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No. 10A Remote Switching System:

System Maintenance

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The 10A Remote Switching System (RSS) is unlike previous electronic switching systems in that its various subsystems can be physically separated by hundreds of miles. Thus, its maintenance plan must make provisions for the day-to-day operation and repair of the separate system components by different Bell operating company craft forces. The maintenance of each of the RSS subsystems is described in this article, as well as the required overall coordination between the various craft forces charged with RSS maintenance.

I. INTRODUCTION

1.1 Maintenance objectives

Overall system requirements and objectives for the 10A Remote Switching System (RSS) are detailed in Ref. 1. From a maintenance standpoint, the objective is to provide continuous and reliable telephone service throughout the life of the system, while providing maintenance capabilities equivalent to those of other ESS systems. That is, the system must be both highly dependable and easily maintainable. The maintainability objective is to have a system in which troubles, when they occur, are easily located and sectionalized, and repair operations can be completed quickly by craft without extensive training in RSS. It is a further objective that the RSS maintenance plan be as consistent as possible with existing Bell operating company procedures for maintaining switching systems and fit the organizational structures and maintenance support systems expected to exist in the 1980s.

1.2 Overview

The No. 10A RSS maintenance plan is similar to that of other Bell System electronic switching systems in its reliance upon hardware duplication of critical system components and its use of program control for fault detection, recovery, and support of repair operations. The RSS is unique, however, in that its various subsystems can be physically separated by up to 280 miles,[2] and the maintenance plan must make provisions for the day-to-day operation and repair of separate parts of the system by different craft forces. For this reason, proper maintenance of the RSS will require considerably more coordination among various Bell operating company maintenance forces than earlier electronic switching systems.

A block diagram of the RSS is shown in Fig. 1. The three major components are

(*i*) The RSS remote terminal.
(*ii*) The data links and interconnecting channel facilities.
(*iii*) The controlling host ESS.

All of the communication (both voice and data) from the remote unit terminates on the host office, which supplies much of the overall control for the system. The communication between the remote terminal and the host ESS is over duplicated data links, controlled at the host by the Peripheral Unit Controller configured in the Data Link application (PUC/DL). The voice channels from the remote terminal connect to the host line network and, thus, present some characteristics of both lines and trunks. Detailed discussions of the software and hardware characteristics of the various RSS components are included in Refs. 1 to 7.

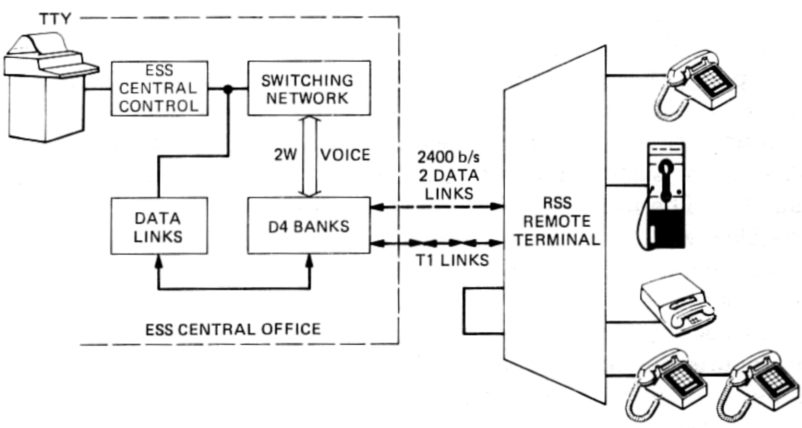

Fig. 1—Remote switching system block diagram (T carrier).

A maintenance plan for the RSS must include all of these separable subsystems and their interactions. In general, existing host maintenance procedures have been extended to include the maintenance of components of the RSS closely tied to the host ESS. Thus, the channels interconnecting the host and the remote terminal are treated, from a maintenance standpoint, much like interoffice voice trunks connected to the ESS. The PUC/DL is treated like any other piece of ESS periphery and is maintained similarly.

On the other hand, the remote terminal itself, where the hardware is distinctly separate from that of the host, is maintained, as much as possible, as a separate entity. The host maintenance teletypewriter (TTY) is the primary interface for remote terminal maintenance, but all remote terminal fault detection, diagnostic control, system state control, etc., are coordinated by the microprocessor controller at the remote terminal. In this way, most maintenance procedures for the RSS remote terminal can be kept independent of the host type (No. 1, 1A, or 2B ESS). The specific host-dependent maintenance capabilities described in this article refer to No. 1/1A ESS.

The RSS per-line circuitry is quite complex because of space, power, and network considerations,[4] while the host ESS per-line circuitry is relatively simple. Extensive loop maintenance functions, such as local test desk access and Automatic Line Insulation Tests (ALIT) exist in the host, but there are no line circuit maintenance functions applicable to the RSS per-line hardware. Host software has been modified to supervise ALIT testing, and to control line test access in the RSS. Software has been implemented in the remote terminal to provide the required per-line circuitry maintenance functions.

Section II of this paper describes the operational relationships necessary to efficiently maintain the RSS. Remote terminal maintenance is discussed in Section III, and PUC/DL maintenance is outlined in Section IV. Section V reviews the approach to RSS channel maintenance, and customer line maintenance is discussed in Section VI.

II. DIVISION OF MAINTENANCE RESPONSIBILITIES

2.1 Overall maintenance coordination

The primary responsibility for the maintenance of the RSS lies with the switching force responsible for the maintenance of the host ESS. The RSS sites are unstaffed, with all TTY messages from the various RSSs appearing on the host maintenance TTY. All alarms associated with the RSS trigger host central office audible alarms and light alarm indicators on the host Master Control Center (MCC). The sectionalization of troubles often requires detailed host office expertise because of the complex interrelationship between the host and the RSS.

The ESS switching maintenance force may be located either in the host central office or in the Switching Control Center (SCC). When the host is maintained from an SCC, the SCC is the ideal point to centralize the overall maintenance responsibility for the RSS. The SCC is normally responsible for the operation and maintenance of all ESS central office equipment within a geographic area, and its responsibility would normally extend to any RSSs served by host ESS offices in that area.

The SCC is responsible for continuous surveillance and trouble sectionalization for the RSS. Since SCC personnel would normally monitor all TTY printout and host alarms, they are responsible for sectionalizing and isolating all machine-generated trouble reports. When a fault is found in the host ESS equipment, the PUC/DL, or the RSS remote terminal, the SCC maintenance force is directly responsible for its repair. In some cases, the SCC will have direct repair responsibility for other portions of the system. In some Bell operating companies, the SCC is responsible for the maintenance of central office carrier equipment. When this is the case, SCC craft will normally be responsible for the maintenance of any host office located channel carrier equipment. In all other cases of RSS troubles, it is the responsibility of the SCC to refer other troubles (e.g., customer loop problems, carrier facility troubles, or data link modem difficulties) to the appropriate maintenance force for follow-up repair. The SCC is also responsible for tracking all RSS repair activities, independent of the specific maintenance force responsible for the repair.

2.2 Remote terminal maintenance

The repair and maintenance of the RSS remote terminal will normally be carried out by ESS switching craft dispatched from the host central office or from the SCC. In some cases, however, because of long travel times or other local problems, it may be expedient to train other available maintenance personnel in simple RSS repair procedures. In these cases, the repair operations will be performed under the direction of switching craft, either at the host or at the SCC.

2.3 Data link maintenance

All PUC/DL faults are reported on the host maintenance TTY and are treated in the same manner as a fault in any other piece of ESS periphery. After the trouble is sectionalized and isolated, the host switching craft will be responsible for the repair. If the fault is found to lie within the data sets, the trouble will be referred to the appropriate force (normally either data services or carrier repair forces) for repair. If the fault is found to lie within the carrier facilities, those normally responsible for carrier maintenance and repair will be called.

2.4 Channel maintenance

The maintenance of the voice channels between the RSS remote terminal and the host ESS is the responsibility of the same force responsible for the maintenance of the host office trunks. This function will be performed at the host trunk test panel or at the trunk maintenance work station at the SCC. This force will be responsible for monitoring the weekly scheduled automatic channel diagnostics, and providing ongoing surveillance of the maintenance TTY output in order to react to channels automatically removed from service by system-error analysis. When RSS channel troubles are detected, it is the responsibility of this force to sectionalize the trouble to either host central office equipment, host carrier equipment, carrier facilities, or remote terminal equipment. Once the fault is isolated to one of these areas, the trunk maintenance force is charged with either repairing the trouble, or referring the problem to the appropriate maintenance group.

When the host trunks are included in a Centralized Automatic Reporting On Trunk (CAROT) center, the RSS channels will normally also be included. Then, the CAROT center will routinely perform transmission measurements on the RSS channels.

2.5 Carrier equipment maintenance

The carrier equipment between the host ESS and the RSS remote terminal is the maintenance responsibility of the Bell operating company force normally charged with carrier maintenance. The switching craft responsible for the host will normally receive the first indication of carrier trouble via TTY printouts and audible alarms. The problem will then be sectionalized further to determine which specific force should carry out the repair. Trouble could lie within the RSS remote terminal frame, within the host ESS carrier equipment, or within the carrier facilities in the outside plant. In the case of T-carrier, particularly, coordination greater than the norm will often be required between the switching craft and the force responsible for carrier maintenance, because the T-carrier equipment at the remote terminal is integrated into the RSS equipment frame. When the switching craft has isolated the carrier problem to the facilities, the trouble would normally be reported to the Facility Operation Center of the T-carrier Restoration Control Center (TRCC) for repair and service restoral.

2.6 Customer loop maintenance

The responsibility for the maintenance of the customer outside plant and station equipment remains with the appropriate maintenance center. In the following, such a maintenance center will be referred to generically as a Repair Service Bureau (RSB). In the future, RSB functions may be split among several other maintenance centers.

The ability to test an RSS customer loop from the local test desk is provided either via a metallic test connection or through a modified remote test system. As with other systems, most customer complaints will be reported directly to the RSB, and it will be their responsibility to sectionalize the problem as either "in" the switching equipment or "out" in the outside plant. If the problem is found to be in the switching equipment, it is the responsibility of the RSB to notify the switching craft for further fault resolution and repair. Customer drop line, terminal equipment, and loop plant problems will be repaired by the appropriate maintenance force.

Customer loop problems that are detected by the RSS will result in TTY output messages that print on the local test desk TTY channel. It will be the responsibility of the RSB maintenance force to react to these trouble reports, sectionalize the problem to either "in" or "out" and either repair the "out" problem or alert the switching craft to problems within the RSS equipment.

III. REMOTE TERMINAL MAINTENANCE

3.1 System overview

The RSS microprocessor controller generally operates under the control of the host ESS processor. In the case of call processing, the degree of host control is large.[5] However, remote terminal maintenance activities are carried out nearly autonomously, with the host ESS acting primarily as a TTY input/output coordinator. Remote terminal hardware fault detection, error analysis, alarm scanning, and processor configuration are performed by the remote terminal microprocessor. The RSS hardware diagnostics are also resident at the remote terminal. The host exercises automatic control over remote terminal hardware diagnostics only for interface circuitry, such as channel interface hardware and data link hardware.

The desired degree of remote terminal reliability is accomplished through hardware duplication of circuitry that affects more than 64 customer lines. To ensure that no single fault will affect more than 64 lines, the RSS microprocessor controller and the data link connecting the remote terminal to the host are duplicated. A block diagram illustrating this duplication is shown in Fig. 2. A complete RSS controller consists of the microprocessor itself, along with its dedicated memory and a dedicated set of fanout boards through which the periphery is accessed. Each microprocessor controller can communicate over either data link. The host determines which data link is active, and the remote terminal decides which microprocessor controller is active.

The remote terminal microprocessor controllers have four allowable states: active, standby, out-of-service, and unavailable. In the normal

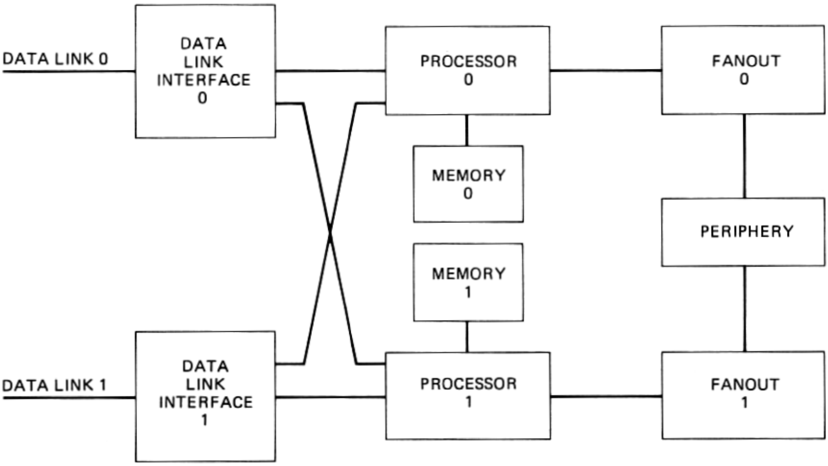

Fig. 2—Remote switching system terminal—system control.

working mode, one processor side is active with the other standby. In this mode, there is no matching between the two sides, but the standby memory is placed in a double-write mode, allowing the active processor to write into both the on-line and off-line memories simultaneously. Thus, if a fault is detected in the on-line controller, a switch can quickly be made to the standby side whose memory has been kept up to date. Any data mutilation caused by the fault will be cleaned up by initialization and audit routines after the switch.

If the off-line microprocessor complex is suspected of being faulty, or its memory is not being kept up to date, it is placed in the out-of-service state. When the off-line microprocessor is marked out-of-service, it is still available for a switch to the active state if a severe fault is detected in the on-line controller. The off-line processor is made unavailable, and a processor switch inhibited, if it has been manually forced off-line or if it has had its power removed. The RSS control complex is discussed in detail in Ref. 3.

Peripheral circuitry, such as the network links and junctors, the various service circuits, and the voice channels between the host and the remote terminal, are replicated.[4] If a malfunction occurs in one of these circuits, the faulty component is identified and removed from service. Generally, there is a sufficient number of remaining circuits to adequately handle the normal traffic with little or no degradation of service.

The primary maintenance interface with the RSS remote terminal is via the host ESS maintenance TTY. Direct TTY communication with the remote microprocessor control system is not possible. A maintenance panel is provided for on-site interaction with the remote terminal, but its primary function is to allow for circuit-pack replacement and repair verification. The capability is provided to verify a failing circuit, remove it from service, remove power from the circuit pack if necessary, replace the pack, and then verify the replacement's correct operation. A software buffer associated with the maintenance panel must be preloaded, via the host TTY, with a list of circuit packs to be diagnosed on site.

During installation and periods when extensive repair activity is necessary at the remote site, remote access to the host maintenance TTY facility is possible. This access will generally be provided via a secure dial up connection to the SCC serving the host ESS. In this case, it is recommended that a voice-grade facility, independent of the RSS equipment, be provided. It is also possible to provide access to the host remote maintenance TTY on a direct, dedicated-facility basis.

3.2 Remote terminal fault detection

The RSS remote terminal maintenance programs detect and recover from a fault, reconfigure the system if necessary, and report pertinent information concerning the fault in a TTY output message at the host.[3,6] Normally, the message will identify the specific circuit in which the fault occurred. The detection of a fault does not automatically initiate a diagnostic of the remote terminal hardware. It is necessary for the craft person to use manual diagnostics to verify and repair the faulty circuit.

Both hardware and software checks are used to detect faults in the RSS remote terminal microprocessor controller complex.[4] There is a hardware sanity timer associated with each microprocessor. If the timer is not periodically reset, a timeout occurs, causing the associated microprocessor to begin executing code to initialize itself and establish a working mode. Repeated timeouts result in more severe initialization levels. In addition, hardware exists to detect parity errors when accessing the memory and fanout boards.

Software fault detection is performed by a set of sanity tests that are repeated approximately every 10 seconds. These tests are designed to fail when the control complex is functioning improperly.

A software check routine verifies the ability of the processors to access the RSS periphery. Peripheral faults are also detected by a number of tests each time the peripheral equipment is used. These include tests for network continuity, tests for proper operation of the logic on the line interface boards, and, on terminating calls, tests of the universal service circuit output voltage levels and logic operation. On terminating calls, proper operation of the high voltage metallic access circuitry is verified, and the ringing current on the customer loop is measured. The failure of any of these tests results in a report to the error analysis programs. The operation of these programs is discussed in Section 3.4.

A number of tests of RSS remote terminal hardware are scheduled on a routine basis. These include a daily diagnosis of the off-line data link (discussed further in Section IV), weekly scheduled diagnostics of the voice channels between the host and the remote terminal (discussed in Section V), and periodical automatic line insulation tests (see Section VI). Remote terminal hardware diagnostics are automatically run once a day. The off-line microprocessor controller is diagnosed and switched on-line daily, and all of the peripheral hardware is diagnosed at least once every four days.

Hardware problems in the remote terminal permanent memory are detected by a memory audit that periodically examines every memory location. Data parity is checked, and the on-line and off-line data are compared. If a fault is detected, the appropriate controller is removed from service.

3.3 Fault recovery and reconfiguration

If a fault is detected in the active microprocessor controller in the RSS remote terminal, an attempt is made to automatically recover and, if necessary, to switch sides to reach a working hardware configuration. The control of this recovery action normally lies with the active processor. If it becomes too insane to initiate a switch, the sanity timer for the off-line processor will time out and initiate a recovery.[3]

Several levels of initialization are available, ranging in severity from a simple restart of the base level program cycle to a complete initialization of all data bases and a reset of all peripheral hardware. Repeated occurrences of faults will cause an automatic escalation of the initialization level up to the point where transient telephone calls are cleared. A complete initialization (which includes clearing stable calls) can normally only be requested manually.

The different initialization levels and their associated recovery actions are:

1. A Level 1 recovery requests any active background task to abort. Program execution is restarted at the beginning of the base level cycle. This level is normally the first action taken if a processor or memory fault is detected.

2. In Level 2, a minimal amount of call store is cleared, any active background task is aborted, and the processors are switched, if possible. An out-of-service processor can be switched on-line unless a switch has been inhibited by TTY request.

3. In Level 3, a minimal amount of call store is cleared, and a set of emergency audits are run. On their completion, the program cycle is restarted.

4. Initialization Level 4 clears all telephone calls in the transient

state and idles their associated peripheral hardware. Any call store memory that is not up to date is copied from the off-line side. The translation checksum is examined, and if it is not correct, a complete translation update from the host is performed. Level 4 is normally the highest automatic initialization level allowed.

5. In Level 5, all call store is cleared, except for a special "never cleared" area containing the data link buffers, traffic counts, and post-mortem information concerning the ongoing recovery action. The periphery is completely idled, and all in-progress telephone calls are lost. The translation checksum is examined, and if found to be incorrect, a complete translation update from the host is performed.

6. All clearing actions of Level 5 are executed in Level 6. The translations are unconditionally updated from the host, and the on-line/off-line roles of the processors are switched, if possible. This initialization level is entered only via a TTY request or a manual request from the reset button on the RSS frame.

When an RSS remote terminal initialization takes place, the maintenance forces at the host and at the SCC are notified via an alarmed TTY output message. This message indicates which microprocessor controller was on-line both before and after the initialization, the level of initialization, and the program address where the recovery occurred. The reason for the recovery action is also given. The reasons include various parity check errors, a sanity timer timeout, an attempt to write into write-protected memory, a request to execute an invalid program instruction, and an attempt to access an invalid peripheral address.

After a few minutes, when it is clear that further recovery action is not going to occur, a "post mortem" message is printed, giving detailed information relative to the recovery. Information is printed about both the first initialization in the current series, and from the most recent initialization. Normally, the initialization process is carried to completion by the RSS remote terminal programs, and no craft intervention is required. If the controller gets in a state where it is continually initializing itself, a manually requested Level 6 initialization may become necessary.

When the periodically executed processor sanity tests fail, the recovery mechanism differs from the multilevel initialization process just described. The failure of one of these tests normally indicates a hardware fault in the on-line microprocessor controller, and the recovery consists of an attempt to switch to the standby side. If the off-line controller is marked out of service, it may or may not be switched on-line, depending on the severity of the fault and its potential effect on the system. If a processor switch is not completed, the original controller remains active, with the processor marked faulty. In this state, the discovery of new processor faults will not be reported via TTY output, unless they are severe enough to cause a processor switch.

Memory faults discovered by the memory audits also result in a processor switch, if possible. A switch will not take place if the off-line controller is out of service.

As with sanity test failures, peripheral faults are also handled outside the multilevel initialization procedure, since they normally result from peripheral hardware problems. If a fault is detected while attempting to execute a peripheral order, one of three problems is assumed to exist. The fanout board involved could be faulty, the particular peripheral hardware being accessed could be faulty, or a transient hardware failure could have occurred in either the fanout board or the periphery.

When a peripheral order fails, it is first retried without altering the system state. If the retry succeeds, a transient hardware fault is assumed and a transient error counter for the on-line side is incremented. If the number of transient errors exceeds a threshold, the system will switch sides, if possible.

If the peripheral order retry fails, the system attempts to switch sides. The peripheral order is then retried from the new controller complex. If it succeeds, the original fanout board is assumed faulty. The off-line controller is then removed from service, with that particular fanout marked bad. If the peripheral order fails on the new side, a peripheral hardware failure is indicated. The now off-line microprocessor controller is left in the standby state, and the faulty portion of the periphery is marked bad so further access problems with the suspected hardware will not result in a processor switch or TTY output.

When two successive peripheral orders fail and a processor controller switch is not allowed, it is not possible for the system to differentiate between fanout and peripheral hardware faults. In this case, the on-line fanout board involved is marked faulty.

3.4 Error analysis and peripheral circuit disposition

When a fault is detected in the peripheral hardware, either through the mechanism described in the previous section or the various per-call tests, the hardware involved is reported to the RSS error analysis programs located in the remote terminal. The circuits analyzed by these programs include network A-links and junctors, Receiver Off-Hook (ROH) tone circuits, metallic access buses, and Universal Service Circuits (USCs). Channels and lines receive modified treatment, as described in Sections V and VI, respectively.

The error analysis programs make use of two techniques for analyzing and pinpointing faulty hardware—peer group analysis and quick check. A peer group analysis program compares the error rate of a particular member of a group of circuits to the error rate of the entire group. The circuits are compared on the basis of a particular error type, and any circuitry that shows a high rate of failure relative to the other members of the group is reported to the circuit disposition programs for possible removal from service.

The second technique used for peripheral hardware error analysis is a success/fail comparison called quick check. The quick check program looks for three successive failures from the same circuit. When a particular circuit fails three times in a row, an attempt is made to automatically remove it from service.

When a per-call failure is detected by either the peer analysis or quick check technique, a TTY output message is generated. This message details the particular circuit which failed and the failure type.

The circuit disposition program, located primarily in the host, is responsible for acting on requests to remove or restore peripheral circuits to and from service. Removal requests can be automatically generated by the error analysis programs as just outlined, or they can be the result of a manual request from the RSS maintenance panel or from the host maintenance TTY. Restoral to service requests can only be made manually.

When a request is received to remove a circuit from service, it may be removed immediately, the request may be denied, or, if the circuit is busy, it may be camped on and removed when it becomes idle. A removal request can be denied if a predefined out-of-service limit has been reached. In this case, a manual request can be made from the TTY to override this limit and unconditionally remove the circuit from service. The camp-on mechanism will not monitor the circuit indefinitely. After a period of time, the program will time out, and it will be necessary to re-request the circuit removal.

In all cases, the action taken by the circuit disposition programs is reported to the craft by host maintenance TTY output messages. The success or failure of a removal or restoral request is indicated. If a removal request failed, the reason for failure is specified. When an automatic request from error analysis results in the removal of a circuit from service, the error type or types is specified, and the reason for removal, either peer analysis or quick check, is given.

The circuit disposition program also formats and outputs information about the status of RSS remote terminal peripheral hardware. Out-of-service lists for network A-links and junctors, metallic access buses, and USCs are output by this program. The current state of any individual line can also be determined and printed via the circuit disposition program.

3.5 RSS remote terminal diagnostics and fault repair

In the RSS remote terminal the circuit pack is generally the smallest replaceable entity. For this reason, the diagnostics for the remote terminal hardware are designed on a per-circuit-pack basis. Each diagnostic tests a complete circuit pack, which often contains many individual circuits. For example, the line interface board contains line access circuitry for eight lines, the first stage of the switching network for these lines, and the metallic interface network between the customer loop and the USC which supplies high voltage control, such as ringing and coin control.

The primary requirement for the design of these diagnostics is testing completeness rather than fault resolution. Thus, the diagnostics are designed to determine which portion of the system (to the circuit pack level) contains a fault, not which specific circuit is faulty. In most cases, a failing diagnostic pinpoints the faulty board, or at most a few suspected faulty boards.

The TTY output message associated with a diagnostic failure will usually include enough information to either determine the faulty board or suggest further diagnostics that should be run. If a more detailed analysis of the failure is necessary, the output message will contain raw data that, when used in conjunction with the diagnostic program listings, will enable this examination to be done.

All diagnostics can be requested manually from the maintenance TTY. The microprocessor controller diagnostics are automatically run daily, and all peripheral hardware is routinely diagnosed on a 4-day cycle. Except for the channel and data link diagnostics, discussed later in this paper, RSS remote terminal diagnostics are not run automatically as the result of a detected failure. Also, a failing diagnostic will not remove circuitry from service because of the lack of failure resolution to the circuit level.

The RSS processor, memory, and fanout diagnostics run on the off-line controller only, but diagnostics for the peripheral circuitry will run whether the equipment is in service or out-of-service. If a diagnostic is run on a circuit pack containing traffic busy circuitry, the tests for that portion of the board are skipped. Thus, there are three possible results for a peripheral circuit-pack diagnostic. It can pass all tests, it can fail some tests, or it can pass every test run, with some tests skipped. Each of these cases is detailed with a TTY output message, with an indication of the number of skipped orders when all tests were not run.

The diagnostics can be run in one of three modes. In the normal mode, the diagnostic is run only to the point where a failure is detected. At that point, the diagnostic is terminated and the failure is reported. The daily routine diagnostics are run in this mode. An unconditional mode exists for cases where the fault resolution of the normal mode is inadequate. In this mode, every diagnostic test is run and every failure is reported. The third diagnostic mode is the repeat mode. The diagnostic, or a portion of the diagnostic, is repeated continually until manually aborted. In this mode, the result of the first run through the diagnostic, either pass or fail, is reported. On subsequent runs, only changes in diagnostic results are reported. This mode is useful when an intermittent failure exists, or when it becomes necessary to use external test equipment to monitor the operation of a portion of the RSS circuitry.

In addition to using the diagnostics for fault detection, they are also useful for fault isolation. In some cases, a diagnostic failure implicates only one circuit pack, but in other cases, the failing diagnostic will implicate other boards. By diagnosing these circuit packs, the particular board that is faulty can usually be identified. In some cases, it may be necessary to use the information in the diagnostic program listings for a description of the test situation and a detailed analysis, using the raw data contained in the diagnostic failure message.

When a fault has been isolated to one or a few suspected faulty boards, a craft person must be dispatched to repair the problem. The RSS maintenance panel is the normal field interface between the system and the craft. Identification numbers of the suspected faulty boards must be preloaded in the maintenance panel repair buffer from the host maintenance TTY. In the field, the craft person can then use the panel to sequentially examine each circuit pack. First, the board is removed from service and diagnosed. If it fails, it is replaced and rediagnosed for repair verification. If it passes, the pack is restored to service. If the diagnostic continues to fail, the fault probably lies on one of the other suspected faulty packs. In this case, the original board can be replaced, and the second suspected circuit pack investigated. This procedure is repeated until every circuit pack stored in the maintenance panel repair buffer passes its diagnostic.

IV. PERIPHERAL UNIT CONTROLLER/DATA LINK MAINTENANCE

4.1 Peripheral hardware

A Peripheral Unit Controller (PUC) is a microprocessor-based, intelligent No. 1/1A ESS peripheral. It communicates with the No. 1/1A ESS through the peripheral unit bus, the scanner answer bus, a central pulse distributor, and a master scanner (see Fig. 3).

Since the PUC is a general-purpose controller used in No. 1/1A ESS for such features as Digital Carrier Trunk, and Electronic Tandem Switching, as well as the Remote Switching System, PUC maintenance considerations will not be specifically discussed. The RSS requires a PUC data link (PUC/DL); that is, a PUC with additional hardware and an additional firmware package that allows it to provide an interface with up to 16 data links. Because of the dependence of RSS on its data links, the PUC/DL maintenance considerations will be discussed. Other aspects of RSS data link operation are covered in Refs. 3, 5, and 6.

Since an RSS can serve up to 2000 customers, its communication link to the host is duplicated for reliability. The two links are operated in an active-standby configuration at a 2400-b/s data rate using the CCITT

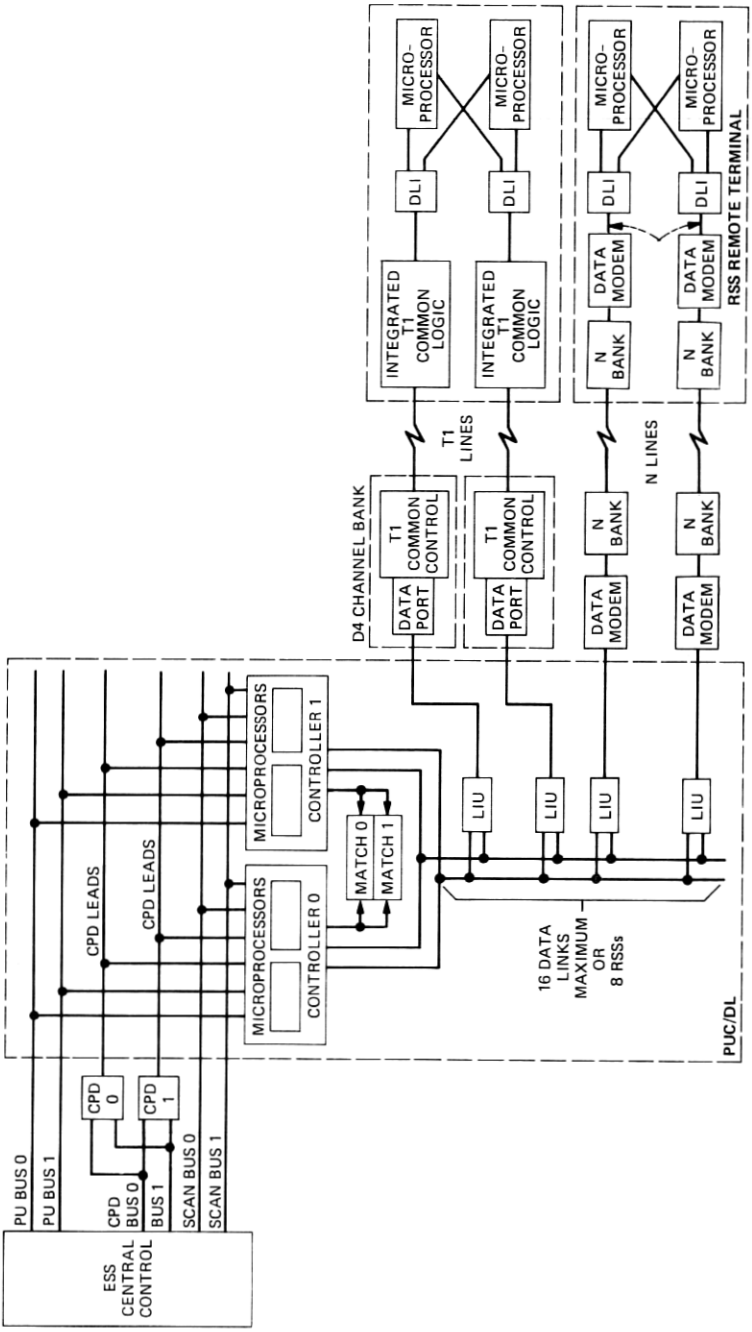

Fig. 3—Remote switching system data links.

X.25 link-level protocol. A PUC/DL frame can support up to eight RSSs. Each link connects the host to the Remote Terminal via either T1 or N-carrier. If T1 carrier is used, the link consists of the following:

(*i*) Line Interface Unit (LIU) in the PUC.
(*ii*) Special D4 channel bank data port plug-in.
(*iii*) Standard interface between the LIU and the data port.
(*iv*) T1 voice channel.
(*v*) Data Link Interface (DLI) board in the RT.

If N-carrier is used the link consists of the following:

(*i*) Line Interface Unit in the PUC.
(*ii*) Standard 2400-baud, full-duplex data set.
(*iii*) Standard interface between the LIU and the data set.
(*iv*) N-carrier voice channel.
(*v*) Matching data set at the RT.
(*vi*) Data Link Interface board.
(*vii*) Standard interface between the modem and the DLI.

It is the task of PUC/DL maintenance to detect link-affecting problems in any of these components, reconfigure appropriately, and to provide diagnostic resolution sufficient to sectionalize the problem.

4.2 Data link trouble detection and recovery

Trouble in the data link can be detected by the host[3] or the remote terminal[3,6] when a carrier failure, a protocol response failure, or an excessive error rate is encountered. When the remote terminal detects a problem before the host, it simply stops responding to the received data, causing the host to detect a protocol response failure. In any case, the host attempts to establish a working configuration using the standby link. The faulty link is then diagnosed and reported to the craft person by a host TTY message. If both links to the RSS are faulty, the remote terminal will go into a stand-alone mode. Host recovery programs continue to periodically diagnose the links and will automatically bring the data links back on-line when the trouble clears.

Faults requiring manual intervention require additional software tools. The TTY messages are provided to request the data link status, restore a data link to service, remove an active link from service, and diagnose a data link. In rare cases, TTY messages can be used to force a link active or detain a link out-of-service; thus, overriding the system checks and forcing the system to use or not use a specified link.

4.3 Data link diagnostic

A data link diagnostic can be requested manually or automatically. It is composed of seven phases which test the various sections of the data link by looping signals at different interfaces, applying enough load to stress the system, and observing the results (see Fig. 4). The

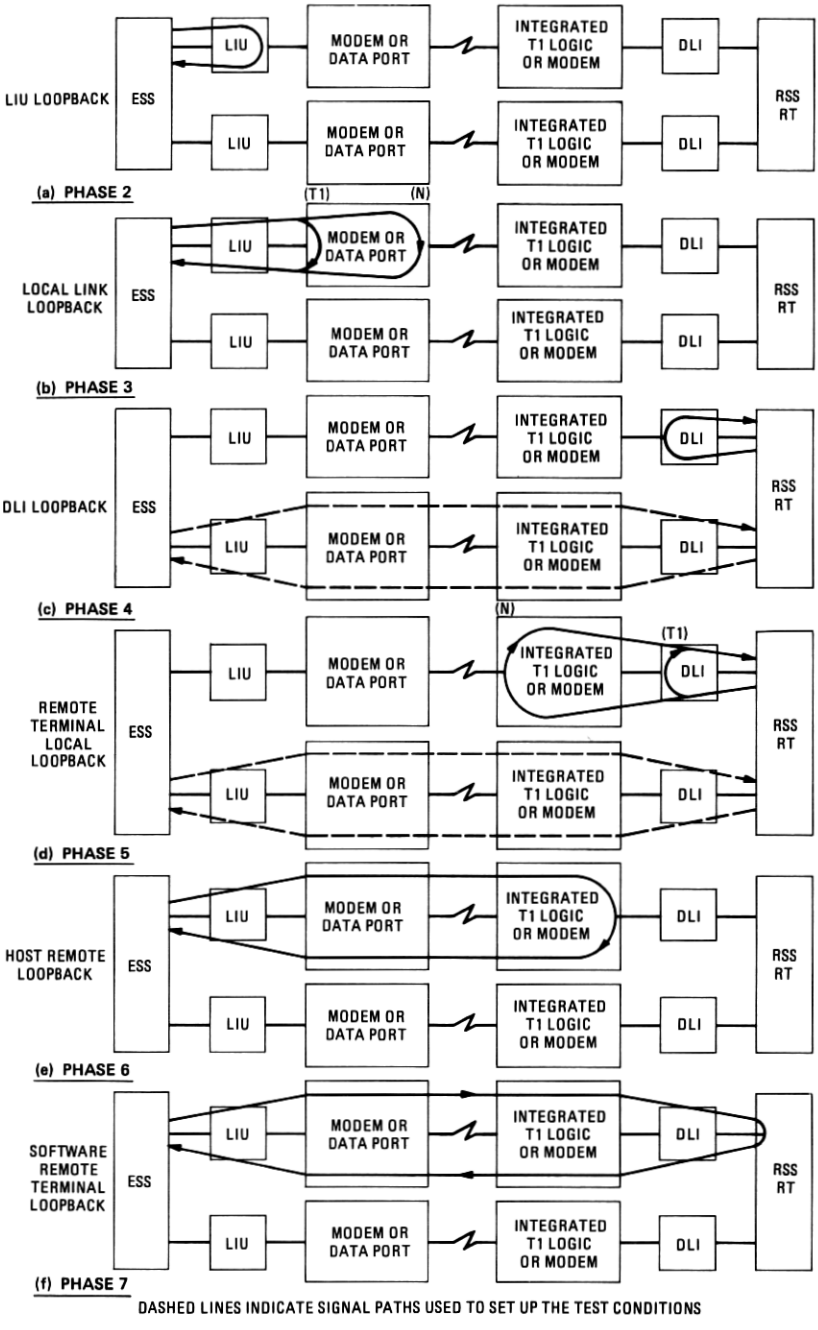

Fig. 4—Data link loop tests.

diagnostic can print in the normal or raw data modes. It can run all phases, begin and end at a specific phase, or loop on a particular phase. Phase 1 tests host access to the LIU. Phase 2 loops the host signal at the LIU. Phase 3 loops the host signal at the host modem or data port. Phases 4 and 5 consist of tests run at the RT. Phase 4 verifies proper operation of the DLI board and performs a local loopback from the remote terminal controller to the DLI. Phase 5 remotely loops the signal at the remote terminal T1 interface or modem, depending on the facility. Phase 6 is a hardware end-to-end loop consisting of 1000 frames of data; fewer than 10 errors is considered as an All-Tests-Pass (ATP), fewer than 100 errors is characterized as a degraded link, and more than 100 errors is considered a failure. Phase 7 attempts end-to-end communication by sending a message to the remote terminal controller, and waiting for a response. This phase fails if a response is not obtained within a reasonable period of time.

V. REMOTE SWITCHING SYSTEM CHANNEL MAINTENANCE

5.1 Channel maintenance overview

A channel is a Special Service Circuit, similar to a voice trunk, connecting the RT to a line appearance on the host No. 1/1A ESS. A channel looks like a line to call processing programs, enabling most No. 1/1A ESS line features to be readily available to any RSS customer when connected to a channel. In the areas of maintenance and traffic usage, however, channels more closely resemble trunks. With a traffic usage of up to 25 CCS/channel, a faulty channel can potentially affect many customers; therefore, weekly diagnostics, per-call-failure tests, error analysis, and manual access arrangements are required to maintain them adequately.

At least a part of every normal RSS call involves a link from the RSS to the ESS consisting of an RSS line circuit, an RSS network connection, and an RSS channel. Since this link did not exist when the Direct Distance Dialing (DDD) transmission allocation plan was developed, it was not given any loss allocation. This link must then have a nominal 0-db loss characteristic. This requirement led to the transmission plan detailed in Ref. 2. This plan requires tight control of the channel transmission characteristics. Automated monitoring of RSS channel transmission performance is provided by the Centralized Automatic Reporting On Trunks (CAROT) system.

Since the RSS is simply a remote extension of the host ESS, the maintenance of both ends of the channel becomes the natural responsibility of the host. This allows the automatic testing of channels to be superior to that provided for most trunks.

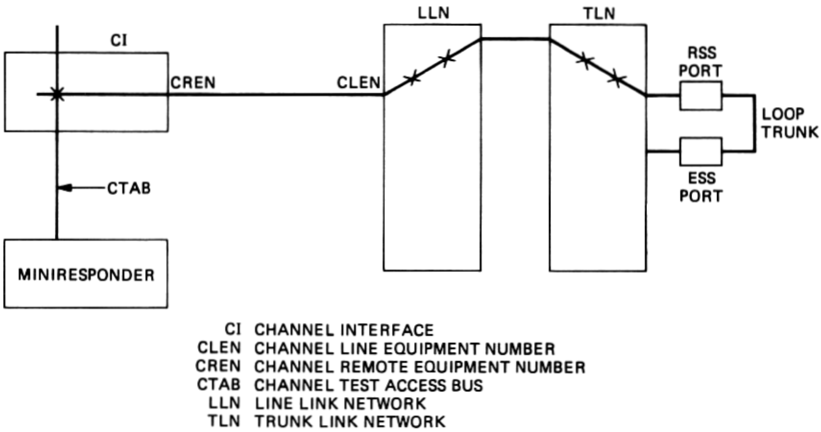

Fig. 5—Remote switching system channel maintenance terminology.

5.2 Design approach

Because of the similarity between channels and trunks, the possibility of using the existing No. 1/1A ESS trunk maintenance programs was appealing. Connecting the host line appearance of an RSS channel to one port of a loop-around trunk allows the unconnected port (and, therefore, the channel) to be treated like a trunk (see Fig. 5). Two criteria were considered vital in the implementation of the design. The first: minimize the differences between RSS channel maintenance and No. 1/1A ESS trunk maintenance so that it is unnecessary for the craft person to learn new and radically different procedures. The second: minimize software changes by making the RSS channel look as much like a trunk as possible.

5.3 Channel maintenance functions

Channel maintenance functions can be divided into two major categories: automatically initiated testing and manually initiated testing.

5.3.1 Automatic maintenance functions

The following six automatic maintenance functions are provided for channels:

(*i*) Per-call failure processing
(*ii*) Audit failure processing
(*iii*) Automatic progression testing
(*iv*) Error analysis
(*v*) Transmission testing
(*vi*) Software state control.

Per-call failure processing refers to the action taken by the channel maintenance programs when call processing suspects a channel fault. Even though a faulty channel can potentially affect many customers, real-time considerations prevent all channels from being fully diagnosed more than once a week. It, therefore, becomes the responsibility of call processing to inform maintenance when a faulty channel is suspected. Examples of per-call tests include testing if off-hook supervision can be successfully transferred over a channel from an RSS line, and a host network continuity test from the channel to a trunk circuit. When such tests fail, call processing programs attempt to place the channel on the Channel Maintenance List (CML). The CML is a queue of channels that are awaiting a system diagnostic. If the diagnostic fails, the channel is retested after a 5-second delay. If the channel fails both diagnostics, it is removed from service (i.e., locked out) as long as the Automatic Maintenance Limit (AML) has not been exceeded. In any case, two messages are printed on all failures to inform the craft person of both the failure and the disposition of the channel. If either test passes, RT error analysis is informed and the channel is returned to the traffic-idle, maintenance in-service state.

Audit failure processing takes place when system audits find a channel in an invalid state. The channel is placed on the Channel Maintenance List for Audits (CMLA). The CMLA is a queue of channels that are awaiting a blind-idle of their hardware. After the channel is hardware idled, the control program attempts to place the channel on the CML.

Automatic progression testing is the primary vehicle used to allow channel maintenance to detect and remove faulty channels before they are used by call processing, and cause calls to be lost. Beginning at 1:00 a.m. every Monday morning, channel automatic progression testing begins at the first idle channel in the first-assigned RSS. The diagnostic, software state control, and printing are exactly as described for the CML. When all channels in the RSS have been tested, testing continues with the first idle channel in the next RSS. Testing continues until all idle channels in all assigned RSSs are tested, or until 6:00 a.m. If testing has not been completed at that point, it is resumed each morning thereafter between 1:00 a.m. and 6:00 a.m. until all idle channels have been tested.

Error analysis for channels is carried out in much the same manner as described in Section 3.4 for the RT. All channel error analysis counts are kept in the RT. A data link message is sent to the RT every time a channel passes a CML diagnostic sequence in the host. In addition, the RT records every time a channel is involved in a half-path continuity, a half-path cross, or a CI board failure. If an individual channel fails in three consecutive usages (quick check failure) or performs poorly in relation to other channels (peer analysis failure), a data link message is sent to the host resulting in the channel being removed from service if the AML is not exceeded.

Automatic routine transmission testing is provided using a CAROT system. Software modifications were necessary to allow:

(*i*) A line equipment number to be substituted for a trunk network number as the circuit identifier for CAROT testing.

(*ii*) A channel modifier digit specifying the state of the balance network and 2-dB pad instead of a trunk modifier digit specifying the trunk state.

The CAROT system interfaces with a Remote Office Test Line (ROTL) in the host machine and a miniresponder[4] in the RT. (The RT miniresponder is a miniaturized single-board version of the 52A responder used in the ROTL.) All appropriate CAROT capabilities that are available on No. 1/1A ESS trunks have been provided for RSS channels. The Processor Controlled Interrogator (PCI) allows the use of the ROTL equipment from the local office or an SCC without the aid of CAROT. The PCI is used primarily to verify that problems reported by CAROT have been corrected.

Software state control refers to the automatic administration of RSS channel maintenance states. Although one of these states is usually related to a hardware state, it is strictly a software construct. This software state, which may be permanent or transitory, is encoded in per-channel memory. The following maintenance states have been provided for RSS channels:

(*i*) ACTIVE—Available for use by both call processing and maintenance.

(*ii*) HIGH AND WET—Host side of the channel is off-hook and not involved in a connection. A channel in the high and wet state is unavailable to call processing. Channels are automatically removed from this state when they go on-hook. The most likely reason for the channel being in the high and wet state is a carrier failure.

(*iii*) CHANNEL MAINTENANCE LIST—Queued for a deferred channel diagnostic and temporarily unavailable to call processing.

(*iv*) LOCKED OUT—Out-of-service and permanently unavailable to call processing without manual intervention. Channels can be locked out by error analysis, automatic progression, or CML processing and manual requests from the TTY or one of the trunk test panels.

(*v*) CHANNEL MAINTENANCE LIST FOR AUDITS—Queue of channels found in an invalid state by the system audits and waiting to be blind-idled. Temporarily unavailable to call processing.

5.3.2 Manual channel maintenance functions

Manual channel maintenance functions can be requested from the

ESS maintenance TTYS, as well as from the ESS trunk test panels. Remote control from the SCC is also possible.

Single-channel diagnostics can be executed in one of two modes: normal and raw. A normal mode diagnostic indicates the general area of the fault. A raw diagnostic printout, with the help of the RSS channel trouble location manual, can be used to localize specific channel faults.

A single-channel transmission test can be requested using the RT miniresponder as a 102-type Far-End Test Line (FETL) for a 1-way (RSS to ESS) loss measurement, a 100-type FETL for a 1-way (RSS to ESS) loss and noise measurement, or a 105-type FETL for 2-way loss, noise, noise with tone, and gainslope measurements. During any of these tests, the switchable transmission components at the remote terminal end of the channel (described in Ref. 7) can be placed in most of their allowed states.

In addition to the single-channel maintenance functions, three types of multiple channel test requests are provided: group tests, repeat tests, and diagnosis of all out-of-service channels. These functions are provided to increase the efficiency of a craft person in localizing a transient fault or a single fault which affects multiple channels. Group tests allow the craft person to request a diagnostic or transmission test on all channels associated with the specified RSS. A repeat test allows the craft person to diagnose a channel 32 times in a row and print only the failures. A diagnosis of all out-of-service channels allows the craft person to quickly verify that these channels are still faulty.

In addition to the automatic software state control discussed earlier, channels can be manually locked out or made active. Manual state changes are not subject to the AML. If manual actions cause this limit to be exceeded, the craft person will be so informed.

Access to channels from manual test positions is provided to permit initial channel alignment and testing, and manual testing when system diagnostics provide insufficient trouble localization. The following functions are provided:

(*i*) DC access from the panel to the channel facility.

(*ii*) DC voltage measurements.

(*iii*) Connection from the panel to the channel to a 102-type FETL.

(*iv*) Monitoring or measuring of ac tones.

(*v*) Connection from the panel to the channel to a 100-type FETL.

(*iv*) Noise measurements.

(*vii*) The ability to send an ac tone from the panel and detect it at the RT.

(*viii*) The ability to control the 2-dB pad, the state of the hybrid balance network, and the off-hook/on-hook state of a channel connected to the panel.

The following channel list functions are provided:

(*i*) A list of all out-of-service channels.

(*ii*) A list of all high and wet channels.

(*iii*) A list of all idle channels in a specified RSS.

(*iv*) A list of all RSSs with the number of out-of-service channels exceeding the AML.

(*v*) A list of all channels in a specified RSS and their overriding maintenance state.

The ability to request the traffic and maintenance state of a single channel is also provided.

5.4 Channel diagnostic tests description

The approach taken by the channel diagnostic is to emulate all operations performed on a channel during a call, verifying in each instance that the channel performs satisfactorily. The hardware components that make up an RSS channel are described in Ref. 4.

The following nine channel tests are performed:

(*i*) Power Cross—A check to detect commercial power crosses at a channel's host line appearance.

(*ii*) False Cross and Ground—A check for path crosses or grounds in the portion of the ESS network involving a channel.

(*iii*) Supervision—A check that the on-hook and off-hook state of a channel can be passed from the RT to the host.

(*iv*) Restore Verify—A check that the line ferrod can be connected and disconnected via the line cut-off relay on the host line link network.

(*v*) Low Line Resistance—A check of the resistance across tip and ring at the host to detect a condition where this resistance is so low that an on-hook channel would erroneously trip ringing and cause false billing.

(*vi*) Showering Line—A check of the resistance across tip and ring at the host to detect a condition where the on-hook and off-hook status of a channel varies depending on whether the channel is supervised at the line ferrod or at a service circuit.

(*vii*) Dial Pulse—A check of the ability of a channel to successfully transmit a dial pulse zero (10 pulses) to a host dial pulse receiver.

(*viii*) AC Far-To-Near—A check of the ability of a channel to successfully transmit an ac tone from the RT to the host.

(*ix*) AC Near-To-Far—A check of the ability of a channel to successfully transmit an ac tone from the host to the RT.

It may be noted that this diagnostic does not provide any test of that portion of the RT network physically located on the CI board. This network testing function is performed by the RSS-controlled CI board diagnostic. This has the disadvantage that complete testing of a newly replaced CI board requires that one CI board and four individual channel diagnostics be requested. The overriding advantage of this approach is that it permits a host controlled end-to-end functional test of the channel without creating an unacceptable resource contention problem with the RSS.

VI. REMOTE SWITCHING SYSTEM LINE MAINTENANCE

6.1 *Line maintenance overview*

The overall approach to RSS line maintenance is to extend from the host ESS all existing line maintenance features and to implement within the RT any maintenance feature uniquely required for RSS lines. Standard line maintenance features are normally divided, both functionally and administratively, into two types:

(*i*) Testing of the metallic customer loop and associated station set.

(*ii*) Testing of the central office per-line circuitry.

While RSS requires no changes to a properly designed outside plant,[2] the RSS per-line circuitry[4] is considerably more complex than the per-line circuitry in the ESS.[8] Both systems have line circuits that provide the basic functions of switching network protection, line attending, and voice network access. However, the RSS's nonmetallic voice-switching network requires that its line circuits provide dial pulse reconstruction, talking battery, and test access, all of which are provided by service circuits in the host ESS. The RSS line circuit must also provide metallic access to its shared service circuits for such functions as ringing and coin control. In addition, space and power considerations require a constant current loop-feed design, which in turn requires special line circuit provisions for anticorrosion biasing, detection of ground start originations, and switchable line feed states.

Therefore, traditional outside plant functions like Automatic Line Insulation Tests (ALIT) and Local Test Desk (LTD) have been implemented by providing new RT hardware[4] with the necessary dc access, and generalizing the host programs to control the new hardware via the data link, whereas new per-line circuit functions, such as diagnostics and error analysis, have been implemented in the RT.

6.2 *Line maintenance functions*

The maintenance functions provided for RSS loops include:

(*i*) Per-call loop tests, performed automatically by the system.

(*ii*) Automatic line insulation tests, normally performed on a routine, scheduled basis.

(*iii*) Manual testing from the local test desk, normally performed only when trouble is suspected.

(*iv*) Station ringer and *TOUCH-TONE** dialing tests, normally initiated from the customer premises when a station set is installed.

* Registered service mark of AT&T.

Maintenance functions provided for RSS line circuits include:

(*i*) Per-call tests of various line circuit functions.

(*ii*) Routine exercises, which provide, on a scheduled basis, a complete diagnosis of the line circuit.

Each of these functions is described in more detail in the following paragraphs.

6.2.1 Loop maintenance functions

The number of per-call loop tests that can be made are restricted by considerations of call setup time and processor capacity. As a result, these tests are limited to those which establish that the line can safely be placed in a connection, and that the subsequent call disposition can be monitored. These tests are as follows:

(*i*) Power Cross Test—Before a metallic connection is set up to apply ringing, a test is made for voltages on the loop which may damage the ringing circuit.

(*ii*) Ringing Continuity Test—Shortly after ringing voltage is applied to a line, a current measurement is made to establish that a ringer is actually connected to the loop.

(*iii*) Showering Line Test—The RSS line circuit is more sensitive to dc loop current in the idle state than in the talking state. This can cause some leaky lines to "shower" (that is, continually appear to originate and then immediately hang up when put in a dialing connection). To prevent this, the line is scanned with the line circuit in both the idle and the talking states when an origination is detected.

When any of these three tests fail, an immediate report is made on a host TTY, identifying the line and the nature of the failure. This immediate reporting, which differs from the usual RSS error-analysis approach, is necessitated by the immediate customer service impact of these failures. Also, in the showering line case, the system must take defensive action (placing the line high and wet) to avoid being flooded with origination reports.

Permanent Signal and Partial Dial (PSPD) timing is another per-call loop "test," but one requiring much different treatment. Although faulty customer loops sometimes evidence themselves this way, PSPD failures are more often induced by customer actions. A PSPD timeout occurs when a line originates but does not dial at all (permanent signal) or does not dial successive digits (partial dial) within 20 seconds. As a result, the line is connected successively to an appropriate recorded announcement, receiver-off-hook tone, and finally an operator. If none of these actions results in the line going on-hook, the line is placed high and wet. After an additional timing interval specified by the Bell operating company, the line is reported on a host TTY. A summary list of all high and wet lines (both host ESS and RSS) is available by manual TTY request.

The Automatic Line Insulation Test (ALIT) provides automatic, routine surveillance of customer loops for insulation breaks in wire, cable sheath, and cable terminals. The RSS lines are tested under the control of the host ESS, using measuring circuitry in the RT. On a schedule established by the Bell operating company, the host ALIT control program sequences through all testable host and RSS lines in order of telephone number. For each RSS line, a data link message is sent, identifying the line and requesting an ALIT test. The RT performs the test, returning the results to the host. Failing results are reported on the appropriate host TTY.

There is one respect in which ALIT failures on RSS lines require special interpretation and screening. The anticorrosion biasing arrangement may be ineffective on lines with localized, very low resistance leakage paths to ground. The ALIT failure reports in this category provide the only automatic indication of an RSS line subject to corrosion.

In addition to performing routine testing, the ALIT circuit in the RSS may be used in the "demand" mode, via host TTY request. These tests may select different test types or ranges from those used for routine testing. Either a single line or all testable idle lines in a particular RSS may be tested via a single TTY request.

The RSS lines are accessible for testing from standard Local Test Desk (LTD) No. 14, or No. 16. Access arrangements depend on the distance from the test desk, through the host ESS, to the RSS. When this distance is within metallic testing range, a metallic access arrangement is provided. In this case, mechanized loop testing (MLT) access is also supported. Otherwise, access is via a modified version of the LTD Remote Test System (LTDRTS). From a user's point of view, both arrangements duplicate the majority of existing LTD functions. Certain functions (e.g., operation of the no test vertical key) do not apply because the RSS testing configuration is different. Other functions, like verifying that a ground start line can originate, cannot be performed because of design limitations. (The required ground start applique is automatically placed in the bypass state and the line is "tested" as a loop-start line.) When an LTDRTS is required, additional differences occur. To use a standard system at the LTD, nonstandard arrangements are provided in the host and the RT. The host must be able to detect a limited set of control oriented test requests (e.g., origination, disconnect, line ferrod), while test configuration requests are detected and acted upon at the remote terminal. This new hardware requires the LTD to use a different test trunk or test trunk group to obtain access to RSS lines than that used to access host ESS lines. It also requires a connection to an RSS line before RTS test battery voltages can be checked. (Existing systems require only a connection to the CDO.) A complete description of the RSS line test hardware is included in Ref. 4.

All customer trouble reports are received at the Repair Service Bureau (RSB) which has primary responsibility for maintaining satisfactory service to customers. The RSB performs tests to determine if the trouble is internal or external to the RSS. Since the RSS line circuitry is more complex than the per-line circuitry of most existing switching systems, and because the RSS line circuit cannot readily be isolated from the customer loop, the internal-external decision is more complicated for RSS lines. In some cases, RSS line and ground start applique diagnostics will be needed to help localize the problem. Therefore, RSS line testing requires more coordination between the RSB and the SCC.

When a telephone set is installed, or repaired, the Station Ringer and *TOUCH-TONE* dialing test equipment can be accessed via a telephone company assigned directory number to perform any of the following tests:

(*i*) *TOUCH-TONE* Dialing Test—A verification that a predetermined digit sequence can be correctly dialed from a 10- or 12-button telephone set.

(*ii*) Automatic *TOUCH-TONE* Dialing Test—A verification that a predetermined digit sequence is dialed at the correct rate from a 12-button automatic dialer set.

(*iii*) Party Ground Identification Test—An off-hook resistance measurement from simplex tip and ring-to-ground.

(*iv*) Leakage Test—An on-hook resistance measurement from simplex tip and ring-to-ground.

(*v*) Ringing Test—A test of the ability to ring the customer phone.

For Station Ringer and *TOUCH-TONE* dialing testing of RSS lines, no special circuits are required at the RT. An RSS line accesses the host ESS Station Ringer and *TOUCH-TONE* dialing test circuit via a channel, and the host circuit is used for the *TOUCH-TONE* dialing tests and for all tone signaling to the line. Party ground identification and leakage tests are performed by the RSS upon host data link request. The results are returned to the host which, in turn, conditions the Station Ringer and *TOUCH-TONE* dialing test circuit to signal the appropriate test result tone. The ringing test is performed by the RSS in a similar manner.

6.2.2 Line circuit maintenance functions

Generally, each time the RSS firmware accesses a line circuit to perform a function, a test is made to ensure that the action is successful. This approach is supported by comprehensive test access and by the fact that the tests can be made quickly (i.e., with an acceptable penalty to call setup time and processor capacity). Among the per-call tests performed on a line circuit are the ability of the circuit to

(*i*) Place the loop feed in the talking (high power) state.
(*ii*) Provide a path for network holding current.
(*iii*) Operate and release relays which provide access to the metallic network.
(*iv*) Place the loop feed in the idle (low power) state.
(*v*) Open the path for network holding current.

Failure of any of these tests is reported on the host maintenance TTY and also analyzed by standard RSS error analysis. If the failures exceed the error analysis threshold a high priority trouble message is printed on the host TTY. Some of these failures are subject to additional processing by the RSS firmware. For example, loss of power to a line circuit causes the line to appear to originate. Therefore, when the attempt to place a line in the talking state fails after an origination is detected, further tests are made and, if appropriate, the failure is reported at the host ESS specifically as a "no power" condition.

All assigned RSS line circuits are diagnosed as part of the RSS routine exercise program. Both the scheduling control and the diagnostic logic reside entirely within the remote terminal. In addition, any single RSS diagnostic may be requested via a TTY at the host ESS. When manually requested, the diagnostic may be performed in any of the three modes described in Section 3.5.

The remote terminal diagnostics are partitioned to permit complete testing of a single plug-in circuit board with a single request. For most customer lines, this partitioning allows all diagnosable circuitry associated with a single line to be tested via a single request for a line interface board diagnosis. Certain lines, however, such as ground start, and coin lines, require an additional request to diagnose the associated ground start applique.

VII. SUMMARY

The RSS maintenance plan has been made as consistent as possible with existing Bell operating company switching system procedures, but the geographical separation of the various system components has required modifications and additions to these procedures. In addition to the switching craft charged with RSS maintenance responsibility, several other craft forces (e.g., outside plant, data services, LTD, carrier, trunk maintenance, etc.) will become involved in the maintenance of various portions of the RSS. The required coordination of these different craft forces will make new Bell operating company maintenance procedures necessary.

The maintenance of each major portion of the RSS has been discussed in detail. Remote terminal maintenance activities are carried out nearly autonomously, with little interaction required between the host ESS and the RT. Both hardware and software checks are utilized to detect system faults, and automatic recovery, circuit removal, and fault reporting are utilized when a fault is detected. Manual diagnostics are available for detailed fault location and repair.

The PUC/DL is a direct peripheral unit of the host ESS. Its maintenance is coordinated closely with that of the host.

The RSS channel maintenance has been made to look as much like ESS trunk maintenance as possible. Per-call-failure tests, error analysis, and manual maintenance access arrangements, similar to those existing for trunks, have been provided.

Numerous existing line maintenance features (e.g., ALIT, LTD access, etc.) have been extended to RSS customer loops from the host ESS. In addition, the increased complexity of the RSS per-line circuitry has made new maintenance functions necessary.

VIII. ACKNOWLEDGMENTS

The design and implementation of the various portions of the RSS maintenance plan, and their integration into existing Bell operating company maintenance procedures have required the cooperation and assistance of everyone associated with the RSS project. It is not possible to acknowledge individually everyone who helped with this plan. Many of their contributions are discussed in greater detail in other papers included in this issue of *The Bell System Technical Journal.* The authors would like to especially acknowledge the help of D. A. Anderson, F. R. Fromm, G. T. Kresan, R. W. Sevcik, and S. R. Staak.

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