I at some future date. The procedure described in Plan I is followed except that the initial cable selected by the Discrete Sizing subroutine is replaced by the coarse gauge cable. In this case, the economic penalty for advancing the placement of the coarse gauge cable is compared to the possible saving derived by deferring the initial Plan I cable and/or a new structure. Should Plan III indicate a saving, the economic worth of oversizing of the coarse gauge cable is also investigated.

The computer analyzes the Removal and Overgauging subroutines over a sufficient number of years to make valid comparisons. It then selects the most economical plan and automatically uses it in further calculations.

To illustrate the application of these computer techniques to the plant engineering job, let us follow the process for the simple problem presented on page 260. First the engineer divides the network into nonconnected sections as shown on page 262 (A). Based on his knowledge of

the problem area, he decided that two alternatives X and Y (A and B, page 262) should be analyzed by the computer. He records the basic data on such items as available facilities and forecast growth, and prepares the necessary section assembly instructions.

This information, together with the economic data, is keypunched and forwarded to the computation center for processing. For each alternative, the program assembles the sections into a network, determines the gauge needed for proper transmission and accumulates the requirements by gauges. This network is then analyzed by the program for the specified study period. The results of the analysis are returned to the engineer in the form of a computer print-out which indicates the immediate and long-range economic and material requirements of each alternative. Selected parts of the computer print-out for alternative "Y" are shown on page 265.

The results of the analysis for each alternative are plotted on the section schematic as shown on alternative Y in figure D on page 262. Based on this analysis and other factors, the engineer makes a decision to follow alternative X or Y or may ask the computer program to analyze a new alternative. Having arrived at a decision, the engineer prepares the necessary work orders.

Recent field experience indicates that the computer program and methods described here relieve the operating engineer of many lengthy routine calculations and permit a detailed analysis of many complex situations which are now resolved by judgment. Thus the engineer can devote most of his time to planning studies and making the final decision. In addition, the program provides a simple and very inexpensive means for evaluating many alternatives for solving a plant relief or extension problem.

The Exchange Feeder Route Analysis Program is quite versatile; although its design is based on current engineering practice, it is compatible with the new engineering concept called "Dedicated Outside Plant" which has been recently introduced into the field. In addition, exploratory studies indicate that the program is an effective analytical tool for the evaluation of new exchange plant systems and equipment proposals. It may also provide valuable assistance in exchange plant fundamental planning studies, the planning of new central offices, and the planning of the future construction program.

The digital computer, in conjunction with a family of suitable programs, holds great promise of becoming a powerful tool in the efficient utilization and design of the exchange outside plant.

# Common Control for Step-By-Step Central Office

Bell Laboratories engineers are completing the development of a system of common control that will make TOUCH-TONE Calling features and uniform dialing procedures available to telephone customers served by step-by-step central offices. Besides these and other customer benefits, engineering studies indicate that selector savings alone will almost pay for the installation of the new common control system in some locations where telephone operating companies plan to offer extended area service.

The significance of this development is heightened by the fact that almost 50 per cent of all dial stations in the Bell System are served by step-by-step offices. The direct customer benefits accruing from step-by-step common control are matched by flexibility and operating economies. In addition to the services mentioned above, step-by-step com-

mon control provides alternate routing of calls, multifrequency outpulsing to other telephone offices and certain maintenance improvements.

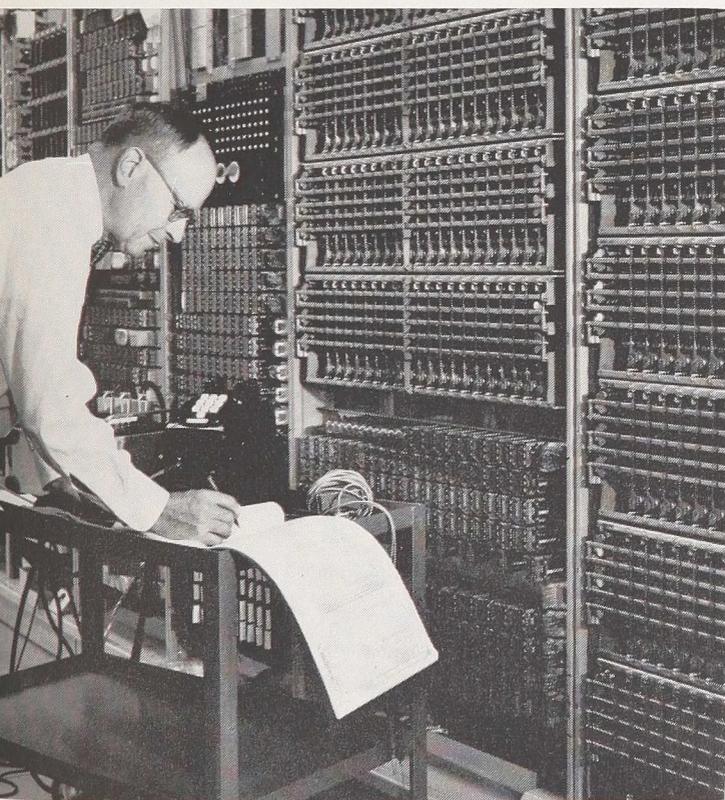
Common control is similar to a memory and logic unit; and like most such systems, common control can process information put into it in one form and release the same information in a different form. For example, common control can transform information inputs so that tone signals such as two-out-of-seven TOUCH-TONE signals from a station can be changed to dial pulses for use by the system or for transmission over a trunk to another office. Dial pulse information signals pulsed into the common control unit may also be converted to two-out-of-six multifrequency signals and outpulsed in this form.

Without common control, the central office equipment is controlled directly from the customer's dial. As each digit is dialed, switches are progressively "stepped." Thus, if all paths to another central office are busy, the customer gets a "paths busy" tone and the call cannot be completed. With common control, if all direct paths are busy, the decoder routes the call to a second group of paths to attempt to complete the call. Such improved methods of code conversion and alternate routing for local and toll traffic result not only in better service to customers, but also in economies in investment and operating costs.

The equipment will be arranged to provide TOUCH-TONE Calling only, common-control features with TOUCH-TONE Calling and common-control features without TOUCH-TONE Calling. If the TOUCH-TONE features are provided first, common control can be added conveniently at any time; the converse is also true. The equipment uses wire-spring relays, crossbar switches, solid-state devices, and other conventional telephone apparatus.

A separate, previously completed, development provides TOUCH-TONE Calling to small step-by-step offices in which common control will never be required. This so-called "non-compatible" TOUCH-TONE would be almost entirely removed to provide common control.

The step-by-step common control project is well along; the first installations are expected to be made in 1965. The Western Electric Works at Hawthorne will manufacture the system.



*In the Holmdel switching laboratory, C. A. Throckmorton tests the crossbar link which connects each call to the step-by-step common control equipment.*

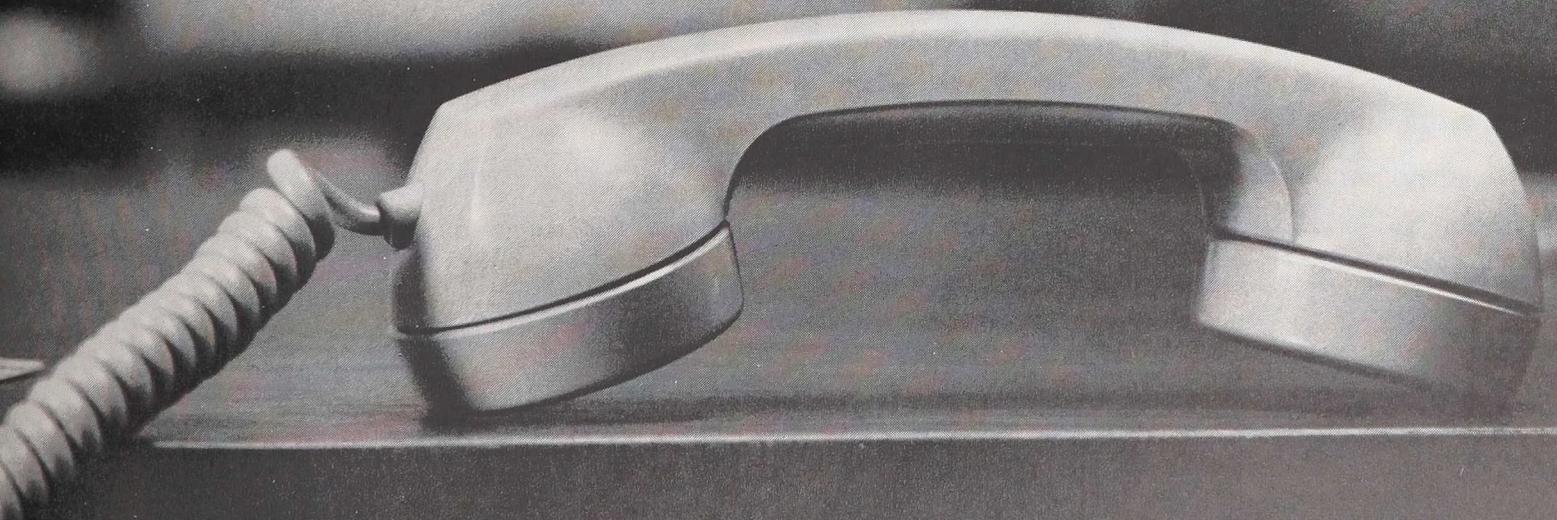


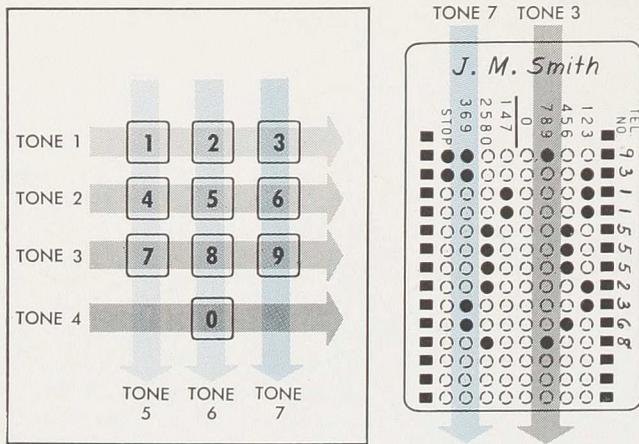
J. H. Ham and J. F. Ritchey

# TOUCH-TONE CARD DIALER Set

FOR MANY YEARS the Bell System has been experimenting with various forms of automatic dialing, to improve speed and accuracy, and to ease the burden of dialing the many digits which are becoming necessary in the modern switching plant. The TOUCH-TONE\* signaling system, which transmits audible multifrequency dialing pulses instead of the DC pulses generated by conventional dial mechanisms, offers a means by which dialing can be performed at a relatively high rate, approaching ten digits per second. The TOUCH-TONE CARD DIALER\* set now provides a means by which this dialing can be done automatically, using a plastic card which has been prepunched or encoded by the customer. A separate card is punched for each frequently-called number; the cards are stored with the telephone in a convenient storage pocket.

\*Bell System Service Marks





Pushing button generates two tones for signaling; holes punched in two columns on plastic card perform same function.

The TOUCH-TONE CARD DIALER set is a combination of a card reader and a standard TOUCH-TONE push-button dial, and can be used to place calls both automatically and manually, using TOUCH-TONE Calling signals. Although the TOUCH-TONE CARD DIALER set uses the card and reading mechanism principles developed for the 661A telephone DC CARD DIALER (RECORD, October, 1961), the concept of card dialing actually began with the TOUCH-TONE pushbutton version and the 3 by 4 coded card followed from it. Exploratory models of TOUCH-TONE CARD DIALER sets were tested in Hagerstown Md., during the spring of 1960. Because of delay in introducing multifrequency signaling, however, the DC pulse dialer was developed for service first. While the cards and outward appearance of the TOUCH-TONE and the DC sets are similar, basic differences exist.

When using either the TOUCH-TONE CARD DIALER set, or the 661 telephone set dialer, the customer selects a card, previously encoded with the desired number, from storage pockets in the set, and inserts it into the card slot. He then lifts the handset, and when dial tone is received, pushes the "Start" bar. Here the similarity to the 661 telephone set mode of operation ends.

### Signaling by Multifrequency Tones

As the card is ejected automatically in the TOUCH-TONE CARD DIALER set by a drive mechanism, holes in the card are "read" and translated into multifrequency dialing signals. (These signals are the same tones heard in manual TOUCH-TONE dialing).

The frequencies of these tones are determined

by the closure of two switches in the 3 by 4 multifrequency signaling matrix. In manual dialing, each of the ten buttons operates a unique pair of switches. With the CARD DIALER signaling unit, holes in the card operate similar switch pairs. Thus, to call a number on the new telephone set, one may either push buttons sequentially, or encode the digits required on successive lines of a 14-line card.

The digit-frequency relationship with respect to the buttons on the manual dial can be considered in terms of horizontal rows and vertical columns: four frequencies are associated with the rows and three with the columns. The column frequencies are all in one group, while the row frequencies are in another. Operating a button transmits a signal made up of the frequencies corresponding to the row and the column which intersect, as shown above.

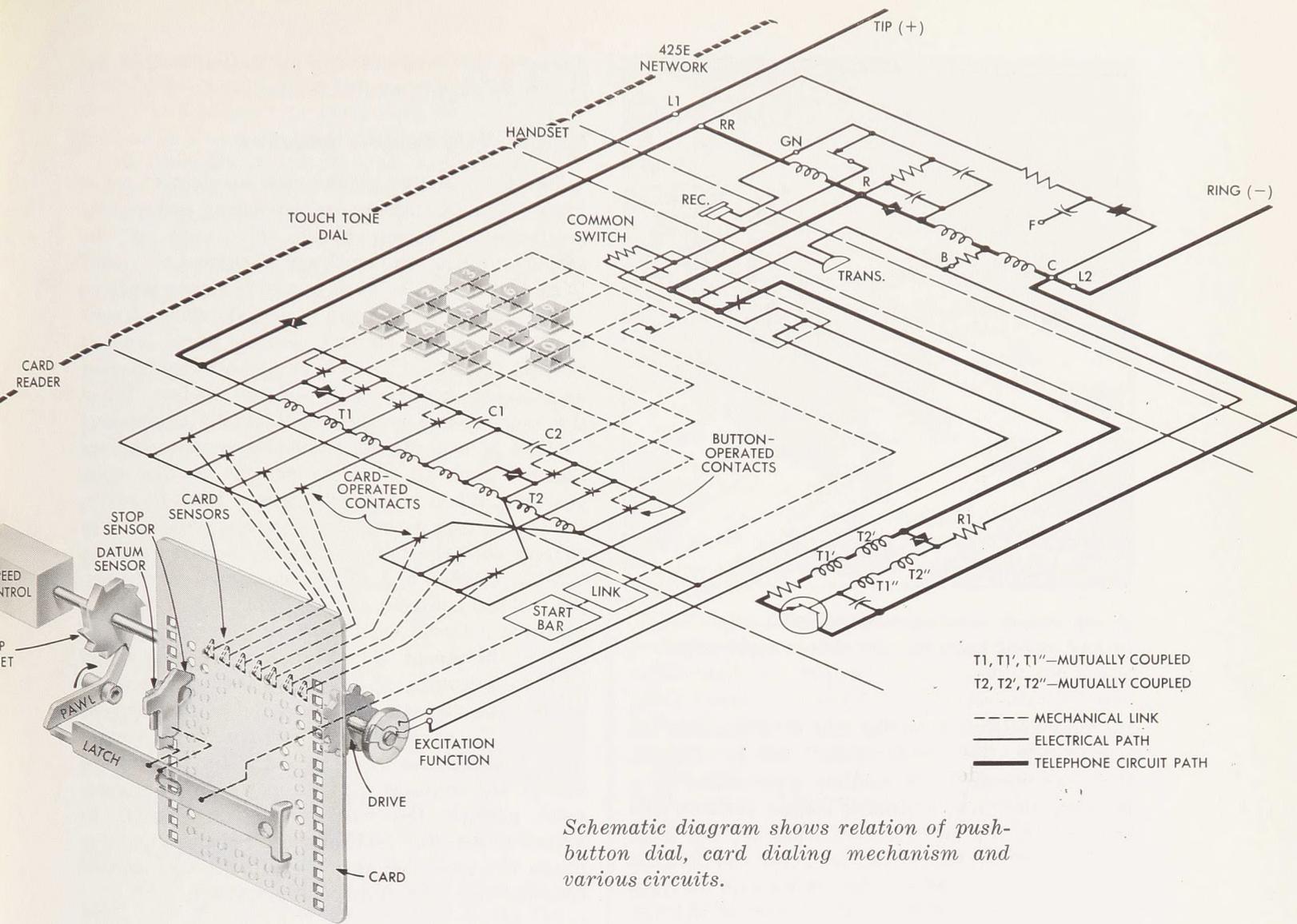
This relationship also forms the basis for the arrangement of the card used in the TOUCH-TONE CARD DIALER set. A telephone number can be encoded by punching two holes in each line to represent the value of the digits. When the card is "read", mechanical sensors fall into the holes in each of the 14 lines sequentially, and close coil-tap contacts to select the proper signal frequencies for each digit.

### Card Reader Parallels Push-button Dial

The functional schematic on page 271 shows the relationship between the card reader, the TOUCH-TONE push-button dial, and the standard telephone set network. Since the button-operated contacts are normally open, the contacts operated by the card sensors can be connected in parallel with the corresponding button contacts. In addition to selecting frequencies, every button operates a common switch which disconnects the handset transmitter to guard against voice simulated dialing errors and connects the TOUCH-TONE Calling circuit into the telephone set network. It also switches an attenuating resistor in series with the receiver, and then interrupts a DC path through the inductor windings T1 and T2 to initiate the signal at full amplitude by shock excitation.

When a customer dials with a card, the start bar moves a mechanical link to hold the common switch in its operated position for the entire dialing sequence. However, since the excitation function must occur for every digit or line on the card, a rotary switch, synchronized with the action of the hole sensors, opens and closes the T1-T2 path as each line of the card is read.

This rotary excitation switch and the mechan-



*Schematic diagram shows relation of push-button dial, card dialing mechanism and various circuits.*

ical link for the common switch make it possible to provide both manual and push-button card dialing from a single circuit package. The mechanical link consists of a pair of plastic molded details, one of which is compliant. This application, incidentally, demonstrates that the spring or elastic properties of certain thermoplastics may be utilized wherever the time duration of loading is short. Excessive creep or stress relaxation characteristics, of course, prohibit long-term loading in tension of these materials.

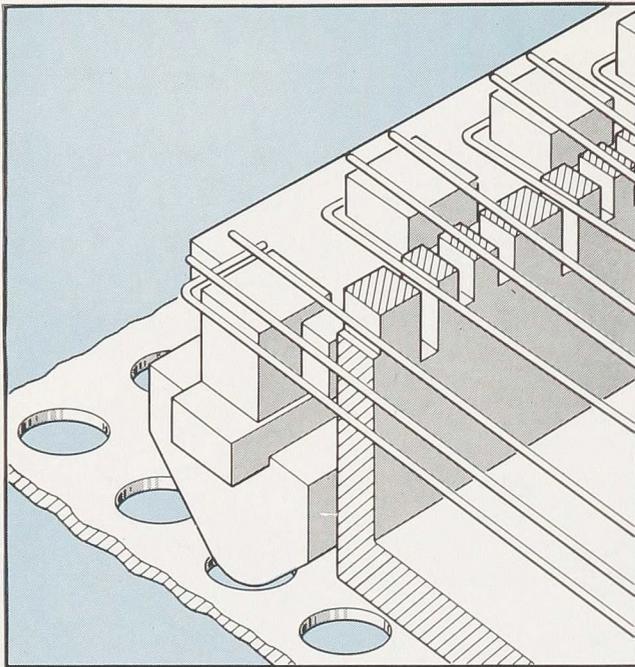
### Access Codes Interrupt Dialing

There are many situations in the telephone plant where a customer must dial a preliminary digit or digits to obtain a second dial tone before dialing can continue. Such digits are called "access codes," and are used most commonly in dialing through a PBX to a central office. Here the digit 9 is used to bypass the local board and

obtain dial tone from the central office. Other exit codes, up to three digits, are used for access to special equipment such as AMA and CAMA. When using an automatic dialer from such locations, a "stop" must be provided to interrupt dialing after the exit code to await the second dial tone.

In TOUCH-TONE Calling using card dialing, a "stop" column is included on the card; a "Stop" hole punched in the line after the last digit of an exit code will stop the card reader before reading the next digit. To continue dialing, the customer must repush the "Start" bar after he hears the second dial tone.

As a card is inserted, it engages a sprocket on each side, and winds a spring to store sufficient energy to eject the card. When fully inserted, the card is locked by a ratchet assembly until the "Start" bar assembly is depressed. There, the mechanical link mentioned earlier has operated



*Detail of hole sensing mechanism: sensors "cam" in and out of holes as card moves vertically.*

the common switch on the dial to disconnect the transmitter. When the "Start" bar is released, it moves upward to a position determined by a latch bar and an overhanging step on the stop-hole sensor. In this position, not fully up, the latch bar has released the ratchet assembly and the card is driven upward; digit hole sensors scan the lines as they move by and operate a pair of coil-tap switches for each line. The speed at which the card is ejected is controlled by a small centrifugal governor similar to that used in the rotary dial.

If a hole has been encoded in the stop column in any digit line, the stop sensor will drop into the hole, releasing the latch bar at that point; the card motion is then stopped by the ratchet-stop assembly. If there is no hole in the stop column, the card proceeds out of the dialer. Because the bottom edge of the card "looks like" a hole to the stop sensor, it releases the latch to restore the start assembly and common switch.

Adjacent to the stop sensor is a datum arm which is positioned by the surface of the card. Its purpose is to maintain a constant distance between the latch bar and the card surface to prevent false operation which could result from dimensional variations or card warpage. Additionally, when the last line is read, the datum arm moves inward and prevents the ratchet assembly from stopping the card motion; the card continues to a final stop position at which the sprocket teeth have dis-

engaged the card and the excitation switch has opened to permit manual dialing.

### **Special Hole Sensors Required**

The hole sensing mechanism consists of seven sensors in a bar having corresponding rectangular openings as shown above. The ends of the sensors nearest the card are V-shaped to "cam" in and out of the holes as a card is either inserted or ejected. The bar rests on the shoulder of each sensor. L-shaped contact springs press the bar against the sensor; a pair of contact springs rest on each sensor as it sticks through the bar. When the sensors are resting against the unpunched surface of a card, the shoulders remain against the bar and all contacts remain in the open position. When a sensor enters a hole, however, the spring pair associated with that sensor makes contact with the L-shaped spring to accomplish a coil-tap closure and select one signal frequency. All coil-tap contacts are held open when the sensors are between card lines or when there is no card in the throat. The highest surface on which any two sensors rest determine the operate plane of the contacts, only a differential motion by sensors into the card produce a closure. If all sensors move together, as when a card is inserted or removed, the contacts remain open. This arrangement permits the hole sensing mechanism to adjust to the card positions and reduces to a minimum the need for absolute dimensional control between the card and coil-tap springs.

### **Interdigital Time Important**

The minimum signal duration and the minimum interdigital time of the TOUCH-TONE central office receiver (RECORD, June, 1961) are each 40 milliseconds. To allow for variations in manufacturing and design, minimum values of 50 milliseconds for both signal duration and interdigital time were accepted as the design objective. This corresponds to a maximum dialing rate of ten digits per second. To achieve this maximum speed, the sensing contacts must be closed for at least 50 per cent of the line-to-line period, and the stop sensor and excitation functions must occur during the interdigital time. In early trials, dialers were adjusted so that the ratchet stop occurred before the excitation function. This proved to be wasteful of the reading period—the stop and excitation functions were performed sequentially, and required more than 50 per cent of the line-to-line motion. The best dialing speeds obtained were only of the order of 5 digits per second. Adjusting the excitation switch so that its closure occurred in parallel with

the stop sensor action made possible a shorter interdigital period. With this arrangement, signal time was increased to more than 50 per cent of the line-to-line period and dialing speeds resulted which approach the 10 digit per second rate.

Just before a "Start"—with the card either in its fully inserted position or at any line stop—the stop sensor is out of a hole, the digit sensors are just entering holes in the next line, and the excitation switch is closed. When the "Start" bar is pushed, the common switch energizes the dial circuit, but no signal can be generated until the excitation switch opens. Release of the "Start" bar begins the reading cycle. After enough card motion occurs to insure that both digit sensors are in a hole, the excitation switch opens and a two-frequency signal is generated. This signal continues until the digit sensors are driven out of their holes by the rising card. If a stop is to occur after this line, the stop sensor will move in and out of the "stop" hole during the interdigital period to release the "Start" mechanism. If a stop is not encoded, ejection of the card continues with the excitation switch and digit sensors operating for each line. The excitation switch closes to begin the interdigital period 30 milliseconds before, and opens 10 milliseconds after, frequency contacts close. This interval is more than adequate to re-energize the tank circuits.

### **Field Trials Successful**

A small number of TOUCH-TONE CARD DIALER sets, built by the Western Electric Model Shop, were put in a customer product trial at Findlay, Ohio, and a market trial at Greensburg, Pennsylvania, during 1962. The observed dialing times for seven digit familiar numbers were essentially the same for card dialing as for TOUCH-TONE manual push-button dialing; for ten digit numbers, however, card dialing was twice as fast. As would be expected, dialing errors from a card were very low, in the order of 0.3 per cent of initial attempts. The errors that were made resulted mainly from the customer selecting a wrong card or from an improperly punched card.

The general purpose TOUCH-TONE CARD DIALER set, made up of a manual push-button dial and a card reader, has been coded the 26B dial; it will be provided in the 1660 telephone set for residential use and in the 1662 set for multibutton key installations. The 26C dial, the first offered commercially, is currently being supplied in the attendants console for the Wide Area Data System (WADS). Present plans are for the complete line to be included in the displays at the New York World's Fair in 1964.

## **New Dial-in-Handset Ending Field Trials**

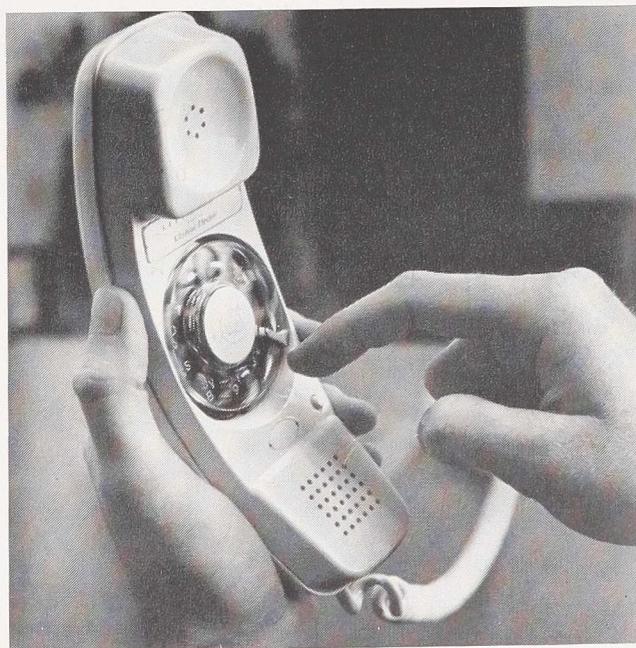
A new telephone, its dial and almost all circuits transferred to the handset, is ending initial field trials in 200 homes outside Detroit.

The loaf-shaped device, known as the Dial-in-Handset, features a dial mounted midway between ear and mouth pieces. It was designed by Bell Laboratories and trial models were turned out in the model shop at Western Electric's Indianapolis Works. The new phone is not yet in production, nor is it available to the public.

Made in two plastic-covered models for wall or desk installation, the Dial-in-Handset is lighter, slimmer and almost a third smaller than phones now in use. The wall model, although slightly squared off at the top, follows the same streamlined pattern of the oblong, symmetrically-curved desk set.

The same handset is used in both models. It contains four of the phone's six major components (today's handsets contain only two) and yet it weighs only slightly more than conventional handsets. Heavy and bulky components, such as the bell and the switchhook remain in the base.

The set's most distinctive characteristic is the "space-saver dial" with movable finger stop. Instead of remaining stationary, the stop moves one space forward as each digit is dialed. With this, the dial wheel can be smaller but the finger holes remain virtually the same size.



*New Dial-In-Handset centralizes dial and talking units to make calling more convenient than ever.*



*Short-haul carrier systems, one of the mainstays of the Bell System's rapidly growing telephone network, are being completely redesigned. Among the requirements for the new system: improved stability of over-all net loss while retaining compatibility with existing equipment.*

## Redesign of Short-Haul Carrier Systems

**I**MPORTANT CHANGES in the nature of the Bell System network and significant improvements in electronic and packaging arts have combined to serve as the basis for a complete redesign of the short-haul carrier family. For the last 12 years, short-haul carrier systems have been one of the mainstays in the rapidly growing Bell System telephone network. The redesign of these systems has followed one of the fundamental principles of the network: that each new or existing unit must fit in and be compatible with the other members. This article summarizes the background of the short-haul carrier systems, the basis for their redesign, and the performance of the first of the redesigned units—the N2 terminal. Subsequent companion articles will discuss the equipment and circuit features of the N2 terminal.

Short-haul carrier systems evolved during the 1946-1950 period from a combination of factors. On one hand was the potential application of new fabrication techniques and advances in electronic circuits and components; on the other was the pressing need of operating telephone companies in the Bell System for transmission facilities to provide short-haul toll trunks in the 15 to 200

*Author plugs an N2 module into its terminal mounting. N1 terminal is shown at his left for comparison.*

mile range. The first short-haul system, the N1 carrier (RECORD, July, 1952), included both terminals and carrier line repeaters to derive 12 voice channels over two cable pairs. The O carrier used comparable techniques to provide four 4-channel groups over open-wire lines (RECORD, April, 1955). A number of hybrid arrangements evolved from those two basic systems: the ON1 and ON2, the ON/K, and the ON radio multiplex (RECORD, November, 1960). Laboratories engineers developed these hybrid systems to furnish more voice channels per carrier transmission path than could be provided by the N1 or O systems. The important features of the short-haul carrier systems are summarized in tabulation on page 276.

The equipment arrangements for the N1, O, and ON carrier units are based on MINAPLAS construction (*Minature Apparatus Components mounted in Plastic*). These sub units along with the transformers, inductors, filters, and vacuum tubes, are housed in plug-in, die-cast aluminum assemblies. Three 12-channel N1 terminals or four 4-channel O or ON terminal groups can be mounted on a standard 11 ft., 6 in., equipment bay.

The number of short-haul carrier channels has grown dramatically in the past 12 years, as shown in the chart on page 279. At the end of 1961, the short-haul carrier systems provided slightly more

## COMPARISON OF N, O, AND ON SYSTEMS

Carrier System	System Feature				
	Line Frequency Range	Number of Channels	Type of Modulation	Control of line Interference by:	Signaling
N	2 groups 36-140 kc 164-268 kc	12	Double sideband AM	Compandors, Frogging of 2 line groups	Built in out-of-band 3700 cps on-off
O	4 groups 2-156 kc	16	Single sideband, 2 channels on same carrier	Compandors	Same as in N
ON	2 groups as in N (Plus radio multiplex for 2 more groups)	24 (48 or 96 for radio multiplex)	Same as in O	Same as in N	Same as in N

than 60 per cent of all carrier channels. Originally, the designers thought that short-haul channels would connect the customer's telephone office with a toll office or connect two toll offices up to a few hundred miles apart. At most, the designers expected that such channels would serve as the two end links in a long-haul toll connection. In the last several years, Bell System engineers have been changing the ways that they use short-haul carrier systems. The factors causing those changes have been Direct Distance Dialing (DDD), new services offered, and changes in technology.

An important feature of DDD is automatic alternate routing which increases the number of *links switched in tandem* to make up a connection. At present, in a tandem-switched connection, there may be as many as four or five links provided by short-haul carrier channels. This increase in the number of short-haul carrier channels in tandem imposed requirements for stability and quality of transmission on the channels which are considerably more stringent than the original design requirements.

A related change brought about by DDD is the increasing proportion of links or trunks made up of two or more carrier channels wired in tandem. The average trunk now has about 1.4 carrier channels in tandem. When a signaling path over a trunk is made up of two carrier channels in tandem, it is desirable to avoid the use of two sets of signaling circuitry working into each other at the junction of the two channels. This cannot be avoided with the 3700-cycle signaling circuitry built into the N1 channel since the 3700-cycle tone is outside the voice band and will not pass

through the junction of two channels. The use of the in-band single frequency (SF) signaling system avoids that extra equipment, and it has been used over broadband carrier channels since 1947 (RECORD, *July, 1959*).

N1 and ON carrier channel units without their built-in 3700-cycle signaling circuits have been available since 1955, and their use with SF signaling has risen sharply. For example, in 1957, only three per cent of the N1 channels were manufactured without the built-in signaling. In 1962, the figure reached about 50 per cent.

Another important facet of the changing short-haul picture is the growth of new services over the short-haul carrier channels designed originally for only voice transmission. Voice frequency telegraph and SAGE data have been transmitted for a number of years on a private line basis, using specially conditioned short-haul carrier channels. The entire DDD network, including the short-haul carrier channels, must now be able to transmit DATAPHONE service signals and Dial TWX signals. In addition, short-haul terminals and repeatered carrier lines now must transmit data in bands wider than the voice band.

A final factor in the changing situation is the growth of new art and technology which gives promise of many advances in carrier system performance. Included are transistors, high-Q ferrites (for inductors and transformers), and solid tantalum capacitors. More sophisticated analytical and design techniques for circuits and systems and new component mounting techniques, such as printed wiring and AMPLAS (Apparatus Mounted in Plastic), are also available.

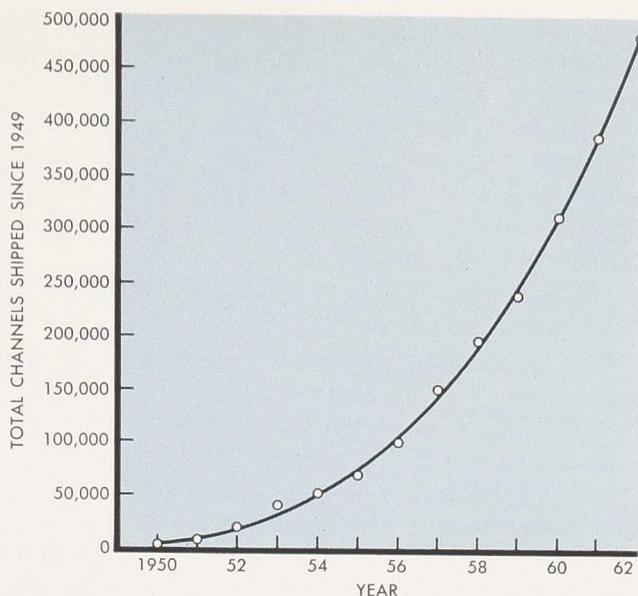
In April, 1960, Laboratories engineers started to redesign the major units in the short-haul carrier family. At about the same time, another Laboratories group started a comparable redesign of the broadband L-type multiplex for much the same reasons. This will be described in a later article.

The prime changes in requirements for the redesigned short-haul carrier units stem from the need to operate more short-haul carrier channels in tandem over the DDD network. This means that improved stability of the over-all net loss of each carrier channel is the most important requirement set for the redesign. Laboratories engineers specified (1) that the new terminals should have long-term changes in net loss that are smaller than those found in existing short-haul systems (of more than 2 db), (2) that short-term changes in net loss caused by battery and temperature variations should be controlled to less than the tenths of db's now encountered, and (3) that the short-term, cyclic variations in net loss, called "beats," which can be as large as 4 db in existing terminals should be eliminated. (The beats are produced by interfering carrier signals from a multiplicity of sources within and outside of a given system.) These net loss variations are measured by a test tone at reference power. Another source of variation in over-all loss results from imperfections in the compandor which introduces different net losses for different powers of input speech. Up to 2 db changes in loss occur in existing short-haul carrier compandors over the normal range of speech power.

Present short-haul channels have a gain-frequency characteristic which starts to cut off below 3000 cycles. Laboratories engineers felt that a higher cutoff was feasible and necessary. Because of the increasing number of short-haul channels in tandem, each channel should have a gain-frequency characteristic that is wider and flatter than present short-haul channels. The new short-haul channels were designed to match the 3400-cycle cutoff of the broadband A-type channel banks used in the L multiplex. The redesigned systems use only the in-band SF signaling systems. This will make possible the improved gain-frequency response and meet the operational needs of modern short-haul trunks.

The new terminals and repeaters should operate on less dc power than used by the present equipment. (This requirement is particularly pertinent for new repeaters used at military bases.

Finally, a very important broad requirement is that the new systems should compete economically with the existing short-haul carrier systems. Installed costs of the new systems should be equal to



*Growth of installed short-haul carrier channels.*

or less than those of existing short-haul systems. Better net loss stability and other performance improvements can increase the equipment cost. However, such increases can be offset by savings from lower power drain, smaller size, and possible savings in engineering and installation for the new equipment. Because the new systems are more stable and easier to maintain, savings can also be obtained in annual operating costs.

A broad plan was drawn up by Laboratories engineers for the development of the new short-haul carrier family based on these changed requirements. The plan includes a redesign of the N1 and ON2 terminals (to provide new 12-channel N2 and 24-channel N3 terminals) and of the N1 carrier line (to provide a new N2 line). In addition, many of the improvements developed for the new terminals and line will be added to the existing N1 and ON short-haul carrier equipment.

As a part of the broad development, the existing transmission plan was retained wherever possible, including frequencies, powers, and relative levels. Thus, each new unit is compatible with other existing units of the short-haul carrier systems. New N2 or N3 terminals can work over N1 repeatered lines, and new N2 repeaters will work on the same lines or in the same cables with N1 repeaters. Telephone operating companies can integrate each improved unit as it becomes available without waiting for the entire redesign plan to be completed.

There is one important exception to this highly desirable compatibility. The new terminals are not designed to work at one end of a repeatered line with a comparable existing terminal at the

other end. Therefore, the new terminals do not have to sacrifice their improved performance to work with the existing terminals. The desirable compatibility was ignored in this case because of the very high rate at which the new equipment will be produced. In less than four years, half of the short-haul carrier systems in service will be of the new design.

In carrying out this over-all plan, the order of development is as follows:

N1A Repeater—transistor amplifiers in N1 repeater

N2 Terminal—redesigned N1 terminal

N3 Terminal—redesigned ON2 terminal

N2 Repeater—redesigned N1A repeater

Bell Laboratories engineers developed the N1A repeater first because an N repeater with low power drain was needed urgently at military installations. The N2 terminal was next because N carrier is still the largest runner in the short-haul market.

The N3 terminal building blocks will provide a 24-channel single sideband bank. In general, its requirements will be the same as the N2 terminal. The basic voice-frequency circuit in the N2 terminal is also directly applicable to the N3 terminal. The twin-channel approach used in ON will be replaced by a 12-channel group. All 12 channels will have the same sideband orientation; however, only every other carrier will be transmitted along with its sideband. Common carrier supplies at the terminals will generate the carriers required at the transmitting and receiving terminals.

Compared to the ON2 terminal, the N3 terminal is expected to be more economical in installed first cost. The ON2 terminal was developed as a mixture of the N1 and O terminals; the N3 terminal will be a completely new design from the start.

The active circuitry for the N2 repeater will be essentially the same used in the N1A repeater. The N2 repeater will include some further refinements in the amplifier circuitry and components and a complete redesign of the repeater filters, frogging group modulator, and the entire equipment package. System analysis and subsequent field tests indicate that the present N1 repeater is the major source of the beats in over-all channel net loss. Replacement filters recently designed for the N1 and N1A repeater will suppress the sources of beats, and comparable filtering will be included in the repeater for the N2 system.

In addition to the development of the major units discussed thus far, other units are being designed as they are needed. For example, non-companded and program channel units and units to transmit wideband data and facsimile signals will be available for both the N2 and N3 terminals.

This, then, is the broad plan for the redesign of the short-haul carrier family. However, what has been accomplished already within the framework of the program?

By the end of 1960, the N1A repeater was developed. During early 1961, these repeaters were used largely to provide intersite communication facilities at Air Force ICBM bases. The N1A repeated line met the tough requirements for the dc repeater power feeds. Since then, the N1A repeaters have been finding their way into conventional N repeated lines. Even in those installations, the somewhat higher equipment cost of N1A repeaters has been offset by the substantial savings in dc power needed to feed the repeaters.

Negative feedback used in the transistor amplifiers has greatly improved the performance of the N1A repeaters. The gain-frequency characteristics are flatter than those for comparable N1 repeaters. The slope values provided make the N1A repeaters a better match for the PIC cable over which they will generally work. The over-all intermodulation performance of the repeater amplifiers and the regulation of the thermistor regulator are comparable to the N1 repeater. Laboratory measurements and field tests of N1A repeated lines indicate that the resistance noise contribution of the transistor amplifier in the N1A repeater is as good as that of the N1 repeater.

The design of the N2 terminal is also complete. Development of plug-in units is continuing to supplement the basic channel and common units. The first N2 installations were completed successfully in Sacramento, California, in western Connecticut, and in other Bell System locations. Improvements achieved in the N2 terminal are highlighted by the comparisons shown in the tabulation on page 281.

The most significant improvement in the performance characteristics of the N2 terminal is the channel gain-frequency response. The 3 db point frequencies are 140 and 3370 cps for an A5 Channel Bank, the basic building block in the L-type multiplex.

The over-all net loss stability of an N2 channel represents an improvement of about 4:1 compared to the original design for the N1 channel. The N2 channels are expected to provide a Distribution Grade (standard deviation of variation of loss from nominal) of 0.5 db during the normal intervals between routine adjustments of over-all loss. The improved tracking of the N2 compandor over the expected range of voice input power is an additional factor leading to the better net loss stability of an N2 channel.

Intermodulation distortion within an N2 carrier channel is a measure of the fidelity with which

## COMPARISON OF N1 AND N2 TERMINALS

		N1	N2
SIZE (Channels in one 11'6" bay)		36 (19" wide bay)	96 (23" wide bay)
POWER (Watts per channel end)		28.8	4.8
PERFORMANCE (terminals back-to-back)	Channel gain-frequency response: Frequency in cycles for 3db points	220 and 3040	200 and 3400
	Net loss stability	—	4:1 improvement over N1
	Compandor tracking error: Average excess gain in db at worst input power	1.4	0.07
	Peak overload power: Dbm at 0 db system level for 0.3 db increase in circuit net loss	+5	+10
	Intermodulation distortion in one channel: Db below fundamental		
	2nd order (A ± B)	31	30
	3rd order (2A ± B)	23	34
	Noise: Dbrn C message weighting at 0 db system level		
Background	<12	7-14	
Contribution due to speech loading in adjacent channels	—	13	
Crosstalk (in db)			
Worst equal-level coupling loss in db	objective = 70		
Far end	—	74	
Near end	—	95	

the channel transmits both voice signals and signaling tones such as multifrequency key pulsing. Laboratories engineers measured the distortion products formed by two voice frequency tones sent into a compandored N2 channel, including the fundamental tones and their second and third order intermodulation products. The performance of the N2 channels is better than the N1 channels, particularly for the third order products which affect multifrequency key pulsing and data transmission. An objective of 42 db for any modulation product is met by the A5 channel bank which is satisfactory for telephoto transmission. Such performance was not an objective for the compandored N2 channel. However, the distortion performance of the new, noncompandored N2 voice frequency amplifier will approach that of the A5 channel bank.

The objective for the maximum noise in N carrier terminals back-to-back is 16 dbrn, C message weighting at 0 db system level. The range of noise shown for the N2 terminals is well within the objective. Another measure of the noise performance

of the N2 carrier terminals is also shown above. Forty per cent of the channels (five channels) were loaded with weighted white noise representing a 0 volume unit (vu) talker at 0 SL. This corresponds to an Air Force requirement for the facilities furnished at ICBM bases. Typical Bell System loadings correspond more nearly to three channels at a substantially lower power. For the 40 per cent loading, the interference (caused primarily by leak-over from adjacent channels) was less than the background noise.

The noise measurements also indicated that an average compandor advantage of 30 db is being obtained in the N2 terminals. This compares with a value of 28 db for N1 terminals. The crosstalk performance of N2 terminals was measured to simulate over-all message channel crosstalk. All of the values measured were better than the 70 db objective normally considered satisfactory for message channel crosstalk.

These results illustrate the high quality of performance that has been built into the first members of the new short-haul family.

#### EAST MEETS WEST VIA TELSTAR II

The second Telstar satellite was tracked recently by a Japanese ground station near Tokyo. The Bell System's communications satellite was followed for a period of 18 minutes on Sunday, July 8, at distances from 8981 to 9268 statute miles from Japan and it was in a similar position for tracking shortly after midnight (EDT) on July 9.

The Japanese, using orbital data supplied by Bell Telephone Laboratories, pointed their antenna at the satellite as it traveled above the Pacific Ocean near Hawaii and headed towards the continental United States. The Bell System's ground station at Andover, Maine, turned on the communications equipment in the satellite, and then the satellite's microwave beacon signal was picked up by the Japanese antenna. There were no communications tests conducted.

Successful tracking exercises required that the satellite be a few degrees above the horizon at both ground stations so that Andover could turn the satellite on and Tokyo could receive the beacon.

#### STATISTICAL METHOD TO REPLACE STOPWATCH

Time study and cost analysis by whistle and stopwatch may soon be as old-fashioned as the sun dial. A new method, developed by Dr. W. Williams of Bell Telephone Laboratories' Mathematics and Mechanics Research Center, will enable management to determine the cost of a job more efficiently and accurately than in the past. The method is based on observation of the number of times a specific operation is performed, rather than the length of time it takes to do it. Thus, the data are more easily obtained and less subject to inaccurate measurements.

The data are used by a computer in solving equations representing the concept that the total daily cost of operations performed is equal to the sum of each individual operation multiplied by the number of times it was performed on that day. With this new method it is possible to compare the times (or costs) of separate operations and uncover relations between them. The method has been studied in a large scale test at Bell Telephone Laboratories and is expected to be used extensively in the near future.

*To synchronize the flow of communications signals from one point to another, the T1 Carrier System designers solved some intricate problems in the timing of a pulse code modulated system.*

## **T1 Carrier System Timing**

**T**IMING is virtually the heart of a pulse code modulation (PCM) system. All parts of the system receive timing pulses which stimulate their various functions and coordinate them in a smooth flow of communications signals. In the T1 Carrier System, timing plays roughly the same part played by oscillators, modulators, and filters in conventional frequency multiplexing systems. In application, however, timing in the T1 system is a radical departure from that of modulated carrier systems.

Time-division multiplexing is the basis of T1 transmission. That is, customers' voices are interleaved in time. Each conversation is assigned an exclusive slice of time. Each slice (also called a time slot or a channel) is scanned periodically, in sequence, to obtain an amplitude sample of the speech information it contains. The samples are changed to seven-bit binary codes, combined in serial form, and ultimately applied to the line as the transmission signal. At the receiver, timing signals reverse the process: Each group of binary bits is decoded to recover its amplitude sample and the sample is demultiplexed or gated out to a channel filter which reconstructs the original voice signal. In this way, the T1 System can handle 24 telephone conversations.

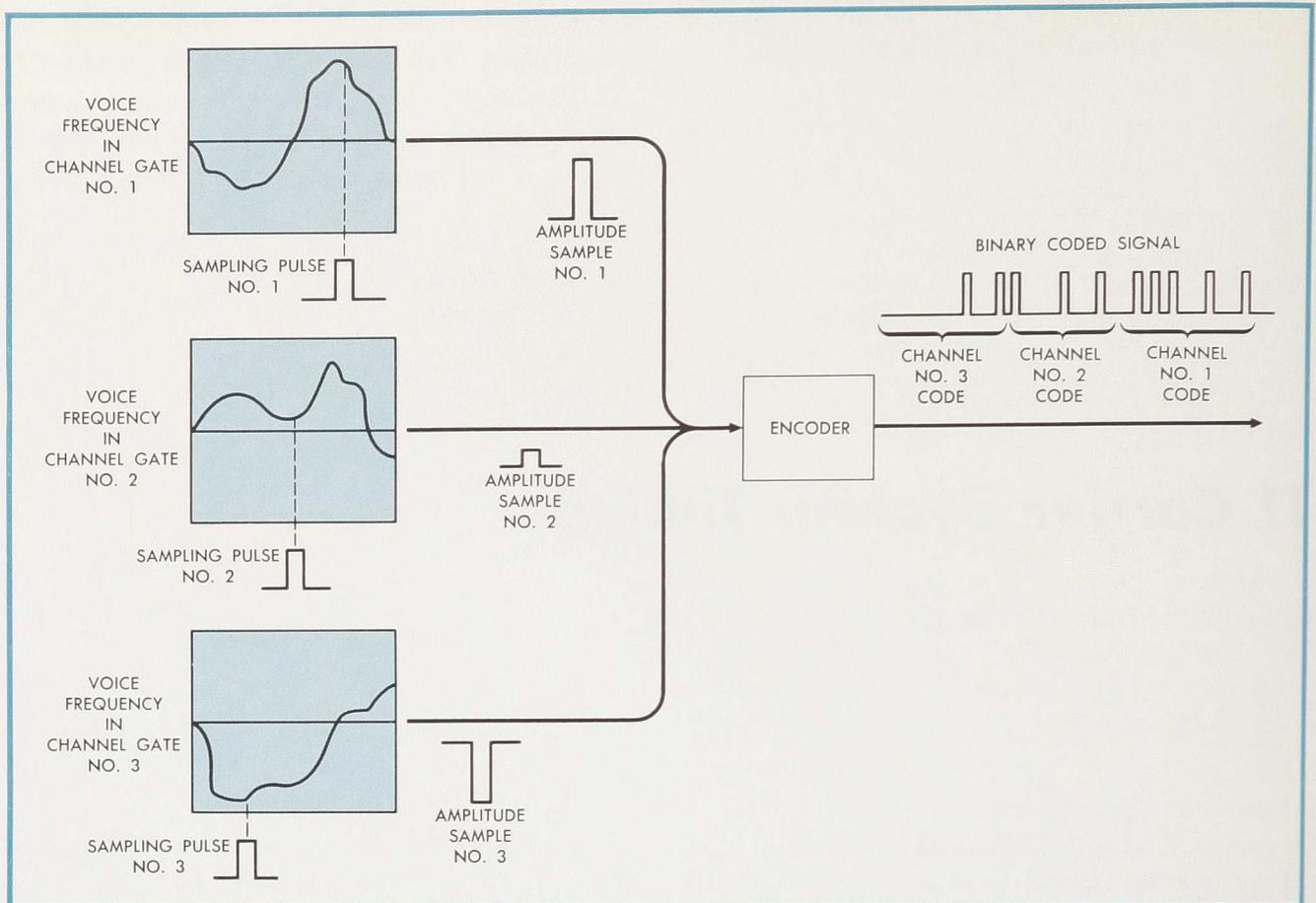
A closer look at the composition of the signal as it arrives at the receiver poses some interesting questions. The input of the receiver is presented with a train of pulses and spaces whose pattern,

shaped by the encoding process, continually changes. The discrete seven-bit binary codes assigned to the amplitude samples of each transmission channel cannot be identified by any random choice of seven consecutive bits. How does the receiver process the pulse train to deliver each sample to the correct channel at a precise time and rate? Furthermore, if a circuit failure disrupts the compatibility of the transmitting and the receiving channel, how does the system indicate the malfunction? The answer to those questions is the subject of this article.

The timing requirements of a PCM system are similar to those of a television system. In both cases, certain functions in the receiver must be controlled by timing information contained in the composite transmitted signal. Moreover, the smallest possible portion of the composite signal should be assigned for timing, so that the maximum use of the channel can be achieved for picture or voice information, as the case may be.

In both systems, the receiver is essentially free-running at a frequency which approximates the system's basic synchronizing rate. In television this is the horizontal sweep frequency rate. In PCM, it is the clock rate. These rates are the heart beat of each system's timing mechanism and the transmitter must maintain them in precise control.

In a television system, 525 horizontal lines, or sweeps, are necessary for a complete scanning (or



*The time-division principle: periodic samples of an information signal will completely define that signal and samples from a number of signals can*

*be transmitted over a common path. In T1 System, these samples are as shown above, encoded into seven-bit binary codes before transmission.*

a frame) of any scene. In a PCM system, a frame is one scanning (or sampling) of all the channels in the system. To continue the analogy between the two systems, we can relate each horizontal line to a speech channel and thus call a television system a 525 channel system.

A very similar process synchronizes the receiver and transmitter timing in each system. Each horizontal sweep of a television transmitter contains a synchronizing pulse which locks-in the horizontal oscillator in the receiver. Hence, the scanning rate in the receiver precisely follows the scanning rate in the transmitter. Similarly in PCM, each channel sampled contains at least one pulse which locks-in the receiver clock frequency to the transmitter frequency. This pulse is not added to the composite transmitted signal; it is part of the seven-bit binary code that is normally transmitted.

Synchronizing either system, however, is only part of the story. A synchronized television system means only that the receiver is scanning left to right in step with the transmitter. But while

one line is scanned at the transmitter, another is scanned at the receiver. This locks-in the picture horizontally, but it incurs vertical roll. A synchronized PCM system means only that channels are sampled at the proper rate. But again, different channels are sampled at the receiver and the transmitter. This leads to high level noise on all channels.

Obviously, more timing information is needed to achieve vertical lock-in and channel alignment in the respective systems. Vertical synchronizing pulses start the scanning sequence in a television receiver to coincide with the transmitter. These pulses, inserted at the vertical blanking period, occupy several horizontal sweep periods. Framing pulses enable a PCM receiver to align and lock-in its channel time slots with those in the transmitter. A frame bit uses only one-eighth of the time allotted for a single channel.

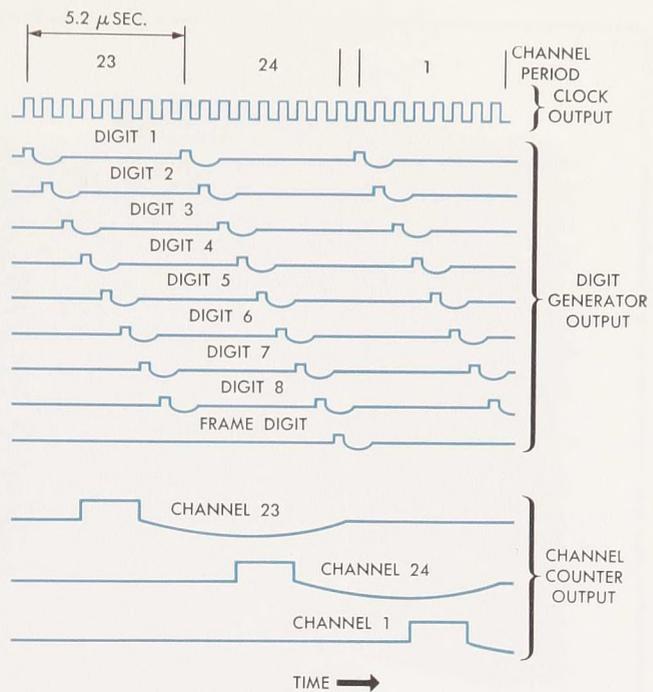
In the 24 channel T1 Carrier System the basic timing rate signal is called the "clock." Its rate is dictated by a number of design parameters including the number of channels, and the 8 kc sam-

pling rate. The clock, derived from the relation between the time of a frame and the number of bits in a frame, is 1,544,000 bits per second. (There are 193 bit periods in a frame—24 channel times and 8 bits per channel plus one additional bit per frame.) Hence, a bit period is  $1.544^{-1}$  mc or approximately 0.65 microseconds. A complete sampling of the 24 channels takes 125 microseconds—about 5.2 microseconds per channel for each frame. This represents eight bits per channel—seven are the binary-coded amplitude sample, the other is a signaling bit. Finally, a framing bit is added at each complete sampling.

Accurate timing of the system requires a synchronized receiver and transmitter and proper framing. The system is synchronized when the timing signals in the receiver occur at exactly the same rate as, and under the control of, the transmitter master clock. It is properly framed when information sampled at any numbered channel at the transmitter is always resampled at the same numbered channel in the receiver.

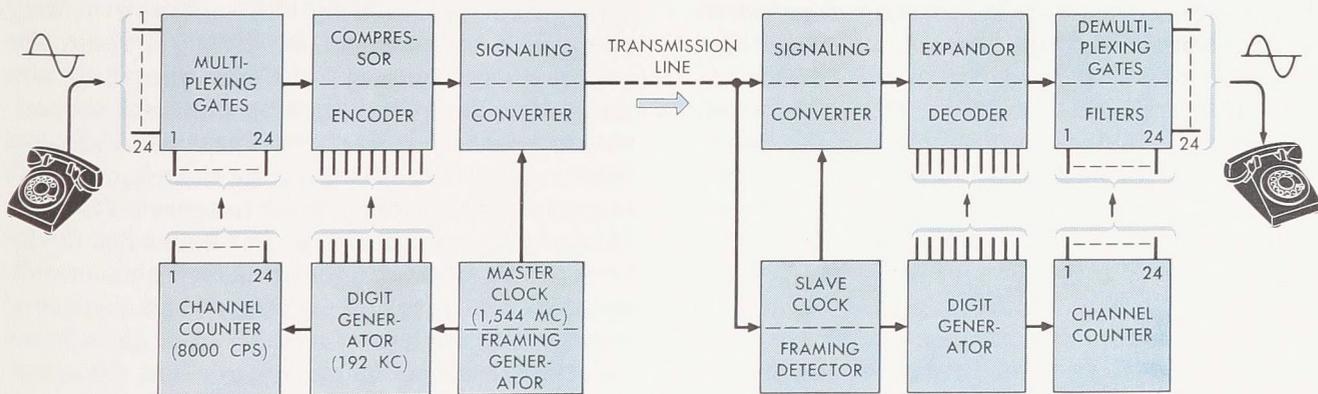
A condition that strongly aids synchronization is that the transmitted pulses are precise submultiples of the transmitter clock. The transmitter maintains a minimum pulse density of one pulse per channel on the line and, thus, reserves an adequate control signal for the receiver and repeaters. The average density increases as the number of channels modulated increases. At the receiver, the pulse train generates, in effect, a slave clock signal that is precisely synchronized with the master clock. Other timing signals—i.e. channel pulses and digits—are derived as submultiples of the slave clock and naturally fall into step with their counterparts in the transmitter. The repeaters also have similar slave clocks to properly time the regenerated line pulses.

For proper framing, the channel sampling sequence in the receiver must maintain a fixed



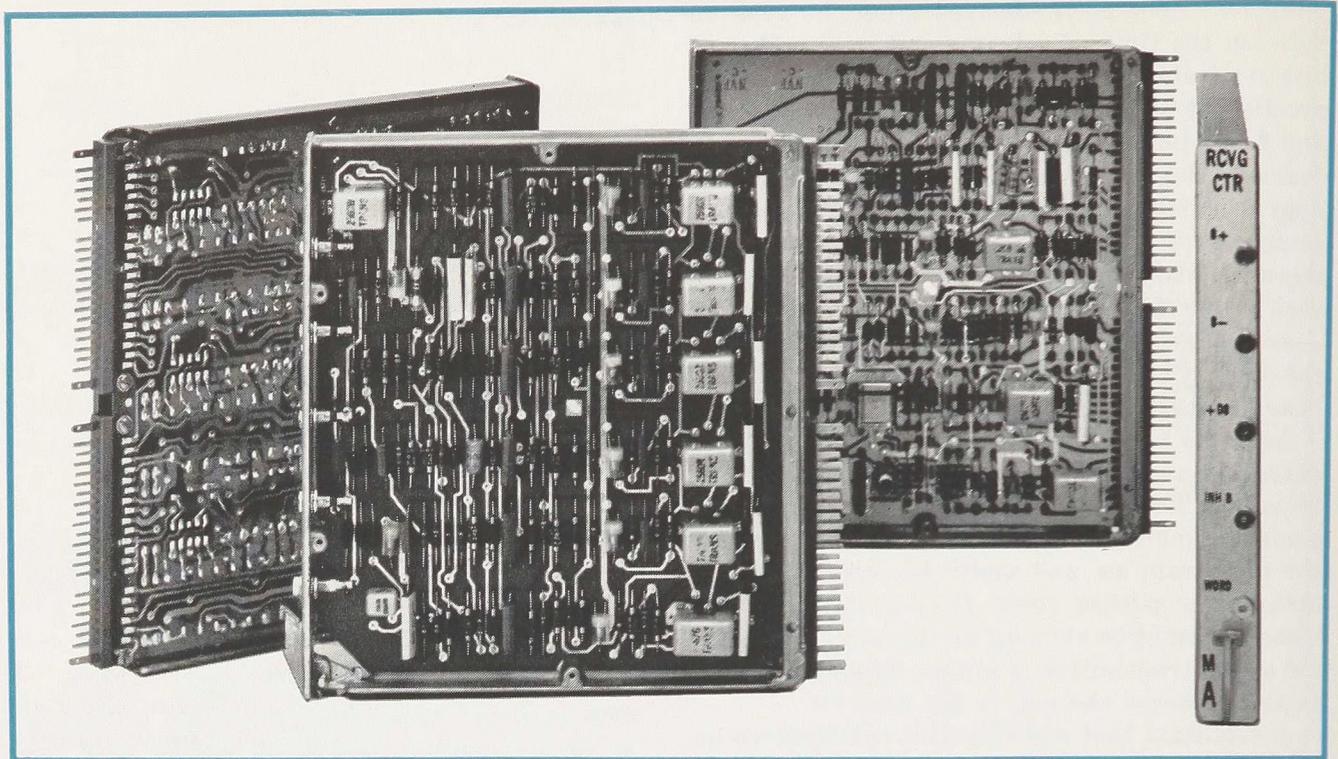
*The digit pulses produced by three consecutive firing, or counting, sequences of the digit generator. This particular grouping illustrates how the framing digit is produced and the position it occupies in relation to the channel periods.*

time relationship with the sampling sequence in the transmitter. In other words, the transmitting and receiving channels must be locked-in. The 193rd framing bit period carries the timing information. At the transmitter, alternate frame bits are supplied with digit pulses. The result is a repetitive ON-OFF pulse pattern which represents a 4 kc component. Other bit periods have either a fixed or a random distribution of pulses; therefore, this 4 kc component forms a unique pattern in the composite signal. The receiver detects this pattern by comparing the received pulse



*Timing is the heartbeat of the T1 Carrier System. This diagram shows how all the functions*

*necessary to transmit signals are ultimately under the control of the transmitter master clock.*



Some of the circuit boards used in T1 System timing. Shown left to right are: digit generator,

transmitting channel counter, master clock and framing generator, and receiving channel counter.

train with its locally generated frame digits. If coincidence is lacking, the receiver slips or delays its timing one bit period a frame until framing digits and framing signal are in the correct time relationship. This aligns the transmitting and receiving channels and the system is "in frame."

A stable crystal-controlled oscillator in the transmitter is the heart of the master clock. Its output—a sinewave—is reshaped by a blocking oscillator into steep-sided pulses which are more accurate timing signals than a sinewave. A stable electrical network in the repeater and in the receiving terminal is tuned to the master clock frequency. This circuit, called a tank circuit, is the heart of the slave clock. It is triggered by the received pulse train whose predominant 1.5 mc component keeps it oscillating at its tuned frequency. The sinewave output of the tank circuit is reshaped and amplified into a replica of the master clock. The drawing at the top of page 285 shows the master clock signal in correct time relationship with three consecutive channel periods.

Relatively high-power, low-impedance pulses are generated by a blocking oscillator in the digit generator. A transformer in the digit generator circuit allows it to virtually tailor several independent outputs to the desired pulse voltages, polarities, and bias conditions. The ringout voltage (or overshoot), a by-product of the blocking

oscillator pulse, is indispensable for counting circuits. This voltage immediately follows the pulse. It appears as the first alternation of a highly-damped wave and has opposite polarity with the pulse.

Actually, the digit generator contains nine blocking oscillator stages. They are interconnected by diode logic gates and fire in sequence under the control of the clock and the ringout voltages. The clock very precisely times the duration of the pulse and the repetition rate of each stage. Drive voltages, which the ringout signals send to each successive stage, maintain the firing sequence. The top drawing on page 283 shows the digit pulses produced by three successive firing or counting sequences of the digit generator. The particular grouping in the drawing illustrates the production of the framing digit and its position in relation to the channel periods. Additional timing logic, not shown in the drawing, enables stage 9 in the digit generator to operate following channel 24 only. The figure also delineates the interdependent roles of the clock and ringout voltages in achieving pulse timing and sequential counting: The ringout voltage from digit 1, and its coincident clock pulse, trigger and time stage 2. The ringout voltage from digit 2, and the next clock pulse, combine to fire and time stage 3, etc. until the sequence is completed.

The 24 consecutive channel pulses are produced by other blocking oscillators in the channel counter. The high-power capability of these oscillators is especially important for the sampling process because the gates need an appreciable current. The firing or counting logic in the channel counter is similar to that of the digit generator. The ringout voltages, together with an equivalent clock signal, control the timing of the channel pulses and the firing sequence of the 24 stages. The clock counterpart is two digits, chosen to produce a pulse of a specific length: The first digit turns a stage on, and the second, which has opposite polarity from the first, turns it off. This controls the pulse time. The drawing on page 282 shows three consecutive channel pulses and digits in the correct time relationship. In each channel period shown in the drawing, digit 4 initiates a channel pulse and digit 7 terminates it. The pulse ringout voltages are stretched out to coincide with these control digits in the succeeding channel periods.

As do other carrier systems, the T1 System has a number of visual and audible alarms to signal failures or interruptions in normal operation. The system detects a malfunction, operates an alarm, and automatically takes the channel or trunk involved out of service. Only major system failures such as timing failures, or interruptions which cause misframing for more than about a second, initiate an alarm. Minor failures such as the loss of a single voice frequency channel, therefore, do not "turn down" the system. To initiate an alarm, the alarm system uses the rate of framing pulse coincidences in the receiver. With the system in frame, the rate equals a 4 kc component of frequency. A frequency selective device monitors the rate and produces a continuous output when the 4 kc component is present. If the normal 4 kc rate deviates or is lost, the detector output falls off. Thus, the device not only causes an alarm during system misframing, but it inherently detects its own failure.

The development of timing in the T1 System has established a fund of information which designers can draw on for the more complex time-division systems that will be developed in the future. The course of the T1 work was marked by a series of varied and challenging problems which were often solved through the design of novel circuits and the application of new logic and pulse techniques. All this is relevant to the future because the coming systems, that may include high-speed data-handling and intercomputer links, will share the basic synchronizing and framing problems that have been discussed here.

## The "Speech Chain"— New Educational Aid

The spoken word is only one link in a complex chain that enables men to communicate with each other. Verbal communication is the result of a process by which thoughts are translated into a chain of codes that extends from ideas to language, to vocal cord movement, to sound waves, to reception by the ear. This "Speech Chain" is the subject of the most recent science teaching aid, produced by Bell Telephone Laboratories, for use in high schools.

The new Bell System Aid-To-High-School-Science unit consists of material for use in physics and biology classrooms and an experiment that an advanced student can do on his own.

Classroom use is based on a book, *The Speech Chain: The Physics and Biology of Spoken Language*, written by Drs. Peter Denes and Elliot Pinson of the Acoustics and Speech Research Laboratory. A motion picture, a phonograph record, and a group of demonstration devices supplement the text. The "Speech Chain," a 19-minute film, includes pictures of the human vocal cords in action and unique x-rays of the vocal tract. "Computer Speech," a five-minute, 33 1/3 rpm record, is a narrated presentation of synthetic speech produced by an electronic digital computer. The demonstration materials, designed to show key principles of speech and hearing are a formant filter unit (which demonstrates the dominant vocal tract resonances) and an artificial larynx (which demonstrates that the sole function of the vocal cords is to produce an audible buzz), and devices which demonstrate delayed feedback speech and degraded speech.

The "Bell System Science Experiment #3" is entitled "Speech Synthesis." The student carrying out the experiment must first become familiar with a fairly sophisticated text by Drs. Denes, Pinson and Cecil Coker, also of the Visual and Acoustics Laboratory, on the interdisciplinary study of electronic speech production. At the conclusion of the experiment, the student will have constructed an electronic voice synthesizer that produces six human-sounding vowels.

High schools and individual science teachers may obtain free, in limited quantities, the record, the texts, and the advanced-student experiments from local telephone companies. The program, begun in 1959, was originated to help the Bell System fulfill its obligations to the community in education.

# news in brief

## **Washington Ceremony Marks Telstar's First Anniversary**

A year ago—on July 10, 1962—Telstar I was launched into space. In recent ceremonies marking this historic event, an exact replica of Telstar I was presented to the Smithsonian Institution in Washington where it will be viewed by millions of Americans.

The satellite presented to the Smithsonian is identical to Telstar I, and served as a standby at Cape Canaveral prior to Telstar I's launching last year. Had something gone wrong with the original, this satellite would have been launched in its place.

During ceremonies at the Institution, Paul A. Gorman, Executive Vice President of AT&T, made the presentation to Dr. Leonard Carmichael, Secretary of the Smithsonian.

The satellite rests on a revolving turntable equipped with telephone handsets that offer a narration of the Telstar experiments to exhibit viewers. The exhibit also includes illuminated panels showing pictures of the launching, the horn antenna at Andover and a drawing of the satellite's orbital pattern. The exhibit will be on display at the Institution during July and August, and then will be placed in storage until the completion of the Museum of History and Technology where it will be prominently displayed.

The actual Telstar I, still orbiting the earth, has been silent since February 21 when it failed to respond to signals from the ground following heavy exposure to radiation. During the months of operation prior to that date, the satellite participated in more than 300 technical tests covering every aspect of transmission, and over 400 demonstrations.

## **Telstar II Stops Operating**

The second Telstar satellite stopped operating on July 16th. Attempts to command the satellite from the Bell System's ground station at Andover, Maine shortly after noon on the 17th were not successful. Continued efforts on subsequent passes have been made to communicate with the satellite, but without success.

The satellite functioned normally on its 450th orbit over Andover on the afternoon of July 16th, and, later, telemetry signals were satisfactorily picked up by the NASA tracking station in Johannesburg, South Africa. Minutes later, when the NASA station in Woomera, Australia attempted to pick up the satellite's 136-megacycle beacon signal, nothing was received.

What happened in space during those few minutes is not known.

The last telemetry data recorded by the Johannesburg station will be analyzed at Bell Laboratories in Murray Hill. Telemetry data, obtained thus far, can give no indication that radiation damage has caused the satellite to fail.

## **FCC Issues Final Decision On WADS**

The Federal Communications Commission has ordered AT&T to cancel within 60 days its tariffs on a full-scale offering of Wide Area Data Service (WADS) in a final decision announced by the FCC on July 25. The Commission's decision was basically the same as the initial decision announced March 14.

The Commission found, according to its press announcement, that the record does not estab-

lish the lawfulness of the flat rate aspects of the WADS tariff and that these flat rates as designed "are unreasonably discriminatory as between WADS customers, and customers of other AT&T services."

However, the FCC allowed AT&T to continue with Developmental Line Switched Teletypewriter Service, a predecessor of WADS, on a temporary basis. But this service, as well as rates charged for TWX, will be subject to further FCC hearings.

While AT&T has not yet seen the text of the final decision, its issuance should not affect plans for filing new WADS TWX schedules early in December.

## **Plans Announced for Canada-U.S. TWX Link**

The Bell System announced recently that it has agreed to join with the Canadian telephone companies in offering a Canada-United States TWX service.

At present, telephone companies in the two countries join in providing private line service and, in connection with message telephone service, DATAPHONE service. These services, however, are of primary advantage to larger users. Like TWX service within the United States, this new service will permit the handling of teletypewriter and other data in relatively small units, a service attractive to the small or occasional user.

Prior to the introduction of TWX within Canada itself late in 1962, TWX service between the two countries was not practicable. The Canadian telephone companies have now asked the Bell System to join with them in providing TWX service between the two countries. The Bell System has agreed, subject to regulatory acceptance in the United States.

Plans call for the new service between the two countries to be effective August 15, subject to regulatory acceptance.

*Certain kinds of intercept traffic occur in short periods of heavy demand before decreasing to normal levels. To lower the high cost of meeting this demand and to reduce the possibility of overload, Laboratories engineers have designed a new portable announcement system.*

# The 11A Announcement System

D. D. Banks

OF the 325 million calls originated by Bell System customers each day, some 3.2 million must be routed to an intercept operator or to a recorded announcement system. This happens when a customer's number has been changed or vacated, when the office code has been changed, or when dialing is incorrect and a vacant or unassigned number or code is reached. To furnish this intercept service, the Bell System spends between 25 and 30 million dollars each year. To reduce this expense where possible, the operating companies began to search for ways to make intercept service more efficient and economical.

They found that traffic for this service was of two major kinds. The first was a relatively constant quantity resulting from random individual number changes, vacancies and incorrect dialing. This traffic is handled satisfactorily by conventional recorded announcement equipment and by operators in permanent installations. The second type of intercept traffic was that which occurs in heavy volume for a short period and then decreases to a small amount per day. This arises from a discrete number of situations, such as the changing of a frequently called number, or the conversion of an office or station to a new type of dialing service.

It was this second type that suggested the need

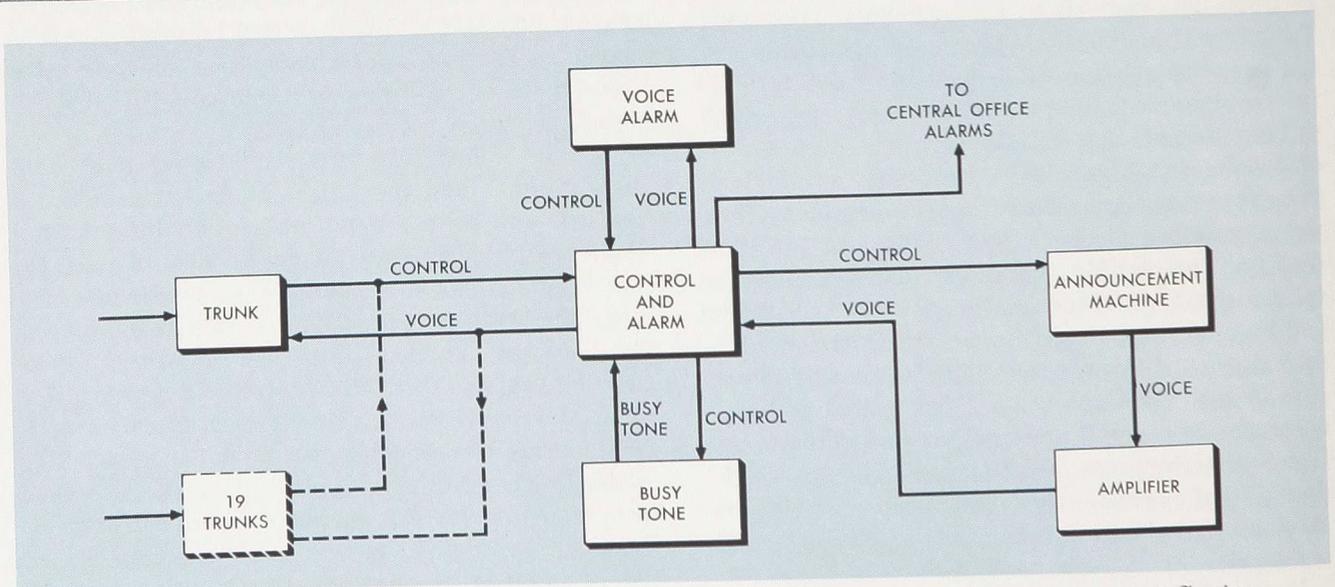
for portable intercept facilities. Without an inordinate amount of extra intercept facilities, the heavy, short-term demand would overload regular equipment, resulting in poor service. It was therefore usually handled by setting up one or more temporary switchboard positions through which calls were directed to operators, who gave changed number information to the customer. While effective, this solution was cumbersome and expensive. As an alternative solution, Bell Laboratories was asked to develop a portable system with recorded announcement equipment which could be used to meet the temporary overloads.

It was hoped that this portable system could be brought into the office involved, quickly installed, and prepared with recorded information covering the status of the office code and numbers intercepted. The equipment would remain in location until calling decreased to a rate that could be handled by normal intercept facilities. The portable set could then be moved to a new location and its recorded message changed appropriately.

Once the basic design had been conceived, Bell Laboratories engineers established the technical requirements for the portable announcement system in more detail. It was to have a capacity of twenty trunks. Its intercepting trunk was to be universal, that is, compatible with Step-by-Step,



*The 11A Announcement System can be placed in any convenient location, such as this vacant space in a switching bay line-up (a). Here the author adjusts busy tone output volume. With the front cover removed, messages can be recorded and checked (b) and additional trunks added as needed (c).*



*This diagram shows the signal paths between circuits within the 11A Announcement System.*

Panel, No. 1 or No. 5 Crossbar Offices. Physically the equipment had to fall within certain dimensions and be light enough for easy moving. Installation procedures had to be simple, inexpensive, and adaptable to a variety of service assignments. If the equipment should fail in service, a visual and audible alarm via the central office alarm system should be given. In the event of a voice failure, all trunks should be made busy. Finally, as with nearly all Bell System designs, existing apparatus and equipment should be used wherever practicable and economical.

With these objectives in mind, Bell Laboratories engineers designed and built the equipment which is now known as the 11A Announcement System. Their design incorporates not only elements of standard Bell System equipment, such as a general purpose recording set, but also some of the latest advances in electronic circuit design. The busy tone, for example, is supplied by a fully electronic circuit, a method which was found to be more economical than running leads to the regular central office tone supply. Electronic design also has the advantage of being physically small and lightweight, thus contributing to the portability of the equipment.

Other circuits within the intercept system use electronic and relay apparatus to perform the necessary functions. The voice alarm circuit and the trunk circuit are part electronic and part relay, while the control and alarm circuit is wholly relay and conventional apparatus. These combinations of electronic and relay apparatus make use of the best features of each to do the most efficient job and are increasingly used in switching design.

Another modern concept used to advantage in the 11A system is that of packaging. The bulk of the circuitry has been reduced to packaged trunks which can be plugged-in and removed easily and which are easily maintained. Each package consists of two trunks, their electronic equipment mounted on a circuit board and the relays mounted on a chassis. With this specially-designed chassis, 20 trunks occupy 17 vertical inches as opposed to 28 inches for conventional mounting plates. All optional wiring within the system is brought out to a terminal strip, making optional features available without changes in the trunk apparatus.

The cabinet which houses this announcement system has been fabricated of aluminum sheet. This measure, like the adoption of electronic packages, serves to reduce weight and enhance portability. Handles are provided for moving convenience and removable front and rear covers

facilitate maintenance. When in use, the front cover may be left off or a small door in the cover opened so that the alarm lamps and message register can be seen. Openings are provided for cable and the a-c supply, and both a six foot cord and a 20 foot extension cord are furnished with the cabinet. When fully equipped, the cabinet forms a neat, 42 by 26 by 10 inch unit which weighs only 120 lbs.

For recording and reproducing the intercept messages, Laboratories engineers adopted a small, general purpose set frequently used in Bell System equipment. This KS-16765 Announcement set accepts a message of up to 2 minutes duration on a magnetic drum. The installation provides means for recording and for playing back the announcement. If excessive ambient noise conditions prevail at the installation site, the recording machine can be easily removed and taken to a quiet location. In addition to an a-c supply, the only equipment needed is a standard operator's headset which is used to check the level of the announcement. The recorder has a variable cycle feature to limit the reproducing cycle to the duration of the announcement and to operate continuously or "stop-start."

The 11A Announcement System can be easily transported to the office requiring intercept service and can be located in a standard line-up or in any convenient location near the source of intercepted traffic. Battery, ground, alarm leads, and an a-c supply are connected to the system. In addition, up to 60 leads are connected between trunk circuits and the intercepted traffic. After a suitable announcement has been recorded, the system is ready to perform.

When a call is routed through this new intercept system, a trunk circuit is seized, ringing is tripped and the control and alarm circuit is activated. The recording machine turns on and the announcement is routed back through the control circuit to the trunk circuit (see diagram on page 288). The voice alarm circuit constantly monitors the voice and, in the event of failure, applies a busy tone to the trunk circuit, lights an alarm lamp, and triggers the central office alarm. As long as any trunk circuit has been seized, the announcement machine will continue to make its announcement, admitting subsequent trunks to "barge-in."

Tests on the completed 11A Announcement System demonstrated that its design objectives had been fulfilled. The equipment is portable, highly adaptable, and of sufficiently large capacity to meet almost any situation for which it might be required. The Bell System now has a reliable means of meeting temporary intercept service at greatly reduced costs.

# Microwave Link for Remote Areas

San Juan Island, due east of Vancouver and only miles from Bellingham, Wash., was recently the center of activity for a team of Bell System technicians. A small area of land had been cleared of brush, rocks and trees. Concrete piers, rooted four feet deep beneath ground, had been placed and a towering antenna stood nearby. In the center of the clearing a seven-foot square aluminum cabin was set up. Inside the 2400 pound structure—insulated by Fiberglas-filled walls and heavy oak flooring—were two TL microwave bays. Their function: to transmit and receive telephone signals simultaneously and automatically.

This unusual TL microwave station or "Station Package," as it is called, was specially designed by Bell Laboratories for remote areas like San Juan. The island needed this transmitter-receiver for a clear and reliable telephone link to shore. Storms and bad weather made cable equipment impossible. Nearby, another transmitter-receiver was set up on Orcas Island. Both units are now relaying phone messages over a 25-mile route between the two outcroppings in Bellingham Bay.

Although TL microwave equipment has been in use in the Bell System for some time (*RECORD, February, 1962*), these two stations are the first to be housed in cabins called "Shelter Stations." The older stations were encased in compact outdoor cabinets and were usually attached to a tower. In addition, the major advantages of the older TL system—low costs, simple installation and reduced maintenance effort—are even more apparent in the new shelter systems.

The new stations almost run by themselves. For example, a newly developed diversity operation provides a margin-for-safety backup device for each microwave package. If transmission becomes weak in one microwave channel, standby equipment takes over automatically until the condition is corrected. Once in operation, the stations require little maintenance.

The packages are so compact and self-contained that they need only be shipped to the site, wired to power and switched on. They are equally suitable for other locations where cables are difficult if not impossible to install—across lakes, rivers,

inlets or deep canyons, for instance.

The Orcas-San Juan project marks not only the first use of the shelter stations in the Bell System, but also their first application in a new service called "Turnkey" by Western Electric's marketing organization. Turnkey is an expanded sales-engineering concept where Western Electric assumes responsibility for all phases of a communications project and when the work is completed, literally "turns over the key" to the operating customer. In the case of the Orcas-San Juan project, the customer was the Pacific Northwest Bell Telephone Company.

Turnkey is flexible. Some shelters have five-foot dish-type antennas mounted on top. These may be aimed straight at associated stations or up at a reflecting plate on a tower that could be as high as 300 feet. This arrangement would be important for deep forest locations where the tower would act as a periscope.

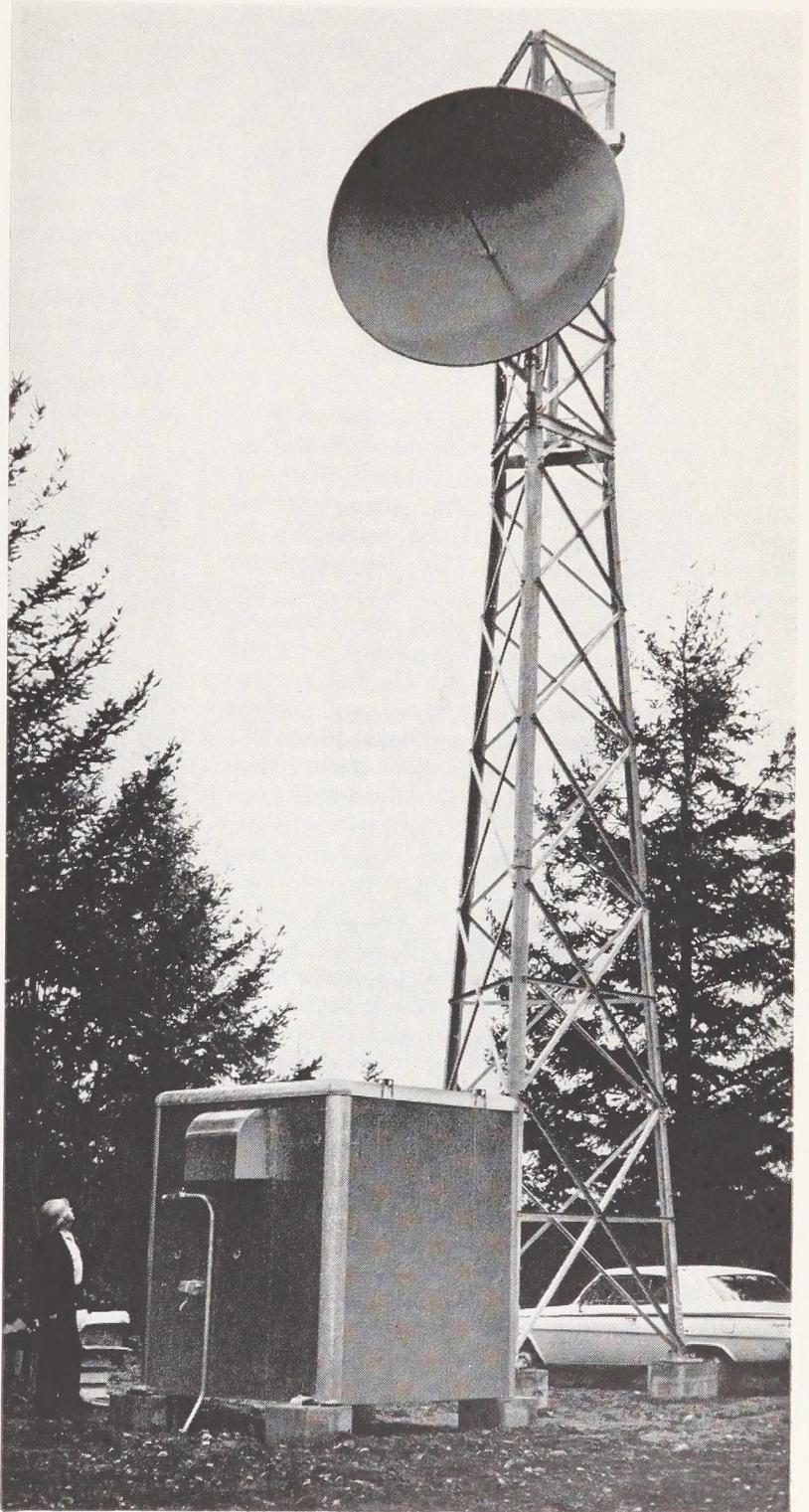
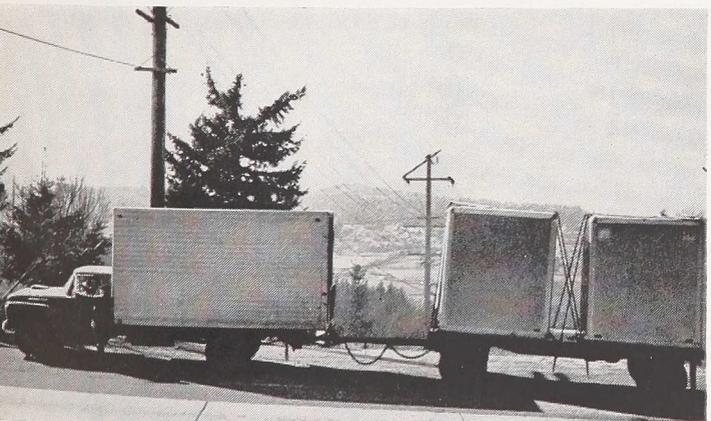
Other shelters will act as relay stations—transmitting signals from one station, amplifying them and transmitting to another station.

The new shelter packages can hold more than two equipment bays—some as many as eight. All models operate in sub-zero cold or near-desert heat, require only routine maintenance and are planned to last for 40 years.

There is also quite a time savings with the new shelters. The older unsheltered microwave stations often required weeks to set up; the new package cuts work time appreciably and provides shelter for the men as well.

For example, the Orcas-San Juan job reduced work-hours from 120 (if the older cabinet stations had been set up) to 25—a 79 per cent time saving. Other savings will come from warehouse and packing costs and from the minimized on-site construction. The shelters go straight from the plant, fully assembled and tested to the installation locations. They can be carried by truck or even hoisted by helicopter over impassable terrain.

Research and development are still going strong. Plans now call for new shelter models with microwave equipment to handle TV signals—educational, network, industrial—often in color.



*Experimental model of TL radio-relay "package" (top left) undergoes testing. Western Electric technicians (middle) install first microwave sta-*

*tion on San Juan Island, after packages were carried cross-country to island destinations (bottom photo). Photo above shows completed station.*

## AUTHORS



R. W. Amory

*R. W. Amory*, a native of Newark, N.J., served in the U.S. Marine Corps and as a First Engineer in the Maritime Service during World War II. He received a B. S. in Marine Engineering from the U.S. Merchant Marine Academy and a B.S. E.E. from Newark College of Engineering in 1951. Mr. Amory began his Bell System career in 1948 as an engineering assistant in the Outside Plant Department of the New Jersey Bell Telephone Co. He joined Bell Laboratories in 1951 and was initially concerned with the design and development of Nike Test Equipment. In 1955, he assumed duties as professional employment representative for the Laboratories in several eastern states. Since 1957 he has been responsible for conducting a number of basic Outside Plant system engineering and economic studies. At present, he is supervisor of a group concerned with the application of digital computers to outside plant engineering. A senior member of the IEEE and author of "Engineering Outside Plant with Computers" in this issue. Mr. Amory lives with his family in Lincroft, N. J.

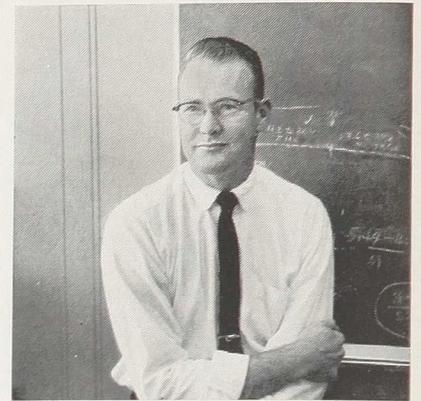
*J. H. Ham*, co-author of TOUCH-TONE CARD-DIALER article, was born in Atchison, Kansas. He received his BS degree in mechanical engineering from the University of Kansas in 1942 and

joined the Laboratories the same year. He received his M. S. degree in electrical engineering from Stevens Institute of Technology in 1948. During World War II, Mr. Ham worked on the development of underwater acoustical apparatus. Since the war, he has worked on exploratory and product development of station signaling devices. In 1956, he was transferred to the Indianapolis Laboratories where he is presently a supervisor in charge of the product development of TOUCH-TONE and magnetic-storage dialing devices.



J. H. Ham

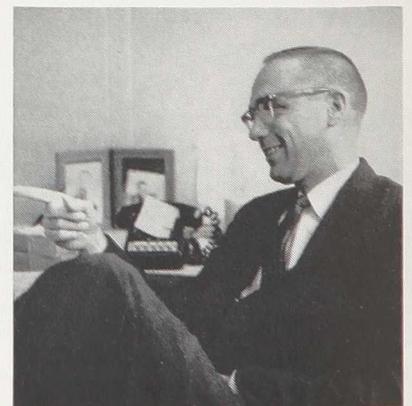
*James F. Ritchey*, co-author of the article on the TOUCH-TONE CARD-DIALER set in this issue is a native of southern Indiana. He joined the Western Electric Company in Indianapolis in 1950 as a tool and die trainee shortly after finishing high school, and then served in the Marine Corps for two years during the Korean War. Returning to Western Electric in 1954, he also enrolled in Purdue University's Indianapolis Extension evening school; the next year he entered Purdue full time. He received his B.S. in engineering science there in 1959 and was hired into the Indianapolis Laboratories BLEP program. Then, in 1961, he entered the CDT program at Murray Hill,



J. F. Ritchey

which he finished in January of this year. Mr. Ritchey is presently a supervisor at the Indianapolis Laboratories with design responsibilities on the automatic reporting telephone, dial pulse detection studies, and automatic dialing telephones.

*Richard C. Boyd*, a native of Detroit, Michigan, received a BS degree from Northwestern University in 1946 and an MSEE degree from the University of Michigan in 1948. That year he joined the Laboratories where he was first concerned with engineering studies of Bell System and military transmission systems. He has been responsible for transmission systems engineering work on short haul, exchange, and rural



R. C. Boyd