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Loop Plant Electronics:

Maintenance and Administration of Loop Electronics

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The economic advantages of loop electronic pair gain systems are clear; however, we must also be concerned about the impact of these systems on service reliability. This paper reviews the maintenance philosophy, procedures and features for the SLC™*-40,* SLC™*-8, and* LSS *systems. It is shown that these systems are designed to have a minimal impact on customer trouble report rates and operating company maintenance functions. Recent field data on* SLC*-40 trouble report rates is presented to demonstrate the viability of the maintenance plans. In addition, the administrative procedures for pair gain systems are discussed.*

I. INTRODUCTION

A watchword in our telephone system today is reliability. Since the loop is an element in every customer's telephone circuit, its reliable performance is essential. However, when loop electronic devices such as pair gain systems are employed, equipment is added to the loop and the potential for failure is increased. It is one purpose of this paper to present the maintenance philosophy, procedures and features for the *SLC*™-40, *SLC*™-8, and LSS systems. The other purpose is to describe the administration of such loop pair gain systems.

Since pair gain systems encompass only a small percentage of loops in any operating company district, maintenance procedures must be designed to fit within the existing operational structure. Therefore, it is appropriate to briefly define the current loop operations environment.

1.1 Loop operations environment

In the loop area the Customer Services Department is responsible for assignment, installation and maintenance of telephone service. The assignment of a particular facility to a customer's order for telephone service is accomplished by the Assignment Center. Assigners use records of cables, crossconnection boxes, and distribution cable terminals to select a spare facility from the customer's home back to the serving central office. Their facility assignment is then forwarded to the installation forces for completion.

The installation forces are responsible for installing the customer's station sets, wiring his home, installing drop wires and interconnecting cable pairs in crossconnection boxes. The station repair forces usually respond to customer trouble reports, and are responsible for maintenance of station sets and household wiring.

The RSB (Repair Service Bureau) has the responsibility for receiving and acting on customer trouble reports. Customer trouble reports are received by the repair attendant who records the customer's complaint, retrieves the customer's line record card and passes the trouble report to a dispatch clerk if the fault is obvious (such as a worn station set cord). Otherwise, the trouble reports go to the test desk where the customer's line is tested to determine if the dispatch of a station repairman or some other craft is necessary. In cases where the test desk finds no trouble, the complaining customer is contacted, and if agreed to by the customer, no further action is taken. The dispatch group functions as the interface between the repair forces and the RSB. They dispatch trouble reports to the station repairmen, receive the results of the repair visits, close out the trouble report, and post the line card records with this trouble report information.

1.2 Maintenance and service objectives for loop electronics

Our objective is to develop a maintenance plan for loop electronics that is compatible with the present operational environment. To achieve this goal, the assignment of maintenance forces to loop electronics must be carefully considered. One must weigh the craft skill level against the availability of the craft. For example, switchmen may not always be equipped for travel to remote terminal sites and PBX repairmen may not exist in some rural areas. In short, the assignment of maintenance responsibilities is partly based on the local environment.

One major objective of the Customer Services Department is to insure that reliable service is provided to telephone customers. As a measurement of service reliability, customer trouble report rates are carefully monitored in the RSB. Although customer trouble report rates are a complex function of environment, cable condition, customer attitudes and many other parameters, it is a major index that is used to judge the performance of the Customer Services Department.

Since subscriber loop electronics adds equipment to a customer's loop, a degradation in overall loop reliability is possible. It is our objective to offer reliability on electronically provided loops that is virtually equivalent to the reliability of loops provided by cable pairs. It is also our intent that this equivalent reliability results in an equivalent customer trouble report rate. In order to accomplish our goal, the inherent reliability of the electronic equipment must not only be high, but maintenance procedures and features must be carefully developed to minimize the customer trouble report rate.

It is one purpose of this paper to show how the maintenance plans for our pair gain systems (*SLC*-40, *SLC*-8 and LSS) accomplish this goal. The discussion of specific systems is contained in Sections II through IV. In addition, results of a customer trouble report rate study on the *SLC*-40 system are presented in Section V. Section VI covers the administrative plan for pair gain systems.

II. *SLC*-40 MAINTENANCE PLAN

The *SLC*-40 system is a 40-channel digital subscriber carrier system, described in a companion article.[1] For the purpose of discussing the *SLC*-40 maintenance plan, refer to the simplified block diagram in Fig. 1. In this figure the central office terminal (COT) and remote terminal (RT) each consist of 40 channel units and common equipment. The channel units in the actual *SLC*-40 system are individual plug-in circuit boards that encode and decode speech signals to and from digital form. These units also provide the necessary signaling functions. The common equipment consists of plug-in circuit boards and power supplies. Its primary function is to transmit the channel unit signals over the repeatered line. The T1-type digital repeatered line includes a spare re-

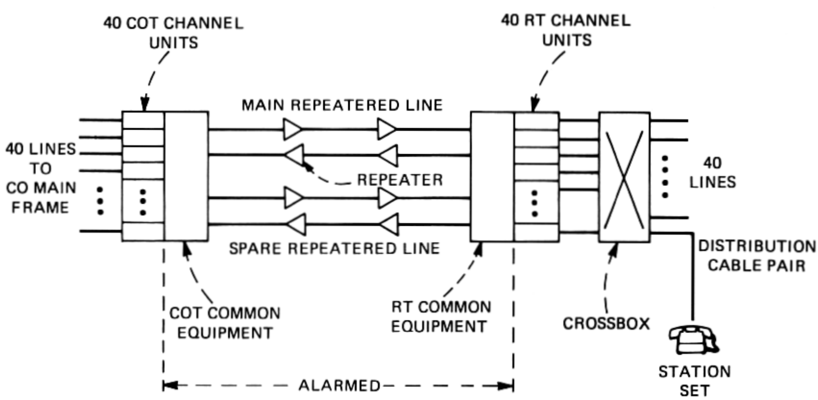

Fig. 1—*SLC*™-40 system block diagram.

peatered line that is automatically switched in case of a main line failure. Both the main and spare repeatered lines require a total of four cable pairs.

The remote terminal (RT) is placed somewhere along the cable route in the area needing additional loop facilities. At the RT is a crossbox which allows the installers to interconnect any *SLC*-40 channel with any distribution cable pair. As will be described, the crossbox is also used for fault sectionalization.

As shown in Fig. 1, the loop circuit provided to a customer via a *SLC*-40 system consists of the following major elements:

(*i*) Central office main frame wiring
(*ii*) *SLC*-40 COT channel unit
(*iii*) *SLC*-40 COT common equipment
(*iv*) *SLC*-40 repeatered line (repeaters and cable)
(*v*) *SLC*-40 RT common equipment
(*vi*) *SLC*-40 RT channel unit
(*vii*) Crossbox
(*viii*) Distribution cable pair
(*ix*) Station set and household wiring

The above items are classified into two major failure modes—common system and single line failures. The common system failures are associated with the COT or RT common equipment and the repeatered line. A failure in any of these elements affects the service provided to all or many of the customers on a *SLC*-40 system. On the other hand, the remaining circuit elements only affect one customer's loop when they fail. If the *SLC*-40 derived loop is compared to the usual voice frequency (VF) loop design, one sees that a VF loop has mainly single line failure modes. The only equivalent to a common system failure is a massive cable failure, such as a severance.

2.1 Common equipment maintenance

When a common system failure does occur it is essential that the outage time be minimized. The *SLC*-40 common equipment and repeatered line are fully monitored, and a failure causes an alarm to be displayed. The *SLC*-40 alarms are interfaced with the standard central office alarm system, so that CO maintenance personnel are immediately notified of system failures. These alarms are classified as either major or minor. A major alarm indicates a disruption in service to a large group of customers on the system, while a minor alarm indicates a nonservice affecting fault, such as a switch to the spare repeatered line.

When a major alarm occurs on the system, it is essential that the RSB be immediately notified by the CO of any *SLC*-40 major alarm so that they can intelligently handle customer trouble reports. The flow diagram in Fig. 2 summarizes the fault localization and repair process. Trouble isolation is begun at the COT where interpretation of the alarm display lamps (see Fig. 3), fuse conditions and power supply voltages can quickly indicate many COT failures. Further diagnostic information is obtained by "looping-back" the COT, that is, connecting its transmitting T1 rate port to its receiving port. In this mode the COT is isolated from the repeatered line and the RT, and it is tested for proper operation. If the performance of the COT in the "loop-back" mode is normal, the trouble is in the RT or repeatered line. The responsible maintenance craft must now visit the RT to determine if the fault is in the remote terminal or the repeatered line. If the fault is in the RT, it is repaired by a plug-in unit change. An alarm display at the RT (see Fig. 3) allows confirmation of proper system operation after replacement of a common plug-in unit. When the failure is located in the repeatered line, appropriate trouble-shooting procedures are followed which identify the faulty repeater or cable section.

The maintenance of the COT will be the responsibility of the central office switchmen, and in many areas this craft would also be responsible for the RT and repeatered line maintenance. However, if the switchmen do not have access to company vehicles, PBX repairmen are assigned to RT and repeatered line maintenance. The PBX repairmen will be dispatched by the RSB after the switchmen have determined that the failure is not in the COT.

2.2 Single line failure maintenance

Unlike the common system failure, single line failures are not alarmed and are only detected through customer trouble reports received in the

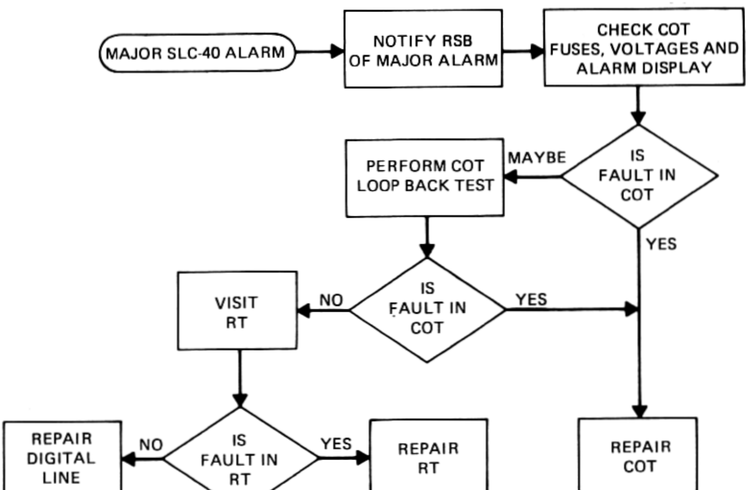

Fig. 2—*SLC*™-40 major alarm fault localization and repair.

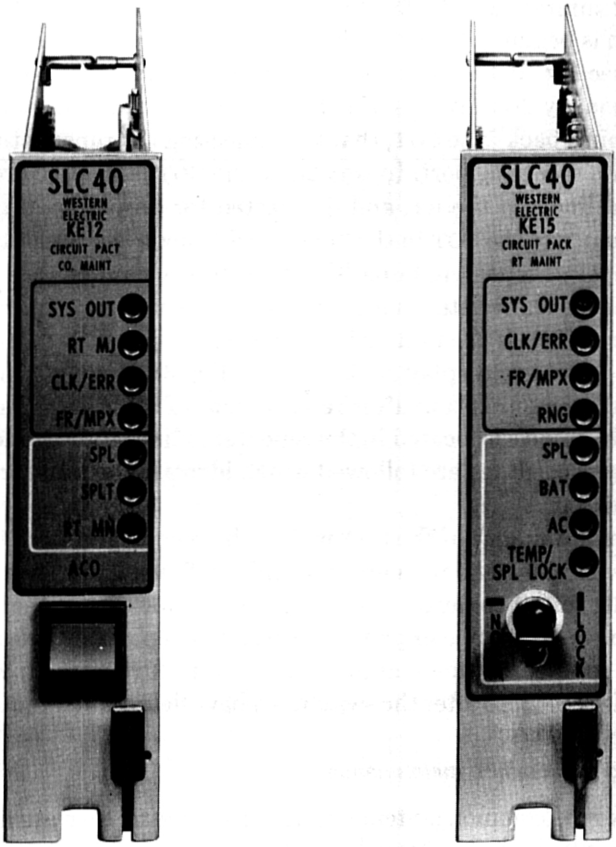

Fig. 3—*SLC*™-40 alarm displays.

RSB. When the trouble reports are received, the RSB first checks for alarms reported by the CO. If there are no alarms, the report is assumed to be related to a single line failure. Since the *SLC*-40 COT and RT channel units are very reliable, troubles are most likely in the station set, household wiring or distribution cable. Central office troubles can be easily detected through standard test desk procedures. However, the test desk cannot "see" any further than the COT. Through analysis of the reported trouble, customer's trouble history and possibly conversations with the customer, the decision to dispatch a station repairman is usually made. We have found that the thorough system alarms and spare repeatered line obviates some of the need for RSB testing, because a portion of the loop circuit is continuously being monitored.*

The station repairman treats this trouble report like any other. Generally he will first visit the customer's premises, and if the trouble is

* Although the *SLC*-40 system does not have RSB line testing features, technology has advanced to the point where these features are economical and will be provided in future digital subscriber carrier systems.

confirmed, attempt to isolate the trouble by testing at the crossbox. If the trouble is not present on the *SLC*-40 channel feeding into the crossbox, then the trouble is in the distribution cable pair. Conversely, trouble in the *SLC*-40 channel is cleared by transferring the customer to an alternative facility or by having the proper craft replace the faulty channel unit. The station repairman does not replace plug-in units in the RT. He treats this trouble just as he would if the customer was entirely served by a cable pair. In this manner, training costs for *SLC*-40 system maintenance are minimized.

III. LOOP SWITCHING SYSTEM MAINTENANCE PLAN

The Loop Switching System (LSS) is a 192-line concentrator consisting of two 96-line concentration systems. The LSS is described in more detail in a companion article,[2] but a basic block diagram is shown in Fig. 4. For purposes of discussion, only the 96-line system modules will be shown. The 96 lines are concentrated onto 32 trunks (usually VF cable pairs), by the switching network that is composed of twelve plug-in circuit boards called line units. Analogous to the *SLC*-40 channel unit failure, an LSS line unit failure affects service for only a few customers (at most eight). The common control in the COT operates the COT switching network directly and the RT network through the data link (employing two pairs). Through the use of a microprocessor, numerous diagnostic capabilities have been incorporated into the LSS. In addition, the fully metallic switching network allows for complete loop testing from the RSB test desk.

The LSS routinely tests the trunk and switching path for continuity, leakage and insertion loss prior to establishing a customer's connection. This test routine virtually eliminates any customer trouble reports due to individual trunk pair failures. It is only in the rare event of a major cable fault that customers' service would be disrupted.

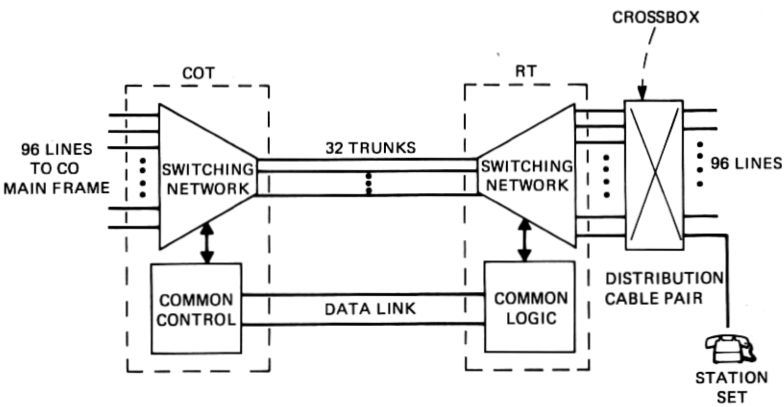

Fig. 4—LSS block diagram.

3.1 Common system maintenance

Naturally a failure of the common control units in the COT or the common logic in the RT can cause an entire system failure. Many data link failures are avoided by using two of the least used trunks as a spare data link. When a fault is detected, a switch will automatically occur. The LSS contains many diagnostic routines that result in a very detailed COT alarm display (see Fig. 5). For example, an alarm is present for each of the COT common control plug-in units. In many cases, the system can also determine whether the trouble is in the COT or RT. In addition, the test and display unit (Fig. 5) allows the craftsman to manually initiate trouble-shooting routines.

As with the *SLC*-40 system, both major and minor LSS alarms are interfaced with the CO alarm system so that switchmen are immediately notified of its failure. The LSS alarm status can be remotely monitored through a dial up alarm query feature. When dialed, this feature transmits audio tones indicating major or minor alarm status and location (COT or RT).

The diagnosis of system failures at either the COT or RT involves checking fuse conditions and power supply voltages and analyzing alarm conditions. The defective plug-in unit can be rapidly identified, changed,

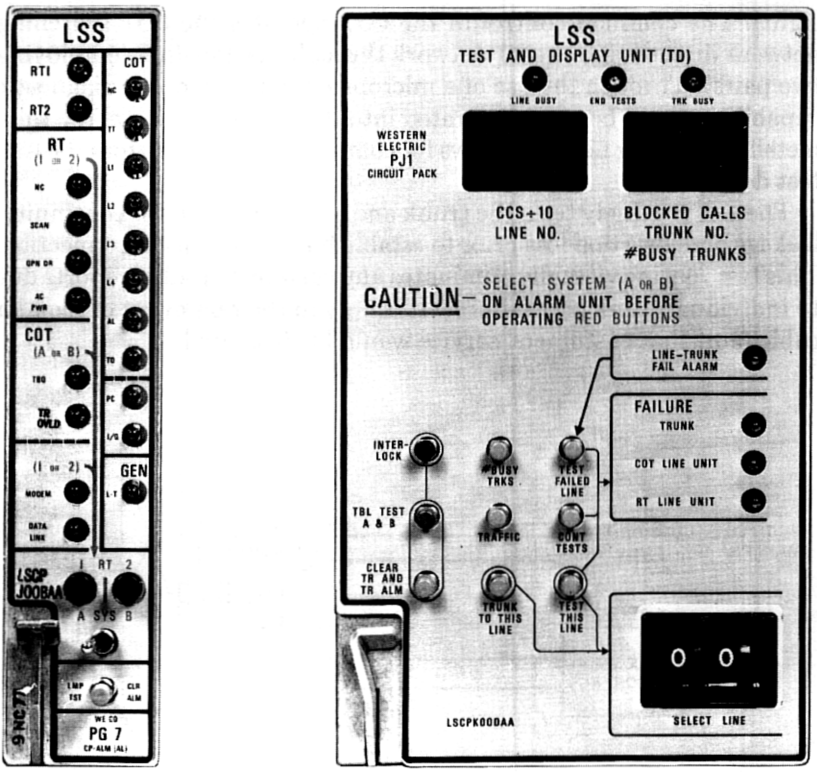

Fig. 5—LSS COT maintenance units.

and proper operation confirmed. There is a small alarm display in the RT maintenance unit to aid in confirmation of system operation (see Fig. 6). This maintenance unit also allows the repair personnel at the RT to initiate the automatic line-trunk testing routine. In this manner, the operation of individual line units and the total system can be very quickly confirmed.

Like the *SLC*-40 system, the COT is always maintained by CO switchmen, and the RT may be maintained by switchmen or PBX repairmen.

3.2 Single line failures

Single (or multiple) line failures in the switching network or trunks

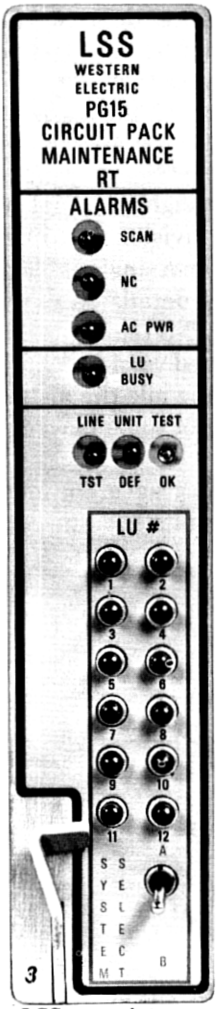

Fig. 6—LSS RT maintenance unit.

will almost always be detected by the LSS and result in a minor alarm. The test and display unit allows these network or trunk failures to be read out of the microprocessor's memory. This unit also enables a rapid retest of stored failures by manual commands.

The system will attempt to maintain the customer's telephone service by selecting good trunks or network paths, but in some cases customer trouble reports will result. Also trouble reports will be due to failures in the crossbox, distribution cable pairs or station set. However, these faults can be detected by the test desk and the proper maintenance craft dispatched. As with the *SLC*-40 system, very few customer trouble reports are expected to be due to LSS failures, and dispatch of the station repairman is most likely.

When major system failures do occur, the CO is instructed to notify the RSB. However, if this notification does not occur, the test desk would not "see" the loop beyond the COT. This clue indicates a system failure that can be confirmed through the alarm query feature.

IV. *SLC*-8 MAINTENANCE PLAN

The *SLC*-8 system is an eight-channel analog subscriber carrier system. Through frequency division multiplexing, eight two-way speech channels are transmitted on a single cable pair. A companion paper describes the system in more detail.[3]

Two versions of the *SLC*-8 remote terminal are available—lumped and distributed. The lumped version contains all RT equipment for one system in a single cabinet, while the distributed system allows the RT equipment for each channel to be placed separately along the carrier frequency pair.

Figure 7 shows a block diagram of the lumped *SLC*-8 system. The COT consists of eight channel units and one common plug-in circuit board.

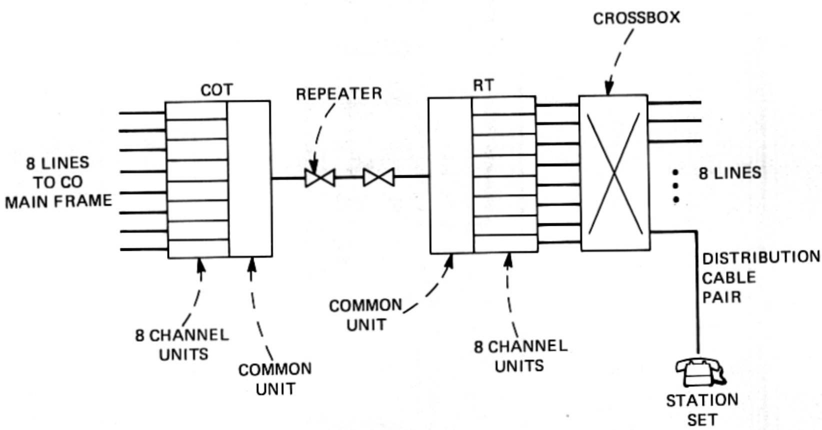

Fig. 7—Lumped *SLC*™-8 block diagram.

The common unit provides power to the repeaters and RT, and also serves as the interface between the channel units and the cable pair. The RT consists of an arrangement of plug-in circuit boards that perform a function very similar to the COT. The bidirectional repeaters are located periodically along the carrier pair. As with the *SLC*-40 and LSS, the lumped RT interconnects to the distribution cable pairs through a crossbox.

The distributed *SLC*-8 system, shown in Fig. 8, allows the channel units to be individually placed at the location of the customer to be served. The channels do not work through a crossbox or distribution cable pair, but rather connect directly to the customer's drop wire. Each channel unit and a power unit are placed in a closure. This combination is referred to as a distributed RT.

The distributed and lumped *SLC*-8 systems are maintained in similar manners. Therefore, the following description of maintenance operations applies to both versions.

The *SLC*-8 maintenance plan differs somewhat from the *SLC*-40 and LSS plan, largely because a comprehensive set of alarms are not economically feasible on analog subscriber carrier systems. Also since these systems are small in line size, they are usually installed in a scattered manner along sparse rural routes, and are most efficiently maintained by station repairmen in the field. CO switchmen will maintain the central office terminal.

The *SLC*-8 has two alarms—one due to COT power supply failure and the other due to carrier line short circuits. However, most *SLC*-8 failures will be identified through customer trouble reports. The *SLC*-8 system has a feature that allows the operation of individual channels to be checked from the RSB test desk. If a channel fault is detected, other channels can be tested to determine if a system failure has occurred. Essentially, the channel test feature is used on *SLC*-8 to gain the same information provided on *SLC*-40 by its alarms.

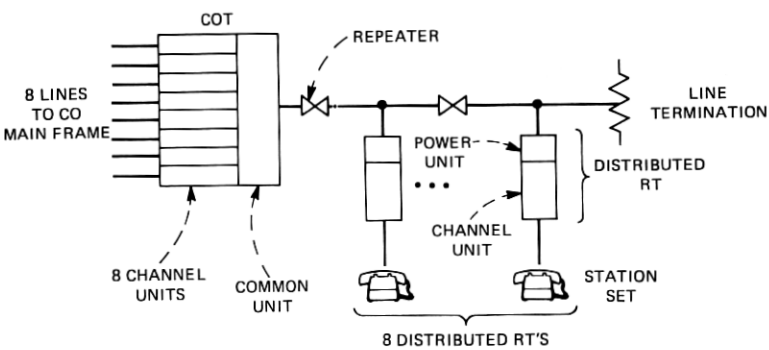

Fig. 8—Distributed *SLC*-8 block diagram.

Many of the *SLC*-8 failures will involve replacing COT or RT plug-in units; however, failures will also occur in the carrier pair or repeaters. These troubles are located by using a distributed RT as a test set. The distributed RT is placed at various points along the carrier line to isolate the fault location. In cases of more obscure troubles, a frequency selective voltmeter may also be used. Since repeaters are single plug-in units, they are easily replaced when defective.

V. FIELD PERFORMANCE DATA

In order to demonstrate that a maintenance plan is viable, actual field performance data must be analyzed. The *SLC*-40 system will be used as an example of the ability of pair gain systems to provide telephone service as reliable as that provided only over cable pairs. Although "black box" reliability estimates for the *SLC*-40 system indicated that the customer trouble report rate performance would be acceptable, studies in an actual operating environment provide conclusive results.

The *SLC*-40 customer trouble report rate data was taken on the first seven systems placed in service. The data gathering began a few months after the systems were installed and continued for one year. To evaluate the *SLC*-40 customer trouble report rate, a control group of voice frequency (VF) lines was also studied. The VF control group was selected from lines in the same area of the same cable route as the *SLC*-40 customers. In all ways the control group customers were as similar as possible to the *SLC*-40 customers.

Table I gives a comparison of the customer trouble report rate for the VF control group and the *SLC*-40 group. The *SLC*-40 report rate appears slightly higher, but this difference is not statistically significant. Essentially the *SLC*-40 customers were provided equivalent service to the VF control group customers. Customer trouble reports associated with *SLC*-40 equipment and feeder cable failures are explicitly shown. In the other trouble report categories, the rate in both groups is roughly equal since these reports are not related to the carrier system performance. These categories include such things as station set, distribution cable and central office failures.

Since the beginning of this study a few minor design and documen-

Table I — Observed data, *SLC*™-40 customer trouble report rate (customer trouble reports/100 stations/month)

	VF	*SLC*-40
Feeder cable	1.0	0.1
SLC-40 COT	—	0.7
SLC-40 RT	—	0.9
Repeaters	—	0.1
Other	4.3	3.9
Total	5.3	5.7

tation changes were made in the *SLC*-40 system. These changes resulted in improved reliability and more efficient system repair. Although the attendant reduction in customer trouble report rate is small, the data was adjusted to account for these changes. The VF rate was also adjusted downward to account for an inequality in the distribution cable trouble report rates that was due to slight environmental differences between the control and *SLC*-40 groups. Table II shows the adjusted comparison between customer trouble report rate of the VF control group and the *SLC*-40 group.

It is interesting to note in Tables I and II that the feeder cable trouble report rate for the *SLC*-40 group is much lower than in the VF group. The feeder cable portion of the *SLC*-40 loop circuit is used for the T1 carrier line and has a redundant path (spare line) that is automatically switched to in the event of a main line failure. Therefore, many cable failures that affect only a small number of pairs (usually one) will not result in the interruption of a customer's service. The same type of failure in the VF control group does result in an outage, hence, the higher feeder cable report rate in the VF group.

This reduction in the feeder cable trouble report rate offsets the *SLC*-40 equipment related trouble report rate, and results in an overall report rate that is essentially equal. The slightly lower *SLC*-40 trouble report rate in Table II is not statistically significant at a 95 percent confidence level.

We expect the data in Table II to be representative of the current *SLC*-40 product. When analyzed in detail, the data not only show an equivalent level of customer service, but also demonstrate the ability of telephone company personnel to maintain the system.

VI. ADMINISTRATION

As mentioned in Section I, it is the Assignment Center that administers the loop facilities. Since the Assignment Center employs well established standard procedures and records, it is the objective of this section to show how subscriber pair gain systems fit within the existing structure. In order to describe the function of the various assignment records, we will first trace through the assignment process for the usual cable pair facility.

Table II — Adjusted data, *SLC*™-40 customer trouble report rate (customer trouble reports/100 stations/month)

	VF	*SLC*-40
Feeder cable	1.0	0.1
SLC-40 COT	—	0.2
SLC-40 RT	—	0.4
Repeaters	—	0.1
Other	3.9	3.9
Total	4.9	4.7

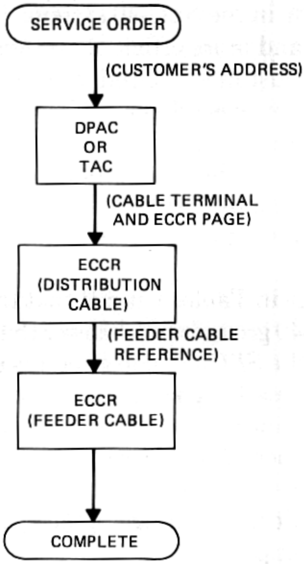

Fig. 9—Conventional assignment process.

Figure 9 illustrates the assignment process, which has been simplified to convey the basic concepts. The facility being assigned is shown in Fig. 10. The customer's service order must first be associated with a cable terminal and distribution cable. Using the customer's address, the DPAC (Dedicated Plant Assignment Card) or TAC (Terminal Address Card) provides the identifying number of the closest cable terminal. The cable terminal is the means by which the customer's residence (or business) is connected to the distribution cable via a drop wire. Also provided by the DPAC or TAC is the page reference for the distribution cable ECCR (Exchange Customer Cable Record). The ECCR is the record of cable pairs, and the page referred to by the DPAC or TAC shows the association of cable pairs to the cable terminal of interest. From the ECCR a distribution cable pair is selected and assigned to the customer.

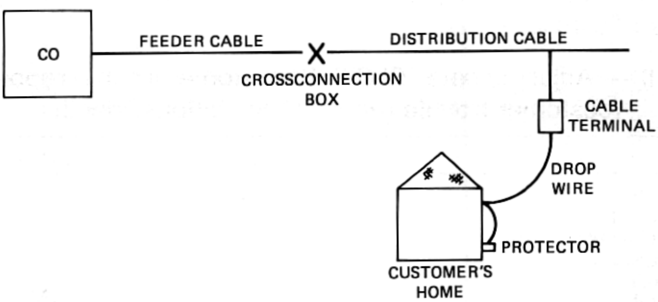

Fig. 10—Assignment example.

In this example, we are assuming that the distribution cable must be interconnected to the feeder cable at the crossconnection box. Therefore, the distribution cable ECCR provides a reference to a group of feeder cable pairs that "feed" the crossconnection box. The feeder cable ECCR is referred to for selection of a vacant feeder cable pair. The assignment of the distribution and feeder cable pairs uniquely defines the interconnection wiring that must be performed by the installer in the crossconnection box.

Now let us assume that we are dealing with assignment of a lumped pair gain system (such as an *SLC*-40 system). Since lumped pair gain systems always have their remote terminals placed in association with a crossconnection box, their assignment is analogous to feeder cable. The pair gain system's line or channel provides the facility between the CO and the crossconnection box. In fact, the distribution cable ECCR will refer to the pair gain system as one of a number of feeder facilities. However, instead of using an ECCR, the pair gain system is administered with a Miscellaneous Central Office Facilities Record (MCOFR). The MCOFR performs the same function for pair gain systems that the ECCR performs for feeder cable pairs. In addition, it allows easy administration of the pair system's plug-in channel or line units. Therefore, the assignment flow for lumped pair gain systems, shown in Fig. 11, is very similar to the normal process.

For systems like the distributed *SLC*-8, the remote terminal equipment is associated with distribution cable terminals. Therefore, the above procedures cannot be used for distributed pair gain systems. In this case more specialized procedures must be employed that essentially treat all customers on the distributed system as if they were all assigned to a multiparty line. Although this represents a departure from con-

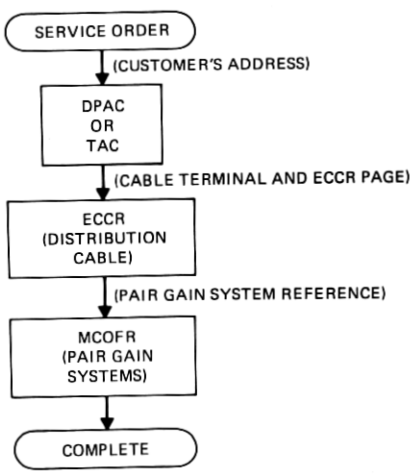

Fig. 11—Lumped pair gain system assignment process.

ventional assignment procedures, distributed systems are only used in very sparse rural areas. Hence, their penetration in any Assignment Center is not high.

VII. CONCLUSIONS

This paper has presented the maintenance plans for *SLC*-40, LSS, and *SLC*-8 systems. These plans are designed to insure customer trouble report rates equivalent to that provided by VF cable pairs, and to fit easily into the existing loop operations environment.

Through actual field performance data on *SLC*-40 systems, it has been demonstrated that our maintenance goals for that system have been met.

VIII. ACKNOWLEDGMENTS

I wish to acknowledge my coworkers at Bell Laboratories and AT&T who have contributed to the *SLC*-40, LSS, and *SLC*-8 maintenance plans. Special recognition also goes to W. P. Arvidson of Bell Laboratories who provided the *SLC*-40 field performance data.

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