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No. 10A Remote Switching System:

System Overview

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This paper gives an overview of the No. 10A Remote Switching System, including background planning studies, system objectives, and information on the major hardware and software elements of the system.

I. INTRODUCTION

This paper is an overview of the No. 10A Remote Switching System (10A RSS), including some background, results of earlier planning studies, system objectives, and information on the major hardware and software elements of the system. Companion papers in this issue of *The Bell System Technical Journal* will discuss some of these elements in greater detail.

The major components of the 10A RSS include a host Electronic Switching System (ESS), one or more 10A RSS frames and data links for communication between the host and remote site(s). Figure 1 details this arrangement. At this time, the host function has been developed for the Western Electric No. 1 ESS machines, and work is now in progress to develop the host capability for the Western Electric No. 1A and No. 2B ESS machines. The data link used for the No. 1/1A ESS-RSS communication function is a new design utilizing an intelligent peripheral unit controller (PUC-DL) which can interface with up to 16 data links. The 10A RSS data link communication makes use of the X.25 protocol. The 10A RSS basic frame can serve up to 1024 lines. A companion frame may be added to allow up to 2048 lines to be served by a single RSS entity. The design is such that the basic element of

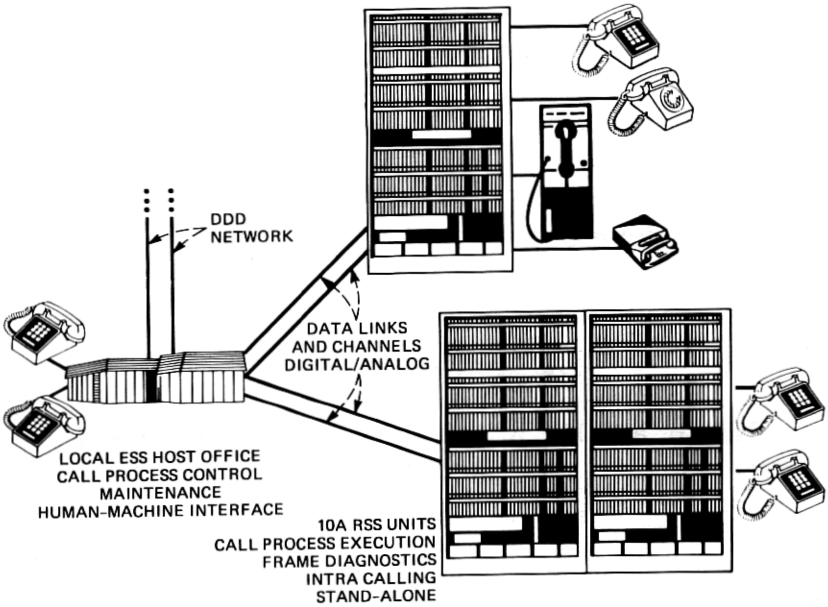

Fig. 1—No. 10A RSS for ESS.

growth can be as small as eight lines. Voice and control communications between the remote and the host can be made over either digital or analog carrier facilities, and the range may be as far as 280 miles, depending primarily on the specific type of transmission facility.

In the event of total carrier system or data link outage, the 10A RSS is arranged to automatically transfer to a stand-alone mode of operation which provides basic telephone service between stations connected to that RSS unit. In the stand-alone mode, special provisions can be made to handle emergency types of traffic such as "911."

All major units of the 10A RSS are duplicated, and a continuous dialogue is exchanged between the host and remote site concerning the overall health of the system. The basic system philosophy is that the remote unit is a complete slave to the host and, in general, merely reports events to the host and then receives a stream of explicit orders from the host concerning that event. All maintenance procedures must be controlled from the host. Initiation of diagnostics and other functions may be further remoted to a Switching Control Center (SCC).

II. BACKGROUND

With the evolution in electronic technology currently in progress, it was evident that intelligent remotely controlled devices could be brought into the central office switching environment. Early work in this area tended toward the design of systems primarily as pair gain devices. That is, electronic systems that allow the extension of the central office to remote areas by means of substituting electronics for wire pairs. Considerable economic advantages evolved from this approach. As investigations in this area progressed, it was recognized that the merging together of an intelligent (although subordinate) remote terminal with an intelligent controlling host would create a new type of switching vehicle with vast potential for serving a myriad of Bell System switching needs. A system which could effectively and economically remote large portions of its network over large distances could rapidly be deployed over major segments of the Bell System network. This would provide the Bell System with the opportunity to bring the advantages of ESS stored program control with its rich feature content into areas that previously could not economically justify the installation of an ESS.

The era of electronic switching began with the introduction of the No. 1 ESS into commercial service in 1965.[1] Since then, there has been a continual evolution of electronic switching systems, designed for particular segments of the switching environment of the Bell System. For example, the No. 1 ESS is a large machine and is best suited for metropolitan and large city environments. To meet the needs of the suburban and rural market, the No. 2/2B ESS and No. 3 ESS machines, respectively, have been created.[2] In spite of this activity, there remains a large segment of Bell System central offices that until the introduction of the 10A RSS could not justify the introduction of electronic switching technology. These offices are primarily in the size range of less than 1500 lines. With the 10A RSS, it is possible to economically provide service to these areas, thereby making available the specializing services, improved maintenance, and the inherent reliability of electronic switching.

III. PRELIMINARY PLANNING STUDIES

In the early design stages of the 10A RSS, the pressing need for a small switching system to serve the multitude of very small Community Dial Offices (CDOs) in the Bell System was very evident. Surveys of operating telephone companies in 1970 and 1971 by Bell Laboratories had identified many of the characteristics and new feature requirements of small CDOs of fewer than 1000 lines in size.

The concept of remote switching had been investigated before for other needs, for example, switching of wideband data services. Until the mid-1970s, there had been no economically or technically feasible solutions to many of the challenges presented by remote switching, such as reliability. However, in the exploratory design stages of the 10A RSS, advancing LSI and microprocessor technology suggested possible solutions to many of these questions.

In 1975, Bell Laboratories began an initial market concept testing study in conjunction with the New York Telephone Company in the Buffalo area. The purpose of this study was to explore the economic potential for remote switching in the replacement and consolidation of small central offices, and to identify other potential applications of remote switching. Besides CDO modernization, this early study pointed out some other promising possibilities. Use of a low start-up cost switch would permit introduction of electronic switching technology to new wire centers at smaller line sizes. The use of electronics in the outside loop plant to reduce the number of physical cable pairs to the central office is called pair gain, and has been used traditionally in long, slowly growing, small cross-section feeder routes in rural areas. The Buffalo study pointed out a need for a larger pair gain system to be deployed in suburban areas when, for example, a new housing development, apartment complex or shopping center threatened exhaust of outside plant facilities. Later studies have confirmed the need for large pair gain systems.

The Buffalo study also supported the collocation of a remote switch in an older electromechanical office to provide ESS features to customers willing to take a number change, or to postpone an equipment or a building growth addition. However, further studies of this application indicated that it is only marginally attractive, largely due to the costs of the split trunk groups and administrative overhead.

Subsequently, systems engineering organizations conducted extensive studies of remote switching which validated economics, developed planning guidelines, and contributed to the decisions concerning host development, carrier compatibility, distance constraints and features. These planning studies, and in particular, the studies relating to the impact of the 10A RSS in the modernization of the Bell System network are described in Refs. 3 and 4.

IV. SYSTEM REQUIREMENTS AND OBJECTIVES

4.1 Size

Based on the primary market objective of CDO modernization, the 10A RSS design was optimized for the 200- to 1000-line range. The initial frame can terminate 1024 equipped lines, and a second frame can be added for a maximum size of 2048 lines in central office applications.

A major advantage of the 10A RSS is its small physical size. A single 7- by 3-ft, 3-in. frame contains all of the switching equipment needed for 1024 lines, plus the necessary transmission facility interfaces to the host ESS when T1 carrier is used. The only major equipment items not included in this frame are the −48 volt central office battery plant, plus its commercial ac power interface, the main distributing frame, and any miscellaneous circuits.

In CDO replacements where floor space is limited, the 10A RSS may prevent costly building additions because of its compact size. A dramatic comparison of a 1000-line 10A RSS with the equivalent step-by-step switch it would replace is illustrated in Fig. 2. Even where floor space is not a problem, the achievement of greater circuit packing density by minimizing size and power requirements permits significant savings in system cost and energy consumption—an important factor in the tight economics of the CDO market. Of course, in pair gain applications small size contributes to unobtrusiveness, as well as economy.

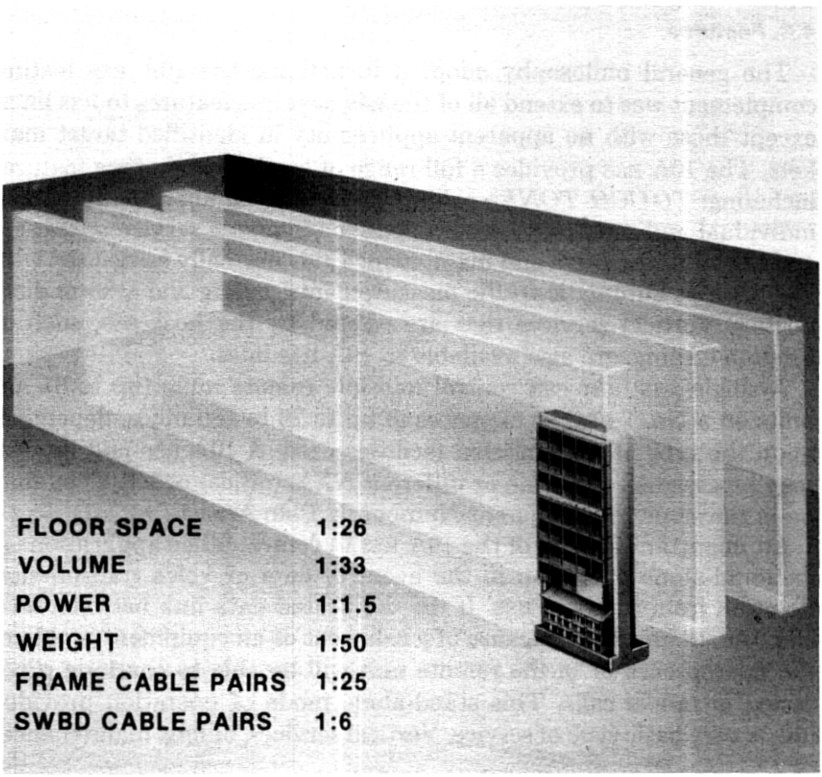

Fig. 2—Remote switching system versus step-by-step comparison (1,000-line offices).

4.2 Cost

The major cost objective for the 10A RSS was that it be competitive with step-by-step equipment life cycle growth costs in the small CDO replacements that are its primary target market. To achieve this objective, a low startup cost was essential. Most of the cost of the system is invested in the line interface circuitry. Line interfaces are packaged with eight on a circuit board which also contains one stage of the switching network. Thus, small growth increments of only eight lines at a time are possible.

The basic concept of remote switching is dependent upon sharing the resources of the controlling host. Since the 10A RSS shares these resources (e.g., service circuits and access to the toll network), a smaller investment is required at the remote terminal in processor intelligence, equipment and trunk groups, than it would for an independent entity.

All of these factors work together to keep costs within the economic framework dictated primarily by the cost profile of CDO modernization.

4.3 Features

The general philosophy adopted in defining the 10A RSS feature complement was to extend all of the ESS host line features to RSS lines, except those with no apparent applicability in identified target markets. The 10A RSS provides a full range of local central office features including: *TOUCH-TONE** calling, automatic number identification, individual and multiparty service, public telephone service operation, and the administrative and maintenance aids normally associated with ESS, such as automatic traffic measurements, billing and system diagnostics. Vertical services that are offered by the host ESS, such as Custom Calling, are also available to 10A RSS lines.

A single ESS host can control multiple remote units (up to 31 RSS units on a No. 1 ESS) at distances of up to 75 to 280 miles, depending upon the type of transmission facilities used. A 10A RSS and its host may be assigned the same or different NXX (office) codes. They may be in the same or in different Numbering Plan Areas.

An important feature of the 10A RSS in central office applications is its stand-alone operation in the event of data or voice transmission isolation from the host ESS. If the duplicated data link between host and remote unit fails, because of a cable cut or an equipment problem, the microprocessor in the remote unit will be able to continue processing intra-RSS calls. This stand-alone mode of operation provides only a very basic type of service. Vertical services, billing, maintenance,

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traffic measurements, and all other functions normally performed by the host ESS are not available in this mode of operation. Calls to directory numbers not served by the 10A RSS are connected to reorder tone source or an optional recorded announcement, although limited special routing may be provided at the option of the telephone company for a few emergency directory numbers.

Another valuable 10A RSS feature in central office applications is its compatibility with existing main distributing frames, battery, and power plant. This, combined with small system size, is particularly important where building space is cramped.

The set of features provided by the 10A RSS is complete enough to make it attractive in a variety of applications, and yet streamlined enough to enable it to be competitive in its target markets.

4.4 Performance

The 10A RSS has a network capacity of approximately 6000 total originating, plus terminating (O + T), Average Busy Season (ABS) CCS (hundred call seconds). There are up to 120 channels provided to the host from each 1024-line frame. Two of these from the first equipped frame are used for the data links of the system, but the rest are free for intersystem traffic and intra-RSS call setup. Channels will typically carry 25 to 30 CCS and are terminated as high usage host line appearances, like private branch exchange trunks.

The 10A RSS has a two-stage, folded, full access, 4:1 concentrated switching network, such that each line can be connected to each and every channel within a 1024-line frame. The 64 by 16 inlet switch is liberally engineered so that any 16 of the 64-line appearances can simultaneously access any of the 16 outputs of the switch. Because of this richness of the network, a relatively high concentration ratio is possible; for example, with a traffic load of 3 CCS/line and a fairly low intra-RSS calling rate of 10 percent, a concentration approaching 10:1 (lines:channels) can be attained. Where the intra-RSS calling rate is higher, this concentration can be much greater, because intra-RSS calls only use channels to the host during call setup—a clear advantage in CDO applications where intraoffice traffic is typically high. Where a large proportion of the lines in a system have fairly high traffic (4 to 7 CCS/line), then the concentration of the inlet switch can be reduced by deloading the line appearance on the 10A RSS.

The 10A RSS has an engineered processing capacity of about 6000 O + T busy-hour calls for a maximum size two-frame system. A 10A RSS also places an additional call processing load on the host ESS, since each 10A RSS call will require between 100 and 200 percent more host processor real time than an equivalent call in the No. 1 ESS host.

4.4.1 Grade of service

The grade of service objective of the 10A RSS design is to provide transmission performance comparable to that of its host ESS from the point of view of the customer. The RSS is considered to be an extension of the host ESS line appearances into a remote serving area, and so it does not have a unique network office class in the toll hierarchy, but is part of the class 5 office. Therefore, there is no additional loss allocation for the host-to-remote voice links. By the introduction of new matching networks and sophisticated automatic loop measurement techniques, the 10A RSS design is able to utilize 0 dB links to the host, and meets or exceeds its transmission objective.

Since 10A RSS dial tone is normally provided by the host ESS, the remote unit network and the channels have been engineered to provide a combined probability of blocking that will result in the same effective dial tone grade of service for 10A RSS customers as those served directly by the host ESS. This is true for all connections requiring access to the host network. To further ensure good performance, an extensive network retry strategy has been implemented for many 10A RSS connections through the host network.

4.4.2 Stand-alone performance

In the stand-alone mode of operation, the 10A RSS traffic handling will be reduced to about two-thirds of its normal call processing capacity. Thus, an RSS operating in this mode will have a capacity of approximately 4000 busy-hour calls.

In transitions to and from the stand-alone state, the 10A RSS minimizes customer annoyance by maintaining stable intra-RSS calls in a talking state.

4.5 Reliability and maintenance objectives

The overall maintenance objective for the 10A RSS is twofold: (*i*) to provide ESS quality, reliability, and maintenance features, and (*ii*) to keep maintenance procedures as similar as possible to existing telephone company procedures in all phases of 10A RSS maintenance, including lines, carrier channels, and data links, as well as the system itself.

4.5.1 Reliability objectives

The reliability objectives of the 10A RSS are the same as that of its host ESS.[1] To enhance its reliability, the 10A RSS design includes hardware redundancy, automatic and regularly scheduled or manually initiated diagnostics, automatic error recovery, and internal error analysis of failures resulting in automatic removal from service of defective units. All essential components (e.g., microprocessor, memory, data link) are duplicated. All other components which affect more than 64 lines are replicated. An automatic switch to off-line duplicated circuits is made when trouble occurs. The stand-alone operation is invoked when both data links fail, and when the host does not respond to a remote terminal prompt within a specified time interval.

4.5.2 Maintenance objectives

Responsibility for maintenance of a 10A RSS is centralized with the switching craft responsible for its host ESS, who may be located at the host office or at an SCC. The 10A RSS teletypewriter messages, alarms, and SCC interface are provided through its host ESS. Although it shares the resources of the host, the RSS is recognized as an individual entity when failures occur.

The following features are provided by 10A RSS for effective maintenance:

(*i*) Built in diagnostics to enable localization of troubles and permit dispatch of the appropriate craft.

(*ii*) Craft/machine interfaces in the form of the host maintenance teletypewriter, a maintenance panel at the remote terminal, and alarm circuits.

(*iii*) Diagnostics to test and identify faulty circuit packs which are replaceable entities.

(*iv*) T Carrier Administration System interfaces at the host ESS.

(*v*) Automatic line insulation testing of customer loops.

(*vi*) Remote loop testing capability via the Remote Test System (RTS) at the Local Test Desk (LTD).

(*vii*) Manual and automatic channel testing capability, including compatibility with Centralized Automatic Reporting On Trunks (CAROT).

Ease, consistency, and centralization of maintenance operations and procedures will be especially important in the remote, unstaffed, small offices and suburban loop plant applications that are the primary target markets for the 10A RSS.

V. INSTALLATION

The installation of a 10A RSS requires four major elements:

(*i*) Proper generic program with the 10A RSS feature package loaded in the host ESS office.

(*ii*) Installation of a PUC-DL frame which can support up to 16 data links. Two data links are required per 10A RSS unit.

(*iii*) Carrier system between the remote terminal and the host.

(*iv*) Remote unit equipped as required.

The 10A RSS host interface has been designed to allow it to be easily installed in a working host environment with no service affecting penalties on the existing system. The 10A RSS frame has been completely tested at the factory by emulating the host interface and performing all possible diagnostic tests. In addition, all circuit packs have been burned in and the entire frame subjected to a strenuous heat and power cycle requirement. All cabling to the 10A RSS frame is connectorized, including the subscriber tip and ring pairs. As a result, the actual installation interval for a 10A RSS unit is short, since all cabling can be performed before the arrival of the 10A RSS frame on site. The frame is then powered up, the data links attached, and the extensive data link diagnostics are then exercised to verify the communication link.

Once the data links are operational, the remaining cabling can be plugged in and the diagnostic programs for all the remote terminal hardware executed to ensure that the hardware is still operational and has not been damaged in transit. Once the hardware is verified, translation data to assign the remote terminal equipment can be entered in on the host service order teletypewriter channel and the system prepared to run the board-to-board verification and final acceptance tests.

Cutover of the new system is routine since the existing hosts provide very sophisticated mechanisms for transferring the system from a precut to a post-cut state.

VI. MAINTENANCE

Remote unit maintenance is scheduled and performed at the remote end. There are over 20 circuit board types. A diagnostic program for each board type is resident at the remote terminal. Diagnostics are scheduled routinely and those that fail are reported to the host. No circuits are taken out of service as a result of these routine diagnostics. The host also has the capability of manually requesting specific diagnostics and also of removing equipment from service. The only exception to this host control is the microprocessor complex. Since it takes time to report a failure to the host and to have the host respond to this failure, an error in the microprocessor complex (e.g., a memory parity error) can cause an immediate switch to the duplicate processsor complex. This remote terminal action is justified by the fact that the delay necessary for host action could cause a degradation in telephone service. In the event of an erratic processor complex causing frequent switching, the host has a mechanism to manually override the remote terminal's action in this area.

In addition to the routinely scheduled diagnostics, the remote terminal performs an extensive set of per-call tests to verify proper operation of the system. These tests include the usual verification of network path continuity and extend to proper operation of various control functions, such as verifying that the High Level Service Circuits

(HLSCS) are generating the proper ring polarity. Failure of these tests generally results in immediate notification to the host so that proper failure actions may be initiated for the call. In addition, the remote terminal retains the identification of the failing circuit(s) and performs peer group analysis on that circuit with a past history record of other circuits of the same type. If the results of this analysis indicate that this particular circuit is performing poorly, a message is sent to the host indicating this poor performance. If the internal automatic maintenance limits have not been exceeded, the circuit is removed from service and the craft people are informed of this removal action. If the automatic limits have been reached, the craft force is alerted and manual action by a craft person will be required to remove the faulty circuit from service.

The transmission objectives for remote switching require that the host-to-remote channels must be maintained at a 0-dB loss. To ensure that this objective is met, a miniresponder is located at the remote terminal. This miniresponder provides the host channel maintenance programs with the ability to measure all the required transmission items, such as ac continuity, gain slope, 1000-Hz loss, 3000-Hz loss, etc. Channel diagnostics are run routinely from the host and can be accessed externally by the CAROT system. In addition, channel diagnostics can be requested manually [from a maintenance teletypewriter (TTY) or a test panel] or run whenever the system detects a fault and the RSS channel is suspect. Even though RSS channels appear on the line side of the ESS network, they receive the same general maintenance treatment as trunks. They can be removed from service automatically up to a predetermined maintenance limit which can only be overridden by manual action.

The major human-machine interface for maintenance of the 10A RSS is the maintenance teletypewriter of the host ESS. This philosophy falls in precisely with the general move of ESS-type maintenance activities into a centralized SCC, where skilled craft people can be effectively pooled to share their expertise over many switching machines and even more remote switching units.

When a trouble has been isolated to a 10A RSS unit, a craft person still must be dispatched to the remote site to make the necessary repairs. To facilitate this operation and to reduce the skill level required of the person making the repair, a maintenance panel is provided at the remote unit (Fig. 3). This panel is under the control of the host, and is not active unless the host issues the proper commands. The panel is precharged via a software buffer with a list of suspected faulty circuit packs. The craft person can only request a local diagnostic on those particular circuit packs. A flowchart is provided on the panel indicating the allowable steps a craft person may perform and their

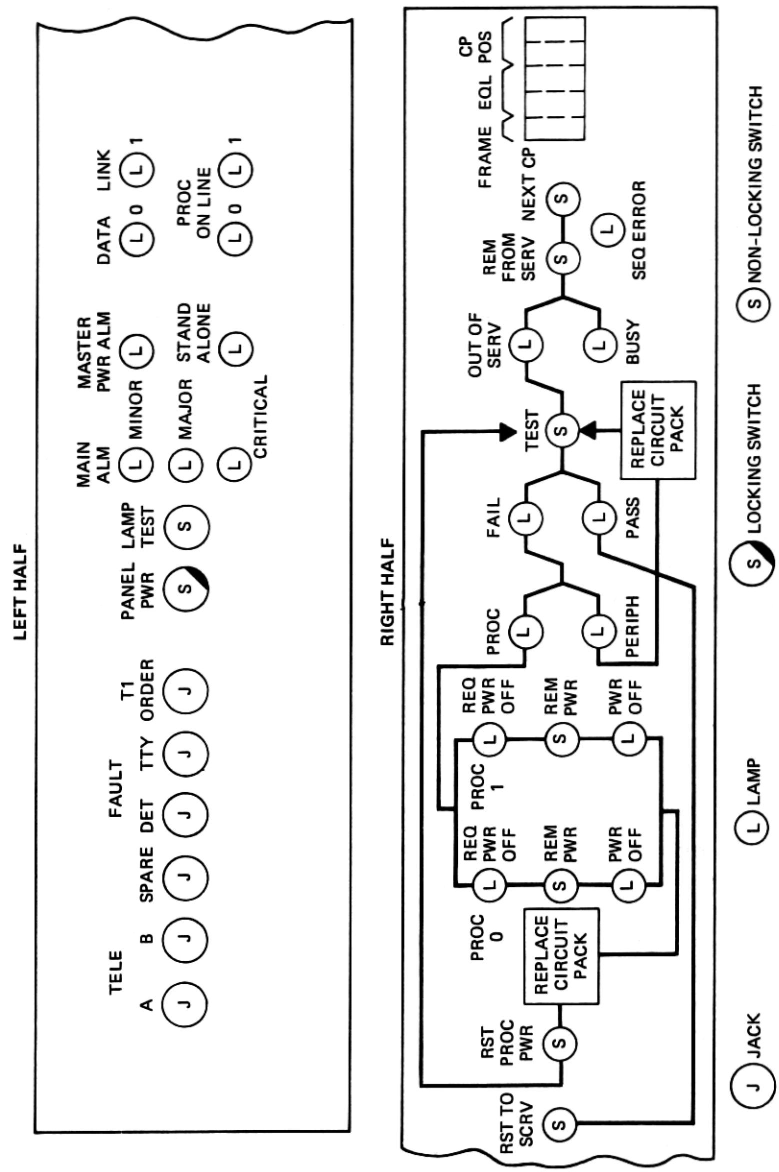

Fig. 3—Remote maintenance panel.

particular order. Any deviation will cause a sequence error and a reversion back to the first step. This panel operation will allow a relatively unskilled individual to successfully verify suspect circuit packs, replace those identified as faulty, while effective control and monitoring is maintained at the host or associated SCC.

VII. HARDWARE DESIGN PLAN

The hardware design of the 10A RSS is a fundamental departure from the equipment and techniques used in previous ESSs designed for local class 5 service. The 10A RSS utilizes a low-level electronic switching network, multifunction programmable high-level signaling circuits, LSI microprocessor control techniques, and ultraviolet (UV) erasable memory technology to implement the functions of the local central office. In addition, transmission equipment and switching equipment have been integrated into the same physical frame eliminating the need for relay technology signaling protocols and redundant circuit functions. The block diagram of Fig. 4 illustrates the major elements of the 10A RSS remote terminal.

The rationale behind these design decisions is the fundamental system objective of providing economical service at small (<2000) line sizes while simplifying both the initial engineering and subsequent growth of the system. A basic characteristic of any low-level electronic network is the concentration of equipment cost in the line interface circuit. Optimal use of silicon technology and dense packaging techniques made it possible to package part of the switching network, battery feed and supervision, and metallic access for ringing and testing for eight customer lines on a single plug-in circuit pack. This circuit pack is the basic growth element of the remote terminal, and it can be equipped as desired, thus deferring major equipment expense until the equipment is actually required.

Another important feature of the remote terminal design is the use of multifunction HLSCs, instead of engineered special-purpose circuits. In a small office environment such as that which the 10A RSS is designed to serve, the small usage groups of a particular type of circuit make it more economical to use a multipurpose circuit, even though the cost of such a multipurpose circuit may be higher than a simple ringing circuit. An additional benefit of this design approach is the elimination of service circuit engineering since the multifunction circuits are always provided in a fixed ratio depending on the number of equipped lines.

The size of the control program [200 kilobytes (K)] made it difficult and time consuming to back up the program store at the host and "pump-up" random access memory (RAM) at the remote unit in the event of loss at the remote. Use of UV memory technology at the

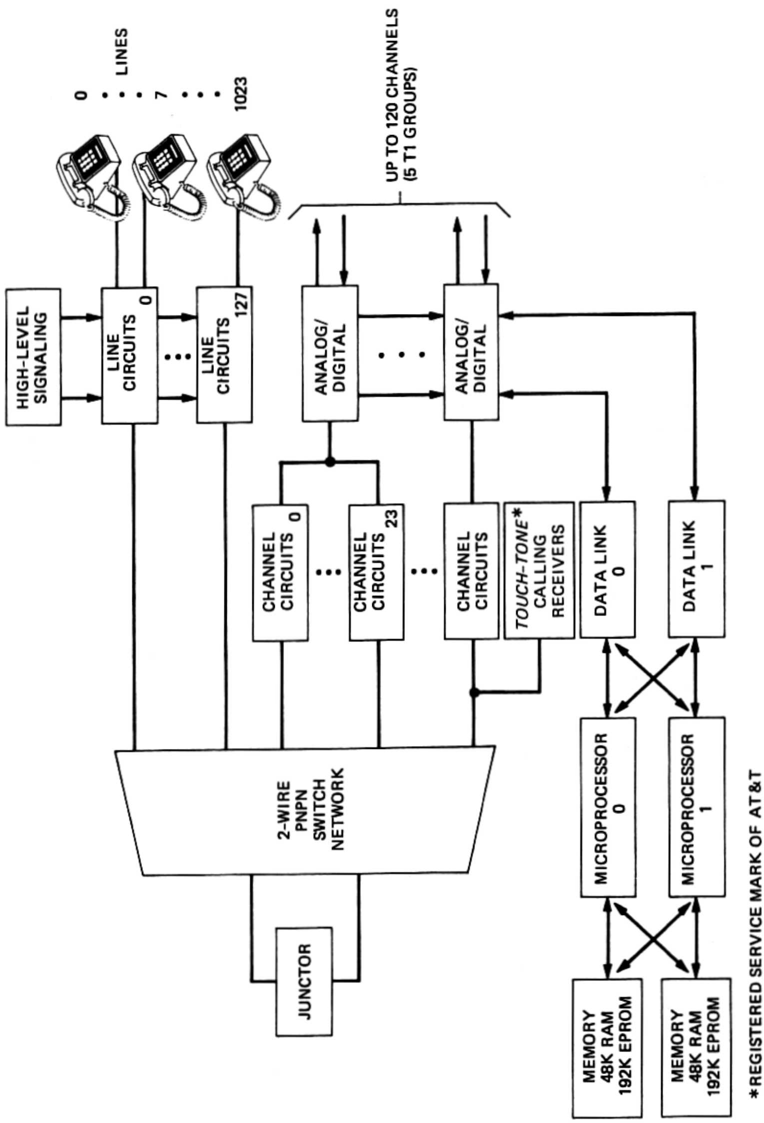

Fig. 4—No. 10A RSS remote terminal hardware.

remote solves these system problems and is expected to be more economical than read-only memory (ROM) memory technology, as long as the program change activity exceeds two changes per year. Use of the microprocessor controller also makes practical major system feature enhancements, such as the ability to handle intra-RSS calls in the remote unit in the event of total data link failure.

Finally, integration of transmission equipment into the design eliminates duplication of function and makes possible substantial equipment savings in both size and cost. The existence of an electronic switching network in 10A RSS requires that most of the functions associated with the channel unit of conventional transmission equipment must be performed on the 10A RSS line interface circuit. This simplified the channel unit design and allowed for compact physical design, an important criteria in the overall 10A RSS objectives. In the case where T1 links connect the host and remote, the functional equivalent of five D-type channel banks have been integrated into the 10A RSS equipment. In the event of interface with N carrier analog equipment, the functional equivalent of the F-type signaling equipment is integrated into the 10A RSS frame.

VIII. SWITCHING NETWORKS

As indicated in Fig. 4, the voice switching network in the 10A RSS is a two-wire space division network which utilizes semiconductor PNPN crosspoints. The crosspoint device itself is an integrated 4 by 8 array of PNPN devices packaged in an 18-pin dip. The low cost and small size of this integrated device makes it practical to design a switching network which utilizes large nonblocking switches in place of conventional multistage switches of similar inlet/outlet capability. For example, the inlet concentrator switch in RSS is a 64 by 16 full-access single-stage switch. The inlet concentrator switch used in No. 2 ESS is also a 64 by 16 switch; however, it is a two-stage switch and is not a full access (nonblocking) switch. The advantage of the full-access switch in the 10A RSS application is the elimination of load balancing within a concentrator group and somewhat higher traffic capability per terminal.

The voice switching network topology in the 10A RSS is a folded, two-stage switch which grows in three basic preengineered increments. For the smallest systems (512 lines), the second stage switch is partially equipped as a 16 by 16 matrix as illustrated in Fig. 5. The 128 junctor circuits illustrated in Fig. 5 are preengineered and packaged on the same circuit packs as the 16 by 16 switch and are never rearranged during subsequent growth. When the number of lines exceeds 512 and/or the traffic load exceeds 1900 CCS, a second group of circuit packs are equipped in the second stage of the switch which build out the 16 by

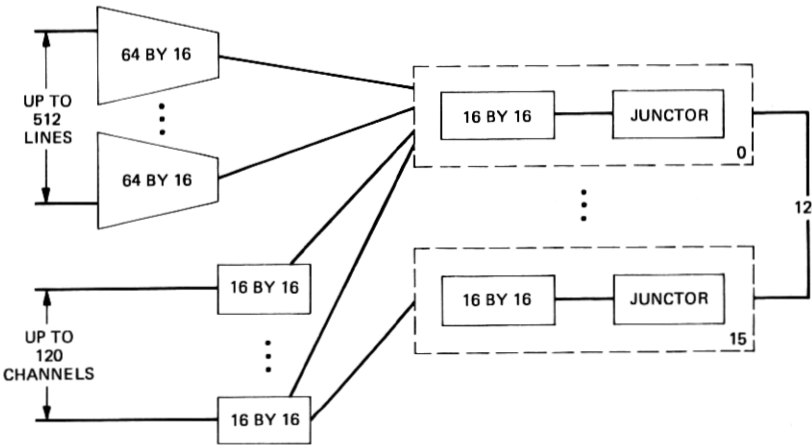

Fig. 5—No. 10A RSS switching network, 0 to 512 lines.

16 switch to a 24 by 24 matrix and add additional preengineered junctors as illustrated in Fig. 6. The final growth phase of the remote terminal involves the addition of a second bay of equipment for up to 2048 lines with interconnection established through reserved junctors when the number of lines served exceeds 1024 and/or the traffic load exceeds 4000 CCS. The low cost and highly integrated nature of the network fabric and junctor circuits makes it possible to preengineer and simplify equipment growth in this manner without substantial cost penalty.

Since the PNPN network carries only low-level voice signals, an auxiliary metallic network must be provided to handle high-level signals such as ringing (88 Vrms) and coin signals. The traffic requirements of this signaling network are such that a continuous path to a high-level service circuit is not required for more than 2 seconds during each 6-second period of time (assuming that loop supervision during the silent 4 seconds of ringing can be provided from the line interface circuit). This signaling network must also provide a path to the loop for occasional continuous line testing purposes without denying service to other nonaffected customers. These operational requirements are met by the topology of the signaling network illustrated in Fig. 7. The HLSCs indicated are reconfigured during each 2-second interval to meet the requirements of a particular loop. For example, the same HLSC may be supplying ordinary bridged ringing during a particular 2-second interval and may be reprogrammed to provide a coin collect function during the next 2-second interval. The universal nature of these high-level signaling circuits makes it possible to preengineer them without regard to the nature of the particular mix of coin, two-party, and

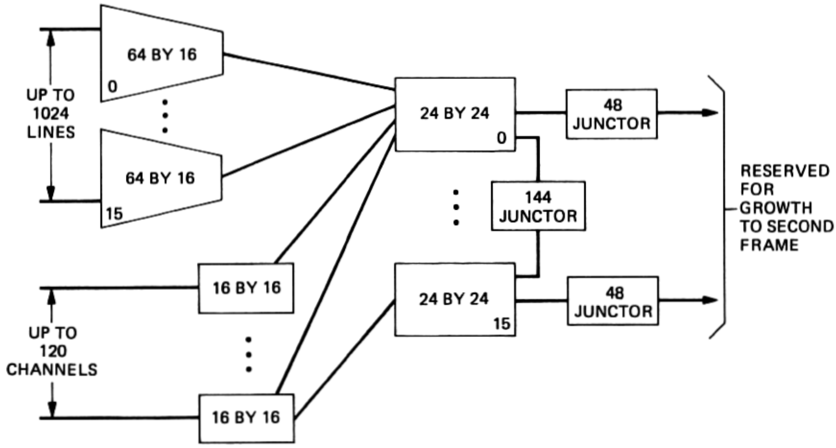

Fig. 6—No. 10A RSS switching network, 512 to 1024 lines.

multiparty lines in a particular group. The circuit design details of both the low-level voice and high-level signaling networks are discussed in the companion article on "Peripheral Systems Architecture and Circuit Design."

IX. LINE INTERFACE

Since the switching network fabric in the 10A RSS is a low-level switch, a line interface circuit is required for each customer line. This circuit isolates the low-level network from high-level signals which may be present on the customer loop, provides battery to the station

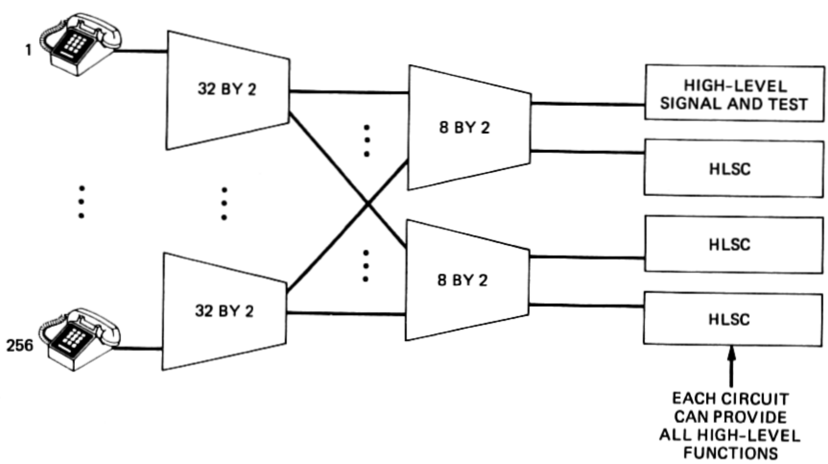

Fig. 7—High-level service circuit network.

set, supervises the loop for origination and switchhook status, and provides high-level switching for ringing and testing functions. The line interface circuits for eight customer lines are packaged on a single circuit pack, along with the first stage switch of the low-level switching network, and this plug-in forms the basic building block for incremental system growth.

An important key to packaging eight line interface circuits on an economical circuit pack is the reduction of heat dissipation both during the scanning for service request and the active talking state of the line. Equally important is the reduction in size of components traditionally used to provide the battery feed and high-level access functions. Important from the long-term operational aspects of the switch is the minimization of energy costs. For these reasons, a new technique has been developed which utilizes a small (1.5 watt) dc-to-dc power converter per customer loop to provide battery and to monitor the customer loop. This efficient converter never dissipates more than 0.8 watts of internal circuit heat at any customer loop length and saves 30 percent of the average busy-hour battery power required for this function over that which would be required if conventional techniques were used. The packaged circuit, including a small ferrite core pulse transformer, switching transistor, and control integrated circuit, is less than half the size of a conventional circuit which performs the same functions.

Additional circuit details are described in the companion article on "Peripheral Systems Architecture and Circuit Design" and in Ref. 5.

X. TRANSMISSION INTERFACE

The basic 10A RSS transmission plan differs from that of previous class 5 offices in that system economics require the RSS remote terminal to terminate on an existing class 5 switch. Maintenance of grade-of-service objectives for all Bell System loops (0 to 1600 ohms) thus implies that no loss can be allocated to the remote terminal or the transmission facilities which connect it to the host. This constraint implies that the actual transmission facility must run with a small amount of gain as measured from channel termination to channel termination. To maintain acceptable singing margin performance over this 0-dB link in the environment of service to both loaded and nonloaded loops on the 10A RSS system, special terminations must be provided at the 2-to-4 wire hybrid circuits depending on whether or not the customer loop is loaded or nonloaded. In the 10A RSS, the determination of the loaded/nonloaded status of the loop is done automatically by a special-purpose circuit [Electronic Loop Segregator (ELS)], while the customer loop is on-hook. The result of this measurement is stored in system memory, and this information is used to pick the proper termination when this loop is involved in a connection to the host over the transmission facility. Additional information regarding the transmission interface is available in the companion article on "System Maintenance."

The overall system cost of implementing this function is minimized by concentrating the 2-to-4 wire circuits and the special hybrid termination function behind the two-wire network in the channel circuits as illustrated in Fig. 4.

It is also significant that the existence of a low-level switching network and line interface circuit in 10A RSS implies that most of the functions usually performed in a trunk circuit on a transmission facility are not required when interfacing with a 10A RSS. The functions which are required in a channel circuit are low-level operations, such as 2-to-4 wire conversion and A/D conversion. These functions can be economically packaged on the same large circuit packs used to package the other equipment in RSS. By taking advantage of this fact, the 10A RSS greatly reduces the amount of equipment required to interface with digital carrier or analog carrier facilities.

XI. CONTROL

The control techniques and duplication architecture of 10A RSS also represent a significant departure from "duplicated matching" and "self-checking" systems previously used in ESS applications. The 10A RSS microprocessors normally operate in a "dual simplex" mode where one processor is in control and is executing instructions in a mode where all memory write operations are executed both in the on-line and in the off-line store (double store write mode). The other microprocessor is in an inactive hold state during normal system operation and is not executing instructions. Error detection circuits and program sanity checks monitor the operation of the on-line processor. In the event that an error is detected, depending on its severity, control is initiated in the off-line mate processor and it becomes the on-line processor. The coupling between the microprocessors which is used to determine the on-line off-line status of the control complex is configured such that several "mutual consent" conditions are required. These conditions are intended to prevent a hardware fault from locking both microprocessors offline or both online.

The small physical size of 10A RSS makes it possible to utilize a dc-coupled parallel access control bus to control peripheral circuits on the frame. Associated with each microprocessor controller is a group of up to 32 fanout boards which serve as interface and control access to the peripheral circuit packs as illustrated in Fig. 8. Control signals from the duplicated fanout boards are OR-ed in the backplane before reaching the unduplicated peripheral circuits. Since final gate failures

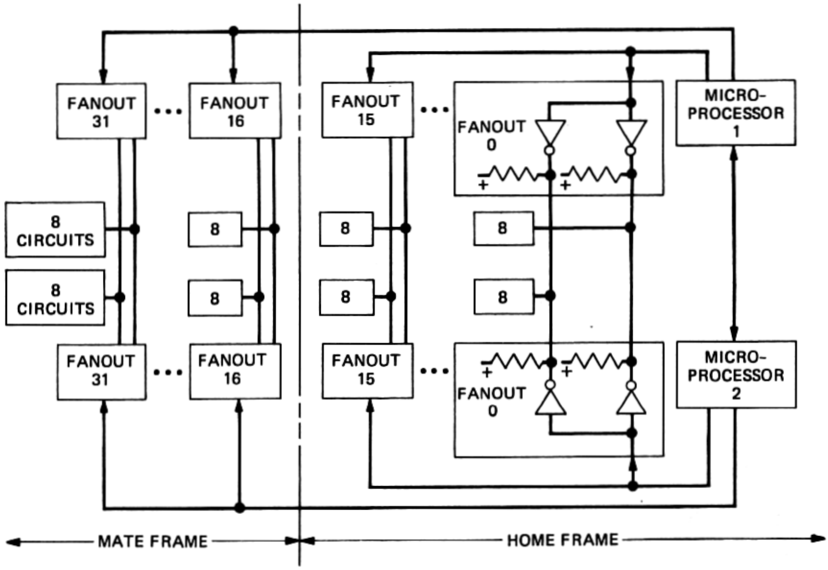

Fig. 8—No. 10A RSS control.

in this arrangement can affect both controllers' access to the affected peripheral circuit group, the number and functions of each circuit type in a peripheral control group must be carefully designed. In the 10A RSS, no more than eight circuit packs share a particular control signal in the backplane. The control assignments are arranged such that no more than 64 lines, 32 junctors, 24 channels, or 4 HLSCs can be affected by such control faults.

Peripheral circuit operations are handled in the microcontroller as memory read or write operations in a dedicated portion of the microprocessor address space. Read or write operations in this dedicated address space are decoded as special operations and sufficient "wait" states are generated in the controller to allow for a basic 6-μs peripheral read or write operation. In a peripheral read operation, data are returned from all eight circuit packs in a peripheral group in a single peripheral cycle. During a peripheral write operation, three of the peripheral address bits are decoded to select only one of the eight circuit packs in a control group. The effect of this additional decoding is the operation of a single control point specified by a unique 16-bit address. This control architecture minimizes the real-time burden of the numerous periodic scanning operations because 8-bit read operations are possible. It also minimizes the program data manipulation complexity of dealing with single-bit control operations by providing a unique address per control bit.

A final feature of the 10A RSS peripheral control is the analog/digital (A/D) nature of the data between peripheral circuit and fanout board. Certain network maintenance and scanner levels are passed from the peripheral circuit packs on the data bus as analog voltages between 0 and 5 volts. A programmable A/D converter provides an adjustable level to the data comparators on the fanout board. If the analog data exceeds the level of the previously programmed threshhold, the result of the peripheral read operation is a logic "1" on that data bit at the processor; otherwise the result is a logic "0". This feature of the design allows powerful hardware level checking at minimal system cost with the added flexibility of programmable level changes in the event of future hardware design changes.

XII. NO. 10A RSS INTERCONNECTION

A 10A RSS system occupies a position in the switching hierarchy as an extension of a class 5 or local office. This is illustrated in Fig. 9. A 10A RSS unit is interconnected to the Class 5 via two distinct facilities. These are data links for signaling and control, and channels for voice connections. As previously mentioned, either digital or analog carrier facilities, or a combination of digital and analog facilities, may be used.

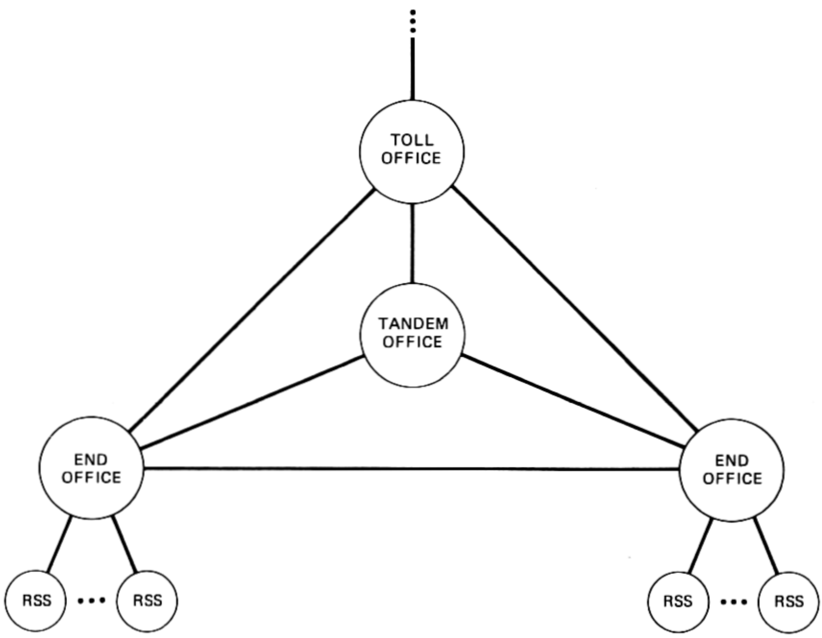

Fig. 9—Position in switching hierarchy.

A 10A RSS can be connected to one and only one host ESS, and a multiple number of RSSs can be served by an ESS.

The ESS provides the DDD network interface for both the incoming calls to, and outgoing calls from, an RSS unit. The ESS also provides the billing interface [be it Local Automatic Message Accounting (LAMA) or Centralized AMA (CAMA)], SCC interface, and the Engineering and Administrative Data Acquisition System (EADAS) interface.

High-level call control is provided by the host ESS over data links to a 10A RSS. A 10A RSS operates as an intelligent switching concentrator controlled remotely by an ESS.

An up-to-date database for each 10A RSS served by an ESS is kept in the host ESS. An abbreviated copy of this also resides in the 10A RSS. When the telephone company personnel modify this database in the host ESS (e.g., to add a RSS line), using ESS administration programs, ESS updates not only its database but also, in real time, the database residing in the affected 10A RSS. The telephone numbers for RSS lines are assigned from the office codes of the host ESS.

From a telephone company's point of view, a host ESS thus serves as a switching node in the DDD network for its subtending remote units. Thus, the introduction of 10A RSS effectively reduces the switching nodes in the network by either eliminating the existing nodes by replacing the CDO, or by delaying the introduction of future nodes when used in a pair-gain application.

XIII. NO. 1/1A HOST DATA LINK SYSTEM

Figure 10 illustrates the data link interconnection between the 10A RSS and its host ESS. The data link system's interconnection with the ESS is of the traditional nature. It is connected to the ESS via the peripheral unit bus system and treated as another ESS peripheral. The major difference between this data link system and any other periph-

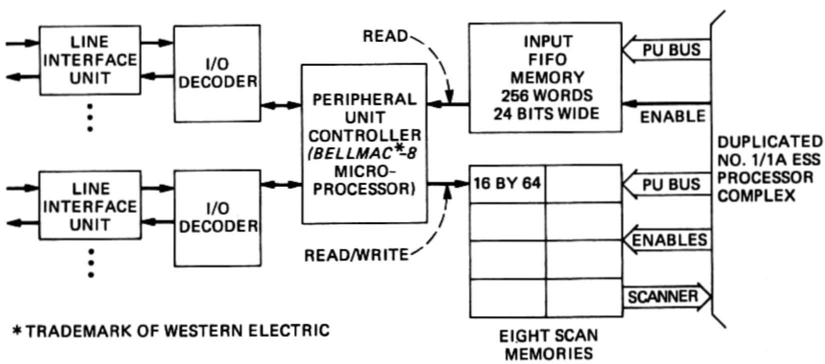

Fig. 10—Data link system block diagram.

eral is that the ESS transmits large amounts of data over its peripheral unit bus to the data link system, and the data link system does the converse over the scanner answer bus. Because of this additional new use of the peripheral bus system, the No. 1/1A ESS peripheral bus system has been modified to provide added data error handling capabilities to ensure the accuracy of data transmission.

The interconnection between a 10A RSS and the data link system is over a 2400 b/s full duplex synchronous link. The transmission facility can be T1 or N or radio carrier. Other digital and analog system links are planned to increase the overall versatility of the system. For added reliability, it is suggested that the facility links should be over diverse facility routes. The data link system supports RS-422/423 line interface requirements. Also, it provides link level X.25 protocol, as defined in CCITT recommendation X.25 of March 2, 1976.

The sections of the data link system consist of an FIFO (First-In/First-Out) buffer memory, scan memory, peripheral unit controller, I/O decoders, and line interface units. All the messages that need to be shipped to a 10A RSS must first be loaded by the ESS into the FIFO buffer. The peripheral unit controller unloads these, forms message frames of 16 data bytes or fewer, and loads these into appropriate destination buffers.

There is only one destination buffer per remote-end device (e.g., one 10A RSS), since the data link controller can concurrently serve a multiplicity of remote devices. The messages are unloaded by the peripheral unit controller from the destination buffers and shipped via the line interface units to the far-end device. The incoming messages from the far-end device are unloaded from the line interface unit by the peripheral unit controller and after appropriate protocol processing, loaded into the scan memory. The ESS receives these messages by reading this scan memory on a scheduled basis.

The heart of the data link system is the peripheral unit controller. It consists of two *BELLMAC**8 microprocessors running in a matched mode per ESS peripheral unit bus. This architecture provides a high degree of redundancy and error checking ability which ensures the overall reliability of the data link system.

XIV. REMOTE TERMINAL FIRMWARE

The 10A RSS remote terminal utilizes the *BELLMAC*-8 microprocessor as the control element. The *BELLMAC*-8 is an 8-bit microprocessor which is specifically designed to efficiently support the C language,[6] since it is a stack-oriented machine with registers that are

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* Trademark of Western Electric.

resident in RAM, and with specific instructions concerning the storage and restoring of register variables. As a result, over 80 percent of the 10A RSS remote terminal software is written in the C language. The remainder is primarily a portion of the operating system kernel and those routines that run on a sufficiently frequent interval that they justified using assembly language. The *BELLMAC*-8 design permits memory-mapped I/O and, therefore, 32K of the available 64K address spectrum was allocated to the 10A RSS periphery. The RSS program required approximately 200K, with additional storage required for transient call data and translations. This requirement necessitated devising a multiple memory bank scheme with the operating system controlling the bank selection mechanism. Figure 11 shows the overall address spectrum. This arrangement required that in certain cases code that must be executed out of RAM (for efficiency or for data access) had to be loaded at a different location than where it was actually executed. An overlay loader was designed to automatically resolve the interbank references, although a slight but still manageable compile time linkage resolution remains within the operating system.

The operating system uses a variety of techniques to minimize program interaction. Each identifiable process has its own stack and register area. Audits are provided to ensure that stacks are not overrun, and a preprocessor is used to determine the nested depth of each process. With the stack system, real-time breaks are simple to implement and code is written in a straightforward manner without the need to artificially preserve variables over a real-time segment.

The operating system consists of three basic levels and a multiplicity of failure levels. The three basic levels are as follows:

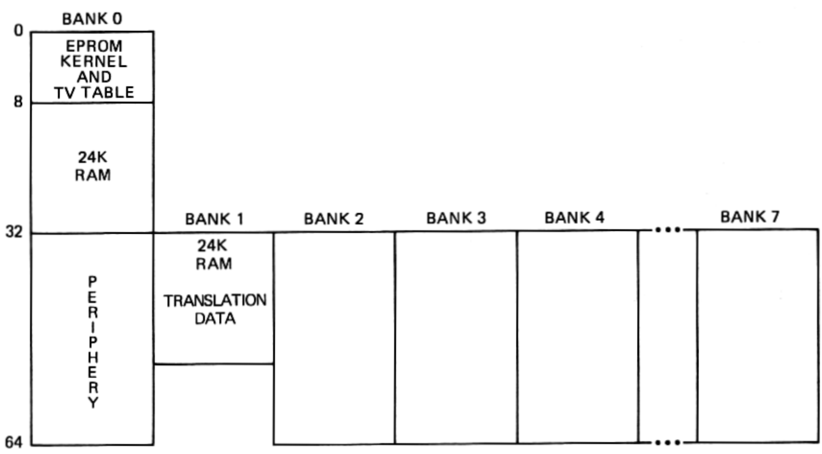

Fig. 11—Remote terminal memory organization.

(*i*) Data link interrupt—Data byte received or ready to be transmitted. This is a random event and at worst case can occur at a 3-ms interval. This is the highest priority job.

(*ii*) 10-ms interrupt—This interrupt is caused by a programmable interrupt chip. Three major jobs are scheduled by this interrupt.

(a) 10-ms repeat supervision—Lines in the dialing state have their on-hook/off-hook status repeated over the channel at a 10-ms rate. This rate ensures that dial pulses will be accurately transmitted to the host.

(b) HLSC execution—HLSCs in the act of setting up a control function, such as ringing, coin collect, etc., require a fast timing rate to control the setting of the various HLSC control points. Once the HLSC is in a stable state, this fast timing is no longer required.

(c) 20-ms repeat supervision—Lines in the ringing state have supervision repeated over the channel to the host at a 20-ms rate. This fast rate is required to minimize any possible speech clipping effects after the called party answers and the final talking connection is setup. This is the lowest priority interrupt function and can be slipped in the event of severe overload.

(*iii*) Base level—Base level is divided into three priority classes, A, B, and C, with class A having the highest priority. A measure of system real-time availability is the C-C (which is the average time it takes to complete the base level loop) and the total number of C intervals within a 15-minute period is output on the host TTY for each 10A RSS. This is analogous to the host base processor cycle time as a measure of the real-time capacity of the machine. Within this C-C cycle, line scanning is performed as a fixed-time interval job. The operating system keeps track of time and only performs line scanning at a 200-ms rate. If the line scan rate exceeds a 200-ms visitation rate, the total number of these slips is recorded in the 15-minute traffic summary for each 10A RSS.

On C level, the operating system allows for a queue of background tasks. Diagnostics and specialized requests from the host are considered background tasks and will be executed in order of arrival. Provisions are made for executing certain background tasks as a priority request, but all background tasks must have an abort capability.

Initialization of the system is under control of the host, but can be triggered automatically either by the host or the remote. The host also has manual control of the remote terminal initialization function. There are four levels of initialization. These are as follows:

(*i*) Reset—System detected a transient error. If possible, a switch to the standby controller was made. The job in progress was lost.

(*ii*) Minimal Clear—System detected multiplicity of errors. Some minimal portion of the call store is cleared. Some transient calls will be lost because of reset of the system constants.

(*iii*) Transient Clear—System experiencing difficulty possibly because of multiple interrupts. The transient area of call store is cleared and all transient calls are lost. If possible, a switch to the standby controller was made.

(*iv*) Stable Clear—System experiencing great difficulty, and all memory is cleared. If the translation data do not meet internal consistency checks, the host is requested to reinitialize the data base. All calls are cleared from the system. This function can only be requested by a manual action.

To perform its call processing function, the 10A RSS requires certain data concerning each assigned line in the remote unit. The database for these translations resides in the host ESS and is periodically transmitted to the remote unit. A set of remote unit programs maintains the translation database and calculates check sum data so that the operating system can verify the correctness of the data.

The operating system maintains several triggers which verify correct communication with the host. If these triggers fail, the operating system will generate a modified transient clear and go into the stand-alone mode. In this mode, new processes are spawned that route call originations to the stand-alone programs, which control the connection to digit receivers and then analyze dialed digits to route intra-RSS calls to the proper terminations. All other calls are routed to reorder or to an optional announcement. Call capacity during stand-alone is somewhat reduced because of limited availability of system resources, but the machine is protected by a last-in/first-out overload strategy which limits ineffective attempts. During stand-alone operation, calls to emergency numbers, such as "0," "911," or other special numbers can be handled with telephone company prepared inputs. Stand-alone can handle all basic telephone service with the exception that all billing functions are suspended. The basic list of call functions handled during stand-alone operation is as follows:

Intraoffice calling
2-party revertive
4/8 party revertive
Manual line (dial "0")
Permanent signal
Multiline hunt (limited)
Special numbers (911, etc.)
Coin intra (coin returned)
Hotel/Motel (no message register actions)

When data communications are reestablished with the host, the stand-alone mode is removed and normal call processing actions are resumed. Stable intra-RSS calls are maintained in the transition out of the stand-alone mode.

XV. STATUS

The first 10A RSS was placed into commercial service in December, 1979, in a rural community in upstate New York. The 10A RSS is located in Clarksville and is served by a No. 1 ESS host located at Guilderland, New York, just outside of Albany. Clarksville is connected to the Guilderland host via T1 carrier. The 10A RSS unit at Clarksville serves approximately 700 lines with a mixture of individual, 2-party, 4-party, and coin service. Performance to date has been excellent with notable transmission improvement. The second 10A RSS installation was cutover in June, 1980, in Neola, Iowa. Neola was the first application of the analog carrier host-remote interface. Additional 10A RSS units have been placed into service. At this time, additional development is ongoing to provide 10A RSS host capability for the No. 1A and No. 2B ESS systems.

XVI. SUMMARY

The 10A RSS represents a major milestone in the evolution to an all electronic stored program controlled network. It is now possible to provide economic modern telephone service down to the smallest size community. The 10A RSS has additional applications in areas such as pair gain and feature extension. Its small size and modular construction makes the system extremely portable and no doubt will enable the 10A RSS unit to be rapidly deployed to restore telephone service in disaster situations or to meet a brief need for additional telephone capacity.

This overview of the 10A RSS system is an introduction to the companion papers that follow.

XVII. ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of many individuals at Bell Laboratories, AT&T, and Western Electric, who have contributed to this work. In addition, the experience of many operating companies provided valuable feedback during the design process.

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