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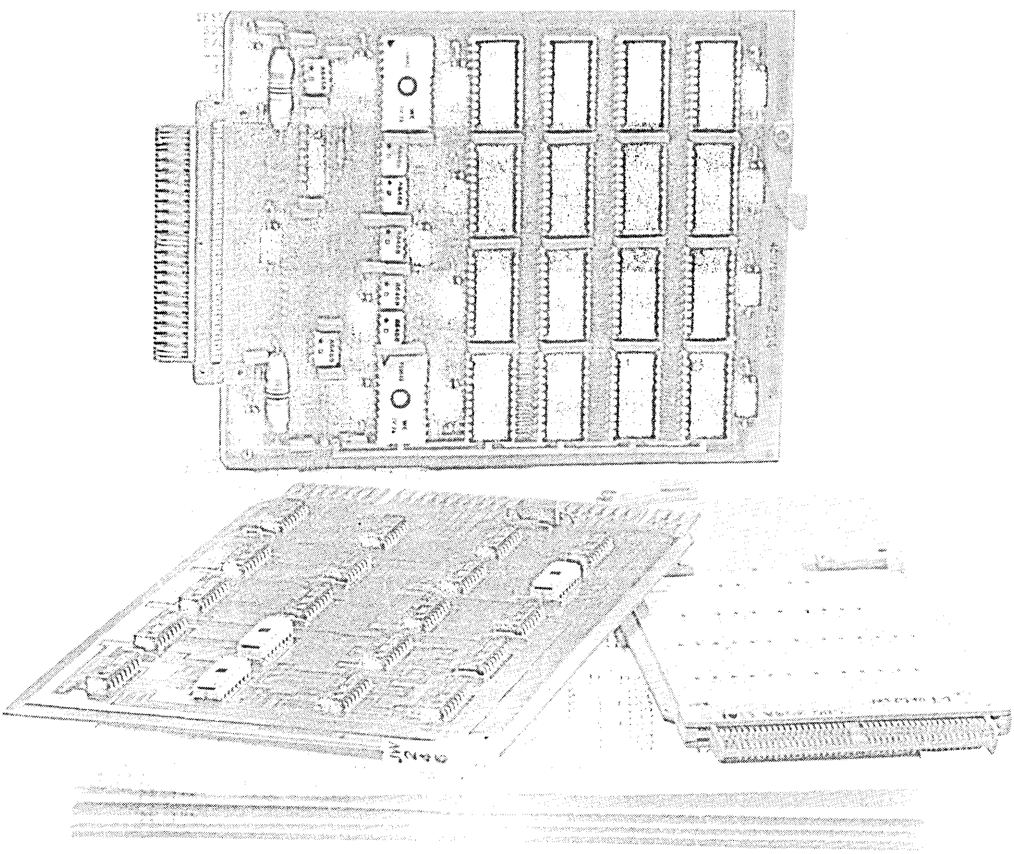
Common Channel Interoffice Signaling



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Common Channel Interoffice Signaling:

An Overview

By A. E. Ritchie and J. Z. Menard

(Manuscript received May 7, 1977)

In May of 1976, a new Common Channel Interoffice Signaling (CCIS) system linked together the last new No. 4A toll crossbar office in Madison, Wisconsin and the first No. 4 ESS toll office in Chicago, Illinois. This was a major milestone in a long-range program to achieve a nationwide Stored-Program Controlled (SPC) network of stored-program controlled switching offices interconnected by a new high-speed, high-capacity interoffice signaling system, CCIS. The SPC network will provide faster, more reliable communications and will make possible a myriad of new communication services. An evolutionary transition to the SPC network is in progress. CCIS is now being implemented in the toll or long-distance network. It will subsequently be extended to Traffic Service Position System (TSPS) units and to Electronic Switching System (ESS) local switching offices to provide customer-to-customer CCIS service.

This issue of the Bell System Technical Journal is devoted to CCIS. This overview and the following articles cover the inception and goals of the program and the implementation of CCIS in the toll network.

In telephony, interoffice signaling has two functionally different components: supervisory signaling, used to initiate and terminate connections, and to indicate call status; and address or control signaling, used to communicate the destination of a call. Supervisory signaling requires two-way communication, and address signaling is usually restricted to one-way forward operation. Historically, with minor exceptions, interoffice signaling for each call has been carried on the same transmission channel which is used for talking. Until the technology required for CCIS became available, this per-channel signaling has been the most practicable and economical approach even though it limited the flexibility and capability of signaling systems.

The early automatic switching systems employed dc signaling techniques, which are still in use today. In dc signaling, the supervisory information is communicated by level or direction of current flow; information content for address purposes is expanded by introducing another variable, such as the time factor in dial pulsing.

The advent of carrier transmission systems, which precluded dc signaling, necessitated the use of some form of ac signaling. This need was filled by development of Single Frequency (SF) systems in which the on and off states of a tone provide the equivalent of two dc states. SF systems require equipment at both ends of each voice channel. They are currently used primarily to provide supervisory signaling in the long-haul analog carrier plant. Another type of ac signaling, the Multifrequency (MF) system, is widely used for address signaling between register-sender type switching offices. This uses combinations of two out of six tones in the voice-frequency range to represent ten digits and up to six control signals. These two systems, SF and MF, now dominate signaling in the intertoll plant, in which analog carrier systems are the predominant transmission facilities. In exchange areas, supervisory signaling is largely provided by dc methods or by digital signals derived from T-carrier channels. MF is widely used for address signaling between types of local switching offices which can utilize it.*

For the past 25 years these per-circuit signaling techniques, with evolutionary changes to improve performance and reduce cost, have worked well during the multifold expansion of the network and the phenomenal growth of direct distance dialing. However, for many years it has been evident that SF-MF signaling has serious limitations with respect to foreseeable service needs of Bell System customers. These limitations are:

Slow speed

The signaling speed is inadequate for present and future needs. While the interoffice link signaling time averages about 1 to 2 seconds, the connection time on multilink calls may be 10 to 20 seconds, most of which is due to signaling.

* See Reference 1 for a full discussion of signaling methods and fields of application.

Limited signals

The signaling capability is essentially limited to bidirectional supervision and unidirectional address information. The system precludes transmission of additional information, such as class marks for special routing and handling of calls, and bidirectional signals needed to provide special services. The inability to signal (except disconnect) during a call limits flexibility to provide some special services.

Susceptibility to interference

The use of voice-frequency signaling on the circuits which are used by customers makes the signaling vulnerable to interference and susceptible to fraud. With SF signaling, carrier failure effects which result in multiple simultaneous tone-off signals can seriously disrupt the operation of switching offices.

Cost

It is expensive to provide relatively complex signaling equipment at each end of every voice channel.

While these limitations have been widely recognized for years, a continuing study effort did not find a solution which appeared viable in the environment of electromechanical switching offices largely because the SF-MF signaling was well matched to electromechanical switching systems and represented a very large investment in existing plant.

However, the opportunity and incentive for a breakthrough came in the early 1960s when it was recognized that the radically new electronic switching systems then under development would ultimately predominate in the network and would need a new signaling system to realize their full potential. This led to intensified studies which culminated in the plan and proposal for the system now known as Common Channel Interoffice Signaling, which provides direct processing-to-processor communication. These studies were coordinated with concurrent planning by the Consultative Committee on International Telegraph and Telephone (CCITT) in Geneva, which produced a specification for an almost identical international signaling system known as CCITT No. 6.

As the planned evolutionary transition to an SPC network is achieved, a series of benefits will be realized:

(*i*) The toll CCIS implementation program which is now under way, in combination with some network rearrangements, or rehoming, will provide CCIS signaling for about 80 percent of intertoll trunks by 1985. This will cut call setup time, improve signaling reliability, reduce effects from external interference, and make possible some new services such as more versatile INWATS.

(*ii*) Extension of CCIS to TSPS is a particularly effective way to make new services available to a large body of Bell System customers. By 1985, it is expected that 96 percent of all customers will be served by TSPS. With CCIS, it will be possible to automate such services as credit-card calls, collect calls, and bill-to-third-party calls by accessing a data base to verify customer-dialed information.

(*iii*) By 1985, it is expected that over 60 percent of all customer lines will be handled by ESS local switching offices. Extension of CCIS to these offices will cut call setup time to about two seconds on CCIS-controlled long-distance calls and make it feasible to pass a variety of additional information about each call between the originating and terminating switching offices or data bases. With this capability, it is possible to provide many new services. For example, the calling number can be sent to a distant office where special treatments such as priority ringing can be provided.

(*iv*) The interconnection of stored-program controlled switching offices by a reliable, high-speed, high-capacity signaling system will also permit more efficient usage and control of the network. For example, the increased call routing flexibility which can be achieved with CCIS will make it feasible to route calls up or down the hierarchy and to systematically modify routing patterns to take advantage of characteristic time differences in busy hours on different routes. The CCIS network can also be used to transmit network management signals (such as dynamic overload controls) to control overloads and congestion rapidly and effectively. The CCIS network may also be useful for the collection and transmission of billing data and some maintenance data.

CCIS is now in service and expanding rapidly in the Bell System domestic toll network. Network evolution is being guided to bring into being the SPC network which will offer important new service capabilities. International CCIS service using CCITT No. 6 in a No. 4 ESS office is expected to start in 1978. Extension of CCIS to local ESS offices is planned for the early 1980s. The story of the development and implementation program which brought this about is contained in the following articles of this issue of the B.S.T.J. It reflects a team effort by hundreds of individuals in Bell Laboratories, AT&T, Western Electric Company, and the operating telephone companies to bring the benefits of modern signaling to Bell System customers in the second century of telephony.

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Common Channel Interoffice Signaling:

History and Description of a New Signaling System

By C. A. DAHLBOM and J. S. RYAN

(Manuscript submitted May 7, 1977)

A new interoffice signaling system known as the Common Channel Interoffice Signaling System (CCIS) has been introduced into the Bell System's DDD toll network. It represents a major step forward in signaling systems by providing high speed data links between processors of stored-program-controlled switching offices to carry all signaling and network control information, completely independent of the communication paths used by customers. As CCIS implementation proceeds it will have an expanding and significant impact on the DDD network system performance due to improved speed of signaling and provision of signals to provide a multitude of new network and customer services. The history of common channel signaling is traced from early mechanical implementation to use of present-day technological advances. The fundamental concepts, basic features, signal formats and system operation are described.

I. INTRODUCTION

Until now signaling systems have to a large extent been provided on a per trunk in-band basis and generally have provided adequate performance for the present-day operating environment. The limitations of the systems have been enumerated in the lead article, and these together with the requirements for higher-speed signaling and vastly expanded signal capacity have led to the introduction of common channel signaling systems for both domestic and international telephone systems.

The concept of common channel signaling is not new but only recently have advances in technology made it possible for large-scale implementation of such systems. As a result, new customer services and sophisticated network controls requiring additional signals become possible, all with complete independence between the transmission channel used by the customer and the channel used for signaling.

II. EARLY COMMON CHANNEL SIGNALING SYSTEMS

The earliest use of common channel signaling employed mechanical distributors and provided for multiplexing the signaling information for 30 trunks on one full duplex telegraph circuit.[1] Eight such distributor systems, catering to 240 trunks, were placed on commercial trial in 1922 and standardized in 1924. The trunks, which were installed between New York and Philadelphia, continued in service through the 1940s. Installations in other cities were limited mainly because there were few trunk groups of a sufficient size to economically justify the system and because maintenance costs were high owing to the mechanical implementation.

A second form of common channel signaling employed voice-frequency telegraph channels to carry the signaling information required for up to 18 trunks over one voice frequency circuit. This was, of course, an improvement over a much earlier plan of using a separate dc telegraph circuit for each voice circuit. In the 1940s development of voice-frequency in-band and out-of-band per trunk signaling arrangements were undertaken, and they became the predominant methods used for interoffice signaling on carrier-derived trunks.[2]

Anticipating significant advances in the available and future technology, interest in and studies of common channel signaling were renewed in the early 1960s. The approaches taken included proposals for signaling on a trunk group basis between markers, in the case of electromechanical switching systems, and between processors, in the case of electronic switching offices. The trunk group concept catered to from 12 to 60 trunks. In this approach, supervisory signaling was assigned to the common signaling path while the address information was transmitted over the individual trunks. An advantage for such a division of the total signaling information was that the continuity of the speech path was checked by the successful transmission of the address information.

Technical and economic studies indicated that if common channel signaling were to be implemented, it should provide for vastly improved signaling speeds and signal capacities for large numbers of trunks and should cater to future needs, then under consideration, as well as to future needs still in a dreamer's mind. Since the future switching system hierarchy was to be electronic with the offices being processor controlled, the concept of using high speed data links between processors was chosen as the most appropriate approach. Such studies at Bell Laboratories, together with concurrent studies and participation in discussion of international signaling needs in the CCITT,* led to the specification of the common channel interoffice signaling system (CCIS) for use in the Bell Systems DDD network and a similar system known as the CCITT signaling system No. 6 for international and intercontinental signaling applications. Such systems were to carry all supervisory and address signaling information as well as a wealth of signals designed to cater to special services and network control features on the interprocessor data link, completely independent of the circuits used by the customer.

III. CCITT STUDIES OF INTERNATIONAL COMMON CHANNEL SIGNALING SYSTEMS

With the expansion of semiautomatic and automatic systems within national networks, it was natural that there would be a desire to interconnect the national networks on a continent. The United States and Canadian telephone networks had evolved almost as a single unit and as a result had a common national-continental system. Such was not the case within Europe. Due to the differences in national signaling systems, when it was desired to establish semiautomatic service between countries in Europe, it was necessary to find a common interexchange language. Two systems, CCITT Nos. 3[5] and 4,[3] were standardized for semiautomatic and automatic service, and system No. 4 is used quite extensively in Europe.

Shortly after the laying of the Atlantic telephone cable in 1956, it was proposed that semiautomatic service be introduced between North America and Europe. The North American signaling system was not compatible with system Nos. 3 and 4 nor with other systems in use in European countries. In addition to the technical differences between signaling systems, e.g., signaling frequencies, method of sending digits, etc., there were certain network differences which the signaling system as the interface between switching systems, and thus between networks, had to take into account.

The United States (American Telephone and Telegraph Company—AT&T), the United Kingdom, German, and French post offices joined forces to design a new TASI[4] compatible signaling system, now known as the Atlantic System. This system provided an intercontinental common language and was used in both the Atlantic and Pacific cables to provide semiautomatic service. As more and more countries were connected to the cables, it became evident that it would be desirable to have a worldwide standard signaling system. The problem was posed

* International Telegraph and Telephone Consultative Committee.

to the CCITT at the IInd Plenary Assembly (New Delhi, 1960); and study of a standard system was authorized.[5]

During the study the Atlantic System was examined, and after some modification was standardized as system No. 5.[6] It is now used in all of the undersea cables to provide both semiautomatic and automatic service. System No. 5 was the only system available which was compatible with the longer propagation delays inherent in synchronous satellites when they were introduced and thus is also the system used today for international satellite circuits.

System No. 5 is a per circuit in-band system; that is, the signals are carried within the voiceband of the circuit used by the customer. It consists of a line signaling part and an interregister part. The line signaling part uses two frequencies, 2400 and 2600 Hz, separately or together in a fully compelled mode. The interregister part for sending address signals uses a multifrequency code pulsed at a rate of 10 digits per second in the forward direction.

During the 1960–1964 studies which led to the standardization of system No. 5, there was a wide difference of opinion over the techniques to be used. Even after the agreement on the specification some had reservations about the adequacy of system No. 5 for the future in a greatly expanded, fully automatic worldwide network. As a result, an agreement was reached that the study of a new signaling system to be known as system No. 6 should be undertaken in the 1964–1968 study period. Some of the major reservations concerning system No. 5 were post-dialing delay, answer signal delay, limited number of signals, interregister signaling in forward direction only, and slow signaling.

There were two schools of thought concerning the new system, one favoring a system utilizing conventional techniques, and the other a system utilizing a new technique, i.e., a separate signaling channel common to a number of speech circuits. Because preliminary studies of common channel signaling then underway at Bell Labs showed promise, AT&T was one of the supporters of the common channel approach. A compromise was reached and a question was formulated which called for the initial study to be of a system with a common channel for line (supervisory) type signals and inband interregister signaling for address type signals.[6]

Guidelines for the design of the interregister and common channel systems were drawn up, and a preliminary division of signals between the two was made. The concept of nonassociated signaling was defined and several important parameters of the data link which formed the basis of the ultimate design were accepted, i.e., the data system to operate over standard 3 or 4 kHz spaced voice frequency channels, the data links to be nonswitched, a serial mode of data transmission to be used, error

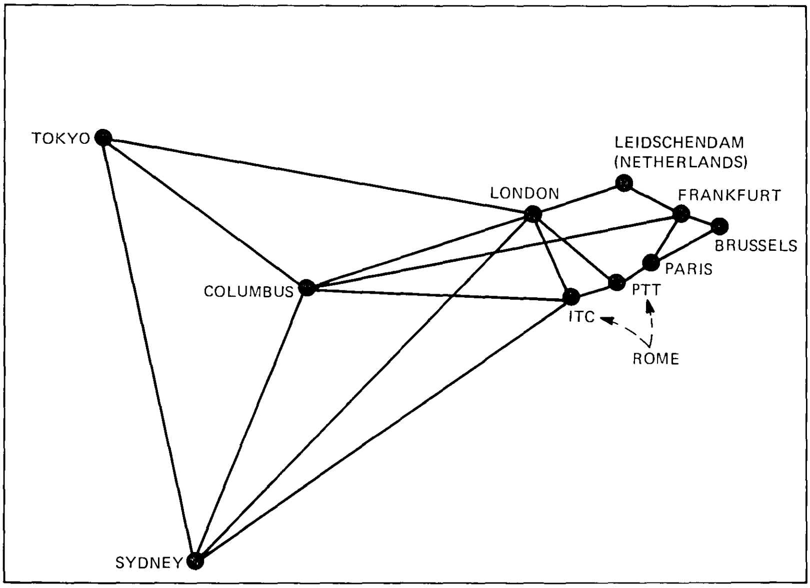

Fig. 1—CCITT system No. 6 total field trial network, phases B and C.

detection by redundant coding, error correction by retransmission, dependability requirements, and security arrangements.

A meeting in Stockholm marked a major turning point in the development of system No. 6. After a review, it became evident that most administrations had become convinced in the course of their studies that a full common channel system should be specified capable of carrying all the necessary signals. The data rate was established at 2400 bits per second, definitions of the signaling network were defined, error detection and correction methods were elaborated, further security methods were defined and guidelines for the format were established.

A series of meetings followed in New York, Tokyo, Prague, and Florence which led to the specification of a common channel signaling system which was presented to and approved by the IVth Plenary Assembly of the CCITT in Mar del Plata during October 1968.[7] At this same meeting, a special group was organized to conduct field trials of the new No. 6 signaling system.

Eleven Administrations or Recognized Private Operating Agencies participated in the field trials. AT&T participated utilizing equipment located in Bell Laboratories in Columbus, Ohio. The other participants and the extent of the trials are shown in Fig. 1.

As a result of the trials, two significant decisions made were: choice of the link-by-link rather than the end-to-end method of making the continuity check of the speech path, and the design of a new format which improved the overall efficiency of the system.

The results of this most extensive field trial gave every confidence that system No. 6 as finally specified would provide the facilities required in a vastly expanded worldwide automatic network, with the desired reliability under actual operating conditions.[3] A vast potential for new signals is available in the format and it has already been shown that the problems of interworking between national systems based on different design philosophies can be eased by utilizing some of this potential.

The final specifications after the completion of the field trials were presented to and were approved by the CCITT's Vth Plenary Assembly, Geneva 1972,[8] which also authorized further study of the structure of the international common channel network, digital version of CCITT signaling system No. 6, maintenance methods for system No. 6, and interworking between international signaling system No. 6 and national common channel signaling systems.[8]

The specification of a digital version of system No. 6 was completed and Recommendations were proposed to guide the design of common channel signaling systems for national or regional use in a compatible fashion so that they may form a part of a future worldwide signaling network. These Recommendations and the specifications of the digital version of system No. 6 were approved by the VIth Plenary Assembly of the CCITT in Geneva in October 1976.[9]

The design of system No. 6 represents a first in many technical areas, e.g., it is the first telephone signaling system to employ a dedicated processor-to-processor high-speed data link. Even more important, however, it is the first system ever designed entirely within the CCITT. This, for a system this complex, is quite a remarkable achievement and, of course, was only possible because of the goodwill of the members and their determination to succeed. In addition to the hours spent in meetings, many more hours of engineering time were devoted to the study in various laboratories around the world.

IV. INTRODUCTION OF COMMON CHANNEL SIGNALING IN THE DDD NETWORK

As indicated in the above section, the studies in Bell and similar other laboratories in the CCITT led to the specification of common channel signaling systems. The international version is known as the CCITT signaling system No. 6 and the system for domestic use in the U.S.A. is designated Common Channel Interoffice Signaling, or CCIS. An intensive development program was undertaken to implement the system in the DDD network to be used between processor controlled switching offices. The first offices considered were No. 4A crossbar offices equipped with the Electronic Translator System (ETS),[10] a processor with sufficient capacity not only to provide the translation function but also to process

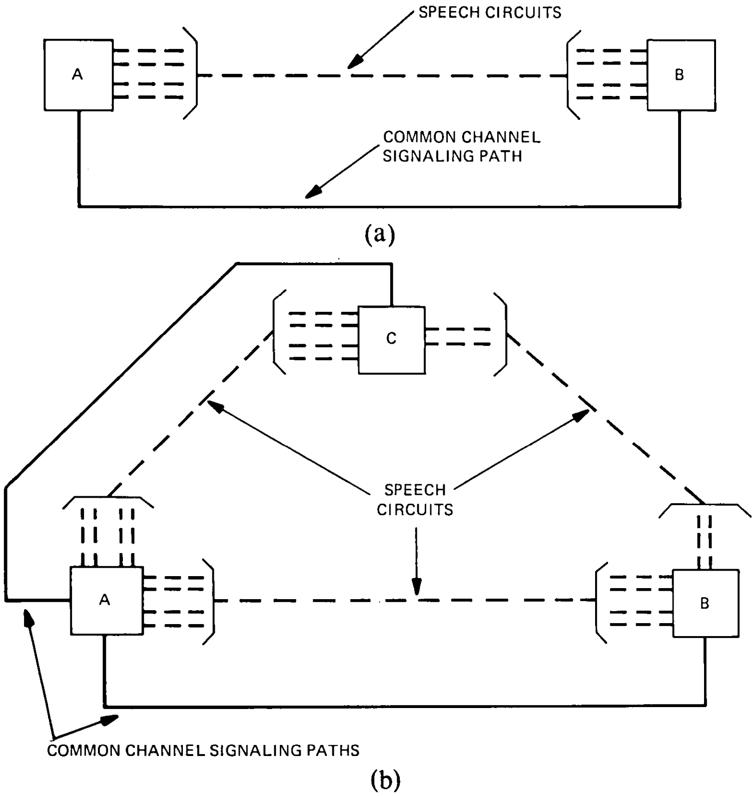

Fig. 2—(a) Associated signaling. (b) Nonassociated signaling.

common channel signaling information. In addition, the choice of the No. 4 switch would insure high penetration of CCIS in the DDD network. The second type of office to implement CCIS was the new No. 4 ESS[11] toll switch then under parallel development.

Systems engineering economic studies of several implementation proposals indicated that in order to accelerate the introduction of common channel signaling a plan that would provide the greatest connectivity at minimum costs should be followed. Obviously, the greater the number of trunks served by a single signaling link, the lower the per-trunk costs would be and since the getting-started costs were nontrivial, serious consideration was given to a signaling network plan that would cater to small as well as large trunk group sizes. A plan which is cost-effective on large trunk groups calls for an associated signaling link. However, since the majority of trunk groups are not large enough to economically support their own associated link a plan was developed which employed a form of nonassociated signaling. The concepts of these two plans are illustrated in a simple fashion in Figs. 2a and 2b, respec-

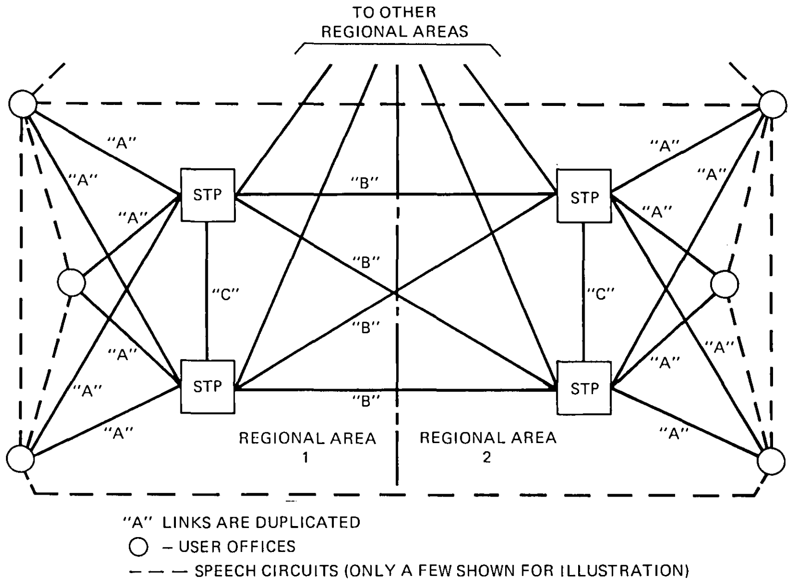

Fig. 3—User offices connected to STP quad.

tively. In the associated case the common channel signaling link is coterminus with the group of speech circuits between offices A and B. In the nonassociated plan the groups of speech circuits between offices A and B and A and C are large enough to economically use associated signaling, while the signaling required for the smaller group of speech circuits between offices B and C is carried over the common signaling paths B to A to C with office A serving as a Signal Transfer Point (STP). This form of nonassociated signaling is also referred to as quasiassociated since there is still some degree of association between signaling and speech paths. A further extension of nonassociated signaling, known as disassociated signaling, is where in a completely separated signaling network the signaling paths do not have a fixed association with the speech paths they serve.

Economics having dictated a form of quasiassociated signaling for the network, implementation planning resulted in the assignment of two signal transfer points in each of the ten regional areas of the DDD network. Figure 3 indicates the chosen arrangement with the STPs interconnected by a quad of "B" signaling links and user switching offices connected to their area STPs by two "A" signaling links. The redundancy furnished by the "A" and "B" links assures a high degree of signaling reliability. In addition "C" links are provided to permit signaling of update and status information between mate STPs and to carry traffic between STPs within the same area under failure conditions. Adaptation of the CCITT No. 6 system to this quasiassociated signaling network required some minor changes which will be discussed in the following system descriptions.

V. DESCRIPTION OF CCIS AND CCITT NO. 6 SIGNALING SYSTEMS

The system description that follows is generally applicable to both the CCIS system for the domestic DDD network and the CCITT signaling system No. 6 for international-intercontinental networks. Where differences exist they will be indicated but it should be recognized that the two systems are completely interworkable and such operation will be catered to at International Switching Centers (ISCs) served by No. 4 ESS offices.

Figure 4 is a basic block diagram of the common channel interoffice signaling system. Table I indicates the definitions of the various components. The system was designed to operate between stored program controlled switching offices where it is not practical to specify well defined equipment interfaces because there is considerable latitude permitted in the distribution of signaling functions between the processor and its peripheral equipment. The major signal transfer functions can, however, be delineated, and the blocks shown in Fig. 4 depict functions rather than specific equipment arrangements.

Each signaling link transmits synchronously a continuous stream of data in both directions. The data stream is divided into signal units (SU) of 28 bits each, of which 20 bits convey information and 8 bits are check bits. The signal units are in turn grouped into blocks of 12, with the twelfth signal unit always an acknowledgment signal unit (ACU). The latter unit is coded to indicate the number of the block being transmitted, the number of the block being acknowledged and whether or not each of the other 11 signal units in the block being acknowledged were received without detected errors. Figure 5 shows blocks of signal units transmitted in opposite directions with one of the ACUs expanded to show the bit make-up. In the example given the third signal unit in block i was received in error and the ACU in block j indicates this fact. In response to this ACU the receiving terminal will retransmit the message which contains the signal unit in error. Thus, CCIS achieves error control by redundant coding and error correction by retransmission.

Common channel signaling can utilize either analog or digital transmission facilities. In the analog case, data modems are provided at each terminal and operate over standard analog voice bandwidth channels. In the digital case, channels are derived either from bit streams of pulse code modulated systems, e.g., subframing bits of T1 lines, or dedicated digital channels. In the digital case no modems are required but an appropriate digital interface must be specified. The present design of CCIS

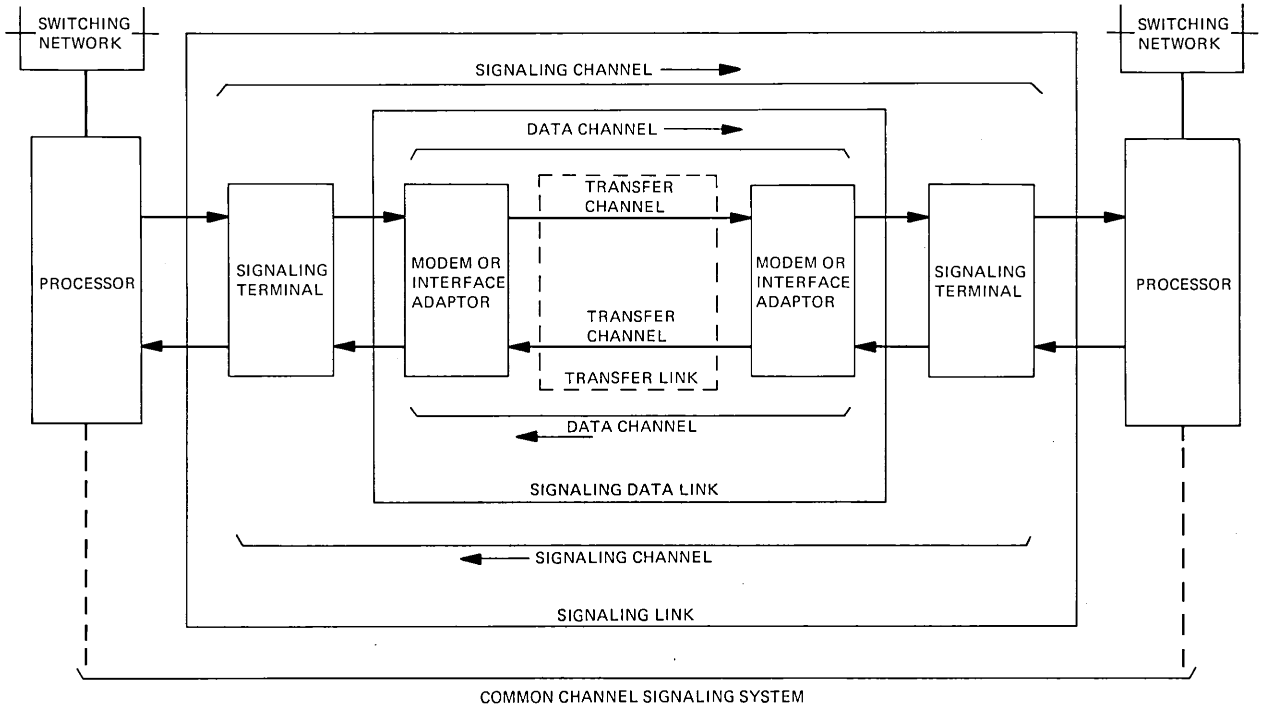

Fig. 4—Basic block diagram of the Common Channel Interoffice Signaling System.

Table I — Definitions of various links and channels in CCIS

	Analog Version	Digital Version
Transfer channel	(Voice-frequency channel) A one-way voice-frequency transmission path from the output of a data modulator to the input of a data demodulator, made up of one or more voice-frequency channels in tandem.	(Digital channel) A one-way digital transmission path from the output of the interface adaptor to the input of the interface adaptor, made up of one or more digital channels in tandem.
Transfer link	(Voice-frequency link) A two-way voice-frequency transmission path between two data modems, made up of one voice-frequency channel in each direction.	(Digital link) A two-way digital transmission path between two interface adaptors, made up of one digital channel in each direction.
Data channel	A one-way data transmission path between two points, made up of a modulator, a voice-frequency channel and a demodulator.	A one-way data transmission path between two points, made up of a digital channel terminating on an interface adaptor at each end.
Data link	A two-way data transmission path between two points, made up of one data channel in each direction.	
Signaling channel	A one-way signaling path from the processor of one switching machine to the processor of another switching machine.	
Signaling link	A two-way signaling path from processor to processor made up of one signaling channel in each direction.	

operates at 2400 bps in the analog application and in the future at 4000 bps in the digital case using the signaling subframing bits. Higher speeds—perhaps as high as 64 kbs—are expected in future designs.

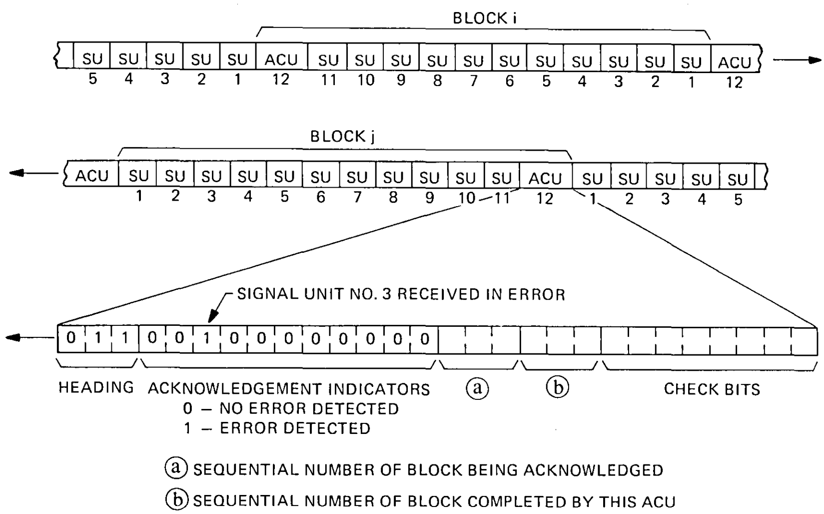

Fig. 5—Block structure, CCIS SUs and ACU.

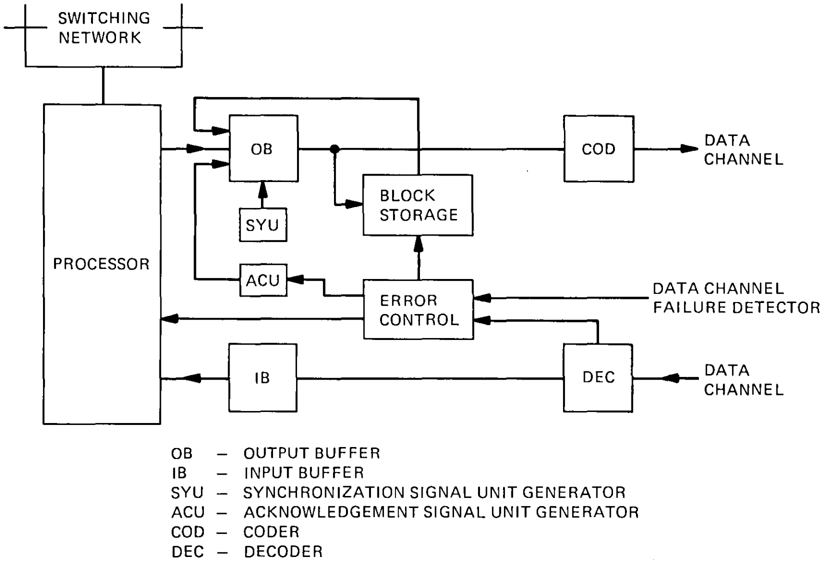

Fig. 6—Functional block diagram of a CCIS terminal.

A functional block diagram of a CCIS terminal is shown in Fig. 6. Signals originating in the processor are transmitted in a specified format in parallel form to the output buffer (OB) where they are stored according to their priority level. The signals are then passed to the coder (COD) in serial form where they are encoded by the addition of check bits and then delivered to the outgoing data channel.

In the receiving direction, signals in serial form are passed from the data channel to the decoder (DEC) where each signal unit is checked for error on the basis of the included check bits. Information-carrying signal units that are error free are passed on to the input buffer (IB) after deletion of the check bits. The input buffer passes the signals in parallel form to the processor for action.

Information carrying signal units with detected errors are discarded and this information is conveyed to the originating terminal via the acknowledgment signal unit (ACU) where action is taken to retransmit the message containing the failed signal units. This procedure requires, of course, that all signal units be stored until they are acknowledged as having been received correctly. Further, signal messages made up of two or more signal units must be stored and if any signal unit in the message is in error the entire signal message must be retransmitted. Signal units that are not carrying information, e.g., synchronizing signal units (SYU) can be discarded if received in error and no request is made for their retransmission. A data channel failure detector complements the error control mechanism for longer error bursts.

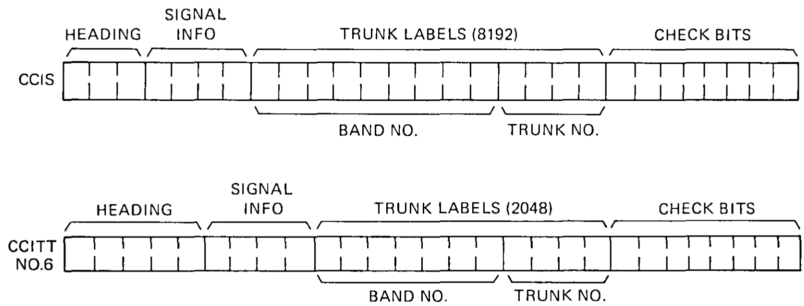

Fig. 7—Lone Signal Unit (LSU) format.

The present modems used in the transmission of CCIS serial binary data over analog facilities employ 2400 bps differential four-phase modulation. The transmitted binary data is grouped into dibits for encoding making the rate of carrier phase shifts or baud rate equal to 1200 per second. The receiving demodulator uses differentially coherent detection to recover the binary data from the line signal. This type of detection is relatively insensitive to the types of distortion and interference found on telephone-type transmission facilities. Timing information is extracted from the zero crossings, on a dibit basis, of the received baseband data signals which provides for synchronization holdover through extended drop-outs and periods of high noise.

VI. SIGNAL FORMATS

As indicated earlier a signal unit is made up of 28 bits—20 bits for information plus 8 bits for a cyclic check code used for error detection. The coding formats for the CCIS and CCITT No. 6 systems differ because of the need in the CCIS-STP signaling network to identify a larger number of individual trunks than that provided for in the CCITT No. 6 system. Figure 7 compares the lone signal unit (LSU) of the two systems. In CCIS, 13 bits are set aside for trunk identification or labels while CCITT No. 6 uses 11 bits. Hence CCIS can identify 8192 trunks while CCITT No. 6 identifies 2048 trunks. In both cases the bits assigned for labels are divided between band numbers and trunk numbers, i.e., 16 trunks within 512 or 128 bands, respectively.

A lone signal unit (LSU) is used to transmit a one-unit message such as a single telephone signal, a signaling system control signal or a management signal. The type of signal is defined by the "signal information" bits immediately following the "heading" code. A multi-unit message (MUM) consists of several signal units in tandem in order to transmit a number of related pieces of information in an efficient manner. The first signal unit in an MUM is referred to as an initial signal unit (ISU) and the

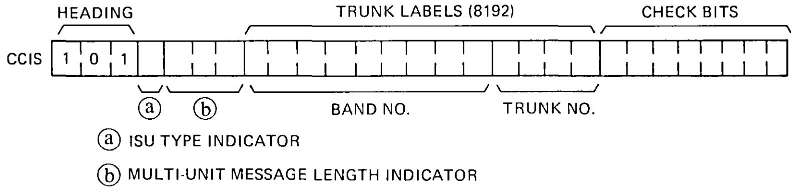

Fig. 8—Initial Signal Unit (ISU) format.

CCIS format is shown in Fig. 8. The second and any following signal units are referred to as subsequent signal units (SSU). The format for the CCITT No. 6 system ISU is the same as for the LSU. Table II indicates the "heading" code to identify the type of signal unit class for the CCIS system.

Table III indicates the "heading" code to identify the type of signal unit class for the CCITT No. 6 system. Being an international signaling system, as opposed to a strictly domestic (regional) or national system, it is necessary to assign blocks of signals for international, regional, and national uses. Another difference should be noted—all heading codes use five bits except for two distinct cases, namely the use of two bits (0,0) to identify subsequent signal units (SSU) and three bits (0,1,1) to identify the acknowledgment signal unit (ACU).

Figure 9 compares the coding of subsequent signal units. The heading codes differ and in the CCITT No. 6 system each SSU includes information on the total number of SSUs in the message. In the case of CCIS the information on the number of SSUs in only contained in the initial signal unit. CCIS has 17 bits for signal information use while CCITT No. 6 has 16 bits. The signal information can be routing information, address digits, etc., as will be indicated in typical telephone signal formats that follow.

In establishing a CCIS-controlled telephone connection, an initial address message (IAM) is transmitted from the originating terminal. This message, made up of several signal units in tandem, will contain trunk

Table II — Heading code for CCIS system

Heading code	Signal type	Signal unit class
000	LSU	Lone signal unit—telephone signals
001	LSU	
010	LSU	
100	LSU	
111	LSU	Lone Signal Units— Telephone signals Signaling system control signals Management signals
011	ACU	Acknowledgment signal unit
101	ISU	Initial signal unit
110	SSU	Subsequent signal unit

Table III — Heading code for CCITT system No. 6

Heading code	Signal unit class
00	Subsequent signal unit
01000 01001 01010 01011	Spare (reserved for regional and/or national use)
011	Acknowledgment signal unit
10000	Initial signal unit of an initial address message (or of a multiunit message)
10001 10010 10011 10100 10101 10110 10111	Subsequent address message (one-unit message or multiunit message)
11000 111001 11010 11011	International telephone signals
11100	Spare (reserved for regional and/or national use)
11101	Signaling-system-control signals (except acknowledgment of signal unit) and management signals
11110 11111	Spare (reserved for regional and/or national use)

identification, abbreviated or expanded routing information and address information. The most common IAM to be used in the DDD network will be an IAM with abbreviated routing information and seven or ten digits for the address, resulting in either three or four signal units for the complete IAM. A seven-digit-address IAM is shown in Fig. 10 for the abbreviated routing information case and in Fig. 11 for the full or expanded routing information case. For the ten-digit address case an additional signal unit carrying three additional digits is added to the IAM.

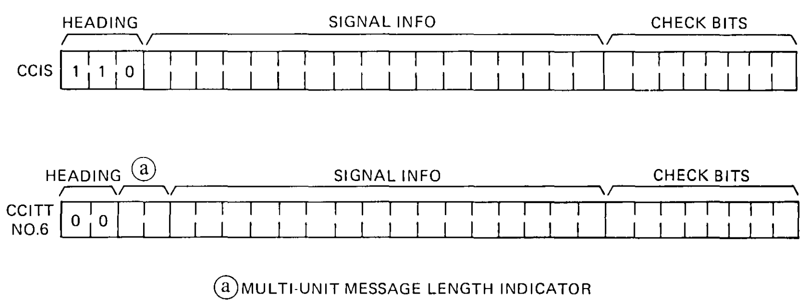

Fig. 9—Subsequent Signal Unit (SSU) format.

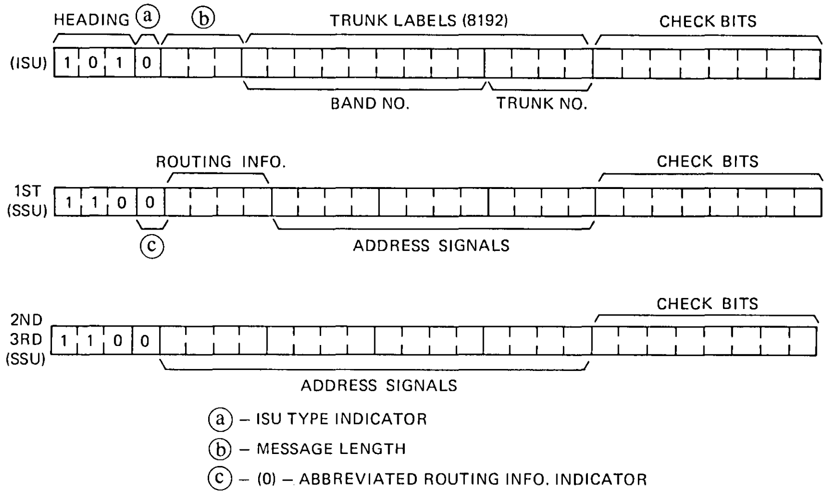

Fig. 10—CCIS Initial Address Message (IAM) with abbreviated routing information.

It should be noted that trunk identification information is included in only the initial signal unit.

In the CCITT No. 6 system the IAM contains similar information but the coding format is different from the CCIS system. An example of a

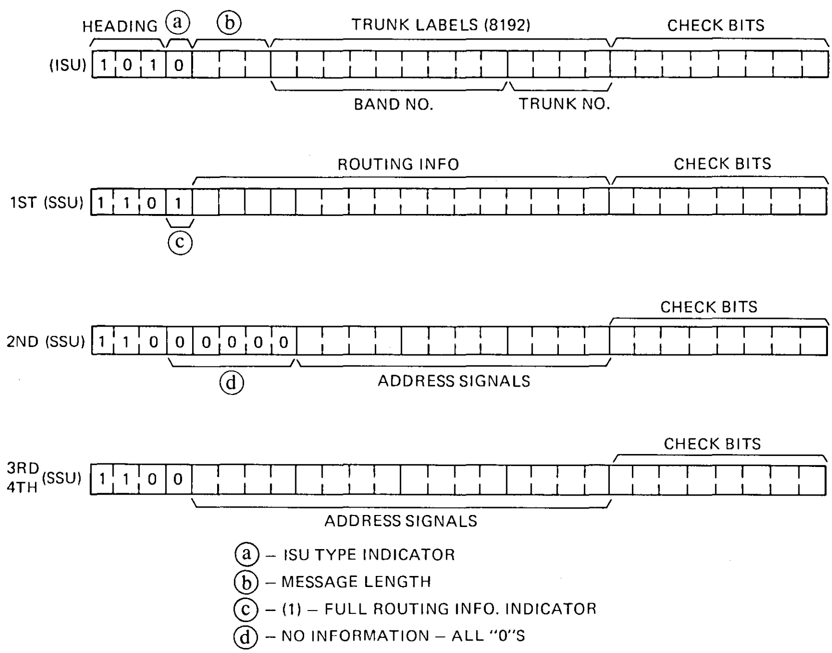

Fig. 11—CCIS Initial Address Message (IAM) with full routing information.

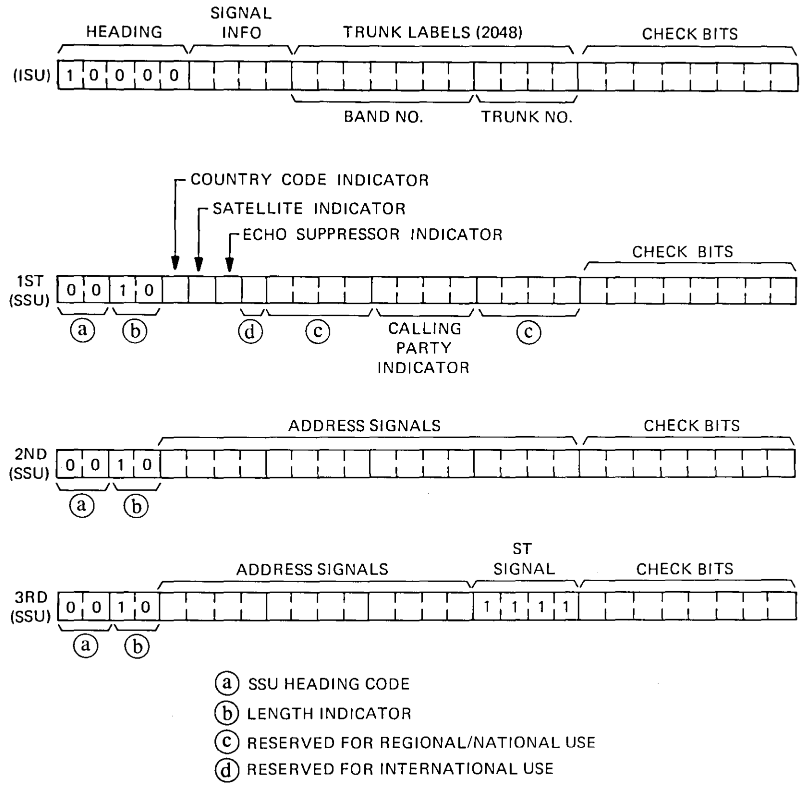

Fig. 12—CCITT-6 Initial Address Message (IAM).

four-unit IAM carrying seven digits, is shown in Fig. 12. An IAM consists of a minimum of three and a maximum of six signal units. Since the CCITT No. 6 system is an international system the routing information contains information on whether a country code is included in the address, whether the connection includes a satellite link or echo suppressors and a calling party category including the language that any assistance operator will speak if one is called in on a connection. The ST signal indicates the end of the address information. If additional code space is available after the ST signal a filler signal (0,0,0,0) is used.

The "calling party category indicator" bits 13–16 contained in the first SSU convey information as shown in Table IV.

In subsequent signal units (2 to 5) the signal information is conveyed in four 4-bit fields and includes address signals, two special operator codes, the end-of-address or ST signal, and two spare combinations. The second subsequent signal unit can also be coded to convey test information when the first subsequent signal unit indicates a test call in the calling party's category indicator.

Table IV — Calling party's categories (CCITT No. 6)

Bits 13–16	Category
0000	Spare
0001	Operator—French language
0010	Operator—English language
0011	Operator—German language
0100	Operator—Russian language
0101	Operator—Spanish language
0110, 0111, 1000	Available to Administrations for selecting a particular language provided by mutual agreement
1001	Reserved—extra discriminating information
1010	Ordinary calling customer
1011	Calling customer with priority
1100	Data call
1101	Test call
1110	Spare
1111	Spare (reserved for regional/national use)

In the CCIS system the complete address message is collected before being transmitted en bloc. In the CCITT No. 6 system the address message can be divided after a minimum number of address digits have been initially transmitted in the first IAM. The remaining address digits can be transmitted in Subsequent Address Messages (SAM) with as few as one digit per message. This method is referred to as overlap operation and is intended to minimize postdialing delays where the originating office is direct progressive controlled, e.g., step-by-step (SXS) switching system.

Having indicated the general coding arrangements for several signals in both the CCIS and CCITT No. 6 systems, it will be interesting to trace the complete setting up and disconnection of a telephone connection using common channel signaling. Since the two systems are similar the description will be limited to the CCIS system.

Before detailing a complete call, another feature of CCIS and CCITT No. 6 should be mentioned. In conventional inband signaling systems where signaling takes place on the same transmission path as that to be used by the involved customers for speech, etc., the continuity of the path is assured by the fact that the signaling information was successfully transmitted and the call established. In common channel signaling systems the path to be set up for the customer's use carries no signaling information and it is, therefore, possible to complete the signaling procedures and not have an acceptable transmission path established. To prevent such an occurrence a continuity check of the speech path is performed on every call to be set up. If the switches are 4-wire, the procedure calls for applying a 2010-Hz tone to the transmit speech path and to have the terminating office loop back the tone to the originating office on the return speech path. If either one of the switches is 2-wire, a different frequency must be used for each direction of transmission. In this

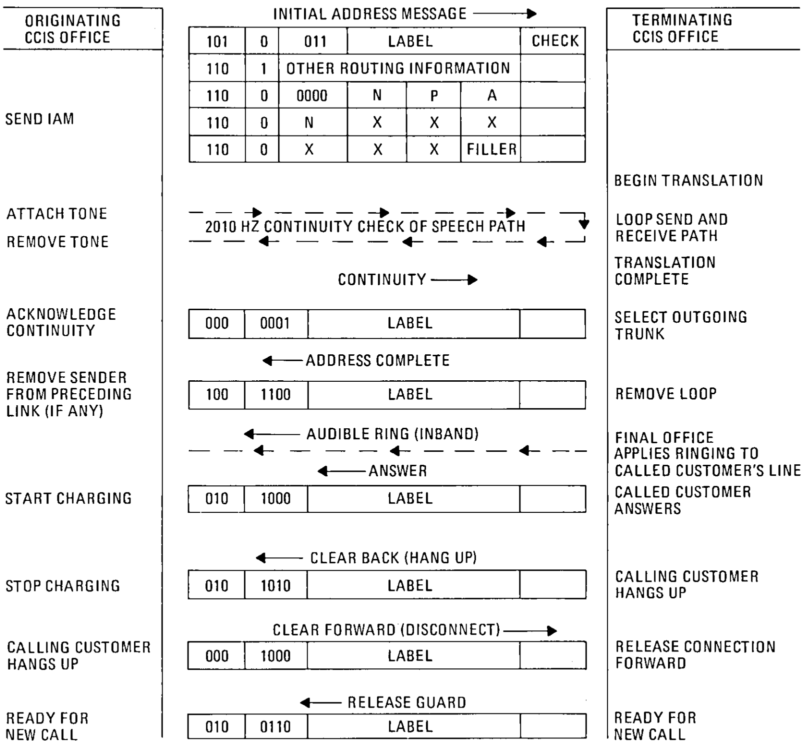

Fig. 13—CCIS signaling for a 10-digit call.

case the terminating office connects a transceiver instead of a loop, which on receipt of tone in the forward direction returns the complementary tone. The level of the returned tone is checked and if it is within certain limits the continuity of the send and receive speech paths is confirmed. The continuity check is made in parallel with the call setup so no delay is experienced.

In tracing a CCIS controlled call, a 10-digit (NPA-NXX-XXXX) call requiring expanded routing information will be assumed. The latter information could indicate that a satellite link had already been included in the connection and that no further satellite links should be used, that echo suppressors are involved, or that the calling customer has a special category indicator associated with his line.

The originating switching office selects an outgoing trunk and formats the initial address message to include the trunk label, the routing information and the address information of the called customer. Figure 13 indicates that the IAM will require five signal units to convey the necessary information. The heading code 1, 0, 1 in the first signal unit indicates that it is an initial signal unit and the fourth bit, 0, indicates that it is an initial address message. The next three bits, 0, 1, 1 convey the information that there are four subsequent signal units included in the IAM. The next 13 bits indicate the band and trunk number of the speech path to be set up. The remaining signal units in the IAM are identified as subsequent signal units by the heading code 1, 1, 0. The fourth bit in the first subsequent signal unit indicates that the next 16 bits are coded to convey expanded routing information. The remaining subsequent signal units convey the called customers address.

Immediately following the transmission of the IAM, the originating office applies a 2010-Hz tone to the transmit path of the speech path being established. The terminating office, upon receipt of the IAM, determines what trunk is involved and applies a loop to the send and receive paths of the speech path, returning the 2010-Hz tone to the originating office. The level of the returned tone is checked and, if it is within established bounds, the tone is removed and a continuity signal is transmitted to the terminating office. If the final terminating office in the connection is satisfied that the received address information is complete, has received the continuity signal from the preceding office, has verified local crossoffice continuity, and is satisfied that no further CCIS called-party condition signals need be sent, it removes the continuity check loop from the incoming trunk and transmits an address-complete signal which is repeated back to the originating office.

When the final office applies ringing power to the customer's line an audible ringing tone is returned to the calling customer over the speech path. When the called customer answers, ringing is removed and an answer signal is returned to the originating office where charging for the call is initiated. At the conclusion of the call, assuming that the called customer hangs up first, a clear-back (hang-up) signal is transmitted to the originating office, which initiates a clear-forward (disconnect) signal, after the elapse of a disconnect timing interval, if the calling customer is slow in hanging up. Reception of the clear-forward signal will be acknowledged by the transmission of a release-guard signal. This latter signal is a positive indication that the trunk is ready to serve the next call. If the calling customer hangs up first a clear-forward (disconnect) signal is sent to the terminating office which responds with a release-guard signal. Either of the last two sequences will stop the charging for the call. It should be noted that all of the lone signal units conveying continuity, address-complete, answer, clear-back, clear-forward, and release-guard information include the label or trunk identification data.

Should it be impossible to complete a call setup due to called customer line busy, vacant number, trunk congestion, etc., an appropriate lone signal unit conveying such information is returned to the originating office in place of the address complete signal. The reception of such a

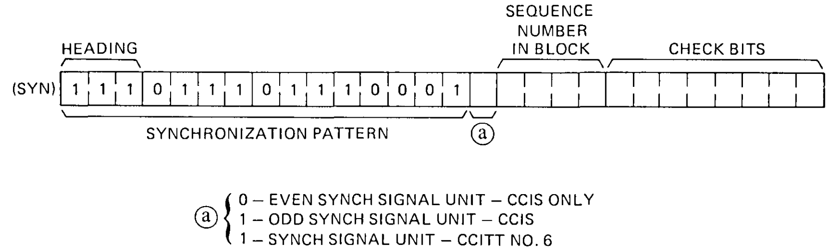

Fig. 14—Synchronization signal unit.

signal will make it possible to apply the usual busy audible tone at the CCIS-equipped office closest to the calling customer and not at the terminating office experiencing the busy condition. This will make it possible to break down the connection immediately, making it available for use by others instead of waiting for the calling customer to hang up after an interval of listening to the busy tone.

In addition to the many call-related signals, of which only a few have been referred to in the preceding descriptions, both CCIS and CCITT No. 6 systems provide a multiplicity of signals involving signaling system control, network maintenance signals, management signals, and other special signals or messages.

Signaling system control signals are related to the signaling link and not to telephone signal information. Among the signals included in this category are the acknowledgment signal unit (see Fig. 5), two synchronization signal units for CCIS and one for CCITT No. 6 (see Fig. 14), and a group of signals providing for load transfers, link changeovers in case of link failures, etc.

In CCIS the two synchronization signals (odd and even) are used in opposite directions of transmission and are a ready means for detecting faulty loop-around conditions on the signaling link. Reception of the same synchronization signal as that being transmitted indicates a fault condition. Additionally the odd and even synchronization signals are used to designate the controlling terminal of the CCIS signaling link. Synchronization signal units are transmitted whenever there is no signaling information being forwarded, with the exception of the twelfth signal unit in the block which is always an acknowledgment signal unit.

The controlling office is one that proceeds with a call if a dual seizure of the trunk is detected while the noncontrolling office withdraws and places the attempted call on another trunk.

Network maintenance signals provide for trunk group blocked and unblocked states, indicators for trunk busy-active, locked out or disabled, blocked and locked out, etc.

Table V — Signal transmit priority structure

Priority	Signal
1	ACUs (12th position in every block)
2	Faulty signaling link information
3	Retransmitted answer signals
4	Initial answer signals
5	Retransmitted telephone signals
6	Telephone signals
7	Retransmitted management signals
8	Management signals
9	SYUs

Network management signals provide for enabling or removal of dynamic overload controls of several levels dependent on the seriousness of the network overload status.

It becomes obvious that the number and classes of signals that CCIS can accommodate requires that a system of signal priorities be established. This becomes even more important as long-range planning proceeds on how to best utilize excess CCIS signaling capacity to transmit other types of information. Additionally, during the transition period from conventional to CCIS systems, consideration must be given to the interworking of such systems when two or more trunks are involved in a connection. As an example, the characteristic of inband supervisory signaling systems that opens the speech path toward the customer whenever signal information is being transmitted, can cause clipping of the called customer's response upon answer of a call if there is excessive delay in returning the "answer signal" to the originating office. As CCIS becomes widely applied this problem is eliminated since all signaling is then independent of the involved speech paths. Table V lists in order of priority the treatment of various signal classes.

If, in the future, signals other than those noted in Table V are transmitted over CCIS links, it might become necessary to break into multiunit messages to transmit any of the signals with priority levels 1 through 8. SYUs can always be deferred as long as any information-carrying signals are awaiting transmission.

VII. SYSTEM CHARACTERISTICS

The following applies equally as well to the CCIS and CCITT No. 6 signaling systems.

7.1 Service dependability

Error rate performance criteria have been established which experience to date has indicated are readily achievable. They include bit error rate: 1 in 10^5, signal unit error rate: 1 in 10^4, undetected signal unit error rate*: 1 in 10^8, and serious undetected signal error rate*: 1 in 10^{10}.

Further, interruption to the signaling service, i.e., including both regular and reserve links, of a duration 2 seconds to 2 minutes should not occur more than once a year. Interruption lasting more than 2 minutes should not occur more than once in 10 years. All of the above criteria were established by the CCITT and adopted as goals for CCIS. Only experience, yet to be gained, will determine if these objectives are achievable. Since achieving the objectives is to a large extent dependent on the types of facilities assigned as signaling links special attention is given to facility selection to assure both transmission quality and diversity. Precautions have also been taken to ensure that the terminal equipment design will not significantly contribute to the overall error or interruption rates.

7.2 Error control

The eight check bits included in every signal unit are provided to detect errors resulting during the transmission of the signal units. Coders and decoders are provided at transmitting and receiving terminals. The coder generates an 8-bit check code on the basis of the polynomial $P(X) = X^8 + X^2 + X + 1$. The code name is "Primitive Polynomial Plus Parity Check" and the code detects all 1-, 2-, 3-bit errors in a word with a minimum distance of 4; all odd number (1, 3, 5, 7, . . . , 27) bit errors in a word; all error bursts of length ≤ 8 bits in a word, where the burst is the number of bits between and including the first and last bits in error in a 28 bit word. The code also detects 127/128 or 99.22 percent of error bursts equal to 9 and 255/256 or 99.61 percent of error bursts ≥ 10 bits.

As mentioned earlier, if an error is detected in a signal unit, the next transmitted acknowledgment signal unit (ACU) conveys that information to the originating terminal so that the affected message can be retransmitted. As indicated in Table V retransmitted signal units have priority over signal units of the same type.

Supplementing the use of check bits in each signal unit is a data carrier failure or loss of frame alignment detector.

7.3 Reasonableness check tables

In the resolution of ambiguous situations as may occur from inappropriate signal content, incorrect signal direction or inappropriate placement in the signal sequence, special procedures are employed to

* The distinction between these two error-rate criteria is illustrated by an error which in the first case causes a false operation, e.g., false clear-back signal, as contrasted to an error which causes false charging or false clearing of a connection.

compare signals to reasonableness check tables. These procedures assist the signaling system in resolving ambiguities. For example if an incoming office receives an incorrect sequence of signaling messages during a call setup it may send a "confusion signal" to the preceding office. That office will then reattempt the call.

7.4 Signal channel loading

The economics of common channel signaling are dependent on the number of trunks that can be served by the system. CCIS "A" links can provide signaling for up to 1500 trunks under normal operating conditions and up to 3000 trunks under emergency conditions. The number of trunks may be increased (or decreased) depending on the characteristics of the traffic, e.g., total occupancy and peakedness. Engineering of signal channel loading can lead to adjustments as traffic measurements indicate to be desirable.

7.5 Security arrangements

Since a common signaling link carries signals for many trunks it is imperative that arrangements be provided to ensure continuity of service in case of a signaling link failure. Referring to Fig. 2 it can be noted that the signaling network is highly redundant in that each user office has an "A" link to each of the two STPs in its regional area and further that each "A" link is provided with a back-up facility.

In CCIS, the two "A" links are operated on a load-sharing basis with each link carrying half of the traffic. Each link is, however, capable of carrying the full traffic load upon failure of its mate "A" link. Spare back-up "A" links are also furnished and can be switched in to carry the failed "A" link's traffic until the failed "A" link is restored to operation. Note also that failure of the "A" link and its back-up facility to the same STP is protected against by transfer of the traffic loads to the "A" link to the second STP in the region.

In the case of the signaling quad, "B" link failures can successively transfer their loads to the remaining "B" links, finally placing all the traffic on a single "B" link. Such a failure situation is considered remote, but protection is furnished to maintain signaling continuity, although with impaired service. Engineering of "B" links provides for 1500 trunks per link with failure of three "B" links placing signaling for 6,000 trunks on the remaining "B" link.

VIII. SUMMARY

The introduction of common channel interoffice signaling (CCIS) into the DDD network and the CCITT No. 6 signaling system into the international telephone network will provide a very significant improvement in signaling system performance, which in turn will impact telephone systems in many ways. Not only will telephone calls be set up more rapidly due to the inherent speed of the signaling systems but the vastly expanded signal capacity of the systems will permit improved control of the telephone networks and provide opportunities to offer new customer services requiring new classes of signal information.

The significance of more rapid call setup time can be illustrated by comparing the time to set up a connection between two end offices over two toll connecting trunks and one intertoll trunk. Such a connection represents about 85 percent of the toll call traffic. Assuming present-day electromechanical switching offices and in-band single-frequency supervisory signaling together with multifrequency inter-register signaling, a connection can be set up in about 10 seconds. With CCIS providing the signaling function and with electronic switching offices, the call set-up time will be in the order of 1–2 seconds. The most significant portion of this improvement is due to the use of CCIS in place of present-day conventional signaling methods. This time may be still further improved by increasing the speed of the signaling links even more, although switching office handling time rapidly becomes a limiting factor.

An important aspect of CCIS is the complete separation of trunk control and communication channel functions. Fraudulent manipulation of the telephone network is eliminated in an all CCIS environment. Further, the entire frequency spectrum of the communication channel assigned to a connection is available to the customer without restriction as opposed to present restrictions made necessary by inband signaling equipment. In addition, false disconnects or talk-offs resulting from customer speech characteristics are eliminated.

Although present CCIS implementation is directed at the intertoll portion of the DDD network, it is obvious that the extension of CCIS to the toll connecting area (class 4 to class 5) is essential to the overall plan to secure the advantages of CCIS for the complete DDD network. Many of the features of CCIS rely on customer-generated and customer-used signals to implement an expanded number of new customer services.

Finally, present-day signaling systems are reaching the end of their capability to cope with the signaling requirements of sophisticated communication networks. CCIS and CCITT No. 6 signaling systems have arrived on the scene at an appropriate time in the new communications era and their impact on the overall performance of telephone networks and new customer service offerings will be dramatic. In fact, a giant step forward in the total telephone art is being achieved by the introduction of common channel signaling on a worldwide basis.

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Common Channel Interoffice Signaling:

Implementation Planning

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To introduce Common Channel Interoffice Signaling (CCIS) into the toll network as rapidly and economically as possible, a great deal of planning had to be done. An analysis was performed to determine which 4A-ETS (Electronic Translation System) offices should be converted to CCIS and the order of this conversion. Practical feasibility constraints also had to be considered. This analysis was followed by coordination with AT&T and the operating companies which resulted in a plan to convert about thirty 4A-ETS switching offices per year to CCIS in 1977, 1978, and 1979. In addition, all No. 4 ESS offices are CCIS-equipped and No. 1(A) ESS will be CCIS-equipped by 1978. The result is that by 1980 more than a hundred toll offices will have CCIS capability.

I. INTRODUCTION

Common Channel Interoffice Signaling (CCIS) is being rapidly introduced throughout the toll network of the Bell System. At present, CCIS is part of every No. 4 ESS office, and many existing 4A crossbar offices with Electronic Translation System (ETS) are being converted to CCIS. In addition, CCIS is being developed for No. 1 ESS and No. 1A ESS toll switching offices, and development is under way to extend CCIS to Traffic Service Position Sytems (TSPS). Exploratory studies are also in progress to extend CCIS to No. 1 ESS and No. 1A ESS local switching offices and to No. 5 crossbar-ETS, No. 2 ESS, and No. 3 ESS as well as to *DIMENSION®* PBXs and other PBXs.

In addition to CCIS, another closely related signaling system, CCITT No. 6, is being developed for No. 4 ESS. This latter signaling system will be used exclusively for signaling for overseas calls. It will be available in 1978 and, over the next few years, will be introduced into the international switching centers, which will all be No. 4 ESS offices.

CCIS is based on the CCITT No. 6 signaling system, and hence there exists a great deal of similarity. Modifications have been made to make CCIS more flexible for domestic use and allow new capabilities and features to be introduced.

CCIS affects many systems and its introduction will take many years. The topic of this paper is the strategy employed in obtaining a near-optimal and practical CCIS implementation schedule.

II. PLANNING PHILOSOPHY

The advantages of CCIS can be realized only if a great deal of connectivity exists among CCIS-equipped switching offices. The savings associated with CCIS are to a large degree proportional to this connectivity as expressed in terms of the number of CCIS trunks in the network.

All No. 4 ESS systems come equipped with CCIS signaling capability. However, at the present time, the bulk of the Bell System toll traffic is handled by 4A crossbar systems and crossbar tandems. For any reasonable deployment of No. 4 ESS, it will be many years before No. 4 ESS handles a significant fraction of the toll traffic. It was therefore imperative to develop a strategy that converted a number of existing toll switching offices for CCIS. It is practical to provide CCIS capability only on processor-controlled switching systems. The 4A-ETS is processor controlled, but the crossbar tandem and the 4A crossbar card translator are not.

Initially, the planning objective was to maximize the net savings in switching equipment. These savings are due to new CCIS trunk circuits on the 4A ETS systems which are cheaper than the conventional SF/MF trunk circuits. Also, no in-band single frequency (SF) signaling sets (used to transmit and receive supervisory tones on analog carrier trunks) are required with CCIS. However, there are also considerable costs associated with modifying a 4A switching office for CCIS operation.

The type of office that would tend to be converted to maximize equipment savings would be a small office with large projected growth. Those offices that are at full capacity (exhaust) at the time of CCIS conversion will contribute little to direct switching equipment savings. This is because considerable costs will have to be incurred to modify existing trunk circuits for CCIS operation. These costs are only partially offset by savings that can be obtained from reusing SF sets. Consequently, few 4A offices at exhaust would have CCIS capability and there would be low CCIS connectivity in the network.

The potential economic benefit from features and services made possible by CCIS will eventually far outweigh the equipment savings directly attributable to this new form of signaling. The sensitivity of the direct switching equipment savings to different conversion schedules was found to be small. The sensitivity of connectivity, however, is considerably greater. Since savings related to CCIS features and services are directly related to connectivity, the CCIS schedule for 4A offices was based on maximizing connectivity subject to constraints on the number of offices that could be modified in any year, due to limitations in manufacturing and installation capability and capital availability.

III. PROBLEM FORMULATION AND SOLUTION

An algorithm was constructed in 1973 to select a predetermined number of 4A-ETS offices for conversion to CCIS each year, beginning in 1977, so that CCIS connectivity is maximized each year. The problem was formulated separately for each year, starting with the first, and the connectivity is maximized subject to a constraint on the number of modifications in that year. For the following year, it is assumed that the switching systems modified in the previous year remain CCIS and a new schedule developed for this year. The process is repeated until all CCIS candidate offices are modified for CCIS capability. This method effectively decouples the problem into a separate problem for each year.

It is necessary to define the notation for a specific year y in order to describe the mathematical formulation of the problem. For year y, let:

M_0 = the set of 4A-ETS offices that are candidates for CCIS conversion in year y.
M_0' = the set of all offices, not members of M_0, which are CCIS in year y. These include No. 4 ESS offices and 4A offices modified to CCIS in previous years.
T_0 = the set of trunk groups having both ends of the trunk groups in offices of the set M_0.
T_0' = the set of trunk groups having one end of the trunk group in an office from set M_0 and the other end in an office from set M_0'.
$T = T_0 \cup T_0'$ = the set of all candidate CCIS trunk groups.
T_m = the set of trunk groups $t \in T_0$ that have one end of the trunk group in office m.
T_m' = the set of trunk groups $t \in T_0'$ that have one end of the trunk group in office m.
M_t = the set of offices $m \in M_0$ at the ends of trunk group t.

$$x_t = \begin{cases} 1 \text{ if trunk group } t \text{ is CCIS} \\ 0 \text{ if trunk group t is conventional (non-CCIS)} \end{cases}$$

$$z_m = \begin{cases} 1 \text{ if office } m \text{ is CCIS} \\ 0 \text{ if office } m \text{ is conventional} \end{cases}$$

p_t = the number of trunks in trunk group t.
n^y = the number of 4A-ETS offices to be modified in year y.

Ignoring for the moment the integrality requirements, the problem can be formulated as the linear program:

$$\text{(A)}\quad \begin{cases} \text{Maximize } \sum_{t \epsilon T} p_t x_t \\ \text{subject to the following sets of constraints:} \\ (i)\ x_t - z_m \le 0 \text{ for each } t \epsilon T, \text{ each } m \epsilon M_t \\ (ii)\ \sum_{m \epsilon M_0} z_m \le n^y \\ (iii)\quad z_m \le 1 \text{ for each } m \epsilon M_0 \\ (iv)\quad z_m \ge 0 \text{ for each } m \epsilon M_0 \end{cases}$$

If we let $f(n^y)$ be the maximum value of the objective function as a function of n^y, it is easy to show that $f(n^y)$ is a concave function of n^y. In fact, the variation of $f(n^y)$ with n^y will be given by a plot like one of those shown in Fig. 1.

The sheer size of the problem in terms of the number of constraints involved necessitates a method other than the simplex method. One method of solving this problem is by using a Lagrange multiplier for constraint (ii). The formulation of the problem using Lagrange multipliers is then:

$$\text{(B)}\quad \begin{cases} \text{Maximize } \left[\sum_{t \epsilon T} p_t x_t - \lambda_1 \cdot \sum_{m \epsilon M_0} z_m \right] \\ \text{subject to the sets of constraints:} \\ (i)\quad x_t - z_m \le 0 \text{ for each } t \epsilon T,\ m \epsilon M_t \\ (ii)\quad z_m \le 1 \text{ for each } m \epsilon M_0 \\ (iii)\quad z_m \ge 0 \text{ for each } m \epsilon M_0 \end{cases}$$

Of course, the value of λ_1 used will have to be chosen such that

$$\sum_{m \epsilon M_0} z_m = n^y$$

[Even though constraint (ii) in formulation (A) is an inequality, the equality will always hold in the optimum solution.]

It can be proved that formulation (B) of the linear program is the dual formulation of a problem of maximizing the flow through a network.[1] A computerized algorithm similar to the one described in Ref. 2 was developed to determine rapidly the maximized flow for the dual problem and thereby obtain the solution of the primal problem (B). The primal is a problem of determining the minimum cut of the network. This solution for any value of λ_1 will therefore always be integer valued.[2] At the nonextreme points of the function $f(n^y)$, the value of λ_1 has to be equal to the slope of the function at that point. The interpretation of λ_1 is discussed in more detail later in this section. However, the solution technique described will only pick up, for each value of λ_1, the extreme points of the constraint set defined in formulation (B). The solution to the linear program (A) for a specific value of n^y that is not an extreme point of (B) has to be obtained by taking a convex combination of the two extreme points of (B) around n^y. However, this will give rise to noninteger solutions to the original problem and these, of course, are not acceptable.

To determine an integer solution to the problem, we have to generate cuts to the constraint set by means of new constraints which do not eliminate any of the original integer solutions to formulation (A) of the problem. However, before we proceed to attempt this, let us look at the nature of the solutions to the problem for different values of n^y.

In the final solution of the linear programming problem represented by formulation (A) or formulation (B), the value of $\sum_{t \epsilon T} x_t$ is strictly increasing for increasing values of n^y. This particular fact suggests an interesting method of generating an integer cut. If the solution of the problem with formulation (B) results in a noninteger solution, introduce a constraint of the form $\sum_{t \epsilon T} x_t \leq k$, but only integer values of k need to be considered. If a solution to formulation (B) yields a solution for a particular value of n^y which results in a noninteger value of $\sum_{t \epsilon T} x_t$, then it is clear that the value of k that should be considered is the largest integer less than $\sum_{t \epsilon T} x_t$. However, this results in the same kind of problem as that with constraints on the number of offices that can be converted to CCIS. This constraint will therefore have to be considered by introducing another Lagrange multiplier λ_2. This results in another formulation of the problem:

$$
\text{(C)} \quad \left\{ \begin{array}{lll} \text{Maximize} \displaystyle\sum_{t \epsilon T} (p_t + \lambda_2) x_t - \lambda_1 \cdot \sum_{m \epsilon M_0} z_m & & \\ \quad \text{subject to the constraint sets:} & & \\ (i) & x_t - z_m \leq 0, \ t \ \epsilon \ T, \ m \ \epsilon \ M_t & \\ (ii) & z_m \leq 1 \ m \ \epsilon \ M_0 & \\ (iii) & z_m \geq 0 \ m \ \epsilon \ M_0 & \end{array} \right.
$$

It is interesting to note that the value of k does not appear explicitly anywhere in the formulation. As a matter of fact, it is not even necessary to know what value of k is being considered. The only consideration should be to keep λ_2 as close to 0 as possible.

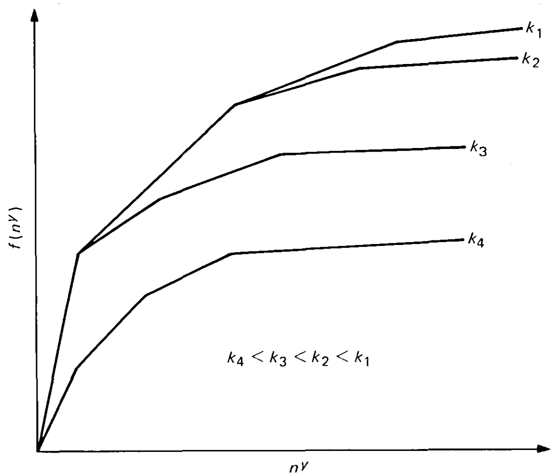

Fig. 1—Linear programming optimal value $[f(n^y)]$ as a function of the number of CCIS office conversions n^y and trunk group conversions k.

The effect of changing the value of k is shown in Fig. 1. Reducing the value of k lowers the maximum CCIS connectivity as indicated. Let us see the effects of changes in the values of λ_1 and λ_2. The objective function represents a plane which for a value of λ_2 equal to 0 is perpendicular to the plane of the paper. The different curves representing different values of k are the projections, on the plane of the paper (the third dimension, perpendicular to the plane of the paper, represents the value of k), of the section of the surface for that value of k. With λ_2 equal to 0, increasing the value of λ_1 amounts to rotating, in an anticlockwise direction, the objective function plane about an axis perpendicular to the surface of the paper. The solution that is obtained for a particular value of λ_1 is the extreme point of the surface at which the objective function plane is supported. Decreasing the value of λ_2 rotates the objective function plane about a horizontal axis in the plane of the paper. (Only negative values of λ_2 should be considered.) By rotating the plane about this axis, new extreme points are available at which it can be supported. At the nonextreme points of the surface, the objective function plane is supported by an edge of the surface. For a given value of λ_2, the value of λ_1 is equal to the slope of the projection of the surface on a plane parallel to the surface of the paper.

However, this method is not exact. Examples can be constructed to show that this method does not always work. In some cases, there does not exist a value of λ_2 such that the integer cut generated does not exclude the optimal solution.

The question naturally arises as to how good this approximation is. One way of judging the "goodness" of this method is to compare it with the linear programming solution for formulation A. It should be noted that the best solution that this method will give is obtained with the smallest value of λ_2 that gives an integer solution. It has been our experience that, except for the first 1 or 2 years, the linear programming solution and the integer solution coincide. Even for the years where they did not coincide, the integer solution has at most only 15 percent fewer trunks than the linear programming solution. For all practical purposes, therefore, the solution was as close to the optimal as one could expect.

A constraint of 30 4A-ETS conversions per year (n^y) was imposed on the solution as a result of Western Electric manufacturing and installation loads and Bell System capital constraints. Within this limit, a trial schedule was determined by the above algorithm, and modifications to the schedule were made by the operating companies, coordinated by AT&T, according to more detailed information about each candidate machine. Since the objective function is fairly flat in the region of the optimal solution the modifications did not significantly affect the connectivity. Finally, a Bell System-wide schedule was agreed to for each year, beginning in 1977, with approximately 30 machines to be converted each year.

IV. PRESENT IMPLEMENTATION PLANS

The first two offices to use CCIS for signaling communication were the Chicago 7 No. 4 ESS, installed in January 1976, and the Madison 4A-ETS, installed in May 1976. Madison was the last new 4A-ETS switch to be installed in the Bell System. Later in 1976, No. 4 ESS switching offices in Kansas City; Jacksonville, Florida; and Dallas were installed with CCIS capability, and the 4A-ETS in Waukesha, Wisconsin, was converted to CCIS operation. Figure 2 shows the switching offices deployed at the end of 1976.

Early in 1976, before the Chicago 7 and Madison offices could communicate via CCIS, the first two pairs of signal transfer points (STPs) were put into operation in Indianapolis, Omaha, Dallas, and Oklahoma City. These STPs, described in another article,[3] consist of the processors from 4A-ETS switching offices that will not be converted to handle CCIS trunks. Generally, these locations were chosen from among those scheduled for early replacement by No. 4 ESSs. By the end of 1977 the remaining 16 STPs were cut over so that each of ten switching regions into which the continental United States is divided now has two STPs to which the switching offices will be connected, as shown in Fig. 3. In 1977, 27 4A-ETS switching offices were converted to CCIS operation, and eight new No. 4 ESSs were installed. By year-end 1979, plans call for about 70 converted 4A-ETS offices and 32 No. 4 ESS offices. The offices will be located approximately as shown in Fig. 4. Also, by year-end 1979, many No. 1 ESS

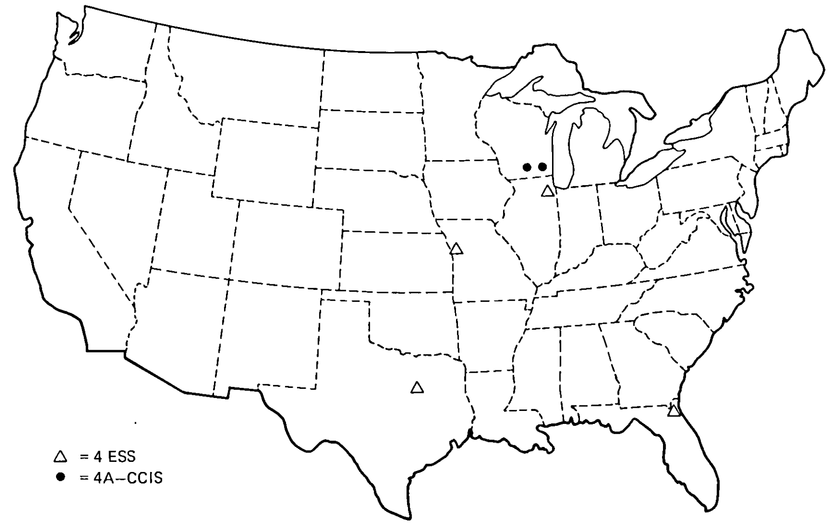

Fig. 2—Deployment of CCIS switching offices by year-end 1976.

toll offices are expected to have CCIS capability. (The first No. 1 ESS toll office with CCIS will be cutover in 1978.)

The number of trunks that will use CCIS for call control grows along with the number of switching offices that are deployed. The offices at both ends of each trunk group must be capable of CCIS before that trunk

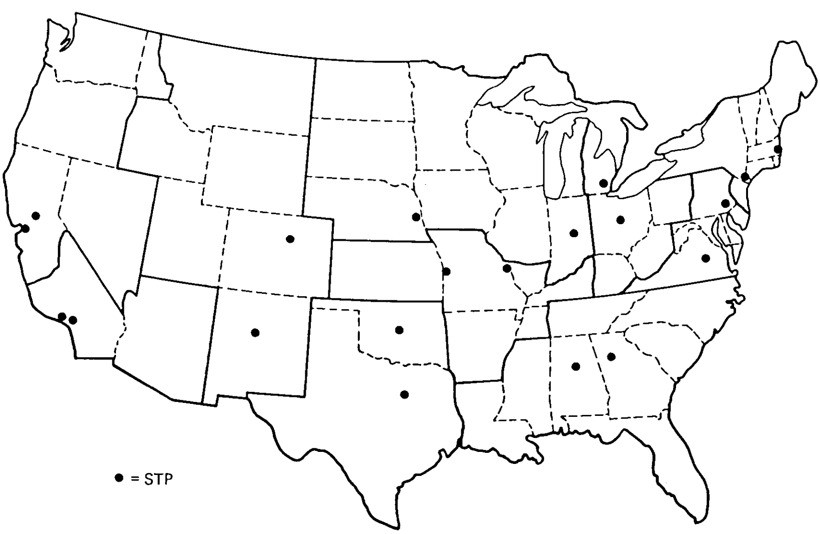

Fig. 3—Location of signal transfer points (STPs), showing a pair in each switching region.

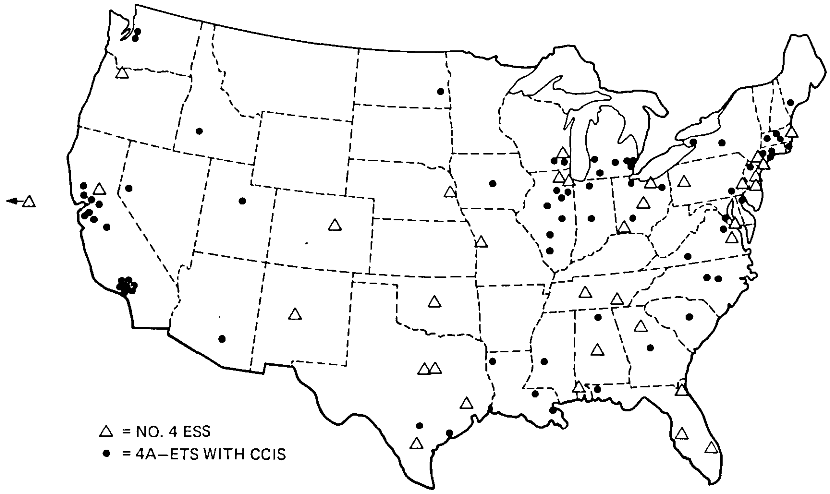

Fig. 4—Expected deployment of CCIS switching offices by year-end 1979.

group can signal in this new manner. There is thus a "squaring" effect in the number of CCIS trunks as a function of the number of offices. This is illustrated in Fig. 5.

V. LOCAL CCIS AND TRAFFIC SERVICE POSITION SYSTEMS

Most of the proposed customer services made possible by CCIS (such as certain forms of automation of collect calls and credit card calls) require some means of providing a direct interface between the telephone customer and the CCIS network. This interface will come about in two forms, by equipping TSPS with CCIS and by equipping local switching offices with CCIS. Studies are in progress on how to best equip local No.

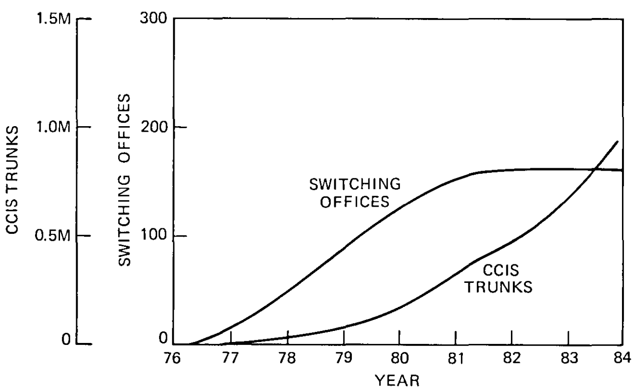

Fig. 5—Planned CCIS-equipped switching offices and trunks by year.

1 ESS and No. 1A ESS switching offices with CCIS. In addition, exploratory studies are being made to examine the feasibility of equipping No. 2 ESS, No. 3 ESS, and No. 5 crossbar-ETS offices with CCIS or a similar improved signaling method. An enhanced signaling system may also be implemented for *DIMENSION* PBXs and other PBXs. All of this would allow new customer services to be offered to most business and residential customers. For customers not served by CCIS-equipped local offices, access to the CCIS network can be made through the Traffic Service Position System (TSPS). This is the system that presently allows many customers to dial the called number for collect, credit card and other operator-assisted special billing calls after dialing 0. Almost 90 percent of Bell System customer lines will have access to TSPS by the early 1980s. CCIS capability is planned for TSPS about 1980.

VI. ECONOMICS OF THE BASIC CCIS SYSTEM

From the above discussion, we can see that the basic CCIS system will be well established by 1980, ready for the implementation of a wide variety of customer services, and cost-reducing network features. It is these services and features that will eventually bear the real economic fruits of CCIS, but at what cost was this flexible basic system established? In fact, the establishment of basic CCIS capability in the toll network results in overall system savings. Although there are significant costs associated with the conversion of each 4A-ETS switching office to CCIS operation, and with the construction of the signaling network itself, there are equipment savings in all toll offices due mainly to the elimination of the supervisory single-frequency detectors and transmitters that must be connected to each end of every analog carrier trunk using conventional (non-CCIS) signaling. By 1980, these and other CCIS equipment savings will begin to far outweigh the costs of establishing CCIS. In fact, in many cases, it has been shown to be economical to convert certain 4A-ETS switches to CCIS operation even though those machines are planned to be replaced by No. 4 ESS within 2 or 3 years from the conversion date. These robust economics have allowed plans to progress for CCIS despite national inflationary and recessionary trends and changing plans for the speed of deployment of No. 4 ESS (and consequent replacement of many 4A-ETS offices). Nevertheless, the big payoff is yet to come, in terms of economics as well as improved, more modern telephone service.

VII. CONCLUSION

CCIS is a major technical revolution in the telephone business, and the plans for implementation are ambitious. By 1980, the CCIS network will be in place ready to serve as a flexible medium for transfer of information among switching machines and other elements of the Bell System communication network. New services, defined by customer needs, will then be more easily implemented. And all of this will have been accomplished at a net capital savings for the Bell System.

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Common Channel Interoffice Signaling:

Signaling Network

By P. R. MILLER and R. E. WALLACE

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The CCIS signaling network provides an efficient, reliable signaling capability for calls between CCIS-equipped switching offices. This article contains a description of the signaling network and the Signal Transfer Points. The discussion highlights the normal signaling message routing as well as the reaction to system failures.

I. NETWORK DESCRIPTION

1.1 General

The CCIS signaling network provides an efficient, reliable common channel signaling capability for all intertoll message circuits between CCIS-equipped switching offices. In order to provide cost-effective signaling for small, as well as large, trunk groups, the nonassociated mode of signaling[1] is used as the primary signaling mode. The system also has the capability for associated signaling in situations when trunk groups of sufficient size exist. The reliability of the signaling network is provided by redundancy in both signaling links and Signal Transfer Points (STPs). This redundancy is utilized by automatic routines at the network nodes which alter the routing of signaling information in order to bypass network failures.

1.2 Network configuration

The signaling network is composed of 20 STPs, two in each of the ten DDD regions, and signaling links interconnecting STPs and switching offices. The STPs in each region are redundant, in that each has the capacity to serve the entire region in the event of the mate STP failure. In the normal situation, signaling traffic is routed in such a manner as to balance the load carried by each STP in a region. Figure 1 shows two regions and the signaling links between various nodes. Signaling links

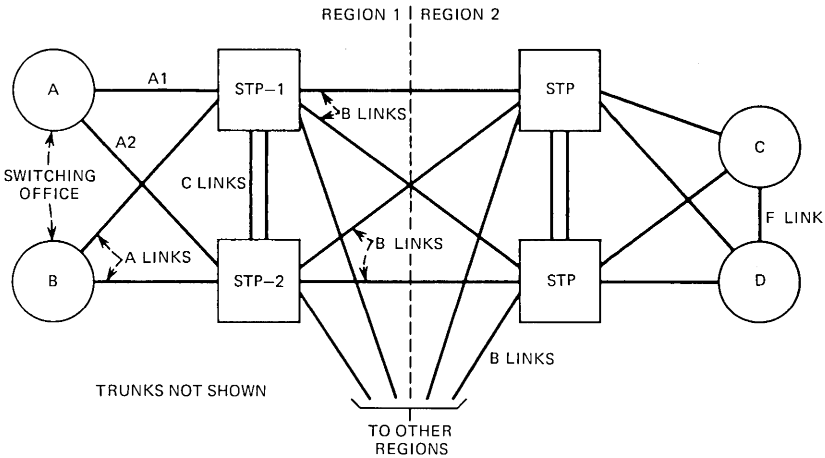


Fig. 1—CCIS signaling network.

which connect switching offices to the STP pair in the same region are called A-links. A-links are always provided in pairs, one link to each STP. The STPs in a given region are fully interconnected to the STPs in all other regions using signaling links designated as B-links. These links are always provided in groups of four, commonly referred to as a quad, between any two regions. Groups of signaling links, such as A-link pairs and quads which provide redundant signaling paths, are referred to as link complements. Under normal conditions the traffic load is evenly distributed over each link of a complement. Signaling links between the two STPs in a region are referred to as C-links. C-links do not carry signaling traffic under normal conditions but provide a signaling path during failure situations. Hence, the number of C-links provided is proportional to the total number of A-links. All of the C-links between two mate STPs are members of one link complement. In contrast to the nonassociated network, the signaling path between switching office C and office D in Fig. 1, referred to as an F-link, is an example of a link used in the associated signaling mode.

All signaling links are composed of a terminal and modem at each end connected by a Voice Frequency Link (VFL) as described in Ref. 1. A-links have the additional ability to operate with redundant VFLs. Figure 2 shows an A-link with duplicated VFLs, as well as the VFL test access features located at the STP.

1.3 Normal telephone message routing

Telephone signaling messages originate at a switching office and are routed through the signaling network, terminating at a distant switching office. The originating office usually begins this process with the identity

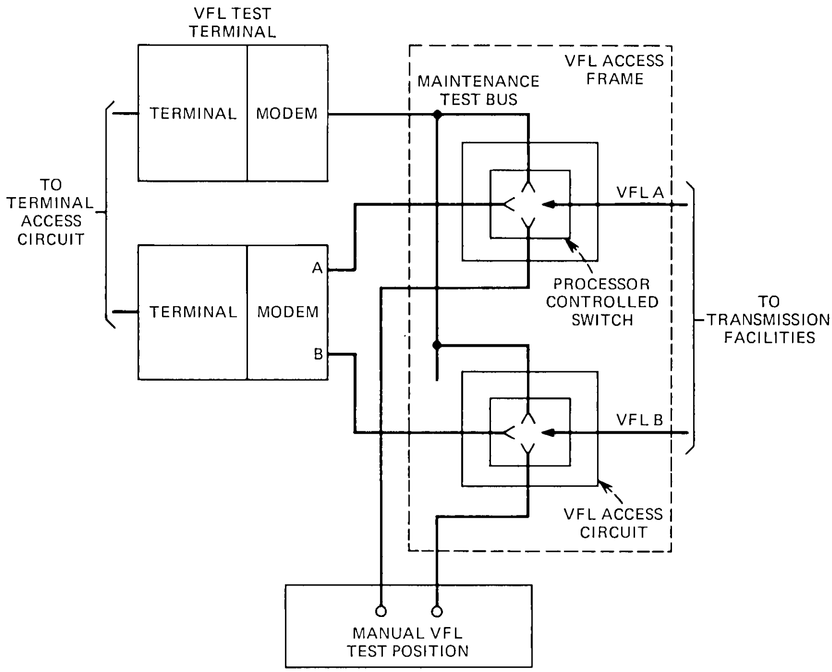


Fig. 2—STP VFL arrangement and dual VFL configuration.

of a specific trunk. This trunk identity is translated to a signaling link number and a label, the combination of which is uniquely assigned to the trunk. Messages pertaining to that trunk, composed of the label, message type, and possibly data, are transmitted to the STP over the designated link complement. The STP, however, does not use the entire trunk identity, since messages for trunks in the same trunk group have similar message routing. Instead the STP examines only a portion of the label, along with the incoming signaling link number, to determine the destination of the message. This portion of the label is called a band and consists of 16 consecutive labels. Trunk groups which consist of more than 16 trunks have additional bands assigned.

The STP, upon receipt of a telephone message, converts the incoming link number and incoming band to an outgoing link complement number and outgoing band by means of routing data stored at the STP. The message is then transmitted with the outgoing band number replacing the original band number on the outgoing link complement. The outgoing link may terminate at another STP (interregional trunk group) or at the terminating switching office (intraregional trunk group). In either case, when the message arrives at the terminating switching office, having traversed, under normal circumstances, no more than two STPs, the incoming signaling link complement and label are translated to the specific trunk. At each node in the network the translation data are constructed to balance the traffic load between all links of a link complement and hence between each STP in a region.

Nontelephone messages do not contain labels and are processed at the receiving node. These messages are used for control, administration, and maintenance of the signaling network.

1.4 Network reaction to failures

The signaling links have two major failure symptoms. First, normal component failures occur, with mean times between occurrences measured in years and requiring manual repair activities. The repair interval is normally of a few hours or less in duration. Second, the VFL exhibits periods of high error rates caused by hits, fades, or other random phenomenon on the transmission facility. High error rates for short periods are processed by the error control mechanisms in the terminal as described in Ref. 1. If the duration of these periods is sufficiently long, (approximately ⅓ of a second or greater), the signaling link is considered as possibly faulty and the signaling traffic temporarily rerouted. If the excessive error rate period persists for 3 minutes or greater a component failure is assumed and the network is reconfigured as explained below. Typically the time between VFL short interrupts is measured in fractions of a day and the duration of the interrupts is measured in seconds. Hence the network failure characteristics are summarized as short interrupts requiring no manual repair which occur orders of magnitude more frequently than component failures.

As an example, assume link A1 in Fig. 1 fails because of an excessive error rate. The failure would be recognized at both switching office A and STP-1. Office A would immediately send all traffic normally routed over link A1 to link A2. STP-1 would send all incoming signaling traffic destined for office A to STP-2 over the C-link complement. When telephone traffic is routed over a C link, an additional signal unit, called a header, is prefixed to the message. STP-2 would then route this traffic, using the information transmitted in the header, to office A over link A2. The terminals at both ends of link A1 would attempt to restore normal operation. If the link is restored within 3 minutes, the normal routing pattern is reestablished automatically and hence no alarms or other immediate notification are provided to the office personnel. Statistics on all failures are kept and reported periodically.

If the failure condition persists for longer than 3 minutes a component failure requiring repair is assumed to have occurred. When 3 minutes of outage has been recorded the terminals at both ends of the failed link are automatically removed from service, accompanied by the appropriate audible and visual alarms, and examined for faulty components. At this time the network configuration is changed to provide optimal routing for the particular situation. In the example above, where link A1 is failed, STP-1 would notify the STPs in the other regions and all switching offices in the same region which route traffic to office A. This notification is in the form of special signal units, called Transfer Restrict (TFR) and Transfer Prohibit (TFP) messages, which are sent for each affected band. When notified, the STPs and switching offices send all traffic, which would normally traverse link A1, directly to STP-2, which then sends the traffic to office A on link A2. Thus, by configuring the traffic pattern for the affected bands to avoid C-links, signal unit delay is decreased and C-link capacity is reserved for short link interruptions. All other traffic to STP-1 would not be affected. This configuration would remain until link A1 is repaired and restored to service at which time the normal traffic pattern would be automatically restored. The algorithms at each node in the network are designed to handle all combinations of single and multiple link failures in order to route traffic as long as a signaling path exists. In the rare event that no signaling paths exist, the affected message trunks are automatically prevented from accepting new calls. These trunks would be immediately restored as soon as a signaling path is reestablished.

The network is also protected against an STP failure. In this event, each terminal at the failed STP autonomously notifies the distant end of the signal link. When notified, the STP in the distant regions, as well as all switching offices in the affected region, will immediately route all signaling traffic to the remaining STP.

Similar network reconfigurations take place whenever a signaling link is removed from service manually for facility rearrangement or other reasons. Manual removal always requires permission from the processors at both ends of the link. Permission granted implies that the network has been reconfigured to avoid this signaling link with no loss of signaling capability.

II. STP DESCRIPTION

The STP basically performs a message routing function and can be characterized as having a large number of signaling link terminations, a high volume of messages and the need for a large routing data base. The STP does not directly perform call processing functions and does not require connection to trunks. It is an independent function which, though intimately related to efficient operation of the toll network, is not directly associated with a toll switching machine. The initial STP has been developed for application in 4A/ETS offices which are not candidates for conversion to CCIS switching office operation. In this configuration the STP is intended to utilize the spare SPC processor capacity for signal unit processing and the Peripheral Bus Computer (PBC) for traffic measurements and data administration. This arrangement has facilitated early introduction of the CCIS network. It is expected that the current STP will evolve into higher capacity configurations as the volume of signaling and other feature traffic increases.

2.1 Hardware organization and maintenance

2.1.1 General

Because of its functional independence the current STP configuration is designed to have a minimum interface, both hardware and software, with the host 4A/ETS switching machine. There are no interconnections between the 4A crossbar frames and the STP equipment. No modification of 4A crossbar equipment is required and no recompilations of ETS data are needed. New hardware additions are principally in the SPC peripheral unit area.

The STP office does require modifications to the SPC processor to provide two important new features: the "dead start" package and the Insulated Gate Field Effect Transistor (IGFET) store capability. The "dead start" package is a combination of hardware-software features which enhance the capability of recovering quickly and efficiently from a "dead" system. This includes such improbable multiple trouble situations as mate store failures and mate failures in critical peripheral units as well as mate processor failures.

The second new feature gives the processor the capability of working with the new IGFET store. The IGFET store is more economical than the Piggyback Twistor stores originally used in the SPC system and is used to provide the additional memory needed for the STP program and office data.

Any PBC-equipped ETS switching machine with the above processor enhancements which was not planned to become a CCIS switching office was a candidate for selection as an STP. Offices in this category were those scheduled for early relief by installation of a new No. 4 ESS,[10] or those not highly interconnected to other offices which were CCIS switching office candidates. Additional criteria for STP site selection were that the office should be served by at least four physically independent transmission routes and each STP should be geographically remote from its mate. These considerations assure the most reliable signaling network and minimize the risk of a single catastrophe affecting mate STPs. There were at least two ETS offices in each of the ten regions suitable for STP selection.

The message handling capacity of an STP operating in combination with a fully loaded ETS is equivalent to one million call attempts per hour. The load carried by a region will normally be split between the mate STPs. In the event of the total outage of an STP, all the traffic for the region must be carried by the mate STP. To insure the availability of this redundant capacity, each STP is normally loaded to no more than half of its capacity. The capacity of the region is then the same as the office capacity, or one million attempts per hour.

As the CCIS network matures and additional new No. 4 ESS machines join the toll network, the 4A/ETS switching machines that are coresident with the STPs will be relieved of their switching functions by the larger capacity No. 4 ESS machines. This step allows the STP to change to a stand-alone configuration with a subsequent capacity increase. The stand-alone STP will consist of the SPC complex, minimal peripheral and ancillary equipment, CCIS terminal equipment and the PBC complex. The capacity of a stand-alone STP is estimated to be two million attempts per hour.

2.1.2 Functional units

Figure 3 is a functional block diagram of the basic STP system. For simplicity, duplication of buses and controllers is not shown. For an explanation of the SPC-ETS complex see Refs. 2 and 3. The installation of an STP in a 4A/ETS office, in addition to the SPC processor enhancements mentioned above, requires the growth of equipment identical to that already provided for the ETS feature as well as the addition of new units developed for CCIS. The growth units include a peripheral scanner frame, a signal distributor frame and a central pulse distributor relay applique unit. In addition, power plant capacity enhancements may be required. The new circuits are the CCIS terminal group frame, the VFL access frame, the VFL test frame and a new unit added to the alarm and display frame.[5] The additions to the PBC complex and its functions are described in Ref. 6.

2.1.2.1 Peripheral Scanner (PSC). This frame is identical to the existing ETS peripheral scanners and will be maintained by the existing ETS software. The STP-PSC will contain only scan points associated with the STP equipment, primarily the terminal frame out-of-service and link security alert points.

2.1.2.2 Signal Distributor (SD). The STP-SD is identical to the existing SPC-SD except that it is equipped entirely with individually controlled general-purpose relay circuits, as opposed to a mixture of specialized piggyback twistor store maintenance circuits and general-purpose circuits. Maintenance for this frame is provided by existing ETS software. The SD frame provides the out-of-service distribute point for the terminal units as well as the VFL access frame. This method of distribution was adopted in order to reduce cost and installation effort.

2.1.2.3 Central Pulse Distributor Applique circuit (CPDA). The STP-CPDA unit is identical to the existing ETS-CPDA and provides additional distribute points to augment those provided by the SD. These

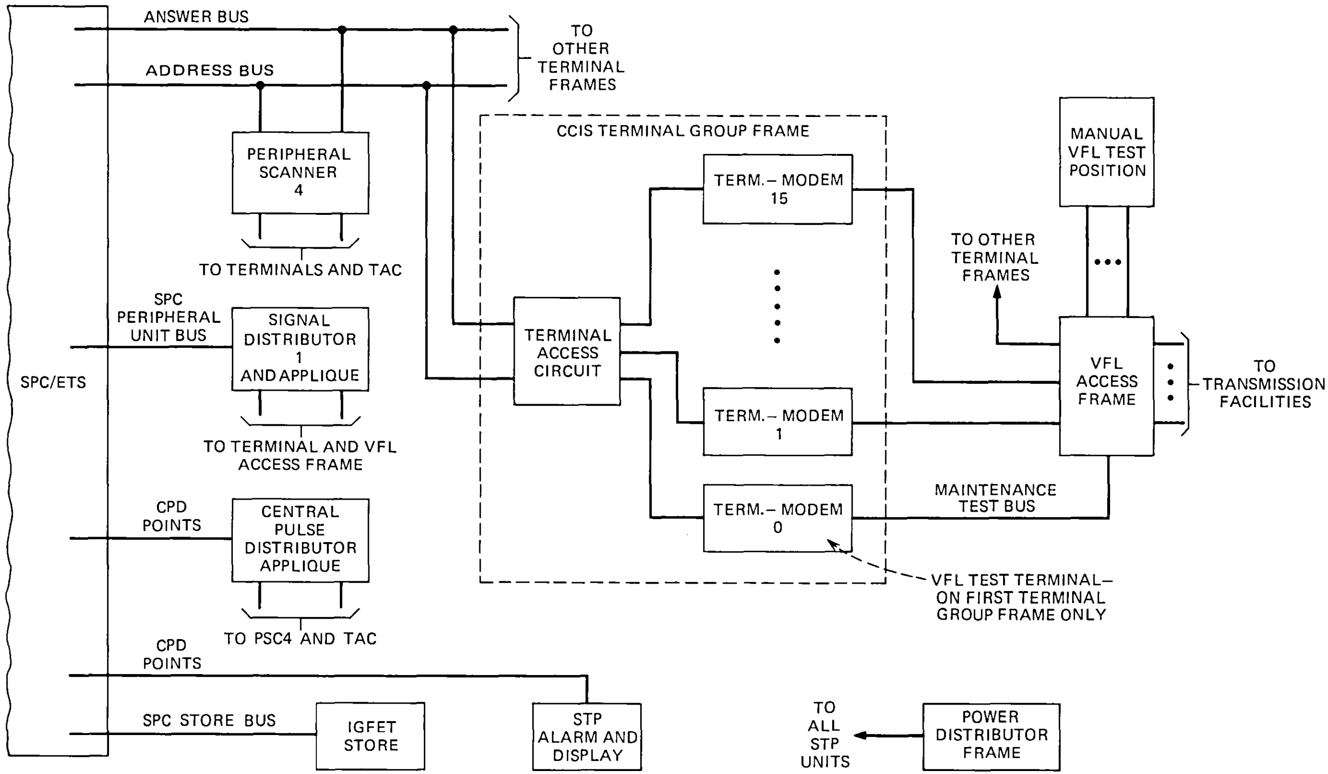
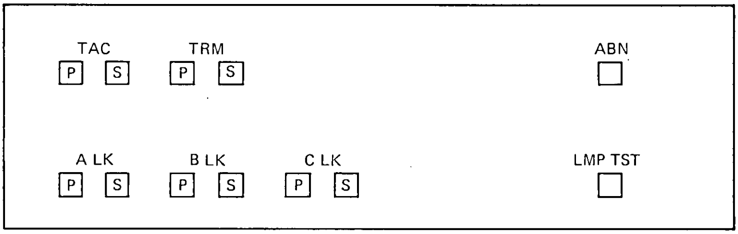


Fig. 3—ETS/STP system block diagram.



P = PRIMARY CONDITION
S = SECONDARY CONDITION

Fig. 4—STP alarm and display panel.

points control the terminal access circuit out-of-service functions and the fifth peripheral scanner.

2.1.2.4 IGFET store. This frame provides the memory for the STP generic program and data. The IGFET store is designed for memory growth instead of the piggyback twistor memory used in current ETS store frames. ETS programs will remain in PET memory.

IGFET stores are duplicated for service reliability. One pair of IGFET frames should handle the requirements of the largest office. Each IGFET frame will mount up to six memory modules. The number of memory modules required in an office is dependent upon the number of CCIS terminals served by the STP office. One pair of modules will provide data memory for enough terminals to connect to nine other STP pairs and 27 CCIS switching offices. A second pair of modules will provide for connection to an additional 52 switching offices.

2.1.2.5 STP alarm and display panel. The STP requires a lamp panel to display the alarm the status information for the A, B, and C signaling links, terminal-modem units, and terminal access circuits (Fig. 4).

2.1.2.6 VFL access frame. The VFL access frame is a new frame designed specifically for the 4A STP to connect the terminal-modems to the signaling facilities, to provide VFL test access to the manual test position and to provide VFL test access to the test terminal unit (Fig. 2). In addition, the VFL access circuits contain adjustable transmission pads which provide the proper transmission levels at the modem and test points.

2.1.2.7 VFL test position. The VFL test position provides manual testing facilities for the CCIS voice frequency links. The position contains test equipment for making transmission impairment measurements of the type commonly used for testing private line voice-band data facilities. Each VFL appearance requires one four-wire jack and a lamp. Test access is provided under processor control via the VFL access frame by means of a TTY input message from the switching maintenance center.

2.1.2.8 CCIS terminal group frame. This complex contains the signaling terminal units and data modems for up to 16 signaling links, as well as duplicated Terminal Access Circuits (TAC) for processor communication with each terminal unit via the peripheral unit bus. At present a maximum of 128 terminals (8 frames) can be equipped in an STP office, however, future enlargement to 256 terminals (16 frames) is anticipated. One terminal-modem unit in each STP office is reserved for VFL testing.

The terminal unit is a small, special-purpose stored program processor which maintains data communication over the signaling link. Synchronization, error detection, retransmission of signal units received in error, and acknowledgment of correctly received signal units are all handled by the terminal unit independent of the SPC processor. The terminal unit also provides multipriority buffering for incoming and outgoing signaling units.

The modem is the interface between the two-way serial digital data stream from the terminal and the two-way analog voice-band signal. One modem is physically and logically associated with each terminal. The modem has two VFL ports which, in the case of A links, are used to switch, under SPC processor control, between mate VFLs. One terminal-modem unit is associated with each signaling link. Backup capability for terminal-modem units is provided by the signaling network plan which requires duplication of all signaling links.

The fully duplicated TACs provide redundant independent access for each terminal unit via the ETS peripheral unit bus. The TAC has no autonomous functions and only one TAC is active at a given time. The SPC processor periodically polls the TAC to determine which terminal units, if any, contain waiting signal units.

2.1.3 Maintenance

The design of the signaling network and the strategy for reacting to signaling link failures was described in Section I. High reliability is an essential requirement of the signaling network. Redundancy is provided at several functional levels to assure uninterrupted service in the event of any single failure as well as a great many multiple trouble conditions. Basic to the signaling link recovery strategy is the assumption that the STP hardware is significantly more reliable than the VFLs. Highly reliable components have been employed in the terminal group and VFL access frames to minimize the component failure rate. The maintenance requirements for the STP are identical to those of the 4A/ETS switching office.[9]

The maintenance programs and procedures of the existing SPC complex are consistent with these requirements. As mentioned previously the ETS growth units added for the STP are maintained by existing ETS programs.

2.1.3.1 Detection. Fault detection in the terminal group hardware is accomplished by a variety of complementary and overlapping mechanisms. The TAC and terminal hardware contain extensive self-checking circuitry. The terminal software includes a self-test exercise program which runs continuously, interleaved with signal unit processing. Routine exercises are run on the TAC and terminal automatically on a daily basis to detect nonservice affecting faults. Faults in the modem and VFL access circuit are typically detected by excessive signal unit error rate or complete loss of the carrier signal.

2.1.3.2 Fault recovery. Faults detected in a TAC or terminal unit will cause a processor interrupt the next time the unit is accessed by the processor. This causes the terminal fault recognition program to be entered. This program determines which unit is faulty and then reconfigures the system with the faulty unit isolated. In the case of a TAC trouble, activity is switched to the mate TAC. In the case of a terminal trouble, a changeover request is made to the link security program. This causes the system to be reconfigured to use the mate signaling link as explained in Section 2.2. Fault recognition then schedules diagnostics on the faulty unit.

Faults which cause an excessive signaling link error rate lasting longer than three minutes will cause the link security program to request diagnostics on the suspect terminal-modem unit. If the subsequent diagnostics at both ends of the link find no trouble, a VFL failure is assumed.

2.1.3.3 Diagnostics and repair. Diagnostics are run on an interleaved basis with call processing. Their function is to isolate a fault to a replaceable component (circuit pack) and to verify circuit operation after the fault has been repaired (circuit pack replaced). The results of a diagnostic are printed on the ETS maintenance teletypewriter in the form of a trouble number. A Trouble Locating Manual (TLM) is provided for each unit type. It associates the trouble number with one or more suspected faulty circuit packs.

Diagnostic programs and TLMs are provided for the TAC and terminal. The terminal diagnostic includes a complete test of the modem and interface to the VFL access circuit. As such it represents the first completely automated test of data transmission terminal equipment incorporated into standard switching machine maintenance procedures. Special control and monitor features were incorporated into the modem design to make this possible.

Diagnostics for the TAC and terminal are written in a high level Diagnostic Language (DIAL).[7] DIAL provides an efficient programming technique and a well structured, highly readable listing which facilitates the manual analysis of diagnostic test results if necessary. The TLMs, in addition to circuit pack information, also contain descriptions of faults related to the interconnections between circuit packs. This information is very effective in locating wiring defects (shorts, opens) which sometimes occur on newly installed frames.

2.1.3.4 Maintenance terminal. As mentioned previously one terminal-modem unit in each STP office is reserved for VFL testing purposes. This terminal can be connected to any VFL via the VFL access circuit under control of the SPC processor. The main function of the maintenance terminal is testing of the reserve VFLs on A links. An automated processor-controlled test of the reserve VFLs is made on a scheduled routine basis to assure their availability when needed. This is a loop-back type test, initiated by the STP with a passive loop-back connected at the switching office. The maintenance terminal is also used to automatically perform the same type of test subsequent to a working mode VFL failure as a verification test.

2.2 Software organization

2.2.1 General

The STP program package is coresident with, but functionally independent from, the Electronic Translator System (ETS) programs. Both program packages are application related entities that operate within the framework of the basic Stored Program Control[4] (SPC) programs. The SPC programs are composed of the executive control, maintenance control, interrupt, and input/output programs, and those programs required for the maintenance of the equipment providing the hardware core of the system such as processors, stores, central pulse distributors, and master scanners. These basic SPC programs are common to the Traffic Service Position System No. 1,[8] the 4A/ETS, and the 4A/ETS/STP systems. In addition, they will continue to support the STP function in a stand-alone mode as the 4A machines at the STP sites are retired.

The STP program package provides for signaling message routing, signaling link security, and the administrative procedures to accomplish recent change and to collect traffic and plant counts. Maintenance software for the Terminal Access Circuit (TAC), the terminal, and Voice Frequency Link frame provide the necessary fault recognition and recovery mechanisms. Signaling link fault isolation and repair is facilitated by manually initiated software procedures, in addition to automatically administered visual and audible alarms. Audits and outage recovery strategies provide for software maintenance and complete the total maintenance picture.

The data base provided for the STP function is logically independent of the ETS data base and is generated and maintained separately. This data consists of routing instructions and signaling link information. The routing data consists of a table for each signaling link complement with one word for each band containing the corresponding outgoing link and band number. Signaling link information contains link type, equipment arrangements and the identification of alternate routes.

When possible, development effort was reduced by providing common programs at both the 4A/ETS/CCIS Switching Office (SO) and the STP to serve common requirements. In addition to the SPC and ETS programs, the STP program occupies 18,000 words of memory of which 10,000 words are common with the 4A/ETS/CCIS switching offices.

2.2.2 Message routing

The primary function of the STP, signal routing, is performed by the message handler program which has been designed to optimize real-time efficiency. The fundamental process is to take an incoming message from one signaling link, change its band number, and transmit it on another signaling link as an outgoing message. The band translation and routing is accomplished by using the band translation table (Fig. 5) provided for each incoming signaling link. Using the band number from the incoming message as an index into the translation table, the outgoing band number and outgoing signaling link number are fetched from memory. The message handler replaces the incoming band number in the first signaling unit of the message with the outgoing band number, and places the message in an outgoing queue of the appropriate terminal. The outgoing link number from the translation table is the preferred route in the fixed routing scheme of the signaling network. Signaling link load balance on any given pair of B links to another region is done by assigning odd band numbers to one link and even band numbers to its mate.

Alternate routing on outgoing signaling links, if required because of an out-of-service condition of the preferred link, is achieved with real-time economy by retrieving an index stored in scratch memory for the outgoing link. The index effects a transfer to a routine which routes the message around a failed link or STP to its final destination. This index is called the transmit switch index, and is kept current by the link security programs so that the message handler may quickly make a disposition of any outgoing message.

In addition to band translation and alternate routing, the message handler is equipped to recognize signal units that initiate processing at the STP. As examples of this, a certain class of non-call-related messages causes the STP to broadcast Dynamic Overload Control (DOC) messages to prescribed switching offices on certain bands while other messages inform the STP of the suitability of a given signaling link to carry traffic. Most non-call-related messages, as well as regular telephone messages, are processed to completion once the incoming message is unloaded from a terminal. Lengthy sequences initiated by certain non-call-related messages are scheduled to be run as background jobs by the message

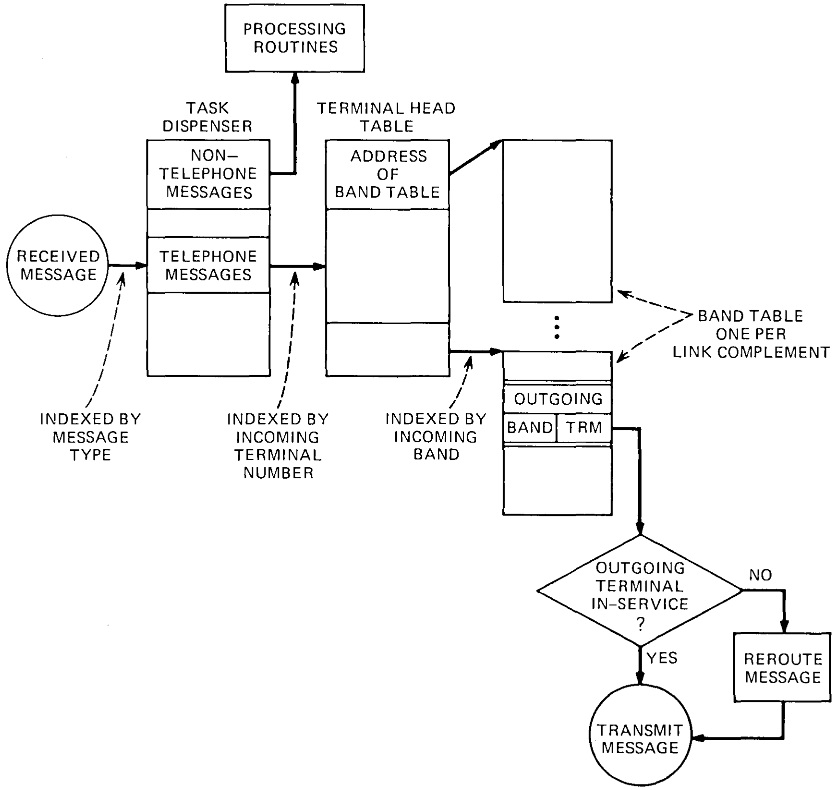


Fig. 5—STP message routing.

handler. The message handler itself is scheduled to execute as two separate tasks, a timed interrupt level job which runs every 10 milliseconds and is responsible for high-priority telephone traffic and a base level job which handles low priority telephone messages and noncall related messages.

2.2.2.1 High-priority message handler. Every 10 milliseconds the high-priority message handler is entered to look for high-priority traffic, currently consisting of answer and changeover messages each of which consists of one signal unit. The high-priority signal present indicators of each in-service Terminal Group (TG) are read looking for set bits which flag a terminal as having incoming traffic in its high-priority receive buffer. The message handler retrieves each signal unit, translates the incoming band, and routes answer messages to the proper outgoing terminal. Changeover events are queued for base level processing. The message handler continues to unload and process the messages from the active terminals associated with the current TG until all of the high-priority buffers are empty at which time the high-priority signal present indicators return to zero. The message handler then moves on to the next TG. After all TGs have been served, the system returns to base level processing.

2.2.2.2 Low-priority message handler. The low-priority message handler which is entered on base level performs functions similar to the high-priority job with the added tasks of Multiunit Message (MUM) processing and filtering a wider class of message types which may require STP actions beyond routing. Upon entry, the message handler reads the low-priority signal present indicators of each TG looking for traffic queued in any of the low-priority input buffers of the 16 terminals. For every flag set the message handler retrieves the first signal unit of the incoming message and uses the first seven bits (the heading and signal information fields) as an index into a task dispenser which transfers control to a specific routine to deal with that message (see Fig. 5). A small percentage of the incoming traffic is trapped and processed at the STP, while the bulk of the messages—Initial Address Messages (IAM) and call-related Lone Signal Units (LSU)—are translated and routed. All LSUs that are routed through the STP are given the same treatment as described above for priority messages. Routed MUM traffic requires timed interrupt protected sequences for the transfer of the message from the incoming terminal to the outgoing terminal to prevent message inter-write. That is, once the outgoing link has been determined using the Initial Signal Unit (ISU) of the incoming MUM, each Subsequent Signal Unit (SSU) is retrieved from the incoming terminal and loaded into the outgoing terminal; the protected sequences prevent any timed interrupt generated low-priority traffic from being loaded prior to completion of the transfer of the last SSU. Incomplete MUMs are currently routed normally by the STP while any block of SSUs not preceded by an ISU is flushed from the network.

Incoming C-link traffic is always processed as a low-priority miscellaneous MUM since the message has been prefixed with a header signal unit which contains the outgoing signaling link number. This outgoing signaling link number is a result of translation performed at the mate STP which was unable to route the message due to the present network configuration. After stripping this header, a unique task dispenser is executed to process that particular message while implicitly recognizing that the message has been received from, and preprocessed by, the mate STP.

Each TG in turn has all low-priority traffic emptied from each of its 16 terminals which is then followed by an interject break to allow time-critical jobs to execute. After all TGs have been processed, the message handler relinquishes control to the next base level job.

2.2.3 Signaling link security

To ensure continuity of service, a large amount of redundancy has been designed into the CCIS signaling network. The signaling link security package at the STP has the responsibility of administering those links which connect it to other nodes in the network—this is the signaling link control function; and of maintaining and disseminating the status of signaling links between distant nodes—this is the signaling network management function. In addition to the obvious need to alternate route for failed links at the STP, the status of distant links is required on a band basis to ensure and optimize routing in the distant region.

Link security is responsible for monitoring the integrity of a working link, for initiating automatic restoral procedures for links subjected to terminal and facility failures, and for facilitating repair procedures on faulty links. Input stimuli to link security consist of signaling link messages, internal fault recognition, scan point notification, and manual inputs such as TTY messages and frame key actions. Broadly speaking, the resultant outputs from link security in response to a given stimulus may result in (*i*) changing the routing for some or all of the bands associated with a link, (*ii*) changing the link status, (*iii*) passing status information to distant nodes (switching offices, the mate STP, and/or distant STPs). The signaling link control function is outlined below and is followed by a review of the signaling network management function.

2.2.3.1 Signaling link control. The health of the signaling link is constantly monitored by the CCIS terminal. For example, the terminal is watchful for internal logic problems, an excessive number of signal units received in error, loss of block synchronization, and other abnormal conditions which may indicate a near-end signaling link problem. Diverse methods are used by the terminal to communicate the near-end problem to the processor. For one class of problems a special message, the processor notification signal, can be generated by the terminal and placed in a receive buffer to inform the processor of excessive signal unit errors, loss of block synchronization, or the buffer-full condition which arises when the last empty buffer slot is used for either a received signal unit or a signal unit loaded for transmission by the processor. Various control register or special data memory bits are read by the processor to identify the particular problem. In another class, the buffer overflow condition, which occurs during a buffer full state when the terminal attempts to put a received signal unit on one of the received link lists and finds there is no buffer space available, is reported to the processor by setting the Central Control Alert (CCA) miscellaneous scan point in conjunction with flags bits in the terminal control register. Finally, that rare class of severe terminal logic problems detected by regular terminal exercise routines forces the terminal to halt and thus deny the all-seems-well response to the processor the next time the terminal is accessed. In this case, the peripheral fault recognition routines are entered.

In addition to monitoring for near-end detected difficulties, the terminal screens the incoming message stream for changeover signal units (COV) which indicate that the far-end has recognized a VFL problem and is in the process of switching traffic to an alternate link. Single COV units are discarded by the terminal; if two COVs are received within 256 signal unit intervals the second COV is passed to the processor in the high-priority receive buffer.

The normal changeover sequence is entered when a problem results in a changeover request and the mate signaling link is operational. Traffic destined to the troubled link is rerouted to the mate. All telephone and management messages waiting in the failed terminal transmit queues and all signal units transmitted but awaiting acknowledgment from the far-end terminal are moved to the mate link's transmit queues. Those messages waiting in the receive buffers of the failed link are unloaded normally by the message handler program. Link recovery procedures then advance the terminal through various states as resynchronization and prove-in are achieved. If the overall recovery timer expires, terminal diagnostics are requested and the craft personnel is notified.

The emergency restart condition arises when a changeover is requested on a signaling link and all other alternate signaling paths are not operational. Under these circumstances all signal units queued on the failed link are dumped while abbreviated recovery procedures are initiated. Emergency recovery prove-in thresholds are lower than those used during normal recovery in an effort to quickly regain signaling ability. During the emergency recovery interval, the affected DDD trunks are automatically inhibited from accepting new call originations.

Signaling link security at the STP is responsive to manual actions that affect signaling link states. Removal from service is a prerequisite for further maintenance activity such as manually requested terminal diagnostics. The manual changeover request can be initiated at either end of a signaling link. A request directly to the processor by the craftsman invokes the near-end procedure. Requests from the far-end are received over the signaling link as a Manual Changeover request message (MCO). Prior to sending the MCO on the link to be removed from service, the requesting office first inspects the status of the mate signaling link to ensure that loss of signaling will not result from a changeover. Before granting the request by sending the manual changeover acknowledgment, the receiving office goes through the same procedure. If both ends approve, traffic is removed from the link, but the terminals will maintain synchronization on the link. Should an emergency restart situation arise while a link is in the manual out-of-service state, link security can seize it and attempt emergency recovery procedures on it. Links manually removed from service can be manually returned to service only by the requesting end or by both ends if a manual request was initiated at both ends. Once manually out of service, link security provides for a number of manually requested procedures to facilitate link fault isolation and repair. Examples are scheduling an automatic test of a VFL, connecting a VFL to the test position, or looping back a VFL at the far end.

2.2.3.2 Signaling network management. The signaling network management function is accomplished at the STP by administering status information on each band for each active B-link complement. Each of the 512 bands are represented by two bits in the band status table. One of the bits indicates that a Transfer Restrict message (TFR) has been received on that band from an STP in the distant region while the other bit indicates that a Transfer Prohibit message (TFP) has been received. The band status reflects the ability of the distant STP to route messages for that band and are used by the STP to make a disposition of outgoing messages on that band intended for one of the B-links of the pair. If there are no signaling restrictions on a band, the band is referred to as "allowed." Messages sent on restricted bands will require C-link routing in the distant region. Prohibited bands represent signaling paths that are blocked due to network failures. Upon receiving a band status message from a distant region the band status table for that incoming B-link pair may be updated and the appropriate switching office notified with a TFR or TFP. Band status information is generated by an STP based on link status changes of A-links and C-links at that STP and its mate STP. TFR and TFP restrictions for a given band are removed upon receiving a Transfer Allowed message (TFA). Additional procedures are provided for regenerating and updating the band status tables for links that have been out of service, as well as maintaining their integrity through audits.

Finally, link security with the cooperation of terminal software is able to minimize the effects of and recover from STP processor overloads and outages. Each terminal is able to recognize that the processor has not been servicing its low priority receive queue. The terminal then assumes that the processor is experiencing difficulties and autonomously informs the far-end node. The far-end processor, after an appropriate timing interval, effects a changeover on the signaling link to reroute traffic intended for the failed STP. As the processor at the failed STP proceeds through its recovery phases, the links are restored to service.

2.2.4 Maintenance features

The signaling link and network maintenance features discussed above are augmented by both hardware and software related processes to complete the maintenance package for the STP. Fault detection, fault recognition, and diagnostics for the TAC and terminal have been integrated into the normal interrupt mechanisms provided by the SPC programs. These programs are common with those at the switching office as discussed in Ref. 9. In addition, the STP has been equipped with an Alarm and Display (A&D) status panel. Once alerted to the existence of a signaling link problem by the audible alarm, the A&D panel is available to the craft as a visual summary of the office troubles. The A&D panel classifies the troubles by unit type and severity. Should multiple troubles exist, both classifications are used in determining the sequence in which to perform the repair.

The display panel has two lamps (primary and secondary) providing three alarm states for each of the five categories (see Fig. 4). A steady secondary lamp indicates trouble in a single member of the unit type in question. A flashing secondary lamp means that two or more members of a unit type are in trouble, however, there is no loss in signaling capability. The minor audible alarm is sounded when this state is entered. The primary lamp is the most urgent warning. This state corresponds to multiple trouble conditions which cause service degradation. The major audible alarm is sounded when the primary alarm state is entered.

Software maintenance is provided by a series of audits which run on a scheduled basis, as time filler jobs, or on demand only. These audits monitor the status information in various link state tables. Discrepancies are automatically corrected and reports are made to craft personnel. Some audits involve the exchange of information between the STP and other nodes.

2.2.5 Administration

The STP has been provided with a comprehensive set of administrative procedures to facilitate data base maintenance and to provide for the collection of signaling network performance data. These features can be categorized into recent change, hardware growth, and traffic and plant measurements. An STP recent change function has been provided to update the band translation and other tables in order to establish or remove the cross-office signaling connections and overload or signaling congestion controls. This function provides for making changes to existing data tables that have been assigned in the data load. These tables may be associated with signaling links either preplanned or in service. The recent change administration can be accomplished via either the SPC maintenance channel or the Peripheral Bus Computer (PBC) port using similarly formatted messages which are oriented more toward the craftsperson and less toward the actual structure of the data table being changed.

Another set of STP programs are used to administer the data state tables associated with the CCIS units. The data state concept allows the installation and growth of CCIS units with minimal impact on an operational system. There are data state tables associated with the terminal access circuit, the terminal circuit, and the VFL access circuit. By changing the data state of a unit, it may progress from the unequipped state through the diagnostic state to the in-service state. Each of the states makes the unit progressively more available to an operating STP system.

Finally mechanisms diffused throughout the STP software collect traffic and plant counts which aggregate in the PBC. Examples of traffic data counts are signal units transmitted and received, initial address messages transmitted and recieved, and near-end and far-end changeovers. Plant data counts include signal units in error per VFL and retransmission requests per VFL. This information stored, analyzed, and reported by the PBC to both traffic and plant personnel contributes to the proper performance of the signaling network on a short-term and long-term basis.

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Common Channel Interoffice Signaling:

4A Toll Crossbar Application

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The No. 4 toll crossbar switching system is presently the backbone of the Direct Distance Dialing (DDD) network. Conversion of No. 4 offices equipped with the Electronic Translator System (ETS) is vital to the rapid introduction of CCIS to the DDD network. CCIS capability represents a major increase in the role of the ETS software in the call switching process. Significant changes and additions to the switching equipment are required to support this expanded software control.

I. INTRODUCTION

1.1 General

The No. 4 toll switching system comprises a family of common control crossbar switchers which presently form the backbone of the Direct Distance Dialing (DDD) network.[1] As of year end 1976, there were 183 Bell System No. 4 crossbar offices serving this network in the class 1 though class 4 categories, including all ten regional centers and virtually all sectional centers. All but 19 were of the 4A/ETS type which utilizes the Electronic Translator System (ETS) to perform the route translation and network management functions. Although existing No. 4 crossbar offices will be gradually replaced by No. 4 ESS, it is planned to retrofit CCIS into about half of the 4A/ETS offices to expedite the conversion of the DDD network from SF/MF signaling and, therefore, take maximum system advantage of the reduced signaling costs, faster call setup, and new services available with CCIS.

The introduction of ETS in 1969 greatly reduced the equipment investment and administrative costs associated with the route translation and network management functions.[2] This stored program control adjunct was intentionally designed to effect minimum change to the basic call processing structure of the No. 4 crossbar system in order to reduce the application expense to in-service offices.

1.2 Impact of CCIS

Introduction of CCIS capability into a 4A/ETS office represents a significant increase in the role of the stored program software in the processing of calls being switched through the system. With ETS the software is used primarily to translate incoming call information, to select the appropriate outgoing route and to provide a number of plant and traffic administration and control features. The control of sequencing the call switching process in 4A/ETS is contained within the wired logic of the common control switching circuits. The software system is only used to obtain a call translation or to report completion of a call switching attempt for traffic administration purposes.

Whereas with conventional signaling all address and supervisory information is received directly by the per-trunk hardware and then transferred to the common control circuitry, for calls using CCIS this information will be received by the processor from the signaling link and must then be acted upon appropriately. Therefore, when calls using common channel signaling are being switched, the software must interact very closely with the sequencing of the electromechanical switching equipment in order to successfully complete a call through the office. To further complicate the control structure, some calls being switched will require only conventional signaling, so that the system must perform similarly to 4A/ETS. Alternatively, the call may use common channel signaling for both the incoming and outgoing trunk circuits, putting the software heavily in control of the sequencing. Finally, the call may use conventional signaling on one side and common channel signaling on the other, making the connection a hybrid sequence. One could quite reasonably visualize the total switching system as a multiprocessor environment, with each of the common control units and senders (perhaps over five hundred in a large office) representing a special purpose, wired logic "processor" working with, and sharing access to, a central stored-program switching processor.

1.3 4A/ETS organization

A brief review of the 4A/ETS will be presented to familiarize the reader with conventional call switching concepts before proceeding with the description of the CCIS application. Figure 1 illustrates the major switching circuits and their interconnection.

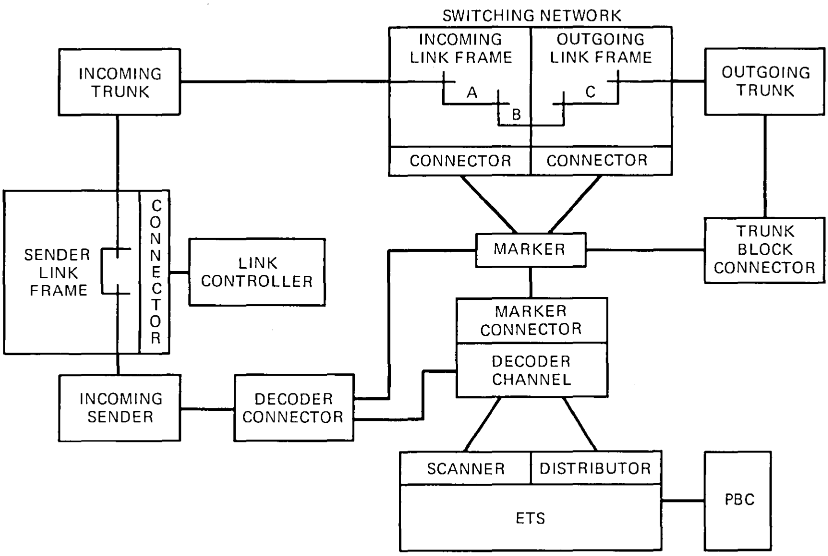

Fig. 1—Block diagram of 4A/ETS.

1.3.1 Network, senders, and trunks

4A/ETS uses a four-stage crossbar switch matrix as the trunk switching network. The switches are mounted on individual incoming and outgoing link frames which are interconnected by junctors (B links) and contain links (A, C) to provide access between the trunk and junctor switches. Since the network design is unidirectional, two-way trunks require an appearance on both an incoming and an outgoing link frame. Furthermore, two parallel networks are necessary to accommodate the engineered traffic load of 240,000 CCS; consequently, incoming trunks are terminated on both networks to allow access to all outgoing trunks.

Incoming trunks also require connection to an incoming sender for registration of the called number address digits used to route the call. Senders are dedicated to an incoming pulsing type [Multifrequency (MF) or Dial Pulse (DP)] or special function [Centralized Automatic Message Accounting (CAMA)]. All incoming senders are capable of outpulsing MF or DP over the cross-office connection to the next office. Trunks are connected to senders by means of a simple two-stage auxiliary crossbar network called a sender link frame. Sender link frames are furnished in groups dedicated to a specific type of sender.

Supervisory signals during the conversation stage of the call, such as answer and ring forward, are transferred directly between the interconnected trunk circuits by means of dc signals simplexed over the transmission pairs of the switched connection.

1.3.2 Common control circuits and connectors

Call switching is controlled by autonomous wired logic electromechanical common control circuits known as link controllers and markers. The link controller connects trunks to senders through the sender link frames while the marker establishes cross-office connections between trunks. A separate marker group is provided for each of the two trunk switching networks; similarly link controllers are dedicated to a sender group. Execution of these switching connections requires the common control circuits to identify the trunk bidding for service and search for an idle server (sender or outgoing trunk). The marker's search is limited to a maximum of 40 trunks in a subgroup as specified by ETS route translation of the called number. Another type of common control circuit is the decoder channel which serves as an interface between the electromechanical switching equipment and ETS. The decoder channel provides ETS with access to the first six digits of the called number for route translation purposes, controls selection of an idle marker in the indicated trunk switching network, and establishes a temporary connection between the ETS and the marker for distribution of call routing data.

During the processing of a call, large amounts of data must be exchanged between the common control and other switching circuits. Temporary communication channels are established through connectors which are arranged in two basic configurations. The first type permits a multiplicity of bidding circuits to access a specific serving circuit. The second type accepts requests to search for an idle serving circuit and connect it to a specific bidding circuit. The connectors also contain logic to queue multiple bids for service. With reference to Fig. 1, the incoming and outgoing link frame connectors and the trunk block connectors are representative of the first type while the sender link frame and marker connectors constitute the second type. The decoder connector combines both connector functions, since several senders share a single connector. Thus, a sender must first gain exclusive use of the decoder connector before the connector will select and connect an idle decoder channel.

1.3.3 Electronic Translator System (ETS)

ETS consists of a common systems Stored Program Control (SPC No. 1A) duplicated processing system and peripheral units dedicated to the 4A application, principally distributors and scanners to interface with the electromechanical switching equipment.[3] Sender requests for route translation of the called number are placed through the decoder channels via the decoder connector. The ETS processor reads the sender input through a block of scanner terminals associated with the decoder channel, determines the appropriate routing and then returns routing instructions by operating the appropriate output relays in the distributor register circuit associated with the decoder channel. Since the incoming trunk group characteristics may influence routing of the call, ETS must also identify the incoming trunk group associated with each call in order to read the appropriate trunk group data from memory during the route translation. Therefore, the link controller informs ETS, through the scanner, of both the incoming trunk and sender identities being switched through the sender link frame. Later, the decoder channel will identify the sender serving the call to permit ETS to link back to the trunk group data associated with the incoming trunk. The markers are also scanned by ETS to determine call disposition following route translation since unsuccessful attempts may be retried or routed to announcement by the marker depending on the routing instructions. These marker disposition reports are sent by ETS to the Peripheral Bus Computer (PBC) which uses them to administer trunk group measurement data.[4]

II. CCIS DESIGN STRATEGY

2.1 General

Among the major considerations influencing design of a new feature addition to an in-service switching system is the relative impact of retrofit application. If a significant number of existing switching entities are involved, the design approach will often strive to minimize the replacement and modification of present equipment to reduce retrofit costs, and may result in a less than optimum package for a new office application. CCIS constitutes an extreme example of this situation since it will be applied almost exclusively to existing 4A switchers. In fact, there was only a single new office application, the Madison 2, Wisconsin installation placed in service in May 1976. Madison is unique as it is not only the first 4A CCIS installation but, with the introduction of No. 4 ESS, it is also the last new 4A.

2.2 Conversion of MF trunk circuits to CCIS

The rapid implementation of CCIS in the toll network over the next few years will make surplus substantial numbers of MF trunk circuits and senders in converted 4A CCIS switching offices. Replacement of these MF trunk circuits by new CCIS trunk circuits would be economically unjustified since in addition to the trunk circuit itself, there is also the cost of outpulsing equipment required for incoming CCIS calls which switch to an outgoing conventional trunk, plus the rearrangement costs of substituting new CCIS trunk circuits for MF trunk circuits as trunk groups convert to CCIS operation. Therefore it was decided to add CCIS capability to in-service MF trunk circuits. Operation in either the MF or

CCIS mode is selected by a switch on hard-wired trunk units or option straps on plug-in trunk units.

The provision of new CCIS trunk and outpulsing equipment will generally be limited to offices with an inadequate quantity of MF trunk circuits eligible for CCIS modification, or in offices where the combined demands of CCIS conversion and growth exceed the supply of surplus MF trunk circuits.

2.3 Reuse of MF senders

The attractiveness of the MF to CCIS trunk circuit modification is enhanced by the ability to use existing senders for outpulsing on incoming CCIS calls which complete to outgoing conventional signaling trunks, since the modified trunk circuits retain access to senders through the sender link frame. Furthermore, extensive changes to 4A call processing sequences are avoided by also connecting a sender on CCIS to CCIS calls, even though the sender usage in this case is apparently superfluous.

This design decision was based on two major considerations. First, incoming trunk circuits are arranged to autonomously request sender attachment from the link controller upon seizure; to negate this function only on CCIS outgoing calls would require an added per trunk instruction from the processor. Secondly, the absence of a sender on this one class of call would require processor capability to seize a decoder channel to switch the call; also the marker would need direct access to the incoming trunk termination on the switching network which is currently furnished by the sender to trunk connection.

2.4 Basic CCIS call switching concepts

The resultant CCIS design approach, adopted for both modified and new CCIS trunk circuits, thus allows the 4A common control equipment to process an incoming CCIS call in basically the same manner as a conventional call. All senders in groups containing modified CCIS trunk circuits are arranged to function as either an MF sender or CCIS outpulser, depending on the incoming call type as will be described in Section 4.1.5. New CCIS trunk circuits are served by one or more dedicated CCIS outpulser groups. An office may contain a mix of MF sender groups serving only MF trunks, combined sender-outpulser groups serving both MF and CCIS trunks, and outpulser groups serving only CCIS trunks.

2.5 CCIS trunk circuit

A CCIS trunk circuit may be viewed conceptually as a conventional MF trunk circuit whose E&M leads are made available to the processor through a distribute and scan point instead of being connected to an SF signaling unit. The scan-distribute interface provides the processor with the ability to control CCIS trunk circuit seizure and release, and to convert supervisory signals for connections to conventional signaling trunks. Supervisory signaling between conventional and CCIS trunk circuits is accomplished by means of dc signals applied on a simplex basis to the transmission pairs of the cross-office connection. However, for CCIS to CCIS calls, the processor transfers signaling messages directly between the signaling links serving the trunks.

Separate functions are assigned to the distribute and scan point depending on whether the trunk circuit is operating in the incoming or outgoing mode.

2.5.1 Incoming call

Operation of the distribute point for an idle trunk circuit seizes it in the incoming mode to start a cross-office connection. If a connection to an outgoing conventional signaling trunk circuit is established, the scan point follows answer and hang-up supervision from the outgoing trunk circuit causing the processor to send corresponding CCIS messages over the signaling link for the incoming trunk. Receipt of a forward transfer message for the incoming CCIS trunk causes the processor to momentarily release the distribute point for approximately 100 ms, causing the trunk circuit to send a ring forward signal to the outgoing trunk circuit. The incoming trunk circuit disconnect timer will not expire on this short pulse and the trunk remains off-normal. On a true disconnect, the trunk circuit releases itself and the outgoing trunk after the timer expires. The scan point is activated during disconnect timing and then deactivated after the trunk circuit has returned to idle to inform the processor that trunk release has been completed.

2.5.2 Outgoing call

The trunk is seized by the marker as directed by the processor, thus conditioning the trunk circuit for outgoing operation. Activation of the scan point signifies completion of this event. If a conventional signaling incoming trunk is connected, the processor converts answer and hang-up CCIS signaling messages from the distant office by using the distribute point of the CCIS outgoing trunk circuit to send cross-office signals to the conventional incoming trunk circuit. A ring forward signal from the conventional incoming trunk circuit results in a momentary release of the outgoing CCIS trunk scan point, causing the processor to send the forward transfer message over the signaling link when the scan point is reactivated. The processor times the release of the scan point to distinguish between a ring forward and disconnect signal. If the timer expires without reactivation of the scan point, the processor considers the cross-office connection to the outgoing CCIS trunk to have been disconnected and sends a clear forward signal over the signaling link.

Success in minimizing the field modification cost for the MF to CCIS trunk circuit conversion is directly attributable to maximum retention of conventional trunk logic. This approach also reduces the processor interface to a single scan and distribute point. Incoming and two-way CCIS trunk circuits require additional circuitry to assist in the performance of the voice path continuity test to be described in Section 3.3.

III. NEW DESIGN

Several new circuit designs were developed for CCIS. The signaling terminal and Distributor and Scanner (DAS) are electronic adjuncts to the SPC processing system and communicate with the processor via the peripheral unit bus system.[5] The other circuits are additions to the 4A switching equipment.

3.1 Signaling terminal

The administration of data flow over the signaling link involves a number of highly repetitive tasks which are executed on an exacting schedule.[6] The entire administration of the signaling link is delegated to the signaling terminal which is primarily a small special purpose stored program processor. The terminal sorts incoming signaling data into the respective priority classes, assembles multiunit messages, and stores the data until the switching processor is ready to retrieve it. Outgoing signaling data is accepted without delay from the switching processor and queued as necessary for transmission.

3.2 Distributor and Scanner (DAS)

The DAS provides the processor with an economical scan and distribute point interface necessary to control the operation of CCIS trunks and common control equipment. Upwards of 1000 scan points and 2000 distribute points are required for the senders and common control equipment. Additionally, a single set of DAS points is required for each CCIS trunk.

DAS executes single point distribute orders primarily used to control trunks and multipoint orders for common control equipment. The DAS also scans the 4A switching circuits and reports only transitions to the processor. Scanning is performed at approximately a 5 ms rate but, to avoid false reports due to relay contact bounce, a transition must persist for two consecutive cycles before it is reported to the processor. This rapid scanning rate aids in achieving the fast call switching objectives established for CCIS. Scan points may be converted to the nonreporting mode which inhibits transition reports but still allows the processor to

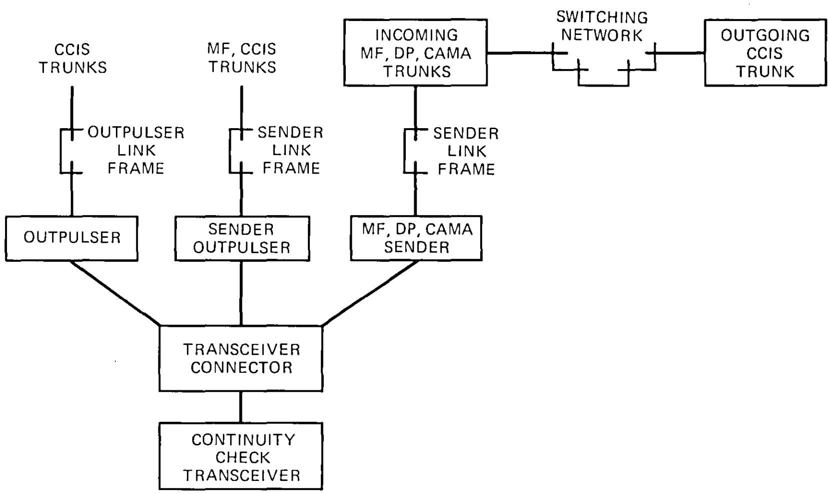

Fig. 2—Connecting continuity check transceiver.

read the scan point state. This feature is used to read blocks of data from common control equipment following detection of a bid for service.

3.3 Voice path continuity check

A continuity check of the interoffice path is conducted whenever a CCIS trunk is selected to switch a call forward. This check not only insures a satisfactory transmission path for the customer, but more importantly precludes billing for an otherwise undetectable faulty connection since CCIS signaling is performed independent of the speech connection. Conventional in-band signaling systems do not require this check since transmission integrity is indirectly verified by the receipt of the called number at the far end via MF pulsing, and at the near end by the wink or delay dial signaling sequence which precedes outpulsing.

The continuity check is performed on a loop basis between 4-wire switching offices, whereas each transmission direction is checked independently when one or both offices involved are 2-wire switchers. For the 4-wire test, a single frequency transceiver is connected at the outgoing office and the transmission pairs are looped by the incoming office. For the 2-wire test, both offices connect transceivers and different frequencies are employed in each direction.

The 4A system connects the continuity check transceiver to the incoming sender or outpulser serving the call, rather than directly to the CCIS trunk, as shown in Fig. 2. When an outgoing CCIS trunk is selected, the continuity check is deferred until completion of the switched connection between the incoming and outgoing trunks. Transceiver access to the outgoing trunk transmission pairs is achieved through the trans-

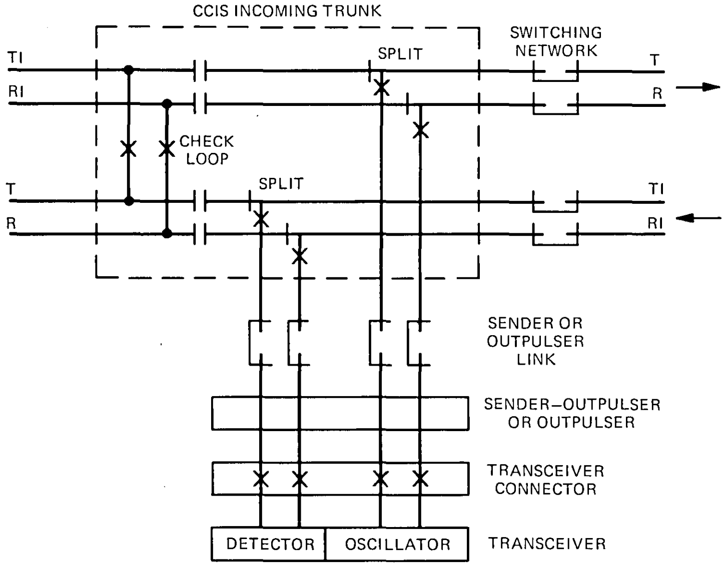

Fig. 3—Continuity check.

ceiver connector, the sender or outpulser link connection to the incoming trunk, and the cross-office connection. Incidentally, the sender or outpulser uses the latter two stages of this same connection to outpulse over a conventional signaling outgoing trunk.

When a call arrives from a 2-wire CCIS office, the transceiver is connected before starting the cross-office connection and the incoming trunk circuit temporarily switches the transmission path from the transceiver back towards the preceding office. After completion of the check, the transceiver is disconnected and the trunk circuit transfers the transmission path from the sender or outpulser link forward in preparation for starting the switched connection to the outgoing trunk. A transceiver is not connected for calls arriving from a 4-wire office, instead the incoming CCIS trunk circuit temporarily loops the transmit and receive pairs when seized by the processor. Figure 3 depicts both the incoming and outgoing continuity check between 4-wire switching offices. The incoming trunk circuit has looped the transmit and receive pairs for the preceding office, while the SPLIT relay provides the continuity check transceiver with access to the outgoing trunk.

Transceiver selection is performed by the processor. The connection to the incoming sender or outpulser is executed by the link controller for incoming trunks from 2-wire offices, and the marker for outgoing trunks. The transceiver connector is a single relay switch to one of the four transceivers dedicated to serve a subset of the senders and outpulsers. This group size represents a balance between efficient transceiver utilization and the size of the connector plus control access from the controllers and markers. Traffic utilization is maximized by allowing transceiver requests to queue for a short interval (1.0 to 1.5 seconds), while a balanced offered load is achieved by distributing the members of each sender or outpulser group evenly among all transceiver groups. Connectorized cables allow for load balancing when transceiver groups are added.

On an outgoing CCIS call, the processor searches for an idle transceiver when the decoder channel reports the marker identity just prior to releasing from the call. If a transceiver is available, the processor operates DAS distribute points associated with the marker to indicate which one of four transceivers has been selected. The transceiver group identity is not required since the marker is connected to the transceiver connector relays of the sender or outpulser through the decoder connector. The marker operates the indicated connector relay which seizes the transceiver and alerts the processor via a scan point. The processor conditions the transceiver by distributing instructions for 2-wire or 4-wire operation, incoming or outgoing test, and transmission level. The transceiver then applies locking ground to hold the connection which the marker senses as a connection complete signal. Upon receipt of a marker report indicating completion of the transceiver and cross-office connections, the processor starts the transceiver timer. The transceiver reports results of the continuity check by tone recognition and timing expired scan points. A successful test is indicated by activation and deactivation of only the tone recognition point. The processor then resets all distribute points to release the transceiver.

If a transceiver is unavailable, the processor so informs the marker. The marker will establish the cross-office connection, report completion to the processor, and wait. If a transceiver does not become available before a software timer expires, the processor distributes a release signal to the marker. The call is terminated by sending an ineffective attempt message to a preceding CCIS office, or distributing a reattempt instruction to the sender to cause a conventional incoming call to be routed to reorder tone or announcement.

Transceiver connection on an incoming call from a 2-wire office is executed by the link controller in a similar manner, except the controllers have direct access to the transceiver connector relays. Continuity check timing is performed by the 2-wire office and may be recycled by a signaling message from the 4A office whenever the accumulation of queuing delays for a link controller, outpulser, and transceiver approaches the timing limit.

3.4 New trunk circuit and outpulser

A new CCIS trunk circuit, outpulser link, link controller, and outpulser have been designed for offices which are unable to satisfy their CCIS trunk demand by conversion of surplus MF trunk circuits. From a system viewpoint, these new electromechanical units are functionally identical to corresponding MF equipment converted to CCIS use. However, they offer lower cost, faster call setup, reduced floor space, and superior maintenance. Trunk circuits are available as either a combined incoming and two-way plug-in unit or outgoing only plug-in unit, and are interchangeable with converted MF plug-in units. New trunk circuits may also be added for CCIS growth to MF sender groups converted to serve incoming CCIS traffic.

IV. MODIFICATIONS

Changes are necessary in all senders, common control equipment, and outgoing link frames to support the previously described CCIS call switching procedures.

4.1 Senders

Sender modifications are divided into two categories. All sender types (MF, DP, CAMA) require the first four modifications described below for CCIS compatibility. Only those MF senders serving incoming CCIS trunks need be arranged for the outpulser function.

4.1.1 Processor access to called number

Prior to CCIS, the senders presented only the first six called number digits to the decoder channel since ETS route translation capability was limited to that number of digits. When an outgoing CCIS trunk is selected, the processor must read the entire called number from the sender in order to formulate the Initial Address Message (IAM) to the next office. Therefore, five additional digits are made available through an expanded decoder connector and presented to the processor by a block of DAS nonreporting scan points associated with each decoder channel. DP senders and older vintage MF senders were arranged to request route translation before called number registration was completed thus allowing overlap outpulsing to speed call completion. This feature is eliminated from the MF sender since selection of a CCIS outgoing trunk requires the availability of all called number digits. Retention of overlap outpulsing in the DP sender was deemed advisable for calls selecting slower signaling conventional outgoing trunks to avoid an increase in call setup time. Therefore, the DP sender is arranged for pretranslation. If the first available outgoing route is CCIS, the processor signals the DP sender to release from the decoder channel and to rebid after all called number digits are available.

4.1.2 Operation with CCIS outgoing trunk

Another sender change is the ability to accept a new outgoing trunk class (CCIS) from the marker. This class conditions the sender to extend the transmission path to the continuity check transceiver, to cancel its retrial timing after completion of the usual checks with the outgoing trunk circuit, and to remain linked to the call until signaled to release by the processor via a distribute point. The sender is held while the outgoing voice path continuity check is performed and until receipt of an Address Complete (ADC) message from the last CCIS office signifying successful call progress to that point. A scan point confirms sender release to the processor.

4.1.3 Reattempt order from processor

When a CCIS call cannot be completed by a succeeding switching office, an ineffective attempt message is returned to the first CCIS office requesting that the call be routed to the appropriate tone or announcement. Unlike CCIS trunks, the processor is not linked to conventional trunks by a distribute point for starting or releasing cross-office connections. Consequently, the sender has been held on the call expressly to aid in establishing another cross-office connection. The sender is signaled by another distribute point to release the previous connection to the outgoing CCIS trunk and rebid for a decoder channel to start the connections to the tone or announcement trunk. The reattempt procedure is also used to retry the call upon failure of the initial CCIS outgoing attempt, e.g., because of a continuity check failure.

4.1.4 CAMA overlap operation

Route translation for a CAMA call is started after the first digit of the calling number is identified following reception of the called number. Thus, the completion of calling number identification and the subsequent initial billing entry overlap the switching process. A delay in the billing entry, particularly on calls requiring operator identification of the calling number, could result in completion of the connection to the called customer before release of the CAMA sender. To avoid this possibility, the Continuity (COT) message is withheld by the 4A CAMA office until the CAMA sender signals completion of the billing entry to the processor via a dedicated scan point. Completion of outpulsing to a conventional trunk or cut thru to the called customer is delayed at the last CCIS office in the connection until receipt of the COT message.

4.1.5 Outpulser function

MF senders in groups serving incoming or two-way CCIS trunks are further modified to function as either an MF sender or CCIS outpulser

Table I — Conditioning Sender or Outpulser

Function	Distribution P2	Distribution P1
Incoming:		
MF sender	—	—
Outpulser: 4-wire, seize decoder channel	—	×
Outpulser: 2-wire, start continuity test	×	—
Outpulser: 2-wire, seize decoder channel	×	×
Outgoing:		
Reattempt	—	×
Release	×	—

and are termed sender-outpulsers. The following description also applies to outpulsers serving only CCIS trunks.*

Upon seizure by the link controller, the processor conditions the outpulser for incoming MF or CCIS service, per Table I, using the same two ditribute points furnished for outgoing operation. In the outpulser mode, MF digit reception is bypassed and a decoder channel is seized either immediately, or upon completion of the incoming 2-wire continuity check. Control is assumed of the incoming trunk relay which applies the 4-wire check loop or switches the transmission pairs to the transceiver for the 2-wire check. The incoming trunk circuit continuity check relay is released upon completion of the 2-wire continuity check, or when the outpulser is signaled to release for the 4-wire check.

When the call completes to an outgoing conventional trunk, the called number digits to be outpulsed are loaded through the decoder connector from a group of DAS distribute points associated with the decoder channel. To reduce modification costs, a maximum of eight digits are loaded in this manner while the existing code conversion instructions through the marker are used for up to three additional digits. Outpulsing of the last digit is deferred until the processor receives the COT message indicating all preceding CCIS switching offices have successfully switched the call. The processor then distributes the release instruction to allow outpulsing to be completed. The 4-wire continuity check loop in the incoming trunk is also released and an address complete message returned to the first CCIS office. Any irregularities encountered during outpulsing will cause the outpulser to reattempt the call in the normal manner.

Outpulser operation following selection of an outgoing CCIS trunk is identical to the previously described sender operation. However, the outpulser is dismissed following the outgoing continuity check and receipt of the continuity message from the preceding office, thus reducing holding time. If a reattempt is necessary following outpulser release, the

* During the remainder of this article, the term "outpulser" will be used to include both outpulser and sender-outpulser operation.

previous connection is released by resetting the incoming CCIS trunk circuit's distribute point and a new cross-office connection is then started.

4.2 Markers and outgoing link frames

Processor selection of CCIS outgoing trunks requires a change in the current marker method of establishing connections through the switching network. For conventional outgoing trunks, the processor preselects a subgroup of trunks and presents the marker with the trunk block connector location of a pair of control leads per trunk. The marker hunts and seizes an idle trunk by means of the sleeve lead, and then identifies the trunk's outgoing link frame appearance by a coded three frequency ac signal on the select magnet lead. After connecting to the link frame, the marker operates the select magnet preparatory to closing the crosspoint and then verifies this segment of the connection via the sleeve lead.

When a CCIS outgoing trunk is selected, the processor presents the marker with the identity of the trunk's outgoing link frame termination during the decoder channel stage, using the same distributor register output field assigned to trunk block connector identity. Two new bits in the distributor register indicate whether an outgoing conventional or CCIS trunk is involved to permit the marker to properly interpret the distributor register output. The marker then connects to the indicated outgoing link frame to gain access to the CCIS trunk preparatory to establishing the cross-office connection. In addition to the marker modification, all outgoing link frames require a complementary modification to make the two trunk control leads available for all or part of the trunk terminations.

Elimination of trunk block connector usage on CCIS outgoing calls removes the administrative overhead of the control lead cross-connections between the trunk and trunk block connector. Furthermore, marker holding time is reduced by approximately 17 percent on outgoing CCIS attempts.

The other significant marker modification is the capability to connect a continuity check transceiver to the incoming sender or outpulser for the voice path continuity check of the outgoing trunk. This operation has been previously described in Section 3.3.

V. SOFTWARE STRUCTURE

5.1 General

The software control structure used in both the 4A/ETS and 4A/CCIS systems is that of the Stored Program Control No. 1A (SPC/1A),[7] which was originally developed for use in the Traffic Service Position System

No. 1 (TSPS No. 1) and 4A/ETS. This structure has been described extensively in previous BSTJ articles.[8] The primary feature of this structure is a hierarchy of hardware and software driven priority levels of program execution. The lowest three levels, known as base (or main), J-level, and H-level, are used for call processing, administrative, input-output, and routine maintenance functions. Levels G thru A, in ascending priority, are used for various types of higher priority maintenance functions, and are entered by hardware stimuli. Level J is entered every 5 ms by a simulus from the hardware clock, and level H is driven by the 5 ms clock as an overflow to ensure attention to high priority timed tasks. Base level is divided into six classes of work by a software algorithm. Five of these classes, named A thru E, are entered in a rotational scheme that causes class A to be entered twice as frequently as class B, class B twice as frequently as class C, C twice as frequently as D, and D twice as frequently as E. The sixth class, known as interject, is used as a very short delay class, and entry into interject is effectively interspersed among the various tasks executed in all of the other classes. This base level control structure, which is actually just a task sequencing algorithm, permits control of intertask entry delays by judicious class assignment. It is a structure that is fairly well behaved with load variations, and overload situations can be controlled by task cancellation within classes or by dynamically shifting tasks between classes to adjust delays.

5.2 CCIS approach

The most significant deviation from the operational software structure of both No. 1 ESS and No. 1 TSPS is the use in 4A/CCIS of an external-stimulus driven approach rather than the periodic entry of internal processing routines that are interconnected by work hoppers. A set of external "call-advancement" stimuli have been defined that are used to drive an individual call from state to state. When a simulus is recognized for a call in a particular state, that call is advanced in the switching process as far as possible and is left in a new state in which it is awaiting another external stimulus to drive it on. These external stimuli are items such as a trunk supervisory scan point changing state because it has become hardware busy, the scan point indication that a common control unit has become associated with this call, or receipt of a message from the CCIS signaling link. Another very commonly used stimulus that is not truly "external" is the expiration of one of several software interval timers that are used for activities such as protection while awaiting an external action, e.g., the response to a message sent over the CCIS signaling link, or for properly timing the interval between a pair of software activities, such as two sequential distributions to trunk hardware to form a ring forward pulse.

The external stimuli are presented to the call processing software by a set of monitor programs that are scheduled in various base level classes according to the delays which may be tolerated in recognizing and acting upon the stimuli. Some of these programs are carried over from the 4A/ETS system. These include routines for recognizing bids for service from sender link controllers, decoder channels, and markers. While these programs are conceptually the same as those provided in 4A/ETS, they have been modified to accommodate new hardware units, e.g., outpulsers and outpulser link controllers, and new processing requirements introduced by the CCIS design. Scheduling of these tasks within base level generally uses the same technique as in 4A/ETS, whereby each of these tasks is permanently assigned to a particular base level class, but entry during the execution of an individual class is contingent upon the expiration of a software timer used to guarantee a minimum time between entries to the task.

New monitor programs have been provided to gather stimuli from the new Distributor and Scanner (DAS) and signaling terminal circuits. The DAS monitor program is scheduled for execution in every class A base level entry, and gathers autonomous scan reports that have accumulated in the DAS since the last entry. Each report is received from the DAS change report buffer, and the change address is examined to determine the hardware unit associated with that point. Based upon the type of hardware reporting and the direction of change, the monitor program will enter a processing program to take the appropriate actions. Upon completion of the processing of this point change of state, the processing program will reenter the DAS monitor. The monitor will then pick up the next entry in the DAS change report buffer, and the process will be repeated until it is determined that no more change reports are available. At this time the DAS monitor will return control to the next class A task.

The monitor for the signaling terminal is very similar to that for the DAS, except that is broken into two separate portions. One of these is executed as a base level class A task, and is used to receive CCIS messages from the signaling terminal's nonpriority receive buffer. Each nonpriority message received, which includes all of the normal telephone signals except Answer, is removed from the buffer by the monitor, and is decoded by a series of table look-ups. Upon determination of the message type, the monitor enters the appropriate processing program for determination and execution of the proper action. Upon completion of this action, the processing program returns control to the terminal monitor, and the next message is removed from the terminal's receive buffer. This procedure is then repeated until it is determined that no more messages have been received by the signaling terminal, and control is passed to the next class A task.

Certain CCIS messages, of which the most significant is the Answer signal, require priority attention due to more stringent limitations on permissible cross-office delays. Upon reception from the signaling link, the terminal sorts the messages from the rest received and places them in a separate, priority buffer for special handling. This buffer is serviced by a portion of the terminal monitor program that is entered as a J-level task at a 10 msec inter-entry rate. This program processes each CCIS message found in the priority buffer in a fashion directly analogous to its base level counterpart, except that all of the message processing is conducted on J-level so as to control the service time. It is interesting to note that simulations have demonstrated that at low traffic levels, the class A reentry time is low enough that nonpriority messages actually encounter less handling delay than priority messages due to the fixed priority monitor reentry rate. At moderate-to-high traffic levels, however, the mean and variance of the class A reentry time become too high to allow servicing priority messages on base level and still meet the cross-office delay requirements.

5.4 Software structures

The software package required to support the CCIS capability is divided into two distinct parts: the generic program and the office data. The generic program is identical for all 4A/CCIS offices which support CCIS trunks while the office data tailors the operation to the characteristics of the individual installation. The office data is compiled by the Western Electric Co. based on information supplied by the telephone company in questionnaires which uniquely define a particular office. The office data is composed of approximately 230 different data table types. This data is required for three primary purposes. First, the generic program must be provided with sufficient information to maintain the office during trouble conditions. Secondly, data is required to describe how equipment is assigned in the office. For instance, the selection of outgoing CCIS trunks is completely processor controlled. Therefore the outgoing link frame appearance of every equipped CCIS trunk must be described in data tables. The third class of office data which is required describes the routing strategy for the office. Nearly all of this data is subject to modification from time to time due to equipment additions to the host office, the addition of offices to the DDD network, changes to routing strategies, etc.

Data which varies on a per call basis is stored in, basically, one of two storage areas; the trunk register or the call register. Each CCIS trunk has three 20-bit words of temporary memory devoted to storage of transitory information. Contained in this area are such items as the trunk's state during call setup and whether this trunk is being used as an incoming or outgoing trunk. The other major storage area for per call information is the call register. Stored here are such items as the digits which were received from the previous office, any special instructions which were received, and the status of the call at all times during the processing. Unlike trunk registers, the call register is not associated with any piece of hardware. Instead, 127 call registers are provided in each 4A/CCIS office. Each call register is 14 20-bit words long. Any call register may be used to process any CCIS call. Because of its very central nature, the call register is the subject of very close scrutiny at all times. Many call failures are noted first by inconsistencies in the state or contents of the call register. Due to the limited number of call registers available for system use, every reasonable precaution is taken to limit the time during which a single call register is associated with a given call.

The storage of the generic program, the office data, and provision of all temporary memory requires nearly 400,000 20-bit memory locations. In addition to a complement of conventional trunks, this memory space will accommodate the data and associated routing translations for between 4,000 and 7,000 CCIS trunks. Additional trunks each require approximately eight to thirteen 20-bit words of memory depending on trunking patterns and exclusive of any route translation changes which might be implied by any such addition. If additional storage is required, a duplicated module of memory (65,536 20-bit words) is added to the system. This should be sufficient to support the maximum expected number of trunks.

VI. CALL PROCESSING

6.1 Call types

A given office will have a combination of CCIS and conventional signaling trunks. This creates four basic call types for the call processing programs to deal with: conventional incoming and outgoing, CCIS incoming and outgoing, CCIS incoming and conventional outgoing, and conventional incoming and CCIS outgoing. These basic call types are further modified by whether the connection is to or from a 2-wire or 4-wire switching office. The call processing programs are arranged to accommodate any of these combinations of call types. By far the greatest software involvement is for a CCIS incoming call which is switched to a CCIS outgoing trunk. The conventional incoming to conventional outgoing call has been previously described.[3]

The processing of a CCIS call is separated into a number of real-time segments. These real-time segments are largely created by the interaction of the software with the hardware at various stages of the call. Because of these many interactions, the call register is used to store the details of the call as it progresses.

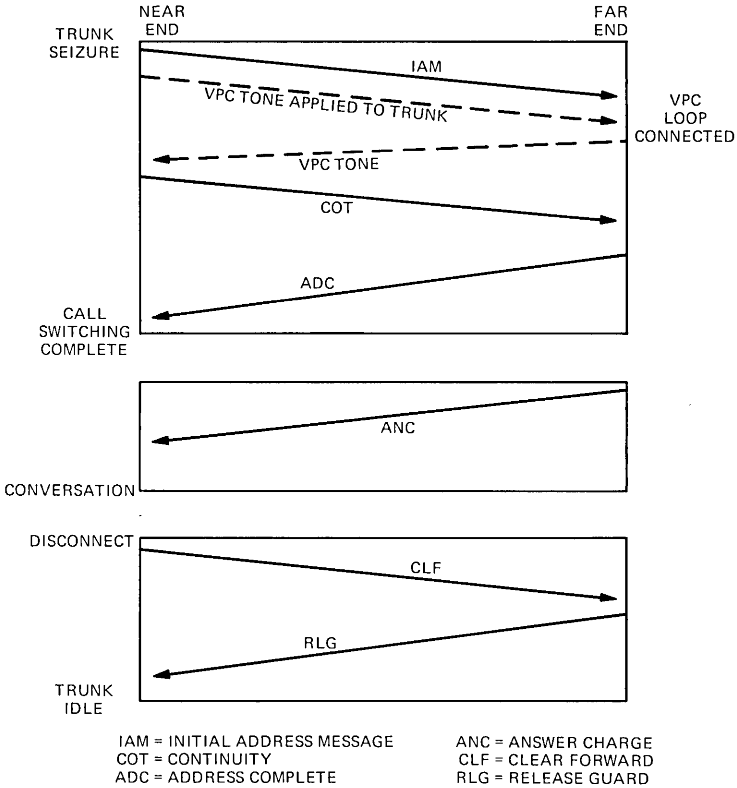

Fig. 4—Typical signal unit exchange.

6.2 CCIS incoming call

6.2.1 Incoming trunk seizure

A simplified sequence of CCIS signals exchanged on a CCIS to CCIS call is shown in Fig. 4. The first stimulus is the reception of an Initial Address Message (IAM). This multiunit message contains the identity of an incoming trunk which has been selected by the preceding office and the called number which will be used for the purpose of route translation. Upon receipt and decoding of the IAM, the status of the identified incoming trunk is changed to indicate it has been selected. A call register is selected and the associated temporary part of the trunk register and call register are linked together. The called number digits, which were received in the IAM, are deposited in the call register. At this point a route translation is made to select an outgoing trunk. If a CCIS outgoing trunk is selected its trunk register is linked to the incoming trunk register and to the call register, the trunk is marked busy to prohibit its selection by another call, and the IAM to be sent to the succeeding office is formed and transmitted via a CCIS signaling link. The selected trunk's identity is stored in the associated call register. Next, the distribute point assigned to the incoming trunk is operated under program control to connect a transmission loop in the incoming trunk circuit so that the preceding office may complete its Voice Path Continuity (VPC) check of the trunk, and to start the selection of an idle outpulser.

If the first available outgoing trunk group selected contains conventional signaling trunks, route translation is deferred since the marker will select the outgoing trunk.

6.2.2 Link controller stage

The next software action for this call occurs when a link controller notifies the processor that it is attempting to establish a connection between an incoming trunk and an outpulser. The validity of the request is checked and if a legitimate incoming CCIS trunk is identified the link controller is notified, via program controlled distribute points, to complete the connection between the incoming trunk and the outpulser. The identity of the outpulser is recorded in the call register and the identity of the incoming trunk is stored in the temporary memory associated with the outpulser (referred to as the STORE table). The outpulser is also conditioned for incoming CCIS operation and performance of a 2-wire or 4-wire continuity check with the preceding office by means of program controlled distribute points. The call register state is advanced, ending this real-time segment. When the outpulser has been attached, a scan point will report that the outpulser is busy. The call register will then be updated to indicate that an outpulser is attached and no additional program interaction will be required at this stage.

6.2.3 Completion of incoming VPC check[5]

During all these operations other activities which occur but require no immediate action will be recorded in the call register. It is possible, for instance, that the preceding office could have successfully completed the VPC check of the trunk. In this case a COT message would be transmitted by the preceding office. When received, the event is recorded in the call register but if this office is not ready to transmit COT to the succeeding office, no further action is taken.

6.2.4 Decoder channel stage

The next hardware stimulus that should occur is the decoder channel request for service. This request will occur immediately following seizure of the outpulser if the preceding CCIS office is a 4-wire switching office. However, for calls from 2-wire offices, the outpulser will have been instructed to delay decoder channel seizure until the preceding office has completed the continuity check of the interconnecting transmission path. When the COT message is received from the 2-wire office, the outpulser is directed by the processor to proceed with decoder channel selection.

As part of its input, the decoder channel will identify, via scan points, the outpulser with which it is currently associated. Based on the identity of the outpulser the incoming trunk's identity will be retrieved from the STORE table. Since the incoming trunk is CCIS, the STORE table will contain the index of the incoming trunk unprotected trunk register. This will be used to retrieve the identity of the associated call register which had previously been stored in the trunk register. The call register is updated to indicate which decoder channel is being used on the call. The results of the route translation, which was performed when the IAM was received, are distributed to the decoder channel via distribute points. However, the first available outgoing route may have contained conventional trunks, therefore, outgoing trunk selection was deferred. Route translation is then repeated at the decoder channel stage and either a CCIS or conventional route may be selected, depending on the characteristics of the first available outgoing route. Selection of a CCIS trunk results in sending an IAM to the next office and the distribution of the outgoing trunk identity to the decoder channel. An incoming conventional call is also connected to a CCIS outgoing trunk in this manner. If a conventional outgoing route is chosen, the processor distributes the trunk block connector location of an idle trunk subgroup to the decoder channel's distributor register and the marker selects an idle outgoing trunk to complete the connection in the normal manner. The called number digits to be outpulsed to the next office are also distributed to the decoder channel and passed to the outpulser through the decoder connector.

6.2.5 Marker stage

When the decoder channel requests release, it is the signal that the marker has been selected. This information is received via scan points associated with the decoder channel. At this time an idle transceiver is selected to perform the VPC check on the outgoing CCIS trunk and its identity is passed to the marker via distribute points. The decoder channel distribute points are reset so that it may release.

When the marker connects the selected transceiver, the transceiver activates a scan point. Recognition of this stimulus causes the program to distribute to the transceiver the information necessary to set the proper tone levels for the VPC check. Once again the state of the call register is updated and another real-time segment ends.

During this time the marker is also attempting to make a connection between the incoming and outgoing trunks. If it is successful it will report success to the processor via scan points associated with each marker. The success of the cross-office connection is noted in the call register. The program now waits to be notified that the VPC check has been completed. If the COT message has been received from the preceding office and there is indication of a successful cross-office connection, the COT message will be sent to the succeeding office and the transceiver will be reset. When the transceiver reports that it is idle, the outpulser will be released. The program waits for the indication that the outpulser has been released and updates the call register.

6.2.6 Call completion

Two stimuli remain before the call reaches the talking state. The first of these is the Address Complete (ADC) message which indicates no reattempt of this call will occur and that all address information may be erased. At this time the call register is released and the ADC message is relayed to the preceding office. The final signal to be received is the Answer Charge (ANC) message. When this message is received the unprotected trunk registers are updated to the answered state and the ANC message is sent to the preceding CCIS office. The call is now in a stable talking state.

If the incoming trunk is a conventional trunk, the answer signal is passed backward by program operation of the distribute point associated with the outgoing CCIS trunk.

6.2.7 Call termination

When the call terminates, several additional CCIS signals will be exchanged. Suppose the calling party disconnects first. A Clear Forward (CLF) message will be received from the preceding CCIS office. The incoming trunk's distribute point is reset to start release of the incoming trunk and the cross-office connection. When the incoming trunk reports release via its scan point, a Release Guard (RLG) message is returned to the preceding CCIS office. The incoming trunk status is then changed to idle. Release of the outgoing CCIS trunk from the cross-office connection is indicated via its associated scan point. After a short interval, to assure complete release of the outgoing trunk, the CLF message is sent to the succeeding CCIS office. Upon receipt of RLG for the outgoing trunk, its software state will be changed to idle thus permitting selection for another call.

6.2.8 Ineffective attempts and reattempts

If, during the translation or processing of a call, it is determined that the call should not be permitted to complete, the preceding office can be so notified via CCIS signals. This condition may arise for any number of reasons. A good example of this capability occurs when a customer dials a nonexistent or unassigned number. In this case a Vacant National Number (VNN) message is sent to the preceding office. It is the responsibility of the preceding office to repeat the VNN message to its preceding office if that incoming trunk is CCIS, or if the incoming trunk is a conventional signaling trunk then a reattempt of this call must be made to route the call to the appropriate announcement. By using these failure messages, it is possible to eliminate some unproductive use of trunk facilities. A failure indication may be received at any time during the processing of the call until the ADC message is received. If the incoming trunk uses conventional signaling, a reattempt signal is sent to the sender to initiate the release of the initial connection. Another decoder channel seizure is required to obtain an announcement routing.

This same mechanism may be used to reattempt a call following detection of simultaneous two-way trunk seizure. When the reattempt occurs, it is necessary to release all common control equipment which may still be processing the initial attempt. The marker will accept a trouble release distribution from the processor to expedite release of the CCIS trunk. Link controllers and decoder channels are similarly arranged to accept the trouble release signal during their normal operation.

VII. NETWORK MANAGEMENT

7.1 General

Network management, the capability of modifying routing patterns and controlling the flow of certain types of traffic in a real-time response to congestion in the switched network, has always been provided in the 4A/ETS system. Due to the limited role of the ETS switching processor in call handling and the inability to carry call history information between offices with conventional signaling, it was not possible to provide many useful network management features.

Modification of 4A/ETS for CCIS operation has eliminated many of the constraints on network management capabilities, and the 4A/CCIS system offers several new and expanded features. Two of the new features take direct advantage of the interoffice communication capability afforded by CCIS.

7.2 CCIS dynamic overload control

The first of these new features, CCIS Dynamic Overload Control (DOC), permits an office that encounters an overload to automatically communicate a distress signal to all connecting offices by the broadcast of a series of DOC signals over the CCIS signaling links to those offices that normally originate telephone traffic to the office. Upon receipt of a DOC signal, the connecting offices will cancel or alternate route portions of its outbound traffic for that office for a brief timed interval or until another message is received canceling the DOC condition. The amount of traffic being alternate routed or canceled is determined by parameters previously set and the level of congestion defined by the received message. Three levels of machine congestion are defined ranging from a relatively mild overload to a complete loss of switching capability. One determination of machine congestion state is made by monitoring the average time between reentries to class E base level work. When this average time is noted to exceed certain threshold values, the proper DOC message is broadcast repeatedly until the condition subsides, at which time messages will be broadcast indicating that the situation has returned to normal.

7.3 Out-of-chain routing

Another new feature makes use of the CCIS capability of sending call history information along with the call address information as a traveling classmark. Without CCIS, it is necessary to be very careful about the routing treatment given calls which overflow from first choice or direct routes. Normally such overflow traffic is offered to a fixed series of alternate routes intended to route the traffic upward in the switched network hierarchy. Rules for specifying these alternate routes are carefully defined to prevent a "ring-around-the-rosy" condition from occurring, and calls thus routed are said to be routed "in-chain." Certain abnormal events, such as peak busy days or machine failures, however, occasionally make it desirable to temporarily establish an "out-of-chain" routing pattern. Without CCIS, such out-of-chain routing must be carefully set up to prevent the "ring-around-the-rosy" condition. To avoid this condition with CCIS, a traveling classmark has been established to describe when a call has been routed out-of-chain. Such a call can then be prevented from being rerouted at subsequent switching points.

7.4 Code blocks

With CCIS the switching processor has access to all of the address digits of a call making it possible to expand code blocking capability to include seven or ten incoming digits rather than the three or six digit capability of 4A/ETS. Certain abnormal network events, such as mass calling to a particular number due to a telethon program or natural disaster, make it desirable to regulate as close to the sources as possible the number of attempts being offered to the network destined for that station without disturbing traffic that may be destined for that same local area but not related to that particular event. With seven or ten digit code blocking capability this can be done, and the control can be specified for application to one of several different percentages of traffic bearing those address digits. Choice of the individual calls to the specified destination to which the control is actually applied at a given percentage level is determined by a random number technique.

7.5 Selective trunk reservation

Another new feature with 4A/CCIS is that of trunk reservation. This feature takes advantage of the fact that selection of the trunk to be used from an outgoing group which uses CCIS is done by the switching processor. With this feature active on a trunk group, when the number of idle trunks in that group falls below prespecified thresholds, controls are applied to the outgoing traffic being offered to that group so as to favor incoming and direct routed outgoing rather than alternate routed traffic accessing the remaining trunks.

7.6 Expanded capabilities

In addition to the implementation of the new features described above, the numbers of controls that can be simultaneously active in the office has been considerably expanded, as has the selectivity of the portions of the traffic load affected by each control. New teletypewriter input messages have been designed to provide for manual activation of the new and enhanced control capability, and new status messages have been provided for display of controls in effect in the system and to describe which trunk groups have controls applied.

VIII. SYSTEM REAL-TIME CAPACITY

There are many different ways in which to describe the real-time capacity of a switching system. One of the most easily understood is to define an upper limit for processor occupancy, make some reasonable assumptions about the characteristics of the incoming traffic, and then describe the number of incoming trunk terminations that can be supported under those conditions. One must also, however, keep in mind any other system characteristics that may also limit system capacity. In the case of 4A/CCIS, the limit of 135,000 marker attempts per hour must be considered as such a limit.

For the 4A/CCIS system, usable processor occupancy of 80 percent can be assumed as a reasonable upper limit. Also, one can assume that each equivalent one-way incoming trunk offers an input of ten calls per hour, that the incoming calls will be divided between conventional and common channel signaling in the same ratio as their respective numbers of trunks, and that these incoming calls will be switched to trunks having conventional versus common channel signaling again by the ratio of the number of trunks of each type. These latter two assumptions are necessary because of the wide variation in the amount of processor time required to switch the different call types.

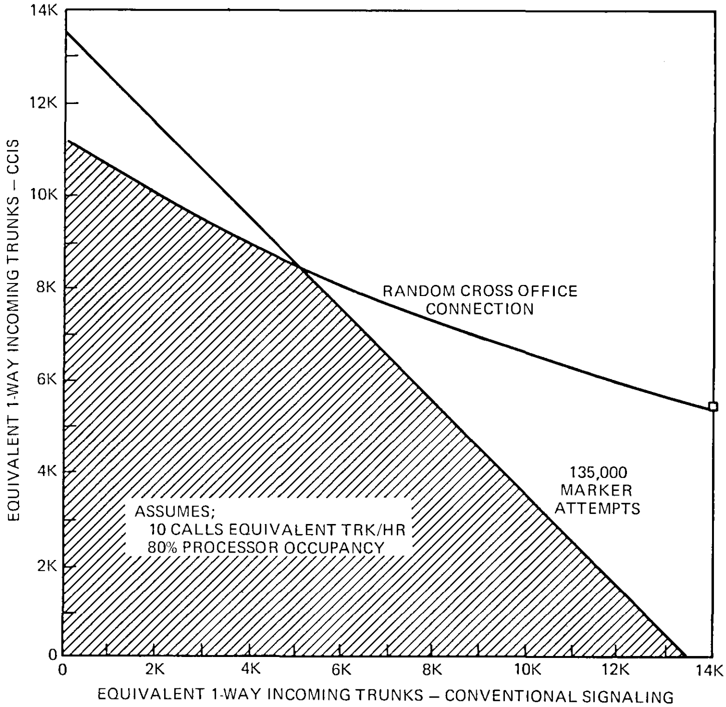

Fig. 5—4A/CCIS switching office equivalent one-way incoming trunk capacity. Crosshatch indicates operating region.

Within the above assumptions, studies indicate that for numbers of CCIS equivalent one-way incoming trunks exceeding approximately 8000, the switching processor is the limiting element in the system; the maximum number of equivalent incoming CCIS trunks that can be handled is about 11,000 (15,400 actual incoming terminations on the average), if no trunks are provided with conventional signaling. For numbers of conventional equivalent one-way incoming trunks exceeding 8000, the total number of marker attempts becomes the limiting factor; in this range the processor real time will not impact the system's switching capacity.

Sensitivity analysis of the effects of variations in the distribution of the types of cross-office connections has been made. The position of a particular switching office within the toll network hierarchy and variations in the types of traffic which it switches, whether predominantly intertoll or toll connecting, may skew this distribution one way or the other. This analysis has shown that the crossover point between a processor real-time constraint and a marker attempt constraint is shifted very little by these variations. Further, these variations were shown to have a nearly negligible impact on the number of trunks that can be handled in the region in which processor real time is the dominant factor. A summary of these conditions is shown in Fig. 5.

IX. MAINTENANCE

9.1 General

A major factor in the success of a telephone switching system is the ability to provide continuous service regardless of component failures. The component failure rate is minimized by the use of highly reliable components in conjunction with adequate circuit margins. The effect of failures on the system, and hence the required maintenance strategy, depends on the degree of concentration of system control. In the CCIS addition to the 4A/ETS, concentration of control varies widely, from the Distributor and Scanner (DAS) which controls a large portion of the system operation, to the individual trunks which provide one message circuit capability. In addition, the 4A/ETS, as well as the CCIS addition, contains a mixture of electronic and electromechanical technologies. The CCIS maintenance features which provide fault recovery and repair, as discussed below, take into account the number of units, system function and hardware technology of each unit to produce a maintenance plan which is compatible with the existing 4A/ETS operation.

9.2 Electronic frames

The implementation of CCIS in 4A/ETS requires the addition of two electronic frames, namely the Distributor and Scanner (DAS) and the Terminal Group (TG).[5] Since these units contain a high concentration of system control, the maintenance requirements are strict, and are summarized below:

(*i*) Immediate detection of all service affecting faults.
(*ii*) Detection of nonservice affecting faults at a rate which is significantly greater than the occurrence rate.
(*iii*) Proper system operation in the presence of any single fault.
(*iv*) Moderate repair time by office craft.

The general fault reaction sequence for the DAS and TG, as well as existing 4A electronic units, is shown in Fig. 6. The primary fault detection ability resides within the individual units, in the form of additional circuitry or software which verify circuit operation, and in the central processor to individual unit communication checks. When a fault is detected, normal processing is interrupted and a special program sequence is executed. This program localizes the fault to an individual unit and reconfigures the system to avoid the suspected circuit. At this point normal processing is resumed with an interleaved diagnostic scheduled. The craftsperson upon examining the diagnostic results effects repair,

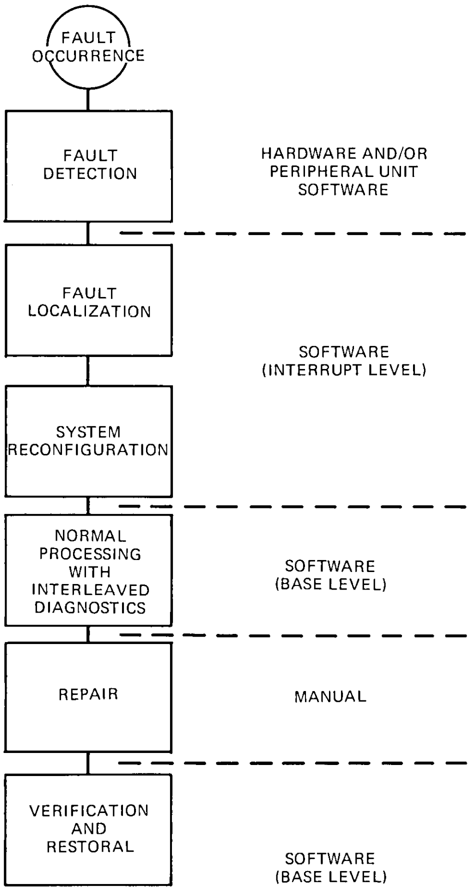

Fig. 6—Fault reaction sequence.

verifies correct operation using the diagnostic program, and returns the unit to service. Both the DAS and the TG follow this sequence; however, there are some differences in the implementation which are discussed below.

9.2.1 Distributor and Scanner

The DAS unit consists of duplicated controllers which access a non-duplicated matrix of scan and distribute points. In the normal mode, the two controllers are running in synchronism and comparing results at critical points in the operation. This matching operation is the major detection mechanism for controller faults. If a mismatch occurs, both controllers immediately stop and signal the central processor. When the processor begins to service the DAS, an immediate interrupt sequence is initiated.

The nonduplicated matrix is designed such that matrix faults affect only a small number of scan and distribute points. The majority of these faults are detected by normal operational checks of the circuits which utilize the points. The maintenance plans for connecting circuits provide for resolution and repair of this class of matrix failures. The remaining matrix faults are detected by the controllers when the point is accessed. Controller detected matrix faults result in the same sequence of actions as controller faults.

When the processor is interrupted, as a result of communicating with the DAS, a fault recognition program is entered. The major object of this program is to distinguish controller faults from matrix faults and take the appropriate action. In the case of controller faults, the failing controller is identified, the system is reconfigured to operate with the remaining controller, and a diagnostic of the faulty controller is scheduled. In the case of matrix faults, the affected scan and distribute points are located and further interrupts on these points are inhibited by setting hardware controls within the DAS. On a deferred basis, the circuits which connect to these points are identified and either automatically removed from service or reported for manual attention, depending on the connecting circuit type.

The diagnostic output identifies the suspected circuit pack or packs to the craftsperson who implements repair. After the repair has been completed the diagnostic is manually requested in order to verify proper operation as well as to restore the system to the normal configuration.

9.2.2 Terminal group frame

The terminal group frame consists of two duplicated Terminal Access Circuits (TAC) and up to sixteen terminal units. The TACs are self-checking and each circuit has full access to all sixteen terminals. Each terminal is a self-checking stored program unit capable of controlling one signaling link. For reliability each signaling link, including the terminal unit, is duplicated.

Faults detected by either a terminal unit or one of the TACs results in a processor interrupt on the next processor access, causing the terminal fault recognition software to be entered. The major function of the fault recognition routine is to distinguish between TAC and terminal faults and to perform the appropriate system reconfiguration. In the case of TAC faults, the failing TAC is identified, scheduled for diagnosis, and the system is reconfigured to use the remaining unit. In the case of terminal faults, the faulty terminal is removed from service and scheduled for diagnosis. Whenever a terminal is removed from service, the signaling network must be reconfigured to use the mate signaling link as described in the next section. The repair, verification and restoration to service procedure for the TAC and a terminal are similar to that of the DAS controller.

9.3 Signaling links

The CCIS signaling link consists of a terminal unit, including modem, at each end of a Voice Frequency Link (VFL).[6,9] CCIS switching offices exchange information over these signaling links in the form of messages consisting of one or more signal units. Because of signaling delay limitations, the occupancy of each signaling link, at the present 2400 bps transmission rate, is approximately 0.6 erlang (six-tenths of the available signal unit slots carrying messages). Assuming each trunk produces an average of ten call attempts per hour, approximately 3000 trunks may be assigned to a signaling link. If only one signaling link were carrying the signaling traffic for these trunks, a signaling link failure would result in a total loss of signaling for all trunks assigned to that link. Therefore, all switching office links are equipped in load sharing pairs, called signaling link complements. Normally, each signaling link carries traffic for up to 1500 trunks, but in the event of failure of one link, the mate link can carry the traffic for all 3000 trunks without excessive signaling delays. Because of the large number of trunks that may be served by a link complement the availability requirements are strict and the reliability of two links is, in some cases, insufficient. Thus a signaling link can be equipped with two voice frequency links, one normally in service while the remaining VFL provides a switched backup. After a failure of the in service VFL, signaling capability can be recovered after a short time by using the standby VFL. During this recovery time the mate link, if available, carries the entire load.

Signaling links directly interconnecting two CCIS switching offices are called fully associated links, or F-links. Normally, trunk groups are not large enough to economically justify F-links. Instead, each switching office connects to each of the Signal Transfer Points (STPs) in the same signaling region over what are referred to as A-links. The A-links are always provided in pairs (complements) and are not associated with a particular trunk group. Each message, consisting of one or more signal units, has a 13-bit label field in the first signal unit. Each trunk is uniquely identified with this label in conjunction with an associated signaling link; thus each duplicated pair of signaling links can support the signaling traffic for up to 8192 trunks. However, as noted earlier, queuing delays limit this to about 3000 trunks. The STP, using routing data, transfers CCIS messages to the distant switching office over the signaling network. Routing at the STP is based on the incoming signaling link number and the incoming label. Note that, in addition to routing messages between links, a portion of the incoming label is translated at the STP. Thus switching offices at each end of the trunk can uniquely identify the trunk by a label which is independent from the label in the other switching office. An administrative process has been established to coordinate labels with trunks at both switching offices and with the STP translation data.

9.3.1 Signaling link fault detection

Terminal faults have already been discussed in Section 9.2. Many other faults, primarily due to transmission impairment in the voice frequency facility, do not cause maintenance interrupt level activity, yet must be recognized since the link becomes useless for signaling. To accomplish this, the terminal checks each signal unit to ensure that it has been received error-free and detects unacceptably high error rates. If the acceptable error rate is exceeded, the terminal notifies the processor that this link is currently not suitable for carrying traffic. The signaling link failure initiates the fault reaction known as changeover, discussed below.

Many facility failures are only in one direction of transmission; however, the CCIS system requires signaling capability in both directions. Hence, when the processor is notified of an excessive error rate, it places the terminal in a mode which continuously sends a specially coded signal unit, changeover, to the far end. On receiving changeover signals, the processor at the far end is aware of the signaling link failure and also initiates the changeover sequence.

9.3.2 Signaling link fault reaction

When the processor receives notification of a signaling link failure a changeover sequence begins. The processor first places the terminal in a mode which retains all unacknowledged and untransmitted messages. Additional messages are diverted immediately to the mate signaling link, while the processor retrieves all untransmitted and unacknowledged messages stored in the terminal of the failed signaling link and retransmits them on the mate link. Some messages encounter a slight signaling delay, but none are lost.

Both ends switch immediately to the standby VFL if it is available and the processors attempt synchronization on the failed signaling link. Until synchronization is achieved, both ends continue to switch voice frequency links, the switching office at a five-second rate and the STP at a ten-second rate to assure overlap half the time. Because of facility diversity, synchronization is usually achieved on the initial attempt on the voice frequency link which was standby at the time of the failure.

When the signaling link is synchronized, each processor measures the error rate to determine the suitability for CCIS service. After a sufficient interval of acceptable performance, the processors at each end of the

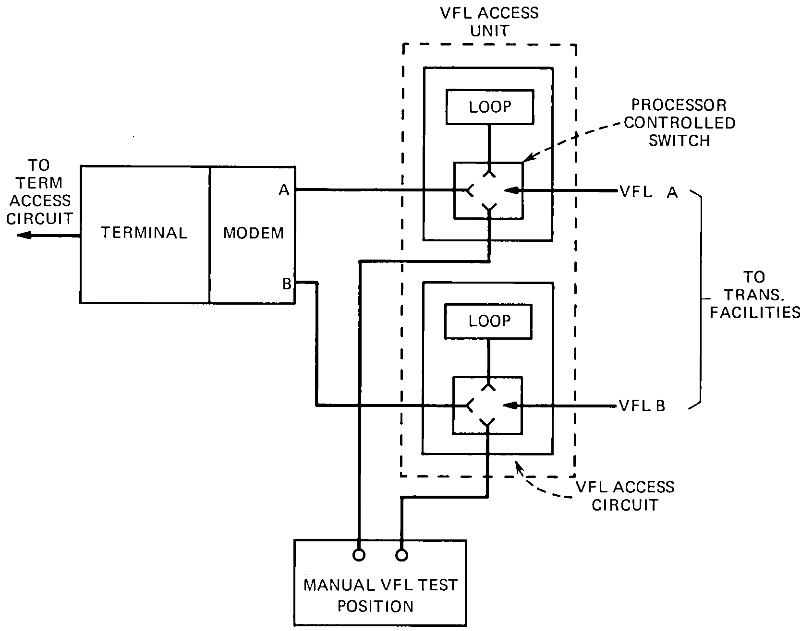

Fig. 7—Switching office VFL test arrangements.

signaling link exchange specially coded signals, load transfer, and load transfer acknowledgment. In addition, information concerning the condition of the signaling network which may affect routing, is received from the STP. Traffic can then be returned to the signaling link which equalizes the load between the restored link and its mate.

9.3.3 Voice frequency link testing capability

The error performance of signaling links equipped with single VFLs is continuously measured by the terminals at each end concurrent with normal service. A special testing capability is provided for A-links, since they may have a standby voice frequency link. Each STP has a maintenance terminal, used exclusively for VFL testing, and each switching office can loop back the standby VFL. The loop back ability, as well as manual test access, is provided by the VFL access circuit as shown in Fig. 7. When the signaling link is active, the two ends can exchange signals to schedule a standby VFL test. The STP maintenance terminal measures the error rate on this looped back facility and can signal the switching office of the pass/fail results. This test may be requested manually from either end, and is scheduled automatically by the STP several minutes after a signaling link failure to determine if the VFL should be reported to maintenance personnel.

Any VFL not actively carrying telephone traffic, including all standby VFLs on A-links, may be connected to the testboard for maintenance. The connection is made by manual request only at each end and is not preempted by any signaling link failures. The VFL must be manually removed from the testboard, at both ends, at which time the system VFL test mentioned above may be scheduled and the VFL returned to service. All VFL connections are controlled by the processor.

9.3.4 Automatic routines and measurements

Every 24 hours, just after midnight, each STP schedules an automatic voice frequency link transfer on half of its A-links. This ensures that all standby VFLs are tested and used by the system and exercises the transfer capability. This exercise is scheduled in such a manner that both members of a link complement are not transferred during the same 24-hour period.

A signaling link status report is printed hourly or on demand to inform maintenance personnel of all abnormal states. These states agree with those previously reported and with office visual status displays.

Every five minutes, the PBC[4] triggers the processor to read all of the plant and traffic counters stored in the terminal. These counts are immediately sent to the PBC for accumulation. In addition, the processor notifies the PBC on each signaling link failure, restoral, or other event needed for PBC exception reports and daily measurements.

9.4 Common control

9.4.1 General

Fault detection for the 4A electromechanical switching equipment resides in the individual common control circuits (link controllers, decoder channels, markers) which employ function timers and critical control lead monitors to sense equipment malfunction. Once a problem is encountered, a punched card record identifying call progress and all switching equipment engaged on the attempt is made available to the maintenance force for analysis. Typically a blocked attempt involves several switching elements, therefore, fault resolution requires analysis of a number of related trouble records to locate the faulty unit. After recording the fault, the common control circuit releases from the call and a reattempt is initiated, either by the sender or outpulser link connector for failures encountered by the link controller, or the decoder connector following decoder channel or marker failures. A different common control circuit is preferred on the reattempt to improve the probability of successful call completion.

The division of the 4A call switching process into distinctive stages, each executed by a dedicated set of common control circuits, coupled with the inherent redundancy resulting from multiple control units, provides an extremely high degree of tolerance to multiple faults. Furthermore, most faults have minor impact on system operation since they occur outside the common control circuits in the trunks and switching networks which comprise the bulk of the 4A electromechanical equipment. Once a faulty equipment unit has been identified by trouble card analysis, the offending trunk, sender, or common control circuit may be tested by office test frames to aid in trouble clearance.

9.4.2 Sender, outpulser, transceiver tests

Prior to CCIS, the Incoming Sender and Register Test circuit (ISRT) functioned as a semiautomatic test frame to perform a series of inpulsing, outpulsing and ineffective attempt tests on the incoming senders and DP registers. Once primed by the maintenance force for a particular test condition by means of keys and switches, the ISRT tests all applicable circuits in sequence. ISRT access to senders is achieved by a test relay which simulates a sender link connection. During the progress of the test, the sender is connected by its decoder connector to both a decoder channel and marker as for a service attempt, but no connection is established to an outgoing trunk.

Continuation of a manually assisted mode of operation was judged impractical in view of the direct processor control of sender functions on CCIS related attempts, as well as the increased testing load generated by the dual usage of senders as CCIS outpulsers and the introduction of continuity check transceivers. ISRT automation involves the substitution of memory relays for the keys and switches previously used to specify test parameters and for the wired sequencer which controlled selection of the circuit to be tested. The processor operates the memory relays at the outset of a test through a dedicated distributor register to specify both the test configuration and the circuit under test. Only the circuit identity distribution is changed as the test cycle advances through the circuits to be tested. Data for each test is stored in processor memory in a group of tables constituting a test catalog. Sender and outpulser requests for routing instructions during the decoder channel stage of the call are no longer dependent on service route translation. Instead the outpulsing instructions (class and either the called number to be loaded into an outpulser or the called number conversion instructions for a sender) are included in the test catalog for distribution to the decoder channel, thus permitting all possible test conditions to be applied regardless of office routing constraints. Continuity check transceivers are tested by a single test segmented into seven phases. Additional tests are performed to check that a sender or outpulser can successfully connect to each of its four assigned transceivers through the transceiver connectors.

The testing schedule is divided into high priority, time filler and low priority segments and a maximum of two ISRT frames may be controlled. High priority tests consist of about a dozen comprehensive tests and are run daily starting at 6:00 a.m. Time filler tests include all other normal service features while the low priority class primarily checks ineffective attempt treatment. The time filler tests are scheduled to follow the high priority tests and continue until 12:15 a.m. when the low priority tests start. Tests are executed continuously unless maintenance personnel interrupt with a demand request via a system teletypewriter to use an ISRT for trouble clearing purposes.

9.4.3 Decoder-marker test and trouble recorder

The trouble recorder is updated to add pertinent CCIS call progress and equipment identification items to the trouble record card. The processor distributes supplementary data to the trouble record, such as transceiver identity and the status of information scanned from common control units.

The Decoder-Marker Test circuit (DMT) is a manually operated test frame which serves to apply various operational conditions to decoder channels and markers. During a test, the DMT simulates a sender and uses the trouble recorder connecting relays of the decoder channel and marker as a substitute for the decoder connector to communicate with these units. The verification of CCIS functions in these common control circuits requires the processor to apply appropriate distribution patterns and/or check for particular scan reports to assist the DMT in the conduct of tests. Coded test instructions to the processor are entered through DMT switches which are connected during the test to the decoder channel scan field normally used to identify the sender attached to a service attempt. Each coded sender identity input instructs the processor to apply a specific test condition. Certain inputs also request the processor to read other decoder channel fields for additional test instructions. For example, to test the marker's ability to connect CCIS outgoing trunks, the outgoing link frame address of a CCIS trunk is entered on the DMT switches which correspond to the called number digit field. During the decoder channel stage of the test call, the processor distributes this address to the marker and then intercepts the CCIS trunk scan report following marker seizure to verify the test connection. The processor distributes test results to the DMT to light test progress lamps and provides additional detail concerning test failures via a system teletypewriter.

The DMT can also provide a rapid check of routing data. Any of the direct and alternate routes corresponding to a specific set of called number digits can be selected for verification and the associated route translation data displayed in a teletypewriter output message.

9.4.4 Outpulser link controller test

This processor controlled test frame tests the link controllers serving CCIS outpulser groups. All service and fault detection functions of the controllers are exercised daily. Processor communication with the test frame is accomplished by means of DAS distribute and scan points. Test results are outputted on a system teletypewriter and a test frame lamp display. Demand tests may be requested through a system teletypewriter.

9.5 Trunk maintenance

The task of the detection of faults within CCIS trunks has been delegated to a group of specialized test frames. These test frames can access any CCIS trunk as directed by manual request or by the trunk maintenance software during routine tests. Access to the trunk unit to be tested is normally through the 4A common control equipment which provide the requested cross-office connection. Using this maintenance approach reduces the amount of logic circuitry required within the trunk unit which would be dedicated to fault detection.

The three basic strategies used for trouble detection on CCIS trunks, along with examples of each, are the following:

(*i*) Per-Call Testing—Voice path continuity check test and retest procedure.
(*ii*) Routine Testing—Routine CCIS intraoffice test circuit testing, routine voice path continuity check retest, and routine transmission testing;
(*iii*) Manual Testing—Integrated manual trunk test frame testing.

The remainder of this section will discuss these strategies.

9.5.1 The voice path continuity check retest

Because on CCIS trunks the voice and signaling are routed separately, it is necessary, in order to prevent poor service and false billing, to verify that there is continuity over each CCIS voice trunk in turn before it is switched in a connection. To accomplish this a per-call voice path continuity check (VPC) is made on each trunk before the call is set up over the trunk, as discussed previously. If the VPC test fails, the call is reattempted on another trunk and the following maintenance actions are performed: (*i*) the failed trunk is temporarily taken out-of-service, (*ii*) a blocking message is sent to the far-end office over the signaling link, and (*iii*) the trunk is scheduled for a voice path continuity check retest.

The VPC retest is performed in the following manner (see Fig. 8). One of four continuity check retest access circuits are seized to initiate the

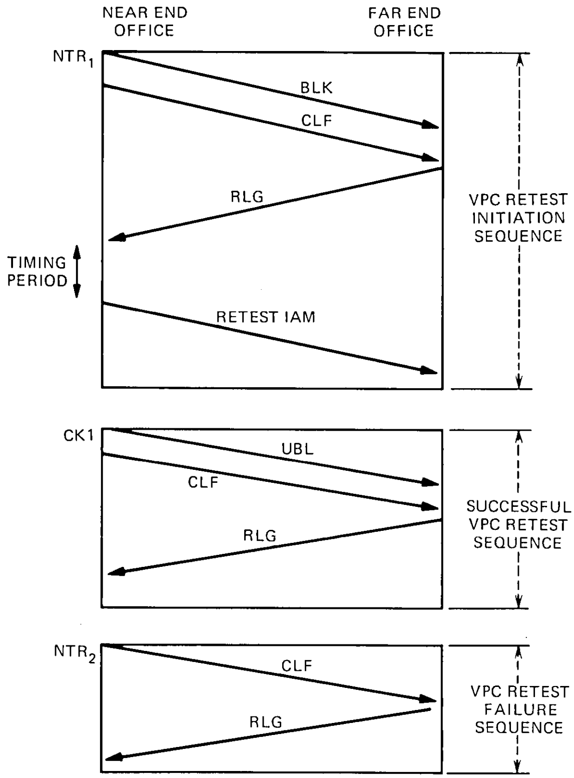

Fig. 8—VPC retest signaling sequence.

retest concurrent with the sending of retest Initial Address Message (IAM) over the signaling link. The access circuits are utilized to gain access to the continuity check transceivers and the failing trunk through the 4A common control equipment. If the terminating office is a four-wire machine, the transceiver will apply a 2010 Hz tone. The distant office in response to the retest IAM will connect the receive side of the trunk to the transmit side through a zero-loss loop. If the terminating office is a two-wire office, the transceiver transmits 1780 Hz. The terminating office, upon receipt of the retest IAM attaches a transponder to the incoming trunk and returns 2010 Hz upon recognition of the 1780 Hz tone. In either case the transceiver checks the level of the returning tone to verify that transmission loss is within acceptable limits.

If the trunk passes the voice path continuity check retest, the trunk is returned to service and an unblocking message is sent over the signaling link so that the trunk is available for service at both end offices. However, if the trunk fails the VPC retest, the failing trunk remains in an out-of-service state and the blocking message remains in effect at the far-end office. In this way a failed trunk is unavailable for normal call processing selection at both offices. In addition, maintenance personnel at the office which originated the VPC retest failure are notified of the VPC failure and the maintenance personnel at the far-end office are notified of a trouble at the connecting end of their trunk.

9.5.2 Routine trunk testing

Routine automatic operational testing of the 4A CCIS trunk relay circuit and cross-office transmission and signaling path is performed by the CCIS Intraoffice Trunk Test circuit (CIOT) frame. This processor controlled frame consists of four access circuits each of which is capable of performing a complete set of tests on any CCIS trunk. Each night at 11:15 p.m., the CIOT begins its testing routine. The routine begins with a series of tests termed self-tests which cause each CIOT access circuit to be tested against every other access circuit. The results of these tests are analyzed to detect a faulty CIOT access circuit and, if one is detected, the faulty unit is automatically prevented from being utilized in the routine trunk test sequence. In addition, the resulting diagnostic messages are provided for the maintenance personnel. Following the self-tests, the routine trunk test procedure will utilize all remaining CIOT access circuits to establish cross-office connections under processor control for testing the incoming and outgoing features of all CCIS trunks which are in service. If a trunk fails a routine CIOT test, it is immediately subjected to another test. If the second test is also a failure, the trunk is removed from service and the blocking message previously sent to the far-end prior to starting the CIOT testing sequence is allowed to remain in effect causing the trunk to be unavailable for call processing in both offices. If the second test passes, no maintenance action is taken. In either a single or double failure situation, the appropriate diagnostic messages are presented to the maintenance personnel.

Each morning at 6:15 a.m., the processor initiates the routine voice path continuity check retest sequence. The sequence is intended to provide detection of circuit failures before traffic is offered to trunks. Prior to the commencement of trunk test activity, a special test is run between the VPC retest access circuits and the CIOT access circuits to detect faulty VPC retest access circuits. As with the CIOT access circuits which fail self-test, VPC retest access circuits which fail this test do not participate in the routine trunk test sequence. The remaining VPC retest access circuits are used to perform tests of all the CCIS trunks in service.

If a trunk fails the routine VPC retest, the trunk is treated as if it had failed a per-call voice path continuity check. The procedures described in Section 9.5.1 then apply.

Routine automatic transmission trunk testing for CCIS trunks is available through the Automatically Directed Outgoing Intertoll Trunk Test frame (ADOIT) or the Outgoing Trunk Testing System (OTTS). In both systems, the test frame requests that a test call be established between it and a specific trunk. At the conclusion of the transmission test, the test frame may request that the trunk be removed from service due to a failure.

It should be noted that for all routine test procedures, limitations are placed on the number of trunks a single access circuit or test frame can automatically remove from service. These limitations were set to prevent a faulty testing unit from turning down excessive numbers of trunks.

9.5.3 *Manual trunk test capabilities*

While emphasis has been placed on the ability of the trunk maintenance software to provide routine and automatic trunk test capabilities, each trunk test mentioned in the previous sections can be requested on a manual single trunk basis for trouble clearance, circuit order work, or installation testing. Of particular interest is the CIOT which allows three of its access circuits to be used for manual testing. The CIOT has a detailed set of tests which, when coupled with the ability to continually repeat a test and test failure-oriented diagnostic message, allow improved trouble sectionalization.

The major portion of manual CCIS trunk testing is provided by the modified Intertoll (or Integrated) Manual Test Frame (IMTF). The IMTF may gain access to a CCIS trunk via a cross-office connection, a belt line connection at the trunk equipment frame, or the Switched Maintenance Access System (SMAS) if the office and trunks are equipped with this option. Manual transmission tests are performed to distant office 10X test lines for loss, noise, gain slope, return loss, and echo suppressor measurements. In addition to transmission tests the IMTF is equipped to perform operational tests such as DC continuity and cross-checks of transmission leads, answer supervision and ring forward operation, pad checks, and echo suppressor control. The IMTF is equipped with a *DATASPEED* ® Model 40 (DS-40) unit for communication with SPC processor. The DS-40 is utilized to initiate testing, to receive test results, to obtain both near-end and far-end software status of a CCIS trunk, and to change the software state of a CCIS trunk.

X. ACKNOWLEDGMENTS

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Common Channel Interoffice Signaling:

Peripheral Maintenance and Administration Support System

By R. C. SNARE

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Common Channel Interoffice Signaling (CCIS) introduces a new network for routing signaling information, new equipment, and new functions for which performance must be monitored. Reliable, timely (within seconds or minutes in many cases), and readily usable performance reports are required by traffic and maintenance personnel to administer and maintain these new capabilities to provide the high quality of service to which customers are accustomed. The Peripheral Bus Computer (PBC) System provides the maintenance and administration support required by the CCIS signaling network, Signal Transfer Point (STP) offices, and toll crossbar switching offices. This article describes the PBC and the support it provides CCIS.

I. GENERAL

As the demand for long-distance telephone service grows, the capacity, capability, and complexity of the nationwide switched network increases accordingly. Increasing demands for service must be satisfied while maintaining the high quality of service to which customers are accustomed. Thus as the capacity and capability of the nationwide switched network increases, so does the need for and complexity of performance surveillance, maintenance and administration of the switching offices. For example, Common Channel Interoffice Signaling (CCIS) now provides the capability to rapidly exchange information among processor equipped switching systems over a new network of signaling, or data, links. This new signaling network introduces new equipment and many additional functions for which performance must be monitored.

To control, maintain, and engineer switching office equipment, voice path circuits, and CCIS signaling links, operating companies must have traffic and maintenance performance data that are reliable, timely, and readily usable. Rapid detection of irregularities which result in the improper transmission of signaling and address data between switching offices is necessary to reduce internal reattempts and lost calls. These events are generally called retrials and ineffective attempts, respectively, and can be caused by trouble in the near or far end switching office or in the interconnecting signal facility.

The Peripheral Bus Computer System (PBC) is an on-site, small computer adjunct to the No. 4 crossbar toll CCIS Switching Offices (SOs)[1] and Signal Transfer Points (STPs)[2] that meets these operating company needs by applying real-time computer technology to the surveillance, maintenance, and administration of the switching offices and the signaling network. The PBC collects and processes per call, real-time data and provides threshold triggered exception reports to alert telephone company maintenance and traffic personnel to trouble and potential trouble conditions due to equipment malfunction or traffic congestion. Extensive historical data are accumulated by the PBC for administrative reports which are used by traffic administration and engineering personnel to make decisions about the quantities and configuration of equipment in the toll switching offices and connecting voice paths and signaling link network. In addition, the PBC data are available to centralized telephone company computers over private lines and dial-up switched lines for network management operations,[3] and long-term engineering and administrative studies. In summary, the PBC is the current state of the evolution[4,5] to provide the No. 4 crossbar toll switching system with modern, on-site performance and administrative data collection and processing capabilities and compatible interfaces with the numerous centralized administrative systems now in service.

II. PBC CONFIGURATION

The PBC connects to the No. 4 crossbar equipment, as shown in Fig. 1, via two interfaces which are the paths by which usage and miscellaneous data are collected from the electromechanical circuits. Data collected over a third interface, an interprocessor interface, comes directly from the call processing and signaling link actions being executed by the software resident in the SPC No. 1A system.

2.1 Central processor, memory, and peripherals

Figure 2 shows the three interfaces (two electromechanical frames used to collect usage data are not shown) and the other components which comprise the PBC. The central processor is a general-purpose mini-

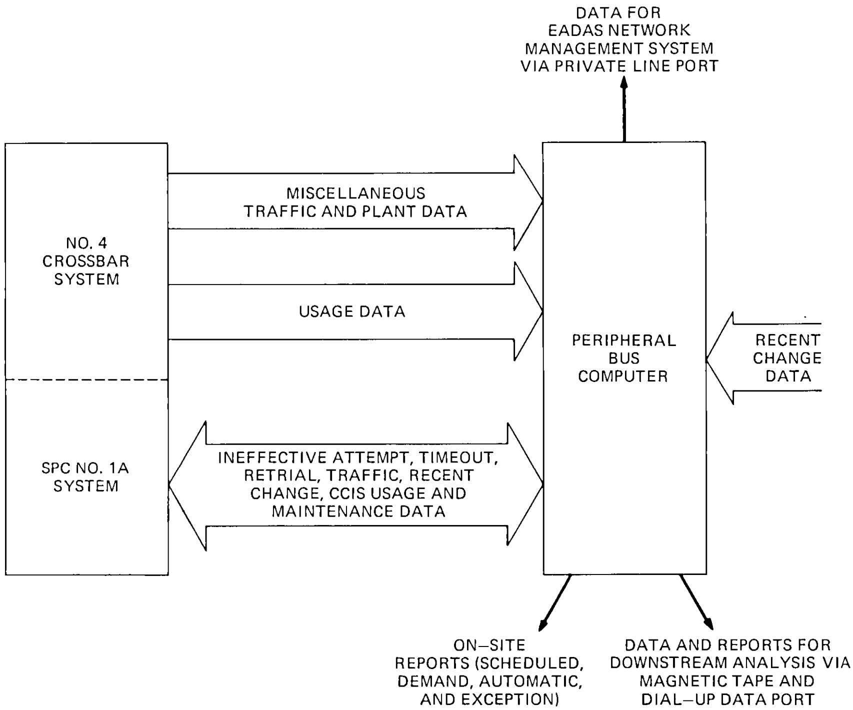

Fig. 1—Functional block diagram.

computer supported by 16-bit core memory (80K words in STP offices and 96K words in switching offices) and one disk controller equipped with two moving head disk cartridge drives containing 1.24 million words each. Associated hardware includes a nine-track industry compatible magnetic tape controller and drive, paper tape reader/punch, and an assortment of I/O interfaces to provide communication with local or remote (equipped with Bell System data sets) *DATASPEED®* 40 terminals and various other remote I/O facilities. The minicomputer central processor, associated memory and peripherals, and data sets are housed in four cabinets. Two interfaces connect with the No. 4 crossbar circuits and an interprocessor interface connects with the SPC No. 1A. These interfaces partially reside in a fifth cabinet (the multicontact relays for multiplexing usage data are mounted on up to two frames located with the switching equipment). The *DATASPEED* 40 terminals and the optional 4210 magnetic tape cartridge terminal shown in Fig. 2 are supplied by Teletype Corp.

The primary human-machine I/O device for the PBC is the *DATASPEED* 40 terminal which is equipped with a keyboard, cathode-ray tube (CRT) display, and a high-speed line printer. Three terminals are required for office (dial) administration, network management, and switching maintenance functions. Up to four additional terminals may

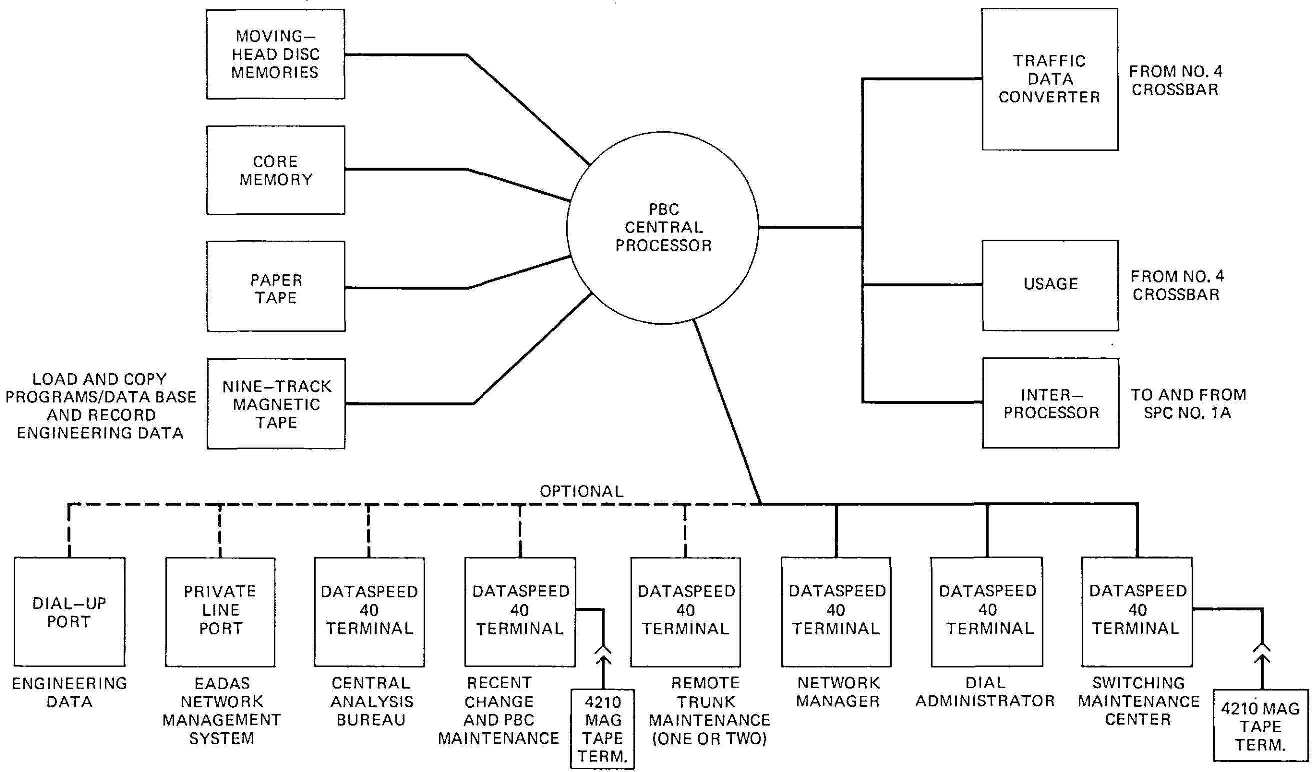

Fig. 2—System configuration.

be optionally provided to send trunk maintenance related exception reports directly to trunk maintenance areas, provide a separate data base management (commonly referred to as recent change) terminal and support centralized trouble analysis operations. Data base management, or recent change, can also be accomplished over the switching maintenance terminal and a 4210 magnetic tape cartridge terminal may be associated with both *DATASPEED* 40s which provide recent change capability.

All on-line software is Bell System designed. The PBC software in No. 4 crossbar offices equipped to perform STP functions for the CCIS signaling network, like the software resident in the SPC No. 1A (Ref. 2), performs two virtually independent jobs. The No. 4 crossbar system with its associated Electronic Translator System (ETS)[6,7] processes non-CCIS calls practically independent of the STP functions. The STP software is coresident with the ETS software in the SPC No. 1A system. Likewise, the PBC in STP offices collects and processes data in support of both the non-CCIS call processing functions of the ETS (Refs. 4 and 5) and the relatively independent CCIS signaling link operations.

2.2 PBC-SPC No. 1A interprocessor interface

Of the three interfaces between the PBC and the No. 4 crossbar and SPC No. 1A equipment, the interprocessor interface is the most important because of the quantity and variety of data which are exchanged between the PBC and SPC No. 1A processors. This interface provides a full duplex communication channel between the 16-bit PBC and the 20-bit SPC No. 1A. As shown in Fig. 3, information is transmitted by the SPC No. 1A to the PBC over the Peripheral Unit Address Bus (PUAB) and information is transmitted by the PBC to the SPC No. 1A via the Scanner Answer Bus (SCAB). The bus repeater circuit shown in Fig. 3 serves to "OR" the duplicated PUABs (and the enable and control lines shown in Fig. 4) for compatibility with the unduplicated bus to the PBC bus access circuit. Similarly, the repeater circuit "expands" the unduplicated answer bus from the PBC bus access circuit by driving both SCABs. The repeater circuit is the demarcation circuit between SPC No. 1A frames and the PBC units. When the repeater is out of service the SPC No. 1A and the PBC are isolated from one another. Any trouble with the interface which causes SPC No. 1A controlled diagnostics to fail causes the repeater to be taken out of service. The repeater is constructed with No. 1 ESS type circuit packs and has standard SPC No. 1A frame control keys, fuse alarm, etc.

The bus to bus access circuit (BBAC) to which the repeater connects provides for transmission of data from the SPC No. 1A directly to the minicomputer memory on a direct memory access (DMA) basis and from

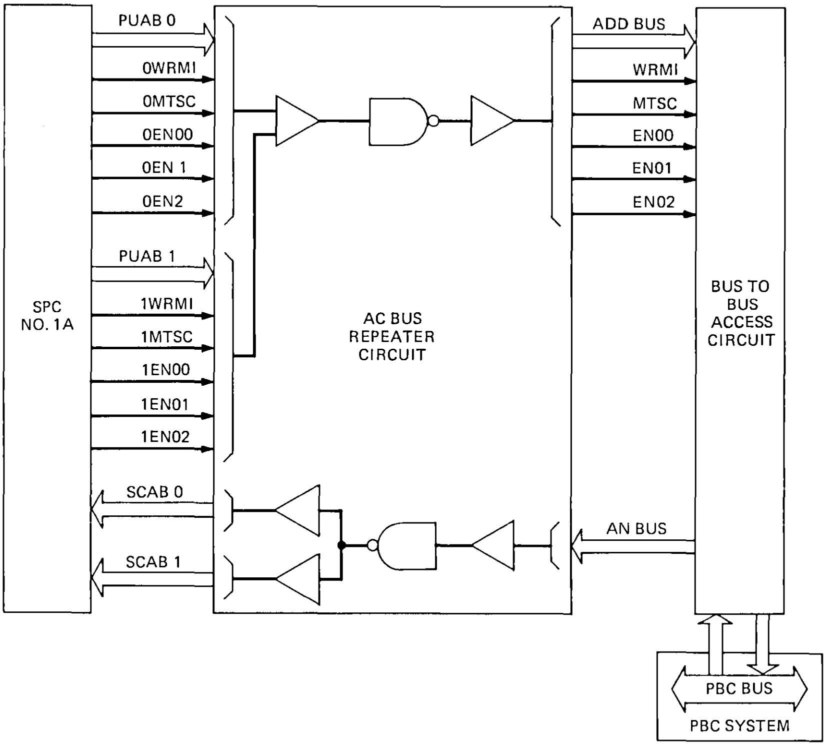

Fig. 3—SPC to PBC interface block diagram.

the minicomputer to the SPC No. 1A on a scan-for-data-present basis. A distribute from the SPC No. 1A using one of the two possible enable signals (EN00 or EN01) sends 21 bits of data to the minicomputer including the 20-bit data field. The distribute (DS) register shown in Fig. 4 holds the distributed data temporarily and the enable is stored in a flip-flop until the DMA control circuitry has gained control of the minicomputer bus. The data are then gated to the minicomputer (PBC) memory as one 16-bit data word and one 5-bit identity code. The DMA address counter determines the addresses of both locations within two 1024 location cyclic buffers. These cyclic buffers are unloaded by PBC software every 20 milliseconds. The PBC can accept data from the SPC No. 1A at a rate up to 80 thousand transfers per second for intervals less than 13 milliseconds without any data loss. The maximum long-term transfer rate is 50 thousand transfers per second to insure no data are lost.

Data are sent to the SPC No. 1A by the PBC writing directly into the control and status (CAS) and scan (SC) registers. The SPC No. 1A periodically reads the CAS register and, upon seeing the scan register full

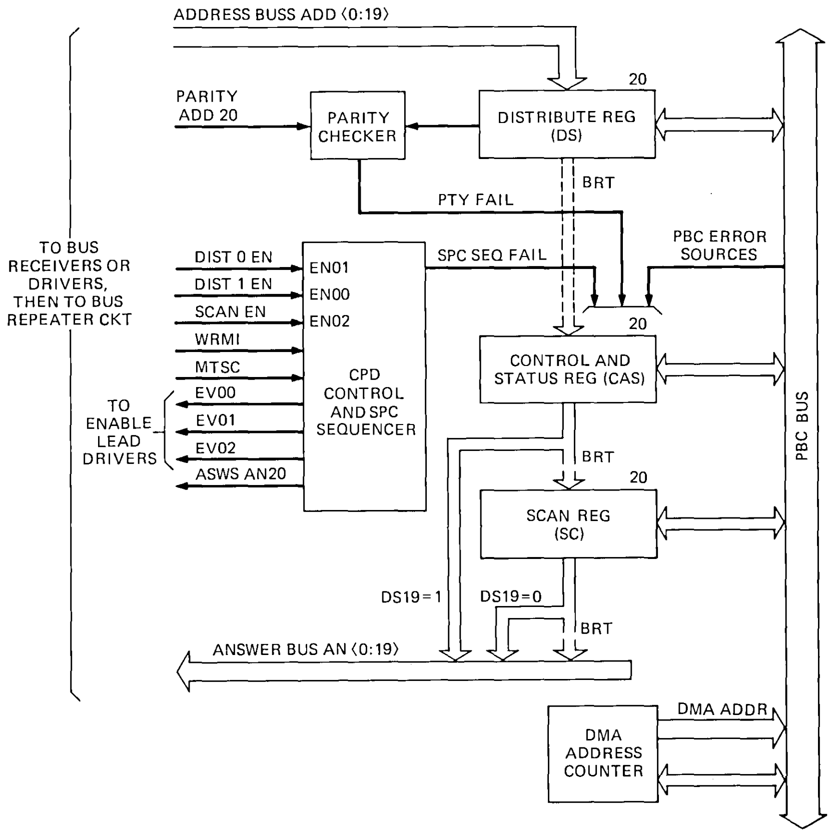

Fig. 4—Block diagram of bus-to-bus access circuit.

(SRF) bit set, causes the 20-bit datum in the SC register and the return identity code and error bits in the CAS register to be gated into the SPC No. 1A by issuing scan instructions to the PBC. The data field of each scan instruction is gated into the distribute (DS) register. If the most significant bit of the scan instruction data field is zero the SC register is read, otherwise the CAS register is gated into the SPC No. 1A. The maximum data transfer rate from the PBC to the SPC No. 1A is about 70 transfers per second and primarily consists of commands to read SPC No. 1A memory and commands and data to change the SPC No. 1A resident call routing and equipment translation data base. This latter function is referred to as recent change.

During the initial setup and signaling preceding the actual data transfer from the SPC No. 1A to the PBC, the CPD control and SPC sequencer circuits shown in Fig. 4 provide the proper signal interchange with the SPC No. 1A and request control of the PBC bus once the data

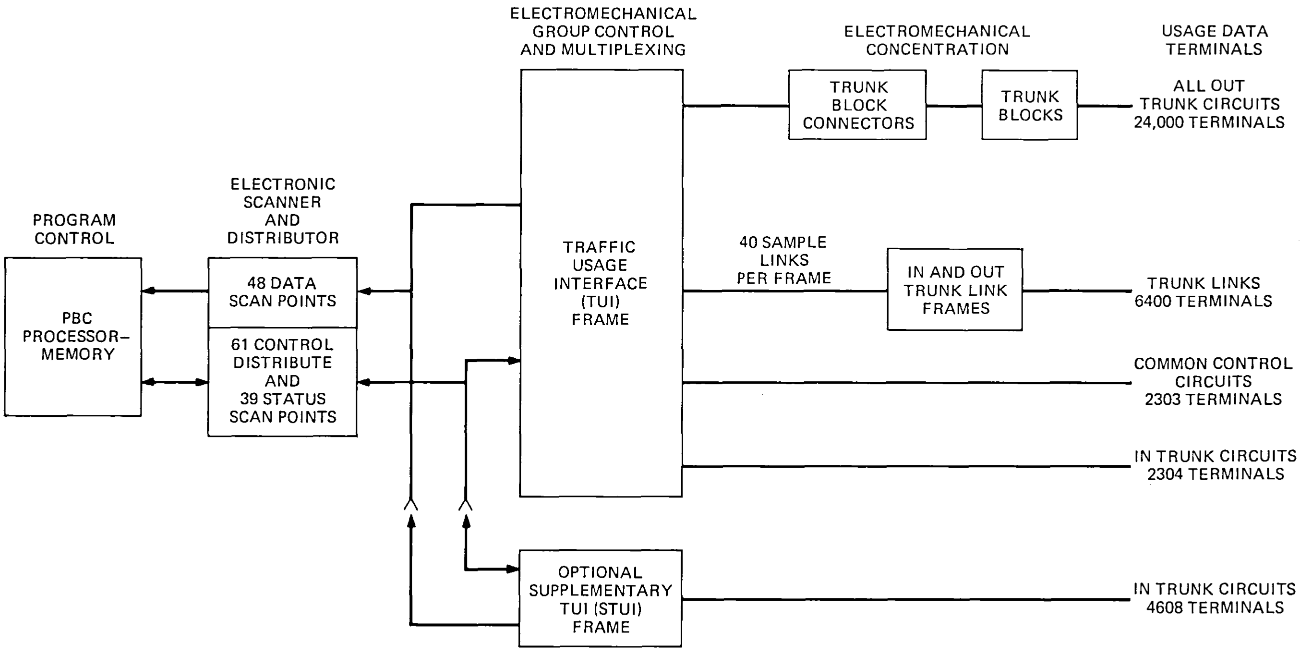

Fig. 5—Usage data collection.

are received. Also, the parity checker circuit computes the parity of the DS register datum and compares it with address parity sent by the SPC No. 1A. A mismatch sets an error bit in the CAS register and inhibits an all-seems-well (ASW) check which interrupts the SPC No. 1A. Other bits in the CAS register are error indications from various sources.

Because the interprocessor interface is the most efficient of the three interfaces, as much of the data required by the PBC as possible is collected from the SPC No. 1A. Only data to which the SPC No. 1A has no access are collected over the other two interfaces between the PBC and the No. 4 crossbar equipment. For example, usage data for CCIS switching office trunk circuits are collected from the SPC No. 1A but non-CCIS trunk usage data are collected over the usage interface shown in Figs. 1 and 2. Furthermore, all data associated with STP functions are collected from the SPC No. 1A.

2.3 Usage interface

Usage data are sampled measurements of traffic load on the various equipment in an office and are accumulated in usage units of one hundred call-seconds (CCS) per hour. Usage data from common control circuits, trunk link frames, and non-CCIS incoming and outgoing trunk circuits are collected over the usage interface. As shown in Fig. 5, this interface is a complex of program-controlled electronic distribute and scan points which direct electromechanical multiplexing and concentration circuits to access specific usage points within the office. Sixty-one distribute control and 39 scanner status points are used to collect usage data from over 39,600 possible usage leads through only 48 scanner data points. The distributor and scanner design provides the capability of isolated single contact relay outputs and individually sensible inputs. The unit is designed to be grown in a modular fashion with either distribute or scanner points. Currently, the distributor and scanner is primarily used to control the usage interface frame(s) and sense results.

A major efficiency in the PBC traffic usage interface (TUI) over conventional usage recording methods is achieved by integrating usage scanning into the switching office architecture. Present usage data collection methods use hardware scanners which require a dedicated lead to each usage terminal to be sensed. Thus conventional usage scanning is expensive in terms of equipment and cabling, administration, maintenance and floor space. The PBC takes advantage of existing switching circuitry to gather outgoing trunk usage. The busy/idle control leads for outgoing non-CCIS trunks (maximum 24,000) are already concentrated in subgroups of up to 40 trunks per outgoing route in trunk block connector circuits. The marker accesses the proper trunk block connector during each call when it is ready to select a trunk to the next switching office. Therefore, through a modest addition to each trunk block connector circuit, the PBC gains access to the 400 trunk terminations on each connector in subgroups of 40 to gather usage data. A 62-lead control bus, plus a dedicated lead per trunk block connector (60), replaces up to 24,000 trunk usage leads. A similar multiplexing arrangement is employed to gather usage data from the switching network through the incoming and outgoing link frames. However, usage data for incoming trunk and common control equipment is gathered by dedicated leads. Consequently, these latter two usage categories comprise most of the equipment in the TUI frames.

Usage scanning is performed at a 10-second rate for the common control circuits, and at a 100-second rate for all other equipment. Besides the common control circuits, approximately 10 percent of the ultimate quantity of the trunk block connectors, incoming trunks and switching network linkage are also scanned every 10 seconds. Once per day during a nonbusy period, various maintenance checks are performed by the PBC on the traffic usage interface, including an individual lead continuity check to each outgoing trunk and switching network usage terminal. Thus, the integrity of the PBC usage data is more easily administered than were past usage measurement systems.

2.4 Miscellaneous traffic data converter interface

The Traffic Data Converter (TDC) interface between the PBC and the No. 4 crossbar equipment gives the PBC access to miscellaneous peg count data which are not available from the SPC No. 1A resident software. The TDC is a special-purpose autonomous scanner which collects peg count data generated by relay contact closures from up to 1022 sources within an electromechanical switching office. All peg count inputs are scanned at approximately a 20-millisecond rate. The TDC, a common systems unit, was originally designed to collect and transmit peg count data to a centralized data collection computer via data link, and is equipped with several words of memory to buffer peg count data awaiting transmission to the central computer. To adapt the TDC to the PBC application, the internal memory and data link interface were replaced with circuitry to permit the TDC to write peg count data directly into a dedicated area of PBC core memory. Every 100 milliseconds the PBC reads these memory locations and processes any waiting peg count data.

2.5 Maintenance

The PBC and all of its interface circuits provide continuous surveillance of the No. 4 crossbar office. There are a number of maintenance programs which are executed by the PBC for the purpose of fault isolation in the peripheral circuits. The maintenance programs are designed to provide little or no interference with the data collection functions of the PBC and do not require the PBC to enter a maintenance-only mode. These programs are separated into two basically distinct functions: fault recognition and diagnostics. The fault recognition programs primarily consist of periodic tests which are executed to prove PBC system sanity and identify conditions which may affect the SPC No. 1A. The prime intent upon detection of trouble is to remove the interprocessor interface from service to protect SPC No. 1A call processing capability. In these cases diagnostic resolution is fine enough to identify single faulty circuit packs. Although not designed for diagnostic purposes, the fault recognition programs are also effective for diagnosis of system troubles during the installation and early service of a PBC. If any of the three interfaces develops a problem, maintenance diagnostic software in the PBC or SPC No. 1A will diagnose the trouble and notify maintenance personnel via the switching-maintenance *DATASPEED* 40 channel or an SPC No. 1A teletypewriter. Either an entire interface or a portion of the usage interface can be removed from service to allow the PBC and the other interfaces to continue functioning.

For nontransient problems within the PBC itself, or with the BBAC interprocessor interface, the AC bus repeater circuit is removed from service to isolate the PBC system and protect the SPC No. 1A. However, trouble with either the TDC or usage interfaces, or both, will not result in the PBC system being isolated from the SPC No. 1A. In these cases, valuable data can still be collected from the SPC No. 1A call processing activity even though the other interfaces with the No. 4 crossbar circuits are not in service. Data collected from the SPC No. 1A permit the PBC system to provide the complete analysis and reports of ineffective attempts, sender retrials and other call irregularities for maintenance personnel, about 95 percent of the analysis and reports destined for the network manager and over one-half the data that the dial administrator expects.

III. COLLECTING, PROCESSING, AND REPORTING PERFORMANCE DATA

All data are initially accumulated in "real-time"files in core memory as shown in Fig. 6. From these short-term files longer term files are accumulated in disk memory and real-time reports are generated (primarily for network management and maintenance). All data are accumulated in raw form, i.e., not calculated, formatted or labeled for any particular output report. This conserves memory because the same data is often required for several different reports. The report calculations, labels and format parameters are controlled by report generator programs rather than redundantly stored in the bulk data files. In addition,

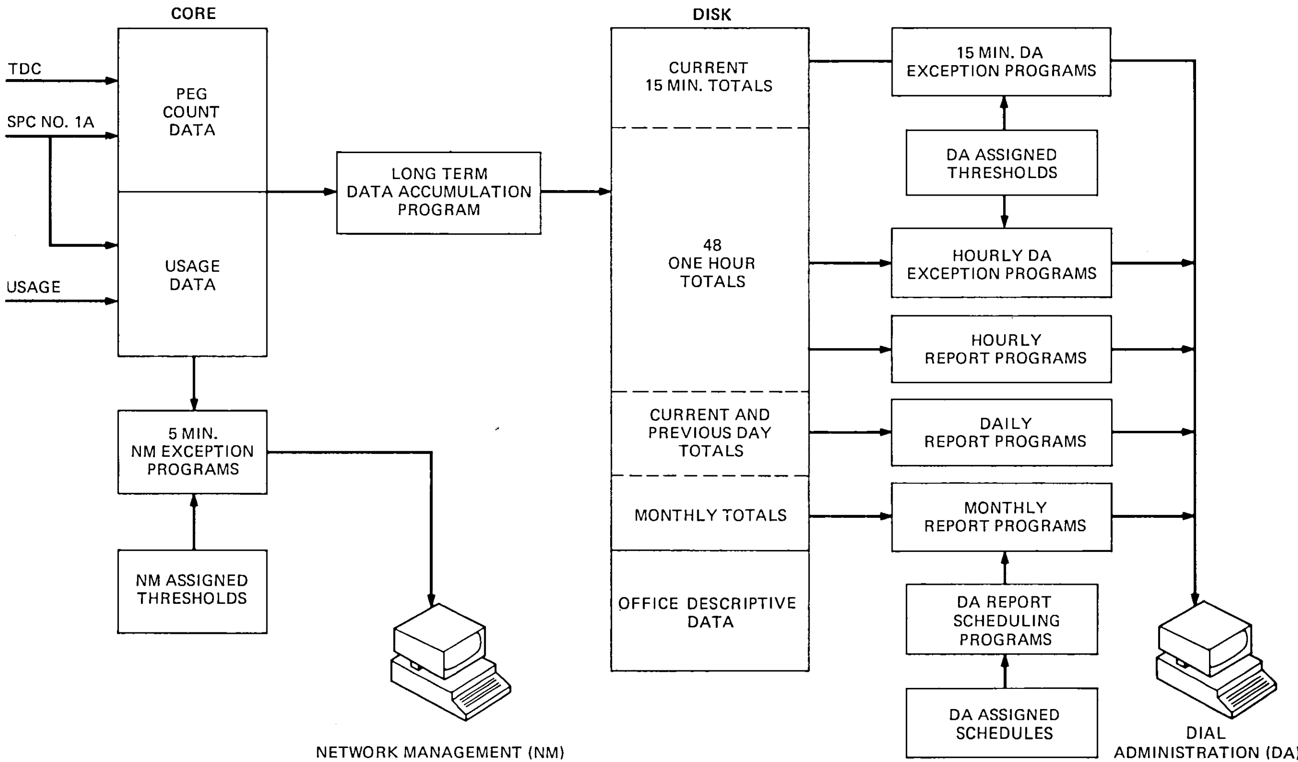

Fig. 6—PBC data accumulation.

raw data entries for many time periods are stored in the bulk data files and output reports, some several pages long, can be demanded for any of these time periods.

Traffic data are collected and analyzed over three intervals of time: (*i*) short-term or real-time (seconds and minutes), (*ii*) intermediate-term (hours), and (*iii*) long-term (days and months) as shown in Fig. 6. Real-time or short-term data are most useful to operating company network managers for monitoring performance during expected peak traffic periods such as occurs on Mother's Day and deciding what temporary network adjustments should be made to handle unexpected traffic generated, for example, by natural disasters. Intermediate-term data are most useful to office (dial) administrators. With this data, they can monitor performance of the switching system components and its associated network, balance the traffic load, ensure quality service, and estimate future needs. This information is also valuable to help network managers plan for future expected high traffic conditions. Long-term data are most useful to equipment and facility engineers in projecting long-term traffic trends and planning for switching office, trunking and signaling link growth.

Maintenance forces must keep the office descriptive data bases (stored in the memories of SPC No. 1A and PBC) up to date with changes to equipment translations, routing patterns and trunk and signaling link assignments. The SPC No. 1A memory contains data that identifies equipment and controls route translation, while the PBC memory contains support data for measurement, analysis and reports. The PBC system also includes the administrative software necessary for managing both the SPC No. 1A and PBC office data bases.

All reports are produced by software report generators which read unprocessed data from the appropriate files, perform any necessary calculations, provide the report labels and align the processed output data with the labels. Reports are generated by four basic stimuli:

(*i*) Automatic—generated by the PBC in response to a system event (such as an interface failure) or a predefined schedule that is part of the system's generic program and cannot be altered by the user.

(*ii*) Scheduled—generated as a result of a schedule which has been entered into PBC memory by persons who are using the system.

(*iii*) Demand—generated immediately in direct response to a request by the persons using the system.

(*iv*) Exception—generated when a threshold value has been reached or exceeded by the contents of a counter (register) or the results of a calculation in PBC memory. Threshold values are numbers which are entered into PBC memory by persons using the system.

The exception report is a concise report intended to alert personnel to a problem or pending problem. Additional information can then be obtained to supplement the exception report by using demand requests to query the details retained in the memory files.

3.1 Signaling link performance

All data associated with CCIS switching office and STP functions are collected over the interprocessor interface between the PBC and the SPC No. 1A. Included in these data are performance measurements of the CCIS Signaling Links (SLKs), which are each composed of a terminal and modem at each STP or CCIS switching office location connected by a Voice-Frequency Link (VFL). Discussion about signaling link data collection, processing, and reports applies both to CCIS switching offices and STP offices. However, the number of signaling links which can terminate in STP offices are over an order of magnitude greater than the number which terminate in CCIS switching offices.

Table I is a list of the names and abbreviations of the counts which the PBC must accumulate for maintenance and traffic reporting purposes. In addition to keeping these counts, the PBC must calculate signaling link occupancy and error rates. Error rate calculations require knowledge of the actual time period covered by the counts (RACU, SUIE, SACU, and RERQ) used in the calculations. This time period can be less than the collection interval time. The SUIE and RERQ counts are maintained on a per-VFL basis, and, thus, the time each of the VFLs is active must also be retained.

The first ten counts in Table I are scored in the signaling terminals as they occur. Every five minutes when the PBC is about to switch the active/passive status of its five-minute core memory accumulators, a command is transmitted to the SPC No. 1A to read and transmit the counter values to the PBC from each in-service terminal and then zero them. Counts 11 through 19 listed in Table I are recorded in PBC core memory as they occur. Items 20 and 21 (EMR TIME and SLK OOS) are computed by the PBC.

The time in emergency restart (EMR TIME) is determined by internal PBC timing. When the "start of emergency restart" distribution is received by the PBC from the SPC No. 1A, flags are set in the PBC for the signaling link and its mate, if it exists. A one-second timer task causes counters to be incremented for the involved signaling links until the "end of emergency restart" distribution is received by the PBC. Similarly the signaling link automatic or manual maintenance usage (SLK OOS) is determined by setting a flag and starting a one-second timer whenever a signaling link out-of-service condition is received by the PBC. In this case, the one-second timer task increments a counter for the signaling

Table I — Signaling link data accumulated by PBC

1. Signal Units Transmitted (SU XMT)
2. Signal Units Received (SU RCD)
3. IAMs Transmitted (IAM XMT)
4. IAMs Received (IAM RCD)
5. ANSs Transmitted (ANS XMT)
6. ANSs Received (ANS RCD)
7. Received Repeated ACUs (RACU)
8. Signal Units in Error per VFL (SUIE)
9. Received Skipped ACUs (SACU)
10. Retransmission Requests per VFL (RERQ)
11. Near-End and Far-End Initiated Automatic Changeovers per VFL (NECO and FECO)
12. Near-End and Far-End Initiated Manual Changeovers (MANNECO and MANFECO)
13. Buffer Threshold Exceeded (BFR THRS)
14. Repeat Buffer Threshold Exceeded (RPT BFR THRS)
15. Buffer Overflow (BFR OFL)
16. Emergency Restarts (EMR)
17. Processor Signaling Congestion Received (PSC RCD)
18. Processor Outage Received (PRQ RCD)
19. Failures Longer Than Three Minutes (FLR > 3)
20. Time in Emergency Restart (EMR TIME)
21. Automatic and Manual Maintenance Usage (SLK 00S)

link until a "changeback" distribution is received by the PBC for the link.

Terminal resident counters RACU, SUIE, SACU, and RERQ are initialized to zero values each time an out-of-service signaling link is restored. As mentioned earlier, calculation of error rates requires knowledge of the actual time interval covered by the error counters. Therefore, the time each changeback occurs is recorded and used at the end of the five-minute collection interval to determine the error counter interval for the signaling links affected by changeovers. Signaling links not affected by a changeover during the collection interval use the collection interval (normally five or thirty minutes) to calculate error rates.

3.2 Retrials, ineffective attempts, and miscellaneous CCIS irregularities in switching offices

Internal switching office faults are detected by the switching control circuits and reported to the maintenance force by a perforated trouble record card per event. Because of the detailed trouble history data presented on each card record, identification of the faulty unit is generally possible by pattern analysis of a few trouble records containing similar trouble data.

Such is not the case for the class of faults which result in retrials or ineffective attempts. These faults are associated with the reception or transmission of the called telephone number and may locate in either the near-end or far-end switching office, or the interconnecting transmission facility. Incorrect customer dialing may also cause ineffective attempts. Consider the reception of an unassigned telephone number at a switching office. Very likely the customer has misdialed. However, the lack of up-to-date route translation information at this office or incorrect translation data in a preceding office can cause the same result. Again, consider a multifrequency (MF) receiver which times out waiting for digit reception. The fault may be located in the MF receiver, the preceding office outpulsing equipment, or the interconnecting transmission path. Inadequate equipment provisioning can also produce call failures.

PBCs in non-CCIS offices analyze a total of 21 retrial and ineffective attempt failure categories to detect persistent problems with up to six received digits and six types of equipment (senders, outgoing trunks, outgoing trunk groups, incoming trunks, incoming trunk groups, and sender link frames). In a CCIS switching office the failure categories to be analyzed are expanded to a total of 46 including the original 21 categories with appropriate modifications required for CCIS. Additional equipment types introduced by CCIS and included in analysis of failures are senders modified to operate as outpulsers (sender-outpulsers), sender-outpulser link controllers, outpulsers, outpulser link controllers, transceivers, and the distributor and scanner (DAS). In addition, the other existing equipment types must also be included in the analysis of CCIS call attempts which fail and include sender link controllers, decoder channels, decoder connectors, markers, and incoming trunk group decade. Finally the number of digits to be analyzed on digit-related failures in CCIS offices is expanded from six to eleven.

Some of the software which accomplishes this analysis resides in the SPC No. 1A memory but most of the associated software resides in the PBC disk memory and is collectively called the Plant Analysis Support System (PASS). The part of PASS in the SPC No. 1A collects all the necessary data for each failure event, identifies the event as one of the failure categories, formats a multiword (number of words depends on the failure category) message, and transmits the message to the PBC. The part of PASS residing in the PBC primarily compares each new failure event with all others already in the specified failure category current analysis file. A customized, separate current analysis file exists for each of the failure categories. When a specific unit of equipment or digit pattern reaches a user set trouble threshold, which can be a unique value per failure category and per each equipment type (consider digits analogous to an equipment type) analyzed within each failure category file, then the PBC outputs an exception report to alert office maintenance personnel of a faulty equipment unit or digit pattern (e.g., vacant national number, incomplete address detected, etc.). Real-time analysis is provided, since each failure event is immediately categorized and sent to the PBC where it is compared against all records in the current analysis

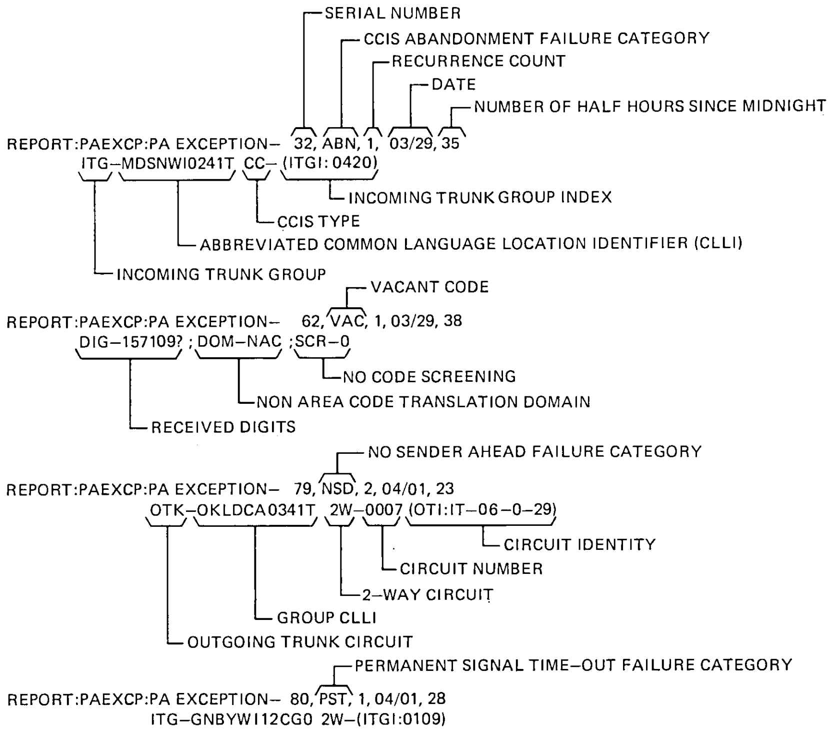

Fig. 7—Plant analysis exception reports.

file for the failure category.

A memory file of exception reports is maintained for between a month and a month and a half depending on the rate exception reports are generated. Several sample exception reports are shown in Fig. 7. Note that trunks are identified with the standard Bell System abbreviated Common Language Location Identifier (CLLI), and overall the reports are relatively easy to understand. All failure event messages contributing to exception reports are maintained for at least 24 hours and as long as space exists in the Pattern Found (PF) file.

If during the day any of the failure category current analysis files overflow, these failure event messages (records) are moved to the No Pattern Found (NPF) file. Also any failure event records remaining in the current analysis files at the end of the day are also moved to the NPF file. The NPF file is then analyzed to produce a daily "worst equipment" report. This is a last effort to identify the worst performing equipment from the data which did not cause exception reports to be triggered.

PASS outputs all reports over the No. 4 crossbar switching maintenance center *DATASPEED* 40 and selected outputs over up to three optional *DATASPEED* 40s. Two of the optional stations are associated

CALL IRREGULARITY AND DISPOSITION SUMMARY

1210 4/ 6/77 TO 0000 04/07/77

TOTAL INEFFECTIVE	479	.16%	DCH 2ND TRIAL	1637	.56%

EM CALL IRREGULARITIES

INCOMING	PC	PA MSGS	OUTGOING	PC	PA MSGS
PST TOTAL	154	118	IKF	46	55
SDR	154	--	NSD	166	157
REG-NC	0	--	DPD TOTAL	99	93
PDT TOTAL	74	68	DPD	--	2
SDR	74	--	XST	--	91
REG-NC	0	--	UXS	44	42
PE TOTAL	127	121	MRE TOTAL	40	30
PEO	--	7	MOF	--	25
PMS	--	114	MPS		5
PMD	41		RVT		

CCIS CALL IRREGULARITIES

INCOMING	PC	PA MSGS	OUTGOING	PC	PA MSGS
ADI DET	1	1	ADC TO	0	0
COT TO	0	0	CON CK FAIL	1	2
IAM IRREG TOTAL	0	--	GLARE	0	0
INVALID	0	--	MISC CC FAIL	2	2
LENGTH CHECK	0	--	COF RCVD	2	--
2ND NON MATCH	0	--	RLG RCVD	0	--
IAM-BLK TRK	0	--	RST+RSB RCVD	0	--
IAM-UNEQ TRK	0	--	BLK RCVD	0	--
ABDN CALL	60	59	SIG NET FAIL	0	--
			MRF RVCD	0	--
CONNECTING	PC	PA MSGS	UQL RCVD	0	--
OP-MFOP ABNR RL	1	1	NO SIG PATH	0	--
NO CREG INC	0	--	ADI RCVD	1	1
NO CREG OUT	0	--	VNN RCVD	14	14
NO TCVR INC	0	--	IMMEDIATE RAT	0	--
NO TCVR OUT	0	--	SDR/OPLS RAT	25	--
CREG TO	3	3	TRK LC RAT	1	--
CREG TO-IGNOR	1	--	CFL RCVD	0	--
NO OP/MFOP	0	--			
NO FACILITIES	0	0	MISCELLANEOUS	PC	PA MSGS
BAD DAS REPORT	1	1	RSB RCVD	0	--
BAD SV REPORT	5	5	RST RCVD	0	--
			UNSTABLE CALL RST	0	--
			STABLE CALL RST	2	--
			SU RCVD UNEQ LBL	0	--
			UNRSNBL SU RCVD	0	--
			UNDEFINED SU RCVD	2	--
			SYS00 MSGS	6	--

MISCELLANEOUS ITEMS

PASS TOTALS			
TOTAL PA MSGS	3664	TST PA MSGS	1253
PA EXCEPTION REPORTS	162	ERR PA MSGS	2
NO TROUBLE FOUND DISPOS	0	PA MSGS LOST IN SPC	100
TROUBLE FOUND DISPOS	0	PA MSGS LOST IN PBC	0
AUXILIARY TROUBLE RECORDS	27	PA INVALID	

Fig. 8—Part of call irregularities and disposition report.

with trunk maintenance areas and one is associated with a central analysis bureau operation.

3.3 Plant (maintenance) reports

The *DATASPEED* 40 terminal located in the No. 4 crossbar switching maintenance center provides I/O capability for data base administration (recent change), maintenance messages and plant reports. The seven

26 REPORT:PMSUIEX

SUIE 5 MINUTE EXCEPTION REPORT
04/01/77 1121 TO 04/01/77 1126

NAME	TYPE	SLK	VFL	CTR TIME	SUIE PC	ERR RATE
*OMAH NE NW MSP 1	A	0-00	A	300	89	.35*
*IPLS IN 01 MSP 1	A	0-01	A	300	40	.16

Fig. 9—Signal units in error, 5-minute exception report.

plant (maintenance) reports provided in non-CCIS offices are described in Refs. 4 and 5. In addition to a variety of smaller changes and additions to six of these plant reports, a CCIS switching office has a Call Irregularity and Disposition Summary (PMCIDS) report, partially shown in Fig. 8, in place of the former Retrial and Ineffective Attempts Summary (PMRIAS) report. The PMCIDS report is divided into the two major parts, non-CCIS (EM) call irregularities and CCIS call irregularities. The PMCIDS report includes, in the EM call irregularities part, all items formerly on the PMRIAS report, and in addition, includes counts of the number of PASS analyzed CCIS failure events by category, CCIS call irregularities, and miscellaneous items moved from the other plant reports. The PMCIDS report can be scheduled and demanded as described for the other plant reports in Ref. 4.

CCIS switching offices and Signal Transfer Point (STP) offices output four additional plant reports which provide signaling link performance data:

(*i*) Signal Units in Error Five-Minute Exception (SUEX) report.
(*ii*) Signaling Link 30-minute Exception (SLKX) report.
(*iii*) Signaling Link Data (SLKD) report which can be scheduled and demanded.
(*iv*) Signal Units in Error Summary (SUIE) report which can only be demanded.

3.3.1 Signal Units in Error Five-Minute Exception (SUEX) report

The signal units in error (SUIE) counts and time marks for each signaling link are used at the end of each five-minute measurement interval to calculate the SUIE rate for each link. A signaling link is included in the SUEX report, shown in Fig. 9, if its SUIE rate equals or exceeds the 0.2 percent threshold value. For each link included in this report the abbreviated Common Language Location Identification (CLLI) NAME (identified by the far-end office name), type, Terminal Access Circuit (TAC) and terminal position (SLK), Voice-Frequency Link (VFL), counter time, SUIE count, and SUIE rate are printed.

The SUIE rate of particular links can be tracked over successive five-minute periods by demanding, via an input message, a printout of the

31 REPORT:PMSLKX

SLK 30 MIN EXCEPTION REPORT
1100 04/01/77 TO 1130 04/01/77

			VFL A				VFL B					
NAME	T	SLK	CTR TIME	SUIE RATE	RERQ RATE	TOT CO	CTR TIME	SUIE RATE	RERQ RATE	TOT CO	RPT ACU	SKP ACU
*OMAH NE NW MSP 1	A	0–00	28.3	.00	.00	0	.0	.00	.00	0	4*	1
*IPLS IN 01 MSP 1	A	0–01	18.3	.00	.00	2*	4.0	.00	.00	1	1	0

Fig. 10—Signaling link 30-minute exception report.

SUEX report over a specified time period even though the link's SUIE rate does not reach the 0.2 percent threshold value. If a signaling link is included in the SUEX report because its error rate reached the threshold, an asterisk (*) is printed after the link's error rate. Signaling links being tracked (demand schedule printout) are identified with an asterisk at the beginning of the line. If no link is being tracked or reaches the SUIE threshold, then no SUEX report is printed.

3.3.2 Signaling Link 30-Minute Exception (SLKX) report

The SLKX report shown in Fig. 10 is triggered by thresholds against five different measurements. If one or more of the following measurements reaches its threshold value within 30-minute intervals ending on clock hours and half hours, the SLKX report is generated:

(*i*) Per voice frequency link signal units in error (VFL SUIE) rate equal to or greater than 0.2 percent.

(*ii*) Per VFL retransmission requests (RERQ) rate equal to or greater than 0.2 percent.

(*iii*) Per VFL failure changeover count equal to or greater than two.

(*iv*) Skipped acknowledgment signal unit (SACU) count equal to or greater than three, and

(*v*) Repeated acknowledgment signal unit (RACU) count equal to or greater than three.

The NAME of each link reaching one or more thresholds is listed in the report along with the type of link, TAC and terminal position (SLK), counter time, SUIE rate, RERQ rate, failure changeover counts, SACU count and RACU count. An asterisk is printed after items which reach or exceed threshold values.

Signaling links can be tracked over successive 30-minute periods by demanding a printout of the SLKX over a specified time period even though no thresholds may be exceeded. An asterisk at the beginning of a line indicates the link is on a demand schedule printout. If no links are being tracked and no exception occurs, the SLKX report is not generated.

3.3.3 Signaling Link Data (SLKD) report

The SLKD report shown in Fig. 11 is not an exception report and can be scheduled and demanded similar to plant reports discussed in Refs. 4 and 5 but on a half-hour basis rather than hourly. The SLKD report is intended to be the primary signaling link information report for the plant (maintenance) personnel. It has a total office counts section, which is always printed first, and a per-signaling link section. This latter section can be much longer in STP offices than in CCIS switching offices because of the greater number of signaling links possible in STP offices. The total office section includes five Threshold Exceeded Counts (TEC), Changeover Counts (CO), Emergency Restart Data (EMR), and a count of signaling link failures less than three minutes (FLR <3) which is computed from total failures minus the FLR >3 count listed in Table I. The per-signaling link section requires two or three lines per link because of the number of per-signaling link report items and the possibility of the signaling link having redundant voice frequency links (VFLs).

23 REPORT:PMSLKD

SLK DATA REPORT
0000 04/01/77 TO 1100 04/01/77

TOTAL OFFICE COUNTS

TEC					CO		EMR		FLR
SUIE	RERQ	CO	SACU	RACU	FLR	MAN	PC	SEC	<3
0	0	0	0	0	1	1	0	0	1

PER SIGNALING LINK COUNTS

NAME	T	SLK	MATE SLK	VFL	CTR HR	TM MI	SUIE RATE	SUIE TE	RERQ RATE	RERQ TE	FLR CO NE	FLR CO FE	FLR CO TE
OMAH NE NW MSP 1	A	0-00	0-00	A	7	59	.00	0	.00	0	0	0	0
				B	2	55	.00	0	.00	0	1	0	0
IPLS IN 01 MSP 1	A	0-01	0-00	A	10	59	.00	0	.00	0	0	0	0
				B	0	0	.00	0	.00	0	0	0	0

NAME	T	SLK	SACU PC	SACU TE	RACU PC	RACU TE	FLR <3	EMR PC	EMR SEC	MAN CO NE	MAN CO FE	OOS (SEC) FLR	OOS (SEC) MAN
OMAH NE NW MSP 1	A	0-00	12	0	0	0	1	0	0	0	1	19	24
IPLS IN 01 MSP 1	A	0-01	0	0	6	0	0	0	0	0	0	0	0

Fig. 11—Signaling link data report.

3.3.4 Signaling link Signal Units In Error Symmary (SUIE) report

The SUIE report shown in Fig. 12 can only be demanded and provides a 24-hour (most recent) summary by half-hour periods for specified signaling links. If the link type is A, then redundant VFLs may exist (shown in Fig. 12 as VFL A and VFL B).

59 OUTPUT:PMSUIE

SLK SUIE DATA REPORT
2300 3/31/77 TO 0400 04/01/77

SLK 00−01:NAME−IPLS IN 01 MSP 1, TYPE−A

	VFL A		VFL B		
TIME PERIOD	CTR TIME	SUIE RATE	CTR TIME	SUIE RATE	
2300 TO 2330	30.0	.00	.0		
2330 TO 0000	30.0	.00	.0		
0000 TO 0030	.0	.00	28.0	.00	← CHANGEOVER TO DUAL VFL
0030 TO 0100	.0		30.0	.00	
0100 TO 0130	.0		30.0	.00	
0130 TO 0200	.0		30.0	.00	
0200 TO 0230	.0		30.0	.00	
0230 TO 0300	.0		30.0	.00	
0300 TO 0330	25.1	.00	.0		← CHANGEBACK TO ORIGINAL VFL
0330 TO 0400	30.0	.00	.0		

Fig. 12—Signaling Link Signal Units in Error (SUIE) summary.

3.4 Network management

One of the three required *DATASPEED* 40 terminals is dedicated to the network management function. Because the network manager primarily uses short-term data for real-time management of the intertoll, toll connecting and tandem networks, the reports, as shown in Fig. 6, are mostly based on 5-minute intervals with the remainder based on 15-minute intervals. References 4 and 5 discuss network management reports in non-CCIS offices. Data collected in non-CCIS offices also must be collected in CCIS offices for the non-CCIS traffic components and for the analogous events produced by CCIS traffic. In addition a considerable number of additional CCIS measurements must be made.

Network managers currently monitor switching offices and trunking networks for trends toward short-term scarcity and overload conditions that can potentially degrade network performance. Overloads and failures in the CCIS signaling network can affect both trunking and switching capacity. For example, trunks can be made inaccessible to new calls for short periods of time when signaling links or STP offices experience heavy traffic overloads. In another example, an overloaded STP may affect the performance of non-CCIS call translation which co-resides in the same SPC No. 1A system. For these reasons the signaling network is monitored by the network manager to observe its effects on trunking and switching performance. However, the network manager does not exercise manual control over the CCIS signaling network but, instead, relies on the automated overload controls described in Ref. 2.

New measurements introduced with CCIS and used by network managers include those associated with signaling links, CCIS common control equipment functions and expanded network management controls. The new measurements are far too numerous to discuss all of them within the scope of this article so only a few of the more interesting ones are described.

NETWORK MANAGEMENT 5 MINUTE EXCEPTION REPORT
WKSH WI 02 41T 4/01/77 1301

REGISTER	IT PC	TC PC	TOTAL	AVG E–E
MARKER	1304	1218	2522	24.7 MS
ITLF	1245	1153	2398	

REGISTER		PC	%MKR
FST–ATB	IT	0	0.0
FST–ATB	TC	1	0.1*

SENDER TYPE	SADR BC	SADR DC	% SAD	GROUPS DC > 0
*MF	74	4	5.4*	A

CROSS OFFICE DELAY	XOD BC	XOD DC	% XOD	AVG XOD TIME–SEC	CONTRIB GRPS MFO	OP
CCIS	35	3	8.6*	0.786		A

	––ANNOUNCEMENT––			–TRUE IMA–	
REGISTER	PC	OFL	%ITLF	PC	%ITLF
ROA	3	0	0.1	3	0.1*
VCA	9	0	0.4	9	0.4*

CCIS SIGNAL COUNTS	––INC CALLS––		–OUTGO CALLS–	
TOTAL CCIS CALLS (IAM)	35	% IAM	30	% IAM
* ANSWERED (ANS)	23	65.7	21	70.0
* TRUNK CONGEST (NTC)	0	0.0	0	0.0
* SWITCH CONGEST (NSC)	0	0.0	0	0.0
NO CALL REG INC	0	0.0		
NO SNDR–OPLS AVAIL	0	0.0		
NO TRANSCEIVER AVAIL	0	0.0	0	0.0

Fig. 13—Network management 5-minute exception report.

3.4.1 Incoming delay measurements

Knowledge about incoming delay in a switching office is important to network managers because delay can propagate congestion to preceding switching offices by increasing the holding time on common control equipment in those offices. In both non-CCIS and CCIS No. 4 crossbar offices Sender Attachment Delay Recorder (SADR) equipment provides a measurement of incoming delay on non-CCIS incoming calls. The SADR has an appearance as an incoming trunk on each sender link frame. When SADR is active it rotates test calls through the sender link frames at the rate of one call every four seconds and transmits to the PBC via the TDC interface the number of test calls placed (base count) and the number encountering delays in sender attachment greater than three seconds (delay count). The PBC then generates exception reports if the percentage of delays exceeding three seconds is greater than a threshold value within a defined time period. The network manager is provided a 5-minute exception report for alerting purposes and a more detailed 15-minute automatic report both of which provide incoming delay measurements. In switching offices which also switch CCIS calls these 5-minute and 15-minute reports, shown in Figs. 13 and 14 respectively,

15 REPORT:NM15RP

NETWORK MANAGEMENT 15 MINUTE REPORT
CITY ST BG ETY 4/01/77 1401

MARKER PEG COUNT

IT 40618 TC 33973 TOTAL 74591

SADR DATA

SENDER TYPE AND SENDER GROUP	SADR BC	SADR DC	% SAD
MF	202	18	8.9
MF –A	22	4	18.2
MF –B	22	2	9.1
MF –C	23	1	4.4
MF –D	22	3	13.6
MF –E	23	2	8.7
MF –F	23	5	21.7
MF –G	23	0	.0
MF –H	22	1	4.6
MF –J	22	0	.0
DP –A	23	3	13.0

CCIS INCOMING DELAY

CROSS OFFICE DELAY	BC	DC	%XOD	AVG XOD
TOTAL	5242	477	9.1	.862
IT TRAIN	2635	242	9.2	.865
TC TRAIN	2607	235	9.0	.859

OPLS (SNDR/OPLS) ATTACHMENT DELAY	BC	DC	%OAD	AVG OAD
OPLS–A	2701	270	10.0	.331
OPLS–B	2541	200	7.9	.301

NON ZERO MC & SQ DATA

REGISTER	PC	CCS	%ACT
MC 1	5	17	1.9
MC 2	1	5	.6
SQL A	43	130	14.4
SQH A	9	10	1.1
SQL B	12	30	3.3
SQH B	11	10	1.1

Fig. 14—Network management 15-minute report.

can also be triggered by outpulser and sender-outpulser (senders modified to also perform CCIS outpulser functions) attachment delay and cross-office delay encountered by CCIS incoming calls.

Excessive outpulser and sender-outpulser attachment delay will be the likely source of incoming CCIS call delay. Possible causes of temporary outpulser and sender-outpulser scarcity which leads to attachment delay can be heavy non-CCIS traffic to sender-outpulser groups and problems with non-CCIS traffic outpulsing to a congested office. In addition, attachment delay measurements alone do not directly monitor all sources of incoming delay. Scarce transceivers (due, possibly, to a facility failure) or processor real-time congestion can also cause incoming CCIS call delay. Measuring the time it takes a call to be connected through the office to an outgoing trunk (cross-office delay) is a measure of incoming delay due to these other factors. Cross-office delay is also attractive as a measure of the delay experienced by common control equipment in the previous offices switching a call. This is true because the sender in the first CCIS office (non-CCIS incoming and CCIS outgoing call) and call registers in each subsequent CCIS office are held up until the cross-office connections of all CCIS offices switching the call are complete and the address complete signal is returned.

Outpulser (and sender-outpulser) attachment delay and cross-office delay are derived from three timing marks distributed to the PBC on each incoming CCIS call by the SPC No. 1A software and associated with one another in the PBC via the Call Register Index (CRIX). The three timing distributes are sent to the PBC during:

(*i*) Processing of the received Initial Address Message (IAM).
(*ii*) Processing of the outpulser (or sender) link controller bid.
(*iii*) Processing of the marker disposition report.

The interval measured by the first and second distributes approximates the outpulser (or sender-outpulser) attachment delay (OAD). The interval measured by the first and third distributes is the cross-office delay (XOD). The OAD measurement is not exact because the controller bid indicates only that an idle outpulser has been selected and a path to it reserved. However, what is measured constitutes most of the OAD and includes the variable part. The measured OAD is thus adjusted by a constant (one for outpulsers and a slightly larger constant for sender-outpulsers) to project the actual OAD which is used on the output reports shown in Figs. 13 and 14. It is interesting to note that both SADR and OAD measurements are taken on sender-outpulser groups which serve both non-CCIS and CCIS trunks.

3.4.2 Signaling link measurements

Network managers in STP offices and CCIS switching offices are provided the five-minute signaling link exception report shown in Fig. 15. This exception report is triggered by a signaling link reaching or exceeding the outgoing percent occupancy threshold value set by the network manager for the signaling link, simultaneous outages of complement signaling links, or certain CCIS terminal buffer overload control activity. An asterisk behind the percent occupancy value on the report indicates the threshold was reached or exceeded. The only discernable difference between the five-minute signaling link exception report output by an STP office and one output by a switching office is the signaling link TYPE and the associated mate signaling links printed. As shown in Fig. 15, STPs report on A-, B-, and C-type signaling links while switching offices report on A- and F- (associated signaling) type signaling links.

35 REPORT:NM5LKX

NETWORK MANAGEMENT 5 MINUTE CCIS LINK EXCEPTION REPORT
MDSN WI 02 41T 4/27/77 1335

SIGNALING LINK NAME, SUFFIX, TYPE							OUTGO DATA		INC DATA					TERM BUFR OVLD			
CITY	ST	BG	ETY	S	T	SLK NO.	SU PC	%OCC	SU PC	%OCC	LINK %OOS	LINK CMPL %OOS	RCVD PSC PRO	THR PC	RPT PC	CTRL %ACT	BFR OFL
IPLS	IN	01	04T	1	A	0-00	10148	43*	10027	43	.0	.0		3	6	26.0	1
OMAH	NE	NW	04T	1	A	0-01	7788	33	7923	34	8.2	.0		0	0	.0	0
IPLS	IN	01	04T	2	A	0-04	7316	31	7491	32	.0	.0		0	0	.0	0
OMAH	NE	NW	04T	2	A	0-05	9440	40*	9490	40	.1	.0		5	2	22.0	0
WKSH	WI	02	41T	1	F	0-08	8260	35*	8157	35	4.2	4.2		0	0	.0	0
WKSH	WI	02	41T	2	F	0-09	7821	33	7803	33	5.6	4.2		0	0	.0	0

35 REPORT:NM5LKX

NETWORK MANAGEMENT 5 MINUTE CCIS LINK EXCEPTION REPORT
IPLS IN 01 04T 4/27/77 1335

SIGNALING LINK NAME, SUFFIX, TYPE							OUTGO DATA		INC DATA					TERM BUFR OVLD			
CITY	ST	BG	ETY	S	T	SLK NO.	SU PC	%OCC	SU PC	%OCC	LINK %OOS	LINK CMPL %OOS	RCVD PSC PRO	THR PC	RPT PC	CTRL %ACT	BFR OFL
DLLS	TX	TL	14T	1	B	0-10	19093	81*	18937	80	.1	.0		5	10	43.3	4
OKCY	OK	CE	14T	1	B	1-03	16971	72*	17003	72	.0	.0	C	3	13	44.7	3
OMAH	NE	NW	04T	1	C	0-06	4217	18	4173	18	12.2	.0		1	0	3.3	0
OMAH	NE	NW	04T	2	C	0-07	5173	22	5204	22	.0	.0		0	0	.0	0
MDSN	WI	02	41T	1	A	3-11	8259	35*	8192	35	2.0	1.9	F	0	0	.0	0

Fig. 15—5-minute signaling link exception report for network management in CCIS STP (below) and switching (above) offices.

Monitoring the CCIS signaling links is a function of network managers because of the links' potential effect on telephone traffic. Presently, however, no capability is provided network managers to directly intervene in CCIS signaling network operation. The five-minute signaling link report indicates both outgoing and incoming signaling link occupancy because excessive signaling traffic in either direction may indicate undesirable answer signal delay. The percent of time a signaling link or signaling link complement (SLC) is reported out of service (OOS) includes the time signaling is inhibited for any reason including receipt of processor failed signals from a distant terminal and the signaling link being in the out-of-service, unavailable, or emergency restart states. One signaling link out of service may explain heavy traffic on the mate link. An outage simultaneously affecting complement signaling links (e.g., both A0 links to mate STPs) leaves no signaling path for corresponding bands of trunk groups which will be marked out of service in the associated switching offices. An F printed in the signaling link exception report column labeled RCVD PSC PRO indicates the signaling link outage is due to processor outage (PRO). Links over which processor signaling congestion (PSC) signals have been received from an STP will have a C printed in this column. CCIS terminal buffer overload control activity which broadcasts group signaling congestion (GSC) signals at an STP or makes trunk groups inaccessible to new call initiations at a switching office will also trigger the signaling link exception report. Note that, again, the CCIS signaling link is identified in terms of the abbreviated (11-character) Common Language Location Identification (CLLI) of the distant office along with two characters which designate suffix and type. Also, mate signaling links are always output together.

3.4.3 Other network management measurements

Besides the delay measurements on the 5-minute and 15-minute reports shown in Figs. 13 and 14, there are sender queue high and low (SQH and SQL), machine congestion levels one and two (MC1 and MC2) and reorder, sender overload, and vacant code announcement (ROA, SOA, VCA) measurements. The SQH and SQL measurements are the same as taken in non-CCIS offices. The MC1 and MC2 congestion states trigger restrictive controls in offices contributing CCIS traffic and the network manager must have knowledge of this activity. Announcements are the end results of ineffective machine attempts (IMA) due to troubles, congestion, or misdialed calls. Announcement measurements details are on the 5-minute exception reports and are therefore not provided on the 15-minute report. It should be noted that equipment reorder, no circuit, and vacant code conditions can cause actual announcement routing to occur in the originating CCIS office and not necessarily in the office detecting the condition. Thus, percent reorder, no circuit and vacant code calculations are based on the counts of detected conditions rather than counts of calls routed to announcements.

The 5-minute and 15-minute trunk group and 5-minute usage exception reports are generated and formatted similarly in non-CCIS and CCIS offices. The CCIS trunk groups are labeled following the abbreviated Common Language Location Identity (CLLI) standard as are the non-CCIS trunk groups. The 5-minute usage exception report shown in Fig. 16 includes outpulser groups, outpulser link controllers, sender-outpulser groups (appropriately labeled), sender link controllers associated with sender-outpulsers (also appropriately labeled) and transceivers.

3.5 Office administration and traffic engineering

One of the three required *DATASPEED* 40 terminals is dedicated to the office (dial) administrator. As shown in Fig. 6, the office administrator uses intermediate- and long-term data to perform the day-to-day and week-to-week office administration functions. Office administration responsibilities include:

07 REPORT:NM5UEX

NETWORK MANAGEMENT 5 MINUTE USAGE EXCEPTION REPORT
WKSH WI 02 41T 4/01/77 1306

EQUIPMENT ITEM	AVG # OUT	MAINT CCS	TRAF CCS	TOTAL CCS	% OCC	PC	HT/A
* TRANSCEIVER GROUP 5	0	.0	.1	.1	0	34	.29
* TRANSCEIVER GROUP 1	0	.0	.3	.3	0	41	.73
* TRANSCEIVER GROUP 0	0	.0	.3	.3	3	55	.55
* IT MARKER	0	.1	6.1	6.2	34	1560	.39
* TC MARKER	0	.4	4.5	4.9	27	1443	.31
* DECCDER CHANNEL	0	.0	4.3	4.3	24	3005	.14
* SLC–A (MF –A)	0	.0	2.5	2.5	21	584	.43
* SLC–B (MF –B)	0	.0	3.2	3.2	27	569	.56
* SLC–C (MF –C)	0	.0	2.7	2.7	23	574	.47
* SLC–D (MF –D)	0	.0	2.9	2.9	24	550	.53
* SLC–E (MF –E)	0	.0	1.4	1.4	12	211	.66
* SLC–F (MF –F)	0	.0	1.5	1.5	13	230	.65
* SLC–G (MF –G)	0	.0	1.1	1.1	9	247	.45
* OLC–A (OPLS–A)	0	.0	.0	.0	0	46	.00
* MF –A	0	.4	31.0	31.4	30	575	5.39
* MF –B	0	.4	29.3	29.7	28	567	5.17
* MF –C	0	.6	31.4	32.0	30	554	5.67
* MF –D	0	.8	30.7	31.5	30	543	5.65
* MF –E	0	.8	10.3	11.1	11	207	4.98
* MF –F	0	.5	10.0	10.5	10	228	4.39
* MF –G	0	1.3	10.9	12.2	12	255	4.27
* OPLS–A	0	.0	1.8	1.8	5	46	3.91

Fig. 16—Network management 5-minute usage exception report.

(*i*) Ensuring proper functioning of all components of the switching system and associated network.

(*ii*) Balancing the load on switching system components.

(*iii*) Maintaining a required level of service.

(*iv*) Collecting and summarizing valid traffic data for historical analysis and use by traffic engineers to provide the required amount of equipment and facilities.

Although some 15-minute and monthly data are provided to the office administrator, most information is reported on an hourly or daily basis as described in Refs. 4 and 5. Probably the most important and comprehensive administration reports are the Machine Load and Service Summary (MLSS), the Ineffective Machine Attempts (IMA) and the CCIS Summary (DACCIS) reports. Other reports are the incoming trunk group reports, the outgoing trunk group reports, the trunk link frame load balance report and the data integrity status report. Discussion in this article centers on the MLSS, IMA, and DACCIS reports. All three reports can be scheduled to report an hour's worth of data on the hour and the half-hour. Also these reports can be demanded for hourly periods beginning on the hour or half-hour up to and including the past twenty-three hours of data and for the 15-minute period preceding a demand. Finally various items on the reports can have threshold values set to trigger exception versions of the reports. The new CCIS measurements included on the office administration reports are far too numerous to discuss them all and, so, only a few are highlighted.

H 19 REPORT:DACCIS
DA CCIS SUMMARY REPORT
OFFICE: WKSH WI 02 41T DATE:03/30/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

SO OFFICE PERFORMANCE

CALL SWITCHED		%	ATTEMPTS	PC	%	BASE	SPC OCCUP	%
CC–EM	988	2.0	INC CC TOTAL	1001			ESTIMATED:	,
CC–CC	0	.0	INC NOT SW	13	1.3	INC CC	CALL PROC	10.2
EM–CC	740	1.6	OUT CC TOTAL	748			CALCULATED:	
EM–EM	45257	95.8	OUT NOT SW	8	1.2	OUT CC	BASE LEVEL	74.0
EM–ANN1	272	.6					TIME TABLE	16.0
CC–ANN1	0	.0	INC CC SW	988	2.1	TOT SW	CALL PROC	10.0
–TOTAL–	47257	100.0	INC EM SW	46269	97.9	TOT SW	––TOTAL–––	100.0
REATTEMPTS							AVG E–E MSEC	20.0
			OUT CC SW	740	1.6	TOT SW		
EM–ANN2	0	.0	OUT EM SW	46517	98.4	TOT SW		
CC–ANN2	0	.0						

(a)

H 28REPORT:DACCIS
DA CCIS SUMMARY REPORT
OFFICE: ANHM CA 01 28T DATE:05/09/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

STP OFFICE PERFORMANCE

CCIS ITEMS	PC	ETS ITEMS	VALUE
OUT SIG UNITS	134358	MARKER PC	53537
INC SIG UNITS	134275		
OUT IAMS	3288	REAL–TIME FOR ETS	14.1%
INC IAMS	3288	REAL–TIME FOR STP	1.9%
OUT ANS SU	2451		
INC ANS SU	2451	AVG E–E TIME	24.5 MSEC
SYSTEM CONGESTION		SPC UTILIZATION	
		BASE LEVEL WORK	68.0%
PSC BROADCASTS	0	TIME TABLE WORK	16.0%
PSC RECEIVED	0	CALL PROCESSING	16.0%
SLK OVERLOADS	0	TOTAL	100.0%

(b)

Fig. 17—(a) Total office part of CCIS summary report for switching offices. (b) Total office part of CCIS summary report for STP offices.

3.5.1 CCIS Summary (DACCIS) report

The DACCIS report provides 15-minute and 60-minute summaries of CCIS activity in the office. The first page of the report provides total office measurements. The remaining pages provide the load and performance data of individual signaling links. Figs. 17 and 18 illustrate the DACCIS report format.

Total office counts of switched calls include CCIS to non-CCIS (EM), EM to CCIS, CCIS to CCIS, and EM to EM calls. In addition, counts of incoming CCIS calls routed to announcement are registered. All counts are made on an actually routed basis as opposed to a first choice basis. If, for example, it becomes necessary to subsequently route to announcement after switching to an outgoing trunk, a count is scored for the original switched attempt and another for the announcement. Examples of CCIS call irregularities are initial address message (IAM) irregularities, Vacant National Number (VNN), glare detected, no outgoing call register, etc. VNN, for example, is a received backward failure signal for a call routed CCIS outgoing and indicates that a subsequent office has found a vacant code condition for the call.

The STP office performance section includes counts for incoming and outgoing initial address messages (IAMs) and signal units (SUs), PSC

DA CCIS SUMMARY REPORT
OFFICE: IPLS IN 01 04T DATE: 05/19/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

SIGNALING LINK LOADS

OFFICE: IPLS IN 01 04T DATE:05/19/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

NAME	T	SLK NO	OUT SU	OUT OCC	INC SU	INC OCC	OUT IAM	INC IAM	OUT ANS	INC ANS	EST % OUT	OCC INC
OMAH NE NW MSP 1	C	00–01	63	0	63	0	0	0	0	0	0	0
OMAH NE NW MSP 2	C	00–02	84	0	84	0	0	0	0	0	0	0
CHCG IL CL 57T 1	A	00–03	2125	1	2070	1	138	216	241	97	1	1
DLLS TX TL MSP 1	B	00–04	2484	1	1720	1	439	75	54	298	1	1
OKCY OK CE MSP 1	B	00–05	1470	1	1315	0	245	114	50	157	1	0
MDSN WI 02 41T 1	A	00–06	5926	2	5810	2	589	616	513	314	2	2
WKSH WI 02 41T 1	A	00–07	7166	3	9410	3	385	1483	1032	302	2	3

SIGNALING LINK PERFORMANCE

OFFICE: IPLS IN 01 04T DATE: 05/19/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

NAME	T	SLK NO	CHANGE OVERS	OOS SEC	–SLK OVERLOADS– PC	SEC	AVG	OVER FLOW
OMAH NE NW MSP 1	C	00–01	0	0	0	0	0	0
OMAH NE NW MSP 2	C	00–02	0	0	0	0	0	0
CHCG IL CL 57T 1	A	00–03	0	0	0	0	0	0
DLLS TX TL MSP 1	B	00–04	0	0	0	0	0	0
OKCY OK CE MSP 1	B	00–05	0	0	0	0	0	0
MDSN WI 02 41T 1	A	00–06	0	0	0	0	0	0
WKSH WI 02 41T 1	A	00–07	0	0	0	0	0	0

NETWORK PERFORMANCE

OFFICE: IPLS IN 01 04T DATE: 05/19/77 PERIOD: 900–1000
DATA INTEGRITY: ETS=300

NAME	T	SLK NO	PSC RCD	CHANGEOVER NE	FE	EMER PC	RESTART SEC
CHCG IL CL 57T 1	A	00–03	0	0	0	0	0
MDSN WI 02 41T 1	A	00–06	0	0	0	0	0
WKSH WI 02 41T 1	A	00–07	0	0	0	0	0
DLLS TX TL MSP 1	B	00–04	0	0	0	0	0
OKCY OK CE MSP 1	B	00–05	0	0	0	0	0
OMAH NE NW MSP 1	C	00–01	0	0	0	0	0
OMAH NE NW MSP 2	C	00–02	0	0	0	0	0

Fig. 18—Signaling link and network part of CCIS summary report (common format for STP and switching offices).

broadcasts, PSCs received, signaling link overloads, marker attempts (non-CCIS switched traffic), and a summary of STP/non-CCIS real-time utilization of the SPC No. 1A. The Traffic Separations (TSEP) report

L DAY
INEFFECTIVE MACHINE ATTEMPTS –TOTAL– LAST REPORT DAY

WKSH WI 0241T PERIOD= 0000 03/24/77 TO END OF REPORT DAY

INTEGRITY ETS= 7192 TDC= 7194

	IT	TC	TOTAL
MARKER PC	246830	232608	479438
ITLF PC	240015	224908	464923

	BASE	DELAY	% DELAY	AVG AT
XOD–IT	5409	149	2.75	.782
XOD–TC	3712	61	1.64	.777
XOD–TOT	9121	210	2.30*	.780
OAD–OP	9248	10	.10*	.302
OAD–MFO	0	0	.00	.000
SAD–MF	20222	0	.00	
SAD–MFO	0	0	.00	
SAD–DP	0	0	.00	
SAD–CAMA	0	0	.00	
SAD–ORP	0	0	.00	

	PC	%	BASE
TOT INEFFECT	744	.15*	TOTINC
RO DETECTED	682	.14*	TOTINC
SOA	0	.00	TOTINC
FRA (–ANN OF)	6	.00	TOTINC
NC DETECTED	56	.01	TOTINC
CAMA DP RO	0	.00	TOTINC
UCA	0	.00	TOT TV
MCA	0	.00	TOT TV
VC DETECTED	2395	.51	TOTINC
LBA	0	.00	TOTINC
SC RESET	7	.00	TOTINC
RO INCOMING	556	.11	TOTINC
PERM SIGNAL	362	.07*	EM INC
PARTIAL DIAL	86	.01*	EM INC
PULS ERROR	44	.01*	EM INC
MUT DIGIT	62	.01*	
STUCK REG–NC	0		
ADI DETECTED	2	.11	EM OUT
IAM–UNEQ TRK		.02	EM OUT
COT TO	41	.05	EM OUT
RO OUTGOING	86	.01	EM OUT
EATR	49	.01	EM OUT
	66	.01	EM OUT
CCIS REATMPT	1	.01	CC OUT
RCPT COF–1A	0	.00	CC OUT
RCPT RLG–1A	0	.00	CC OUT
RCPT RST–1A	0	.00	CC OUT
RCPT BLK–1A	1	.01	CC OUT
RCPT UQL–1A	0	.00	CC OUT
CON CK FL–1A	0	.00	CC OUT
GLARE–1A	0	.00	CC OUT
CREG TO–REAT	0	.00	CC OUT
IAM IRREG	1	.01	CC INC
INVALID	0	.00	CC INC
LENGTH CK FL	1	.01	CC INC
2ND NO MATCH	0	.00	CC INC
NO CREG OUT	0	.00	EM–CC
CALL ABANDON	0	.00	CC TOT

	PC	CCS	%OCC
SQL (A)	0		
SQH (A)	0		
SQL (B)	0		
SQH (B)	0		
MC1	1	.08	
MC2	0	.00	

	PC	%	BASE
TOTINC	465107		
EM INCOMING	455736	97.96	TOTINC
CC INCOMING	9371	2.01	TOTINC
TOTOUT	462161		
EM OUTGOING	454716	98.36	TOTOUT
CC OUTGOING	7445	1.61	TOTOUT
CC TOTAL	16816	3.61	TOTINC
DCH 2T	3836	.82	ITLF
EM–EM	445580	95.80	TOTINC
EM–CC	7009	1.50	TOTINC
EM–AN1	3147	.67	TOTINC
EM–AN2	25	.00	TOTINC
CC–EM	9136	1.96	TOTINC
CC–CC	0	.00	TOTINC
CC–AN1	0	.00	TOTINC
CC–AN2	0	.00	TOTINC
TPC TOTAL	461819	99.28	TOTINC
THRU	172738	37.40	TPC TO
INCOMING	83624	18.10	TPC TO
OUTGOING	166952	36.15	TPC TO
NON–THRU	38505	8.33	TPC TO
IT GOING	339690	73.54	TPC TO
TC OUTGOING	122129	26.44	TPC TO
SDR CAMA	0	.00	TOTINC
CA DPR (ADJ)	0	.00	SDR CA
TOT TVTR	0	.00	SDR CA

	RECD	SENT
ADI	5	2
NSC	0	0
CFL	0	2
SUBTOT	5	4
VNN	22	36

Fig. 19—Part of ineffective machine attempts summary report.

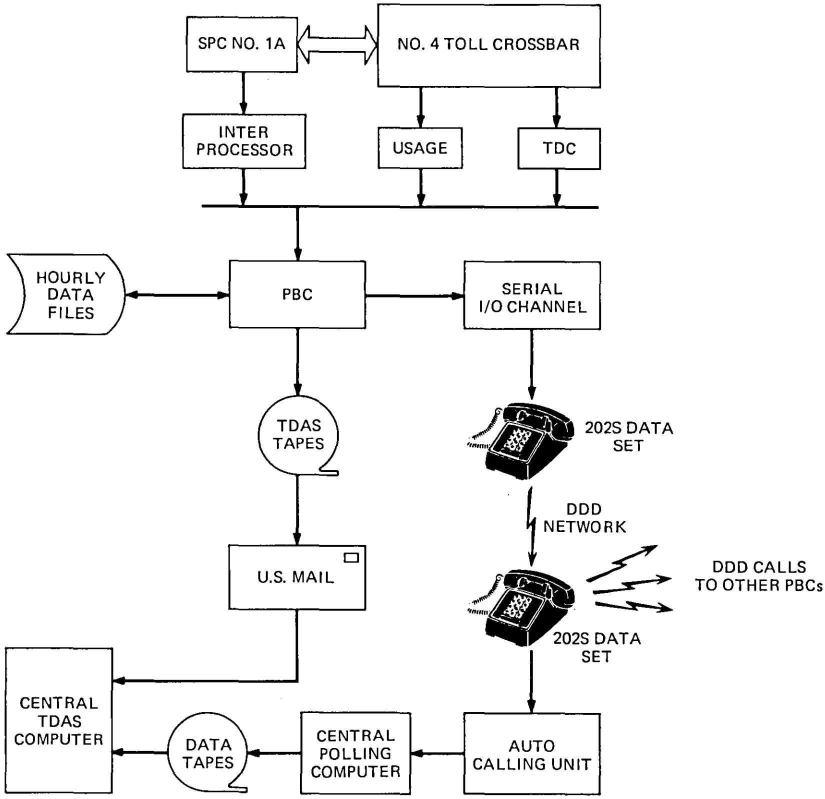

Fig. 20—TDAS interfaces with No. 4 crossbar CCIS offices.

used for division of revenue purposes also provides a real-time utilization summary in STP offices.

3.5.2 *Ineffective attempt (IMA) and load service summary (MLSS) reports*

The IMA report is partially shown in Fig. 19. Note that SADR (shown as SAD), OAD, and XOD measurements are summarized on the IMA report as are the SQH, SQL, and office congestion states (MC1 and MC2). All CCIS ineffective attempts, retrials, reattempts, time-outs, and miscellaneous other failures are summarized on the IMA report. In addition, CCIS signals sent and received and Voice Path Continuity (VPC) tests are summarized.

The MLSS report described in Refs. 4 and 5 is basically expanded to include occupancy and holding time summaries for the new equipment and groups including outpulsers, sender-outpulsers, outpulser link controllers sender-outpulser link controllers, and transceivers.

3.5.3 Interfacing with other systems

The long-term data required to perform engineering studies of the switching office are provided by two PBC features illustrated in Fig. 20. An optional dial-up data port can be installed which allows hourly traffic separations, trunk group, and common control equipment data files to be transmitted over the switched commercial network to a central polling computer once a day. The central computer forwards the data to a Traffic Data Administration System (TDAS), or equivalent, which enables an operating company to do engineering and division of revenue studies for No. 4 crossbar systems. As an alternative, the PBC provides this data on magnetic tape in a format which can also be processed by TDAS. TDAS enables an operating company to minimize, manage, and control the traffic data collected from a variety of switching offices for engineering use. TDAS tape entries must be made once a day during a study period. The PBC places a "restart" mark on the tape so that a single magnetic tape can be used to accumulate several days' worth of data for long-term engineering studies before it is sent to the operating company's TDAS-equipped computer center.

One additional data port is provided as an option by the PBC system. This port requires a permanent data link and is designed to interface with a centralized network management system which will poll the PBC system every five minutes as discussed in Ref. 3.

IV. MANAGEMENT OF THE OFFICE DATA BASES

As mentioned earlier, the data which describe the office equipment translations and define the routes over which calls are sent reside in the SPC No. 1A memory while the data which provide the proper associations among the raw measurement data and processed, labeled output reports reside in the PBC memory. The data bases are initially generated by Western Electric from completed questionnaires submitted by the telephone company for new installations or major growth additions. The daily, routine management of these two data bases are accomplished via the facilities provided by the PBC. Data base management is composed of three major functions:

(*i*) Recent change—the capability to implement real-time data base changes formatted in user language.

(*ii*) Verification—the capability to read the data bases by the No. 4 crossbar decoder marker test circuit software for advance verification of pending route changes and by the PBC for output in user language formats which facilitate comparison with office records.

(*iii*) Off-line change order generation and storage—the capability to record change orders on a storage medium regardless of the state of the system.

4.1 Recent change

The Recent Change (RC) function is accomplished by software which resides in both the SPC No. 1A (minimal) and the PBC and which can change the SPC No. 1A data base and the PBC core and disk resident data bases. The appropriate RC programs are selected and executed by entering the desired input messages on either the *DATASPEED* 40 terminal associated with the No. 4 crossbar switching maintenance center or a second, optional *DATASPEED* 40 provided for data base management activities. The RC software programs are divided into control and change functions. The control software allocates and releases disk memory storage during the change process, updates status indicators, builds change orders, communicates with the SPC No. 1A via the interprocessor interface and actually writes the new data into memory when the change order is activated. Some control programs are executed by entering control messages while others are executed as subroutines to change programs. The change software translates input change message fields into addresses and data to be used by the control software. Change programs are executed by entering change messages. Change orders are built by entering combinations of control and change messages in the proper order. Control messages are used to begin, end and activate or cancel a change order.

A change order is entered into a PBC disk resident RC order buffer where it is held for verification tests and until the order is either activated or canceled. When a change order includes changes for SPC No. 1A data tables, a control message causes the new data to be transmitted across the interprocessor interface to the SPC No. 1A software which holds it in a temporary buffer for verification tests and until the change order is either activated, canceled or the next change order is transmitted to the SPC No. 1A for verification and activation or cancellation. During the change order transmittal the SPC No. 1A actually transmits a copy back to the PBC to ensure the change data was received error free by the SPC No. 1A. A well-defined handshake protocol and a set of error messages further ensures integrity of the change order.

4.2 Verification

Numerous verification facilities are provided. At the time a change order is first entered into the RC order buffers in disk memory, a response message prints out the data currently in each of the tables in a column beside the actual field label and beside a column containing the new data. Any field which differs between the old and new data columns will blink on the CRT between low and high intensity to attract attention to the changes pending in the change order buffer. The field labels are those used on the office data compiler records.

If call routing data in SPC No. 1A memory are to be changed by a RC order, the change data can be transmitted to the SPC No. 1A and its accuracy verified in advance of change order activation via the decorder marker test circuit keys, lamps and teletypewriter output messages.

A variety of readout verification messages and data table audits are provided which allow both the SPC No. 1A and PBC data bases to be queried over any of the PBC *DATASPEED* 40 terminals (RC order inputs and outputs are restricted to the two terminals identified in paragraph 4.1). The outputs of these verification and audit messages are in labeled formats similar to the office data compiler records for ease of recognition.

One further verification facility is the use of a comparison between the magnetic tape copy of the verified data base made after the last RC orders were activated and the contents of memory before and after the new RC orders are activated.

4.3 Off-line RC order preparation

The optional 4210 Magnetic Tape Terminal shown in Fig. 2 is an alternative to manual *DATASPEED* 40 keyboard entry of RC orders into the PBC disk buffers. Any 4210 terminal associated with any type of compatible keyboard device (teletypewriters, *DATASPEED* 40, etc.) independent of the PBC can be used to record RC order messages on the 4210 magnetic tape cartridges. The recorded cartridges can then be read by the 4210 terminal(s) directly onto the appropriate PBC *DATASPEED* 40 CRT's as an alternative to manual keyboard entry. From this point all other RC operations to verify and activate or cancel the RC orders are independent of the 4210 terminal.

The 4210 cartridges provide a means of long-term, bulk storage of RC orders for backup purposes and off-line, advance recording of future RC orders. Recording RC orders on 4210 magnetic tape is several times faster than punching paper tapes due to more streamlined RC messages, editing features of the *DATASPEED* 40/4210 terminal combination, and the reusable nature of magnetic tape for error correction. Furthermore, entry of RC orders recorded on 4210 cartridges is about ten times faster than entry using paper tape. Considering the increased size and complexity of the data base in a CCIS office, these data base management improvements are needed.

V. ACKNOWLEDGMENTS

The work described in this article was accomplished through the combined efforts of many people in Bell Laboratories and Western Electric. Through their timely contributions, too numerous to acknowledge individually, the development of the PBC system was completed in time to support the first CCIS installations.[8] The author also thanks Mr. R. C. Nance for his technical advice during the PBC development.

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Common Channel Interoffice Signaling:

No. 4 ESS Application

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Common channel interoffice signaling (CCIS) is provided as an integral part of No. 4 ESS. The unique hardware required for CCIS consists of a common systems CCIS terminal and associated access circuit, continuity check transceivers, and unitized terminal equipment for CCIS trunks. The control of the CCIS hardware and the logic required for CCIS administrative functions is provided by programs resident in the 1A Processor. This paper discusses the system design requirements, the signaling hardware, and the software design for CCIS in the No. 4 Electronic Switching System.

I. INTRODUCTION

No. 4 ESS, a large-capacity toll switching machine, was originally designed to handle two basic address signaling systems, Dial Pulse (DP) and Multifrequency (MF). With the introduction of common channel signaling into the domestic toll network, No. 4 ESS included as part of its initial offering the Common Channel Interoffice Signaling (CCIS) capability. Other papers discuss the basic system architecture,[1] hardware,[2] and call-handling software[3] of the No. 4 ESS with emphasis on the DP and MF signaling systems. This paper deals with the specific hardware and software design associated with CCIS. Section II describes the overall CCIS design constraints, system architecture and hardware as it applies to No. 4 ESS. Section III describes the CCIS software organization and functional implementation.

II. SYSTEM DESIGN

The major components that compose the basic system architecture for No. 4 ESS are illustrated in Fig. 1. The 1A Processor controls all ac-

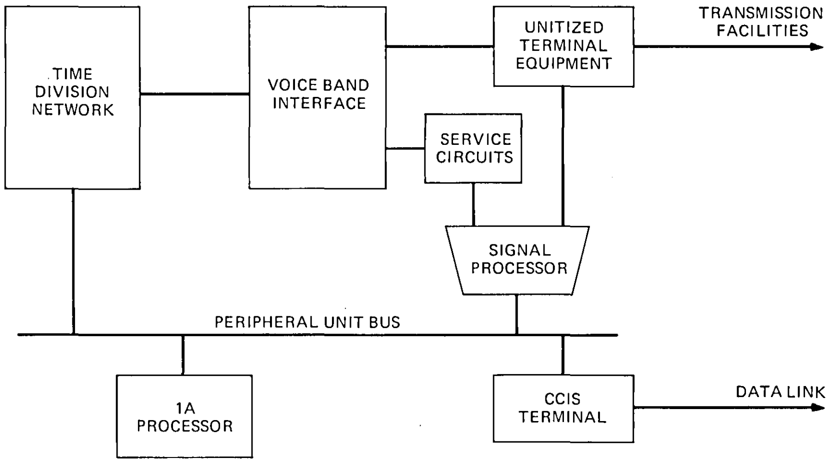

Fig. 1—No. 4 ESS system architecture.

tions of the No. 4 ESS by executing programs residing in core memory. The digital time division network, under control of the processor, establishes connections between all trunks and service circuits. Trunks for all signaling types are housed in unitized terminal equipment frames. Since all switching is done in digital format, any analog signals must be converted to digital format by voiceband interface units.

The Signal Processor (SP) is an autonomous unit which performs the supervisory scanning and distribution functions for E and M trunks. It also performs scan and distribution functions for service circuits, power control, and office alarms. The CCIS signaling terminal interfaces a CCIS data link which carries supervision and address information for CCIS trunks. Both of these signaling units, as well as the time division network, are controlled by the 1A Processor over a peripheral unit bus.

2.1 CCIS hardware

The major hardware modules required for common channel signaling in No. 4 ESS are CCIS terminals, CCIS continuity check circuits, and trunk terminal equipment. The CCIS terminal used in No. 4 ESS is the common systems design[4] used in 4A/STP, 4A/CCIS and No. 1 ESS toll. Up to 16 CCIS terminals are housed in a terminal grouping frame (TGR) and there can be up to 16 TGRs in a No. 4 ESS office. Data transmission between the 1A Processor and the CCIS terminals takes place over the peripheral unit bus via a Terminal Access Controller (TAC). The TAC is duplicated and is a part of the terminal grouping frame. The CCIS terminals are stored program controlled units and are initialized by the 1A Processor. Once initialized they perform all required CCIS data link operations asynchronously from the 1A Processor. The terminals notify the 1A

Processor via a "signal present" scan point when they have received data.

The CCIS Continuity Check Transceiver (CCT) is configured and housed similiar to other No. 4 ESS service circuits (e.g., MF transmitters and MF receivers). The CCTs are packaged and powered in modules of six and are mounted on a miscellaneous frame. Each CCT is assigned a unique termination on the time division network and has control access from the signal processor. Four distribution points are provided for each CCT to allow the 1A Processor to set the operating mode (2 wire or 4 wire) and to sensitize the receiver to the expected round trip via net loss of the trunk. Each CCT uses one scan point for reporting the completion of a successful continuity test.

CCIS voice trunks are similar to those equipped for E and M supervisory signaling except that the Single Frequency (SF) to E and M conversion is not provided. Echo suppressor control, if required, is provided via a signal distribution point in the signal processor. There are no other connections for supervisory or address purposes. Up to 96 CCIS trunks without echo suppressors (48 with echo suppressors) are housed in a CCIS unitized terminal equipment frame.

2.2 CCIS data link

Load-shared CCIS data links are provided between No. 4 ESS switching offices and CCIS Signal Transfer Points (STPs).[5] A pair of data links, one to each STP, is engineered for up to 3000 CCIS trunks. Each CCIS data link consists of a CCIS terminal at the No. 4 ESS, a voice frequency link (VFL), and a CCIS terminal at the STP. For reliability, each data link has both an active and standby VFL. As shown in Fig. 2, the two VFLs and the CCIS terminal are terminated on the time division network. Under program control a connection between a VFL and the terminal is made through the time division network to establish the CCIS data link. This configuration allows switchable access to both the VFLs and the CCIS terminal for automatic or routine maintenance actions.

2.3 CCIS software

As with the hardware, the No. 4 ESS software architecture is modular and for the most part independent of signaling type. Several major program modules are provided for CCIS functions: a call-handling module, a CCIS link security module, and various initialization and hardware maintenance modules. Each of these modules was designed to use as much as possible the same major data and timing structures provided for E and M signaling call types (MF and DP).

Every trunk in No. 4 ESS is assigned a 2-word trunk register (TR) to record the call and maintenance state of the trunk and to provide link-

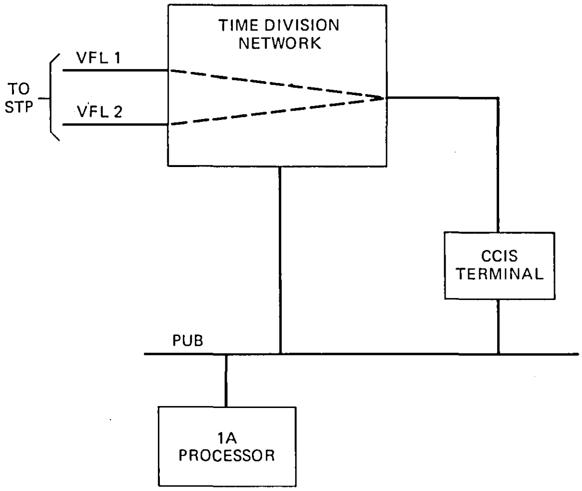

Fig. 2—CCIS data link configuration.

ages to other software structures. An item in the TR indicates whether the trunk is equipped for a CCIS call. This substate allows CCIS call states to be consistent with the call states defined for the other signaling types. All call programs in No. 4 ESS use a common set of TR data layouts, timing lists, and queueing strategies.

The basic structure used to maintain call information during the call setup stage is the 64-word call register (CR). Information in the CR records the state of the call, the incoming and outgoing trunk states, the received digits, connected service circuit information, and routing and outpulsing data. CCIS programs use the general layout of the CR for the CCIS call function. Some new states and data items (e.g., terminal label of trunk) are unique to CCIS.

The trunk structures and trunk translation data organization within the No. 4 ESS is based on the trunk signaling appearance (TSN) on the signal processor. This organization allows SP reports associated with E and M trunks to be handled efficiently. As a CCIS trunk does not require a signal processor for signaling purposes, a pseudo assignment of a TSN is made for each CCIS trunk to maintain commonality of the translation data and call structures. The SP to which the CCIS trunk TSN is assigned does not have to be physically equipped. This allows the CCIS trunk structure and translation data structures to be common, but does not require actual equipment expenditure. To maintain this commonality requires a translation from this internal identification (TSN) to an external identification (terminal and label) when call-related CCIS messages are transmitted. When receiving CCIS messages, the reverse translation must be made.

The design and implementation of the CCIS call-handling module in the No. 4 ESS was based on a "reasonableness table" developed to indicate the domestic CCIS call flow. This reasonableness table which identified the call actions required of every CCIS message in every call state was also used to specify the design for the 4A/CCIS and No. 1 ESS toll machines.

The call-handling functions performed for incoming CCIS calls are independent from those performed for outgoing CCIS calls. This design allows a convenient interface with the non-CCIS (E&M) call-handling programs. The interfaces between the various call-handling programs are simplified because the same data structures are used. Communication between the modules is by direct transfer to perform a defined function.

The CCIS link security module is responsible for maintaining a viable CCIS signaling configuration. As the link security function is not common to other types of signaling programs, it requires independent programs and data structures to perform the CCIS signaling link security functions. The link security module uses three data structures to perform signaling security functions. A 2-word data structure is used for quick reference by call processing to determine the general status of a CCIS link and to determine the backup CCIS link if required. An 8-word register is used to keep detailed status, perform timing functions, and queue multiple CCIS terminal action requests. The third structure keeps signaling status on the bands associated with a signaling link.

CCIS initialization and maintenance functions, including trunk maintenance, CCIS terminal fault recognition, and diagnostics, do not require any major unique data structures. These functions are provided by appropriate additions and modifications to programs responsible for E&M trunks and signaling equipment. A special initialization routine is used to load and initialize the program that is resident in the CCIS terminals.

III. SOFTWARE ORGANIZATION

This section describes the software modules that provide the CCIS functions in No. 4 ESS. The largest module is the call-handling module which performs the actions directly associated with the switching of CCIS calls. It is divided into two programs, the CCIS task dispenser and the CCIS call task routines. As shown in Fig. 3, the CCIS task dispenser interfaces directly with the CCIS terminals. CCIS call messages are distributed by the task dispenser to the appropriate call task routines. These routines perform the actions necessary to respond to the call stimuli and advance the call state. These actions include the sending of CCIS messages, calling special purpose service routines and interfacing with E&M signaling programs.

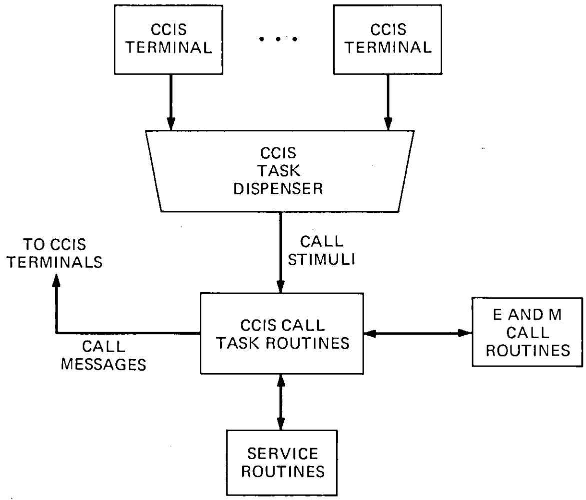

Fig. 3—CCIS call-handling module.

The CCIS link security module is primarily responsible for maintaining a viable configuration of CCIS signaling links. It performs actions in response to error conditions on CCIS data links and in response to manual requests from the maintenance personnel. Figure 7, which is described in Section 3.2, shows the major interfaces with the link security module.

The CCIS fault recognition module responds directly to maintenance interrupts from the TGR. Its main function is to configure components of the signaling hardware (terminal access controllers and terminals) in response to hardware failure indications and schedule appropriate diagnostic routines.

CCIS diagnostic programs, resident in the file store, are paged into core and executed upon demand of fault recognition programs or maintenance personnel. Separate diagnostic programs are provided for the TAC and CCIS terminal.

CCIS trunk maintenance routines respond to manual and automatic test activities associated with CCIS trunks. These programs also respond to CCIS trunk problems (ineffective attempts) as they are detected by the call-handling module.

A CCIS terminal initialization module is used to load and initialize the program which is resident in the CCIS terminal. This module is called whenever a terminal is brought back into service after diagnosis or during system initialization.

There are several other software modules in No. 4 ESS which provide administrative functions for CCIS. These include the recent change and verify capability for CCIS related translation structures, traffic and plant measurement counters for CCIS calls and signaling equipment, network management routines to handle CCIS dynamic overload control (DOC) signals, and a special trunk query routine scheduled by the audit system.

The remainder of this section describes in detail the operation of the call-handling and link security modules. The description of the call-handling module includes the actions associated with a switched CCIS-to-CCIS call.

3.1 CCIS call-handling

The CCIS call-handling programs in No. 4 ESS are organized to provide a convenient interface with the CCIS signaling hardware and to provide efficient interfaces with other signaling and administrative programs. The two major programs are the CCIS task dispenser and the CCIS task routines.

3.1.1 CCIS task dispenser

The CCIS task dispenser provides the major operational interface with the CCIS terminals. Two separate task dispenser routines are provided, one for each of the two priorities of received CCIS messages. The terminal's high priority buffer is unloaded by a CCIS task dispenser routine which is scheduled every 10 ms by the interject level executive control program. The low priority buffer of the terminal is unloaded by a CCIS task dispenser routine which is scheduled once per base level by the executive control program. Each of the two dispenser routines first scan the signal present points for all TGRs to identify which ones have terminals with messages waiting to be unloaded. Those TGRs with terminals containing messages are then polled to determine which of the associated 16 terminals have messages. A separate set of signal present points is provided for each priority and they are duplicated. A software masking arrangement is used to filter out signal present indications from terminals that are in a maintenance state. Once a terminal is selected, its receive buffer is unloaded until it is empty. Each call message is decoded by the task dispenser and sent to the appropriate task routine which handles that type of message. Once the task routine completes action on that message it returns control to the task dispenser which unloads the next call message. Messages are unloaded until all terminals are empty or a predetermined threshold (set by the overload program) is reached.

3.1.2 CCIS task routines

The CCIS call task routines perform the actions necessary to advance the call state in response to CCIS call stimuli: the CCIS call functions performed are sufficiently different from other No. 4 ESS signaling types to require separate programs. However, these programs use the common structure, data translators, and E&M call processing routines as much as possible. Whenever the call action to be performed is common to all signaling types or is special purpose (e.g., translations), an interface is made to a common service routine. Actions unique to other signaling types, (e.g., E&M supervisory actions) are performed in general by those signaling programs. In those cases any appropriate data is passed along with the call control.

There are several major interfaces between the CCIS call-handling programs and other operational feature programs in No. 4 ESS. *Translations*—CCIS translation and office data is retrieved from the data base using translation subroutines. These routing and trunk hunt routines are common for all signaling types. *Overload*—The overload control program monitors the occupancy of the CCIS queues and transceivers and places governors on the amount of work to be performed by the CCIS call-handling programs. *Network*—All actions required of the time division network (path hunts, network connections) are performed by a special-purpose network program. *Traffic*—General CCIS call data is passed to the traffic and plant measurements programs for the pegging of various event counters. These counters are subsequently summarized on machine status reports. *Network Management*—Interfaces exist with the network management program for placing routing controls (e.g., route skip, code block) on CCIS calls. *Initialization*—Initialization programs are called to initialize CCIS call-handling structures during system abnormalities. A special interface is required to govern the number of CCIS messages transmitted to prevent terminal buffer overflow. *Audits*—All the CCIS programs provide defensive checks (e.g., address range check) as part of the logic. Should a check fail, program control and any relevant data is passed to an audit routine for analysis.

3.1.3 CCIS-CCIS call

The CCIS-CCIS call is composed of the following three functions: supervision (seizure, answer, disconnect, abandon), addressing, and continuity checking. How these functions are implemented in the No. 4 ESS is described in the following text and associated pictorial representation of the hardware and software relationships.

A CCIS incoming call is initiated upon receipt of an Initial Address Message (IAM) for an idle trunk over the CCIS data link. The CCIS call-handling program translates the label in the IAM into a network appearance and busies the CCIS trunk in memory to outgoing seizures. The CCIS call-handling program then performs the following incoming

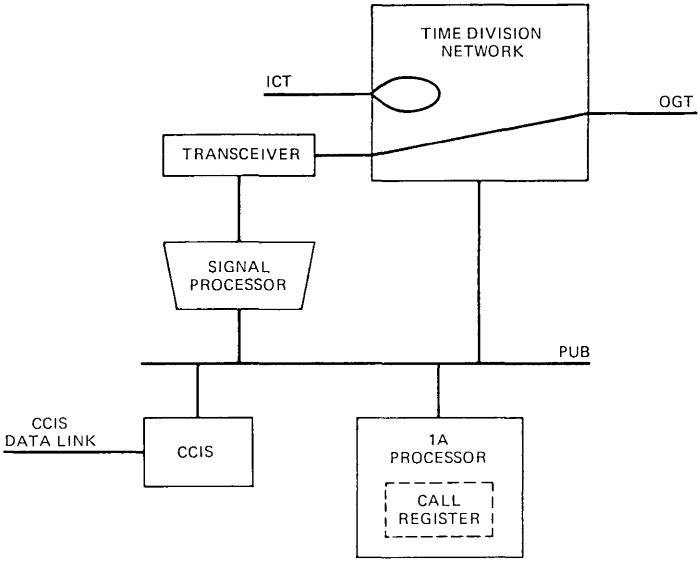

Fig. 4—Incoming and outgoing continuity checking.

functions; seizes and initializes a Call Register (CR), places the trunk information and the address information in the CR, and directs the network program to send orders to the time-division network to connect (loop) the incoming trunk's (ICT) transmit and receive sides for the incoming continuity check. Next the CCIS call-handling program requests the digit analysis and routing program to translate the address digits to obtain an outgoing route. The trunk subgroups in this route are hunted using the trunk hunt routine to obtain an Outgoing Trunk (OGT). If a non-CCIS trunk is selected, non-CCIS call-handling routines are given control of the call. If a CCIS trunk is selected, the outgoing portion of the CCIS call-handling program busies in memory the outgoing trunk to other outgoing calls, it then initiates the outgoing continuity check by hunting a transceiver, causing it to be connected through the time-division network to the outgoing trunk, and initializing the transceiver via an SP distribute point. When these actions are complete an IAM is formulated and sent for the selected outgoing trunk over the CCIS data link.

Figure 4 illustrates the system configuration at this point in the call. The incoming trunk is being tested for continuity by the preceding switching office. A transceiver connected to the outgoing trunk through the network is performing the continuity check on the outgoing trunk. A call register has been seized in memory and is linked via the trunk register to the call. One of two call stimuli are expected at this time; (*i*) a continuity (COT) message for the incoming trunk indicating a successful continuity test of the ICT or (*ii*) an outgoing continuity report via the

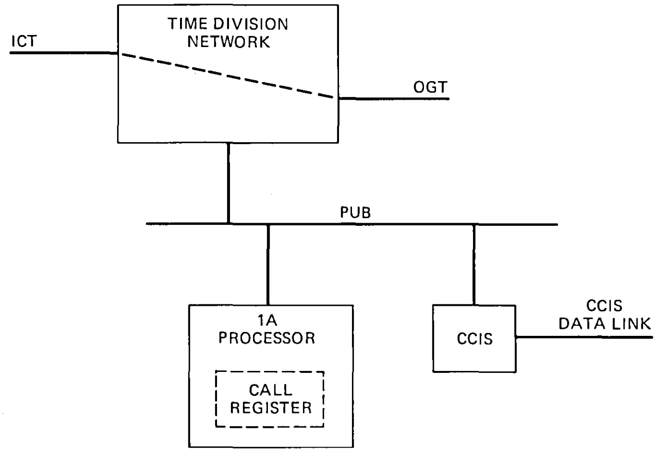

Fig. 5—Waiting for address complete.

signal processor indicating that the transceiver has successfully completed the continuity test of the OGT. If a COT message for the incoming trunk is received first, the CCIS call-handling program will abandon the loop on the ICT and wait for the outgoing continuity report. If the outgoing continuity report is received first, the transceiver is disconnected from the outgoing trunk and made idle. The call then waits for a continuity message for the ICT. When both the ICT continuity message and outgoing continuity reports have been received, a path is reserved in the time division network between the incoming trunk and the outgoing trunk and a COT message is sent for the outgoing trunk. The call is placed in the state "waiting-for-address-complete" as illustrated in Fig. 5. The CR is still linked to the call which allows retrial and announcement treatment in the event of outgoing call irregularities.

The next call setup signal expected is the address complete (ADC) message for the OGT. This message indicates the call has been successfully routed over the last CCIS trunk in the built-up network connection. The CCIS call-handling program requests connection of the incoming and outgoing trunks through the time-division network using the path previously reserved. At this point the CR is released (all transient data is erased) and the call is put in the waiting-for-answer state. No reattempt or call failure messages can be acted on once the call has reached this state since the CR data has been erased.

If a backward failure message (e.g., vacant national number, confusion) is received for the outgoing trunk rather than an ADC, processing of the call is discontinued and the outgoing trunk is made idle by the sending of a CLF. Depending on the type of failure, the call-handling program may retry the incoming call or terminate it by passing the same failure

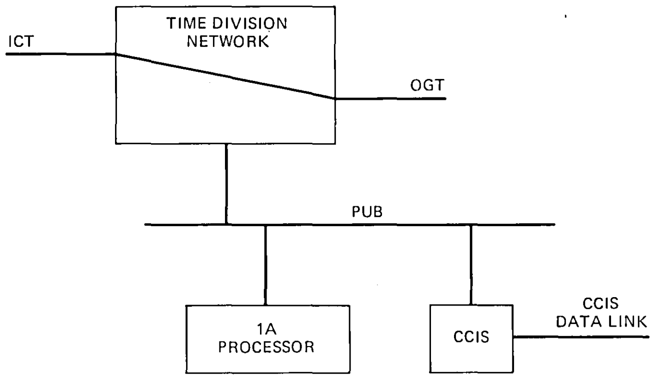

Fig. 6—Waiting for answer or talking.

message for the incoming trunk. In the latter case the program will place the incoming trunk into a call state which waits for an acknowledging CLF from the previous office to idle the ICT.

If an answer message (ANC) is received for the outgoing trunk, the call-handling program will send an answer signal for the ICT and place the call into the talking state. Error conditions on the signaling channel can cause an answer signal to arrive before the ADC. In this case, the call-handling program will advance the call directly to the talk state by performing the actions described above. In the talking state, clear back (CB) and reanswer (RA) messages will be passed (OGT to ICT) as they are received. Figure 6 shows the configuration of the system in the waiting-for-answer and talking states.

The CCIS call-handling program will abandon calls in any state when it receives a clear forward (CLF) message for the incoming trunk. A release guard (RLG) message is sent for the incoming trunk to acknowledge the idling of the trunk. If there is an outgoing CCIS trunk associated with the call, a CLF will be sent for the outgoing CCIS trunk. The OGT then goes to a state where it is waiting for a RLG. If a network connection is up, it will be taken down.

3.1.4 E&M-CCIS call

On hybrid E&M to CCIS calls, the outgoing CCIS functions are performed as if the ICT had been CCIS. Since continuity is assumed to be inherent on an incoming E&M trunk, the COT message can be sent for the outgoing CCIS trunk when the outgoing continuity check is completed and the incoming and outgoing trunk network path is reserved. The receipt of ADC for the outgoing trunk causes the ICT to OGT connection to be made and the call to enter the wait-for-answer state. The receipt of ANC for the outgoing trunk will cause the CCIS call-handling program to send an off-hook on the E&M trunk. The clearing sequences are also similiar. An on-hook condition on the E&M trunk causes the call to be terminated and both the ICT and OGT are made idle. The E&M ICT is made idle by releasing the M relay (on hook). A CLF will be sent for the CCIS outgoing trunk. If a backward failure message is received for the CCIS outgoing trunk, the call is either retried or terminated. If the call is terminated the incoming E&M trunk is connected to an announcement.

A special case of an E&M to CCIS call is one where the ICT requires call recording for Centralized Automatic Message Accounting (CAMA). Both the calling and called numbers are received by the CAMA program before an outgoing trunk is hunted. If a CCIS trunk is selected, the call progresses as previously described for E&M to CCIS calls up to the waiting-for-answer state. If an answer signal is received for the CCIS OGT, the charge administration routine in the CAMA program is called to record the answer time. The same routine is called when the ICT goes on-hook to record the disconnect time.

3.1.5 CCIS-E&M calls

An incoming CCIS call may be switched to an outgoing E&M trunk. On this hybrid call, the regular E&M trunk seizure and outpulsing routines are entered to perform the outgoing functions. The last digit is withheld from the outpulsing routines until a COT message is received for the CCIS incoming trunk. This prevents the possibility of the call being set up all the way to the called party before the continuity of the ICT talking path is verified. The CCIS call-handling program will send an ADC for the incoming trunk when the COT is received for the ICT, providing an E&M trunk has been successfully hunted and seized. Failures detected prior to the sending of address complete (e.g., all trunks busy) will cause the appropriate CCIS failure message to be sent for the incoming trunk. After outpulsing is completed, an off-hook on the outcoming E&M trunk causes an ANC message to be sent for the incoming trunk. Upon receipt of a CLF for the CCIS ICT the CCIS call-handling program will send a RLG for the ICT and place the OGT on-hook by releasing the M relay.

3.1.6 CCIS trunk maintenance

The trunk maintenance features for CCIS trunks are very similar to those provided for E&M trunks. Normal trunk maintenance functions such as routine signaling and transmission tests and manually requested calls to far end test lines are the same for CCIS and non-CCIS trunks. The continuity retest and the translation integrity check are incorporated as additional maintenance tests that can be run on any CCIS trunk. There are special routines to administer blocking and unblocking signals for CCIS trunks. The trunk maintenance features for collecting, analyzing, and outputting data associated with call irregularities is also applicable to CCIS trunks. The CCIS call-handling programs are used as much as possible to handle the signaling sequences associated with test calls. This approach simplified the trunk maintenance design and provided clean software interfaces.

The voice frequency links are treated essentially as normal voice trunks by the trunk maintenance program. They can be switched to a manual test position for all normal manual testing activity. An interface with the link security module is provided to inhibit trunk maintenance activity for a VFL that is being used as part of a CCIS data link.

3.1.7 Initialization procedures

During system initialization special procedures are required to idle CCIS trunks. Because there is no access to the trunk circuit to place it on hook (as is the case for E and M trunks) the CCIS data link is used to notify the far end of trunk idling actions. In the lower level initialization phase of No. 4 ESS (phases 1, 2, and 3) individual Reset Trunk (RST) messages are sent for all trunks that are in a transient state (not waiting for answer or talking). In the highest level phase (phase 4), Reset Band (RSB) messages are sent to idle all CCIS trunks. The CCIS data link must be resynchronized in a phase 4 because the connection between the terminal and the VFL has been removed during the network initialization.

3.2 Link security

CCIS link security is another major software module in No. 4 ESS. Its functions include monitoring the error performance of CCIS data links, responding and reconfiguring CCIS data link components (CCIS terminals, VFLs) to maintain a viable signaling channel, responding to band status messages from STPs, and providing an interface for the maintenance personnel to perform test activity on the CCIS data links. The No. 4 ESS link security system is designed to work in a load-sharing configuration as described in Section I. Each CCIS terminal is dedicated to a data link.

Figure 7 shows the major interfaces with the CCIS link security module. Stimuli to link security can be received from any of the following sources: internal data in the CCIS terminal, fault recognition programs, maintenance personnel, or the STP (via the CCIS terminal receive buffers).

Permanent translation data is provided for each pair of CCIS data links which includes the identities of the CCIS terminals, the associated VFLs and time division network assignments. This translation status along

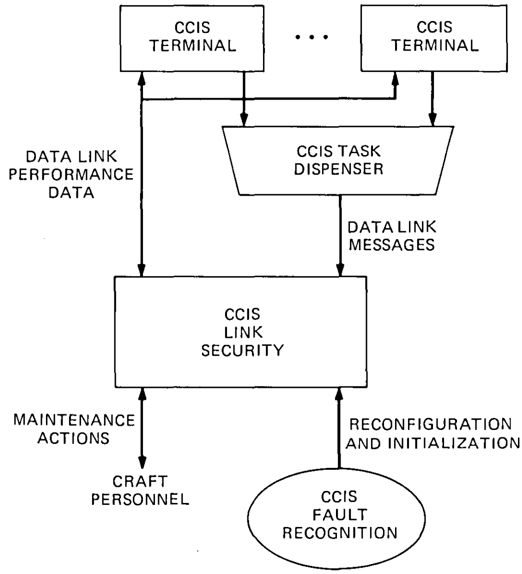

Fig. 7—CCIS link security module.

with three status tables are used by the link security module to perform its actions. The operational link status table provides a summary of the operational status of the data links for all the bands assigned to the data link. Detailed data link status information for each band, such as "restricted" or "prohibited" conditions, is maintained in a band status table. The CCIS call-handling programs interface with both of these tables to determine the operational status of a CCIS signaling link and band. These tables are updated by status messages received from the STP. The link security terminal register is a software data block reserved for each CCIS terminal and contains the specific state, condition indicators and event timers for the terminal and associated signaling link. The link security program responds to data link stimuli by consulting this register to determine the state of the signaling link. This register is also used to queue multiple requests for a signaling link waiting action by the link security program.

3.2.1 Link security actions

The link security program receives its inputs from the CCIS terminals via messages received over the data link (through the CCIS task dispenser) or by direct scanning of the CCIS terminals. In the later case the CCIS terminal will report data link status changes via a scan point assigned on the signal processor. This scan point is driven by the software in the CCIS terminal. The terminal is interrogated directly by link security to determine the particular condition the terminal is reporting (e.g., synchronization achieved, buffer overflow).

One condition reported in this manner is a synchronization report indicating that the signaling link has become operational. In this case the link security program will request an update of the band status information from the STP. When the update is completed, the status of the data link is updated in the operational link status table and the state of the link is changed in the terminal register. The data link is then available for carrying CCIS signaling information.

Another condition reported from the terminal is a high error rate on the signaling channel. In this case the data link has become inoperable and changeover procedures are invoked. Any messages waiting transmission that are stored in the CCIS terminal serving the failing data link are transferred to the transmission buffer of the CCIS terminal serving the load sharing (mate) data link, providing it is operational. The terminal status is updated in the operational link status table to direct call-handling actions toward the in-service CCIS terminal. Standard recovery procedures are started to resynchronize the failing data link. The resynchronizion is attempted using both VFLs. The CCIS terminal is switched between the two VFLs every three seconds. If the data link does not resynchronize within three minutes, the CCIS terminal is taken out of service and diagnosed. If the data link resynchronizes on either VFL, the data link is put in service and signaling is restored as described previously. Bad VFLs are reported to trunk maintenance programs for further maintenance actions.

Hardware faults within a CCIS terminal or TAC are detectable through an all-seems-well mechanism over the PUB. These failure conditions are handled by the peripheral bus fault recovery program on a maintenance interrupt level. This program isolates the failure to the CCIS equipment and calls in the CCIS fault recovery program to establish a viable CCIS configuration. If a CCIS terminal is removed from service, the CCIS fault recognition program interfaces with link security to update the status of the CCIS terminal to an out-of-service state. CCIS messages are not removed from a faulty terminal since access may be restricted. The CCIS fault recognition program will request a diagnostic for the faulty terminal. When the CCIS terminal passes diagnostics, a report is made to link security and normal recovery procedures are invoked by link security.

The interface between the craftsperson and the link security module is primarily for maintenance of the CCIS data links and is handled by teletypewriter (TTY) input and output messages. A craftsperson can manually remove a data link from service by inputting an appropriate TTY message. The link security module will check the input message for validity, insure that the load sharing data link is in service, and then request concurrence of the STP by sending a manual changeover message. The STP will respond with a manual changeover acknowledgement which will cause link security to remove signaling information from the data link and force new signaling information to the load-shared data link. A manual restoral to service input message will return signaling traffic to the data link. Manual configurations of CCIS terminals and VFLs are similiarly requested and handled by link security with proper acknowledgment (via the data link) of the STP. A request for the operational status of any CCIS data link may be made at any time via TTY messages.

The link security program also responds to data link configuration requests from the STP (via CCIS messages). These messages may, for example, request a test of the inactive VFL on a data link. In this case the link security program will loop the VFL so that it may be tested by the STP. The STP will notify the No. 4 ESS via a CCIS message whether the test passed or failed. If a VFL fails this test it is reported to trunk maintenance.

Other data link messages processed by link security include those which contain band status information. These messages are sent by the STP to reflect the partial or total loss of signaling capability in the CCIS signaling network. In response to these messages, link security updates its band status tables as appropriate and removes or restores affected trunks from service.

A unique feature of the CCIS terminal is a timer which insures the sanity of the main processor. In No. 4 ESS, should the 1A Processor fail to access the CCIS terminal within a specified time, the CCIS terminal will automatically transmit processor outage signals on the data link. Processor outage signals can also be received over the data link from the CCIS terminal at the STP. The link security program will respond to these signals from the STP by evoking special congestion procedures which throttle the signals transmitted on the CCIS data link. Similar procedures are evoked by link security if a buffer overflow condition is detected from the CCIS terminal.

IV. SUMMARY

This paper describes the major hardware and software subsystems necessary to provide CCIS in the No. 4 ESS. The authors would like to acknowledge other major contributors to the software development for CCIS, L. D. Bethel, T. J. Cieslak, R. L. Else, A. M. Frantzen, S. F. Heath, M. T. Smith, and M. Sundararaman as well as the hardware designers, E. Grueser, R. Metz, W. H. Schurter, and R. E. Wallace. This team combined to provide a successful introduction of CCIS into the No. 4 ESS.

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Common Channel Interoffice Signaling:

Technology and Hardware

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The CCIS hardware is a mix of electromechanical, discrete electronic, and new integrated electronic technologies blended together to allow economical conversion of No. 4A/ETS offices while at the same time matching the technology of the electronic toll offices in which it is incorporated. Connectorization and plug-in assemblies help achieve a design that can be readily maintained and administered.

I. INTRODUCTION

In the early development stages of this new signaling system the need for an integrated electronic technology approach for new units became apparent. A major new unit, the CCIS terminal, is required for the system operation in No. 4 ESS offices as well as in No. 1 ESS toll and in No. 4A/ETS offices. The thin film, beam leaded integrated electronic technology under development for the new No. 4 ESS design has been chosen for this equipment. Other units required in No. 4A/ETS offices only are based on Dual-In-Line Packages (DIP), printed circuit board and electromechanical elements more nearly matching the technology of that system.

This mix of hardware improves cost economies and takes advantage of manufacturing techniques already being employed by Western Electric. Using No. 4 ESS technology in the terminal design minimizes maintenance and administrative complexities in those offices. The design for No. 4A crossbar is optimized for conversion of offices by providing options for converting existing equipment rather than requiring the purchase of new frames.

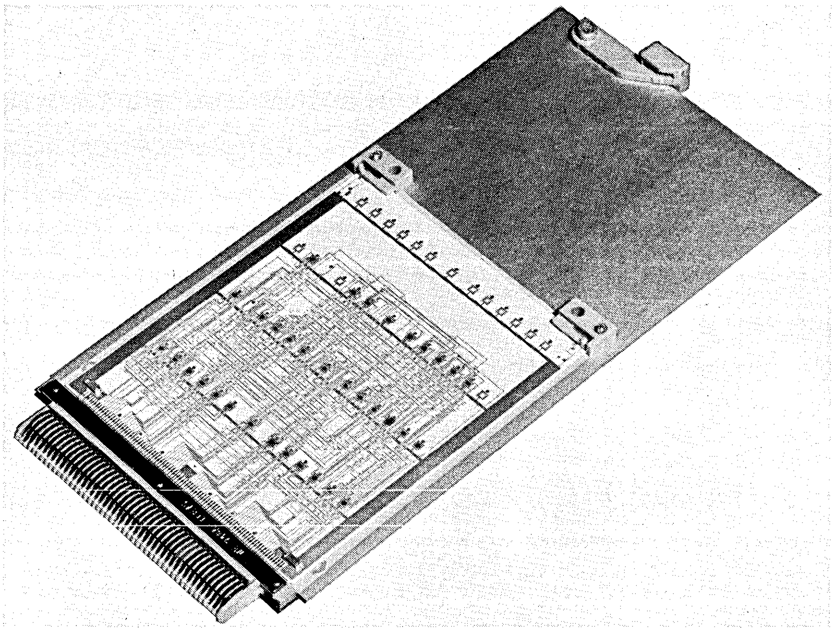

Fig. 1—Ceramic circuit pack.

II. APPARATUS AND HARDWARE TECHNOLOGY

2.1 Integrated electronic hardware

A new family of hardware, developed for use in No. 4 ESS, is used for CCIS equipment that resides in both No. 4A crossbar and No. 4 ESS offices. The hardware includes housings, connectors and circuit packs developed specifically for integrated circuit application. One type of circuit pack uses a unique ceramic carrier for mounting beam lead devices. The connector design assumes use of a rigid multilayer backplane for mechanical support and for distribution of power throughout each functional unit. The unit package is compatible with standard seven foot electronic frames.

The ceramic type of circuit pack which provides for logic circuitry is shown in Fig. 1. These packs place devices in predetermined locations. Connectivity between devices and to the attached connector is via conducting paths on the ceramic surface unique to each code. A system of computer programs generates the specific conducting array including crossover points for each circuit pack design. The back of each ceramic has a continuous ground plane primarily for shielding of the active devices and their connecting arrays. Ground shielding is also provided in the connector by a predetermined assignment of leads to ground via a connection at the ceramic. Circuit packs which use epoxy glass circuit

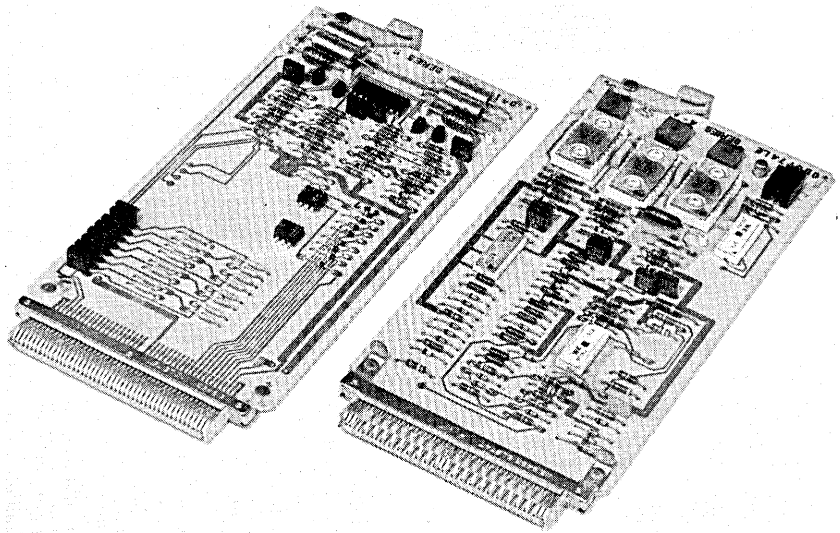

Fig. 2—Epoxy glass circuit pack.

boards and are employed for components other than beam lead devices are shown in Fig. 2.

The circuit pack housings are fabricated by forming sheet metal with ample open space to provide passages for air to aid in dissipating internal heat. These housings accommodate either 14 or 16 circuit packs.

Battery and ground are distributed across the unit by copper planes imbedded as layers in laminated multilayer backplanes. The insulating separators use an epoxy glass compound. Backplane designs are dependent upon each specific application. Connection from each layer is achieved by plated-through-holes which accommodate connector pins and have land areas on both outer surfaces of the backplane. The backplane forms an integral part of the unit mechanical structure as shown in Fig. 3. The pins of the connectors are inserted into the backplane and every pin of the connector is soldered to provide mechanical attachment and torsional support for the terminals. Each pin is individually removable to enhance repairability. Families of voltage converters, of the type shown in Fig. 4, have been designed for general use with this hardware. These converters use the office system voltage as input.

2.2 Dual-in-line integrated package hardware

The hardware system used for carrying dual-in-line integrated circuits is shown in Fig. 5. These packs are used to mount the Western Electric DIPs and other inline circuit components. The circuit pack is a double-

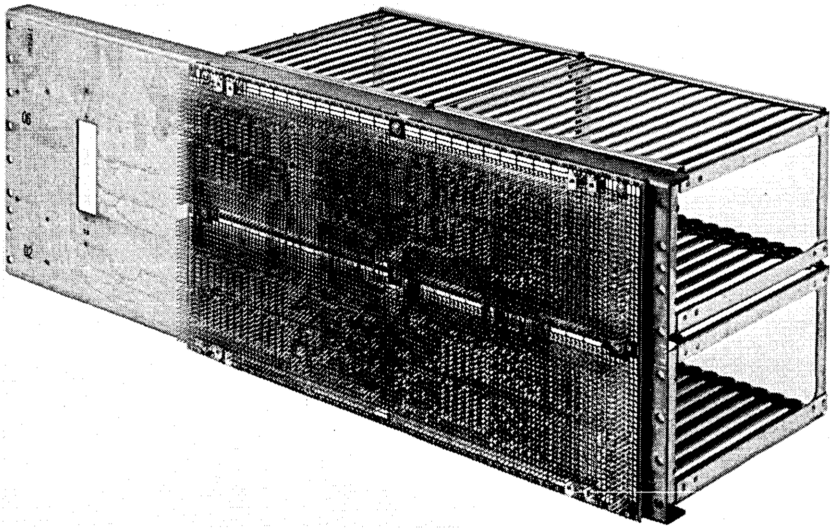

Fig. 3—Unit structure.

sided, epoxy glass board with plated through holes, gold plated fingers and is supplied with a card ejector. The connector which mates with this board has bifurcated contacts, used for ground, power, and signaling. The connector requires solderless wrap backplane wiring.

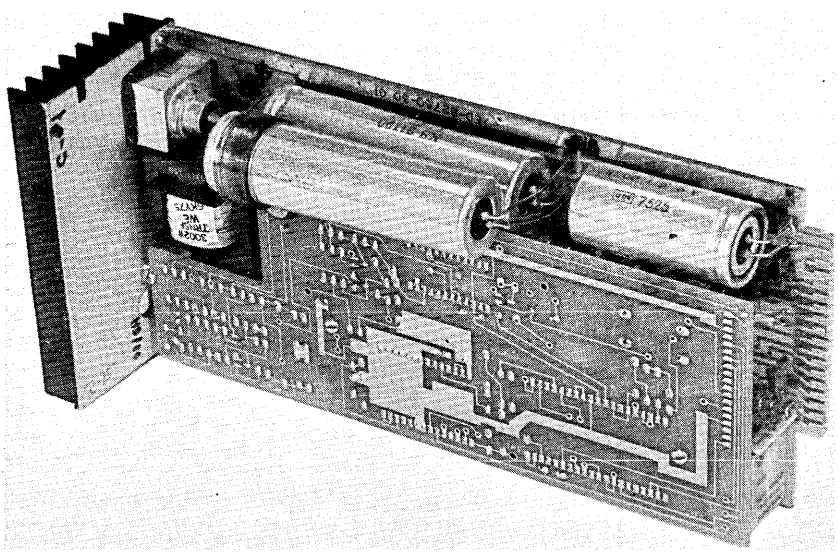

Fig. 4—Voltage converter.

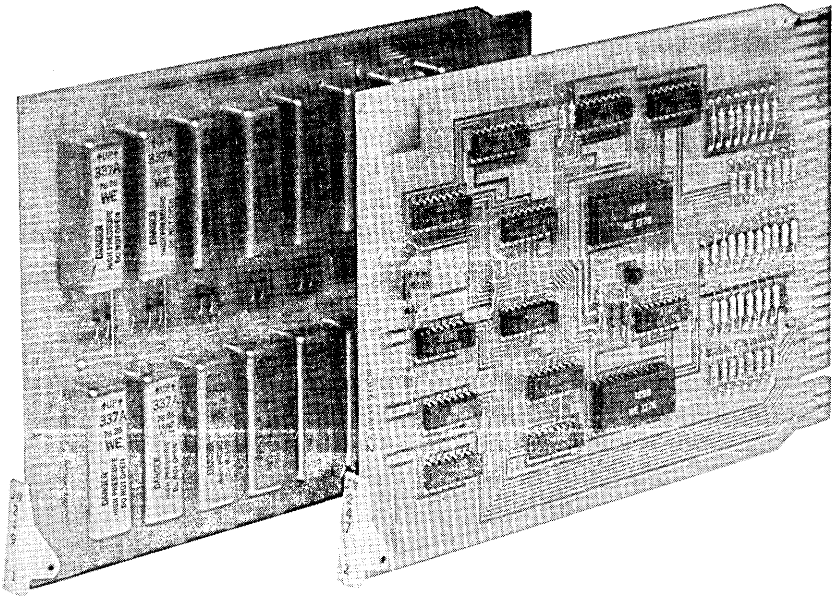

Fig. 5—Typical circuit packs for dual in-line packages and discrete components.

Two apparatus mountings for this type of circuit pack have been used, one for 11 packs and one for 16.

2.3 Discrete electronic and electromechanical hardware

Discrete electronic circuit packs are also used in combination with electromechanical hardware in the switching equipment area of the 4A crossbar machine. To accommodate this discrete electronic circuitry, circuit packs of the types shown in Fig. 6, have been designed.

Many new or modified functions are required in the existing portions of the 4A crossbar machine to provide CCIS capability. These are provided using existing electromechanical type hardware. Consequently many units are provided or modified using mounting plate units employing relays and switches with conventional solderless wrapped backplane wiring.

III. TERMINAL GROUP

The terminal group consists of equipment frames which contain CCIS terminals with associated Terminal Access Circuits (TAC). Separate configurations and TAC designs are provided to operate with No. 4A crossbar, No. 4 ESS and No. 1 ESS switching systems.

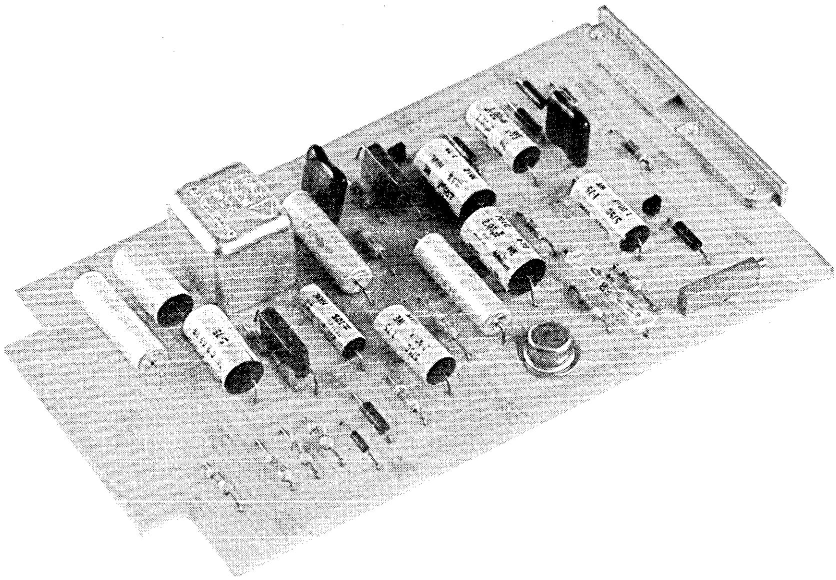

Fig. 6—Discrete component circuit pack.

3.1 No. 4A crossbar system terminal group

The specifications for the CCIS system define three basic functional blocks:

(*i*) A modem
(*ii*) A processor
(*iii*) A signaling terminal

The distribution of signaling functions between each functional block in a stored program control system is dependent upon the processor real time/peripheral hardware tradeoff.

Through the use of ESS 1A logic[1,2] and random access Insulated Gate Field Effect Transistor (IGFET) memory, the No. 4A CCIS terminal group implementation permits an extensive number of signaling functions to be assigned to the signaling terminal and modem at a reasonable cost.

A circuit not explicitly defined as part of the system specification is the Terminal Access Circuit (TAC). This circuit is tailored to the bus system of the host system central processor. Duplicated terminal access circuits interface the processor with up to 16 signaling terminal units.

The signaling terminal itself is a self-checking stored program controlled unit, with signal unit buffers realized by dynamically allocated linked-lists. This unit is common to the No. 4A and No. 4 ESS[3] CCIS systems.

A functional block diagram of the 4A terminal group is shown in Fig. 7. Each CCIS terminal unit is served by two TACs that provide a redundant path to the processor. Each terminal unit operates as a simplex unit and stores both outgoing signaling messages awaiting transmission and incoming messages until ready to be processed. The terminal unit also performs error control through redundant coding and retransmission of signaling messages found to be in error. Each terminal unit is dedicated to a modem that services one end of the signaling link. The modem forms a digital-analog interface between the terminal unit and the voice frequency link.

The CCIS terminal group consists of one CCIS terminal basic frame and two CCIS terminal supplementary frames. The terminal basic frame, shown in Fig. 8, is a 2-bay ESS frame. The frame mounts duplicated input-output and TAC units and up to six terminal units along with their associated fusing, power converters, and power control equipment. The input-output unit provides connectorized access to the SPC No. 1A processor busses. Terminal unit growth is facilitated by the use of connectorized flat-tape cables to connect the unit to the TACs.

Up to five additional terminal units can be mounted on each of two supplementary frames as shown in Fig. 9. Like the basic frame, fusing, power converters, and power control equipment associated with the terminal units are also mounted on the frame. Interconnections between the TAC units on the basic frame and terminal units on the supplementary frames are implemented with connectorized flat-tape cable.

Each terminal access circuit is capable of interfacing with Peripheral Unit Address Busses (PUAB) and with Scanner Answer Busses (SCAB) of the SPC No. 1A processor. Since all communication between the SPC No. 1A processor and the associated terminals is controlled by the TAC, the TAC must perform the following functions:

(*i*) Receive instruction and data from the central processor via the PUAB.
(*ii*) Check, decode, and analyze the information.
(*iii*) Select the sequence to be used.
(*iv*) Communicate the information to the proper terminal.
(*v*) Check the terminal response.
(*vi*) Transmit the requested data to the central processor via the SCAB.

Although duplicated, the TACs are operated in the simplex mode, with only one TAC active at a given time. The TAC is enabled via the Central Pulse Distributor (CPD). Since data or an operation code (opcode) can be communicated to either TAC over either PUAB, these enables are decoded by the TAC to determine the word type and the proper bus.

Commands from the processor either result in a terminal unit opera-

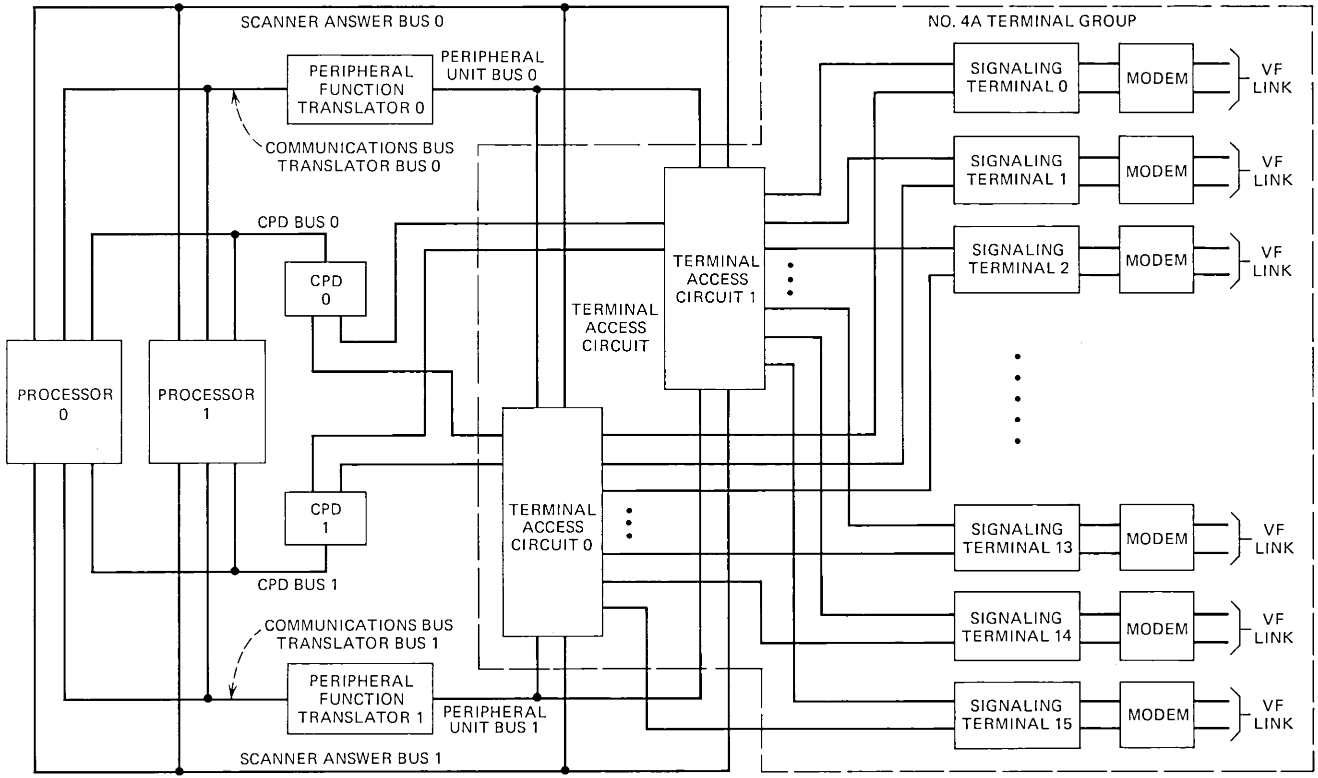

Fig. 7—No. 4A crossbar terminal group block diagram.

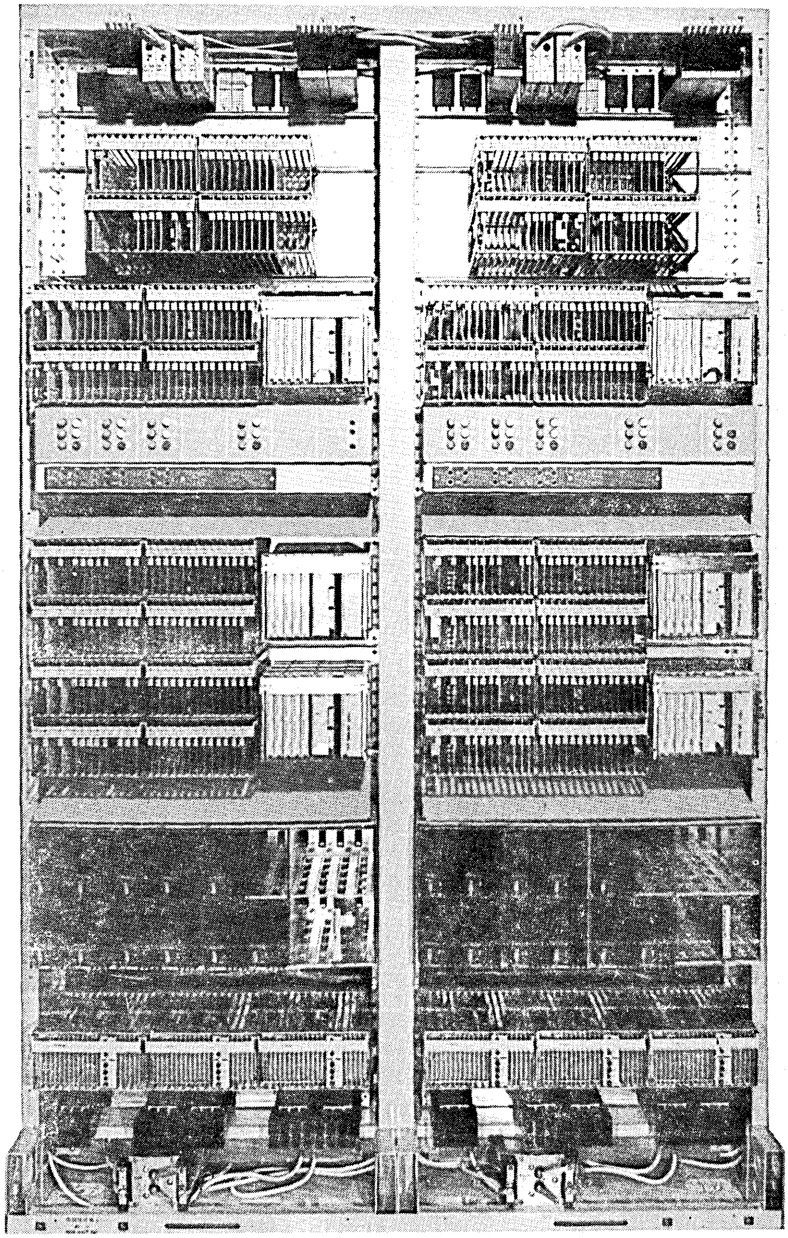

Fig. 8—4A terminal basic frame.

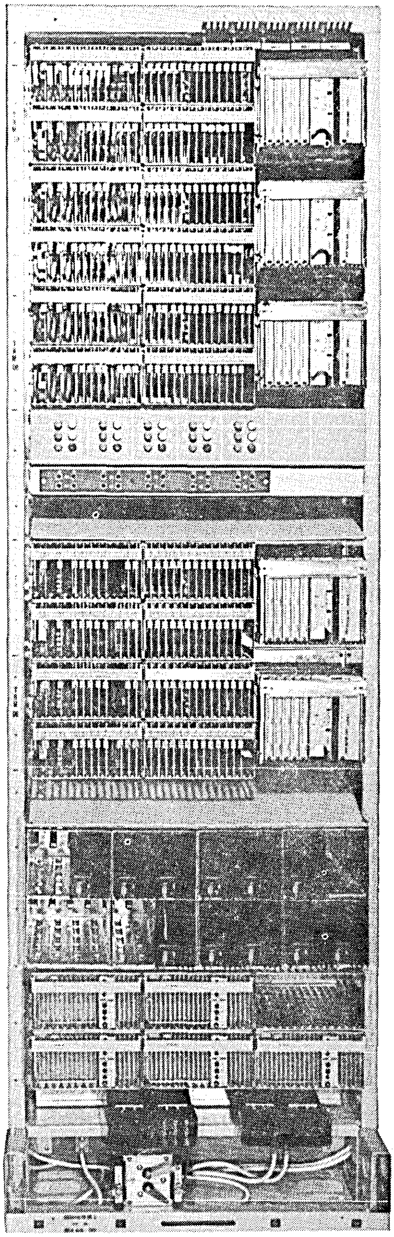

Fig. 9—4A terminal supplementary frame.

21	20	19 13	12 4	3 0
MTCE TEST BIT	PARITY	OPERATION CODE	ADDRESS	TERMINAL NUMBER

(a)

21	20	19 13	12 0
MTCE TEST BIT	PARITY	OPERATION CODE	DATA

(b)

Fig. 10—(a) Terminal operation command format. (b) TAC operation command format.

tion or an internal TAC operation. The former commands are formatted as 20-bit words as shown in Fig. 10a. The opcode defines the task to be performed, the address specifies a particular register or memory location, and the terminal number indicates the terminal to be used. For TAC operations the instruction format is as shown in Fig. 10b. In this case, the data field contains information to be used during the task defined by the opcode.

The sequences initiated by the proper enabling of the TAC are controlled by a wired logic sequencer driven by a 12.5 MHz oscillator.

Communication with the terminal units takes place over two dedicated busses per terminal. Twenty-three bits of data plus a parity bit are transmitted over the 24-bit bidirectional TAC-To-Terminal (TTT) bus, and a 6-bit opcode plus a parity bit is communicated from the TAC to the terminal over the 7-bit Terminal Opcode bus (TOP). Additional leads are dedicated to each terminal for enable, all-seems-well, trouble, and buffer status signals.

The CCIS terminal unit is a small, self-contained, high-speed, stored program processor with an order structure tailored to CCIS operation. All signaling link related functions in the terminal unit are controlled by an internal stored program. The flexibility of this approach assures that the terminal can evolve with both the international and domestic signaling formats and can be compatible with data links using higher bit rates.

Figure 11 is a functional block diagram of the terminal unit. There are three separate control entities within the terminal. The Instruction Controller (IC) provides access to the program memory and executes the internally stored program. The Data Memory Controller (DMC) provides access to the data memory for both the internal stored program and the third controller, the I/O Controller (IOC). The latter handles all communications with the TAC. The three controllers operate asynchronously

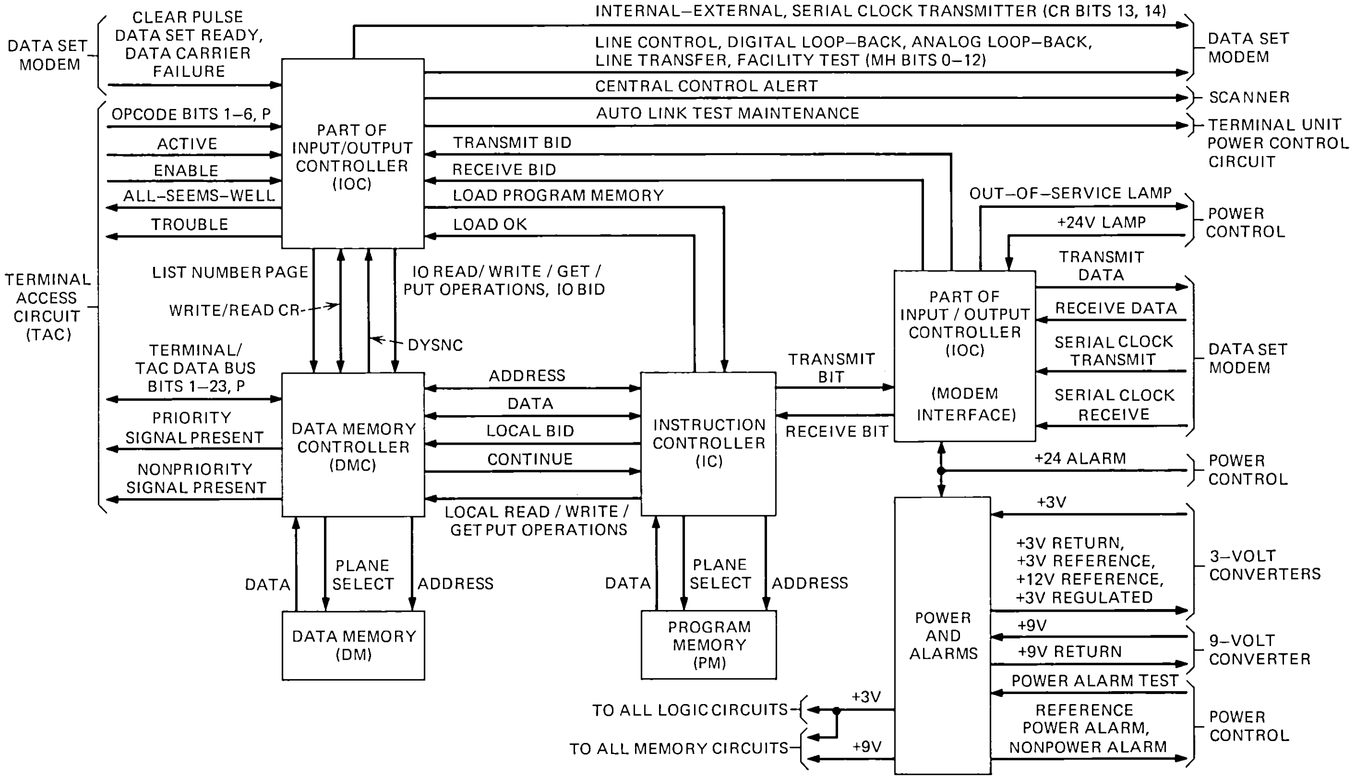

Fig. 11—Terminal unit block diagram.

with respect to each other and interact by requests, or bids, and acknowledgements. When one controller bids for service from another it waits until an acknowledgement is received before gating the data and removing the bid. The DMC can receive bids from both the IC and the IOC for access to the data memory. Both data and program memories are random access IGFET memories.

The instruction controller consists of an instruction sequencer, decoder, instruction address register and logic circuits used by the stored program. The set of instructions that can be executed by the IC are referred to as the internal order structure of the terminal and consist of logic, transfer, and memory access instructions.

A seven-phase instruction cycle is derived from a 12.5 MHz oscillator. The basic instruction cycle timing is shown in Fig. 12. As shown, the Instruction Address Register (IAR) is incremented during phase 1. Two phases are allowed for address propagation and plane select decoding prior to reading the memory. Phases 4, 5 and 6 allow for decoder and logic circuit settling times before loading internal registers. The sequencer is halted in phase 6 on bids to the DMC until the acknowledgement signal is received from the DMC. The sequencer can also be halted on command from the processor and is halted automatically upon detection of an error which affects normal terminal operation.

The program memory can be equipped with up to sixteen 128-word modules, or planes. The output of the program memory drives the instruction decoder directly, where the opcode is decoded along with various parameters to be used in the programmed operation.

All logic operations under control of the internal stored program involve the use of a 23-bit Logic Register (LR). The functions associated with the LR include rotation, masked insertion, incrementation, check code generation, and interface with the modem. Referring to Fig. 13, generation of an 8-bit check code is performed by executing a 1-bit rotation with the cyclic check code feedback logic enabled. For transmission, the contents of LR bit one is gated to the modem interface and the LR is rotated one bit to the left. Likewise, for receiving serial data from the modem, the LR is rotated one bit and the current receive bit from the modem interface is gated into LR bit nine.

The internal order structure of the terminal unit is tailored to the performance of CCIS signaling functions. The instruction repertoire is summarized in Fig. 14.

Of the 12 bits per program word, the first three to six bits are used for the opcode, the twelfth bit is a parity bit, and the remaining bits are used for option and parameter fields. All instruction addressing is direct and program flow is sequential, except where altered by transfer operations.

Access to data memory is provided by the DMC. The DMC can receive

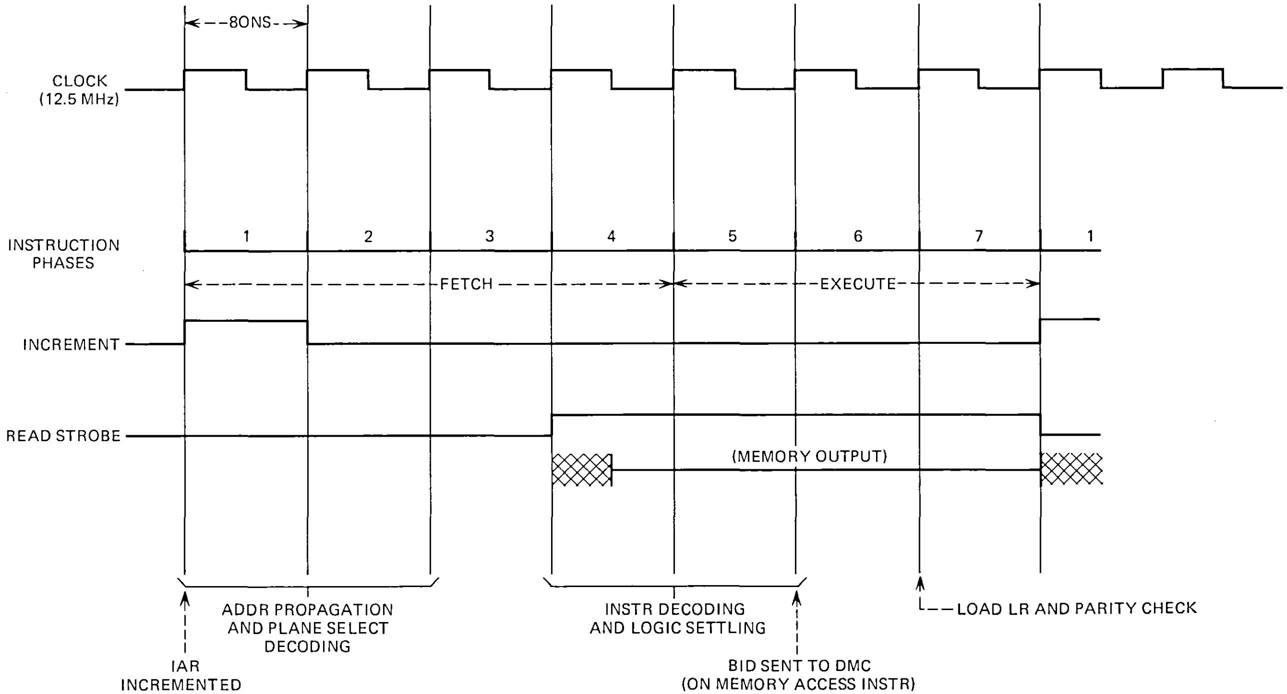

Fig. 12—Terminal instruction cycle.

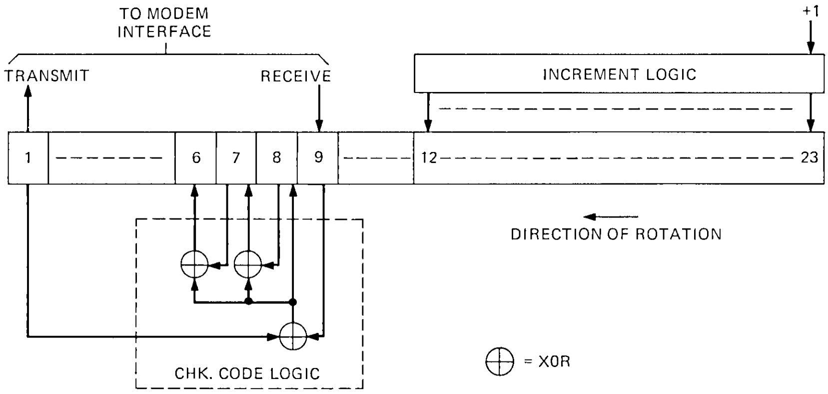

Fig. 13—Logic register layout and check code generation.

INSTRUCTION	DESCRIPTION
MOVE	COPIES CONTENTS OF REGISTER RI INTO REGISTER R2
ROTATE	CAUSES ENTIRE CONTENTS OF LOGIC REGISTER TO BE ROTATED (WITH END–AROUND CARRY) TO THE LEFT N BITS
INCREMENT	ADDS ONE TO THE CONTENTS OF THE LOGIC REGISTER
LOAD	INSERTS A FIELD OF DATA INTO THE LOGIC REGISTER WITHOUT DISTURBING THE REMAINING BITS
TEST BIT	TESTS THE VALUE OF A PARTICULAR BIT IN THE LOGIC REGISTER
TEST BYTE	TESTS A FIELD OF BITS IN THE LOGIC REGISTER
TEST DIRECT	COMPARES A FIELD OF BITS IN THE LOGIC REGISTER WITH A CONSTANT STORED IN THE INSTRUCTION
READ	READS A 23–BIT WORD OUT OF DATA MEMORY
WRITE	WRITES A 23–BIT WORD INTO DATA MEMORY
READ CR	MOVES THE CONTENTS OF THE CONTROL REGISTER INTO THE LOGIC REGISTER AND LEAVES THE CONTROL REGISTER UNCHANGED
WRITE CR	WRITES ONE OR MORE BITS IN THE CONTROL REGISTER
GET	RETRIEVES A 23–BIT ITEM FROM A SPECIFIED LIST
PUT	PLACES AN ITEM ON A SPECIFIED LIST

Fig. 14—Terminal unit internal instruction set.

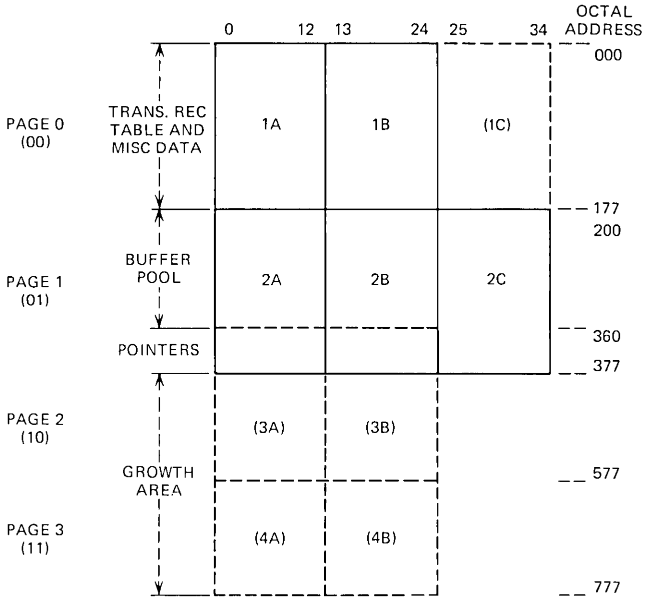

Fig. 15—Data memory organization.

service requests from both the instruction controller and the I/O controller. As a result of these bids, the DMC generates the memory address, selects the data path to or from the memory, administers the signal unit buffers, and provides the necessary memory timing sequence. A common 12.5 MHz oscillator is used to drive the DMC and the IC.

Data memory, independent of program memory, is provided for receive and transmit buffers, buffer pointers, and the transmit record table, as well as for miscellaneous data required by the internal program. The organization of the data memory is shown in Fig. 15. As shown, the memory is divided into four pages, denoted 0, 1, 2, and 3, each page having as many as three sections, denoted A, B, and C. Each section is implemented with a 128-word IGFET memory plane, identical to that which is used in the program memory. Unlike program memory, however, data words may be 24 or 34 bits in length. The longer word length is used for the receive and transmit buffer area, and typically consists of a 20-bit signal unit, an 8-bit link forward pointer which gives the location of the next item in the buffer, and various parity bits.

Receive and transmit signal unit buffers are realized by "first-in, first-out" linked-lists, 16 of which can exist simultaneously in the buffer area of data memory. Each of the 16 lists has associated with it a word in memory which contains a first-in pointer and a last-in pointer, specifying the location of the first-in and last-in items on that list, respec-

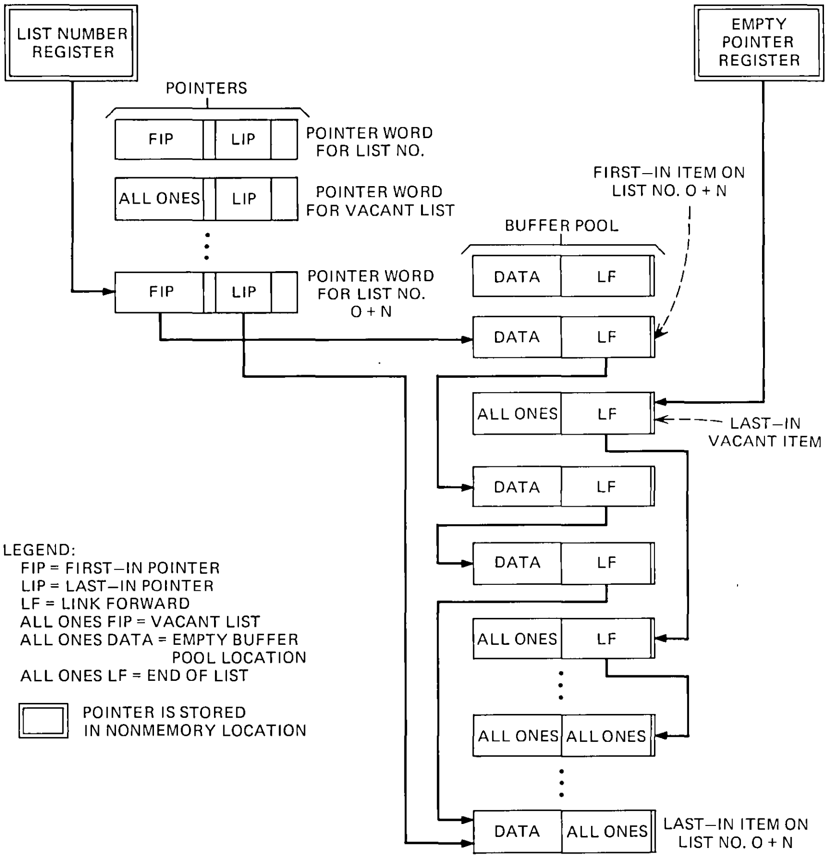

Fig. 16—List linkages.

tively. The items on a given list, not necessarily occupying sequential memory locations, are linked to one another through the use of link forward pointers stored with each item. Data memory locations in the buffer area are dynamically allocated to a specific list on an as-needed basis. Unused buffer locations are linked together on a "last-in, first-out" linked-list, referred to as the empty list. Figure 16 provides a simplified overview of these list linkages.

Decoding and sequencing of input/output operations are handled by the IOC in a four phase sequence. The remaining I/O operation, controlled by the terminal's program, is the serializing of data to and from the modem. The modem transmit and receive clocks set flags which are tested by the internal stored program. Servicing the transmit and receive flags must occur within one bit time of the modem clocks to avoid an overflow condition.

Data transmission is accomplished utilizing the 201D modem, a synchronous unit capable of data transmission at 2400 bits per second (bps) over 3002-type or equivalent, 4-wire lines. A 4-level Phase Shift Keying (PSK) modulation scheme is used. Although similar to the 201B and 201C modems, the 201D is designed to be mounted directly on the terminal unit and to be diagnosed by the processor via the TAC and terminal units.

Several overlapping techniques are employed within the terminal unit to detect faults. The primary means, which tests approximately 60 percent of the terminal's circuitry (excluding memory), is an internal self test exercise. This exercise is run whenever the terminal's signal unit processing software is idle. Supplementing these tests are hardware parity checks, a program memory sequence coding check, and a basic sanity test provided by the servicing of receive and transmit flags set by the modem. Upon detection of a fault, a particular bit is set, depending upon the failing test, in a register dedicated to recording errors for interrogation by the processor.

3.2 No. 4 ESS terminal group

Although the Central Control (CC) of the No. 4 ESS[4] System differs from the SPC No. 1A employed in No. 4A, the terminal frame designs for the two systems are functionally the same and physically similar. The terminal unit design described in Section 3.1 is common to the two systems. Peripheral bus requirements for the No. 4 ESS CC, however, dictate a terminal access controller (CONTR) design somewhat different from that of the No. 4A TAC.

The No. 4 ESS CCIS terminal group is comprised of three frames, arranged in a similar physical configuration to the No. 4A terminal group previously described. As shown in Fig. 17, the basic terminal frame accommodates up to six terminal units, duplicated peripheral bus interface (IPUB) and terminal access controller (CONTR) units along with their associated fusing, power converters, power control, and voice frequency link level adjustment equipment. Adjustment of the voice frequency link transmit and receive signal levels is achieved through attenuator and amplifier modules associated with each terminal-modem, rather than with external voice frequency link access circuits. Terminal growth beyond the basic frame is accomplished with up to two supplementary frames, each of which mounts up to 5 terminal units.

Like all peripheral units in No. 4 ESS, the CONTR employs coded enabling to respond to a CC order. With coded enabling, each peripheral has a unique name and monitors the peripheral unit bus at all times. When an order is sent over the peripheral unit bus, only that unit whose name matches the name accompanying the order responds. The name,

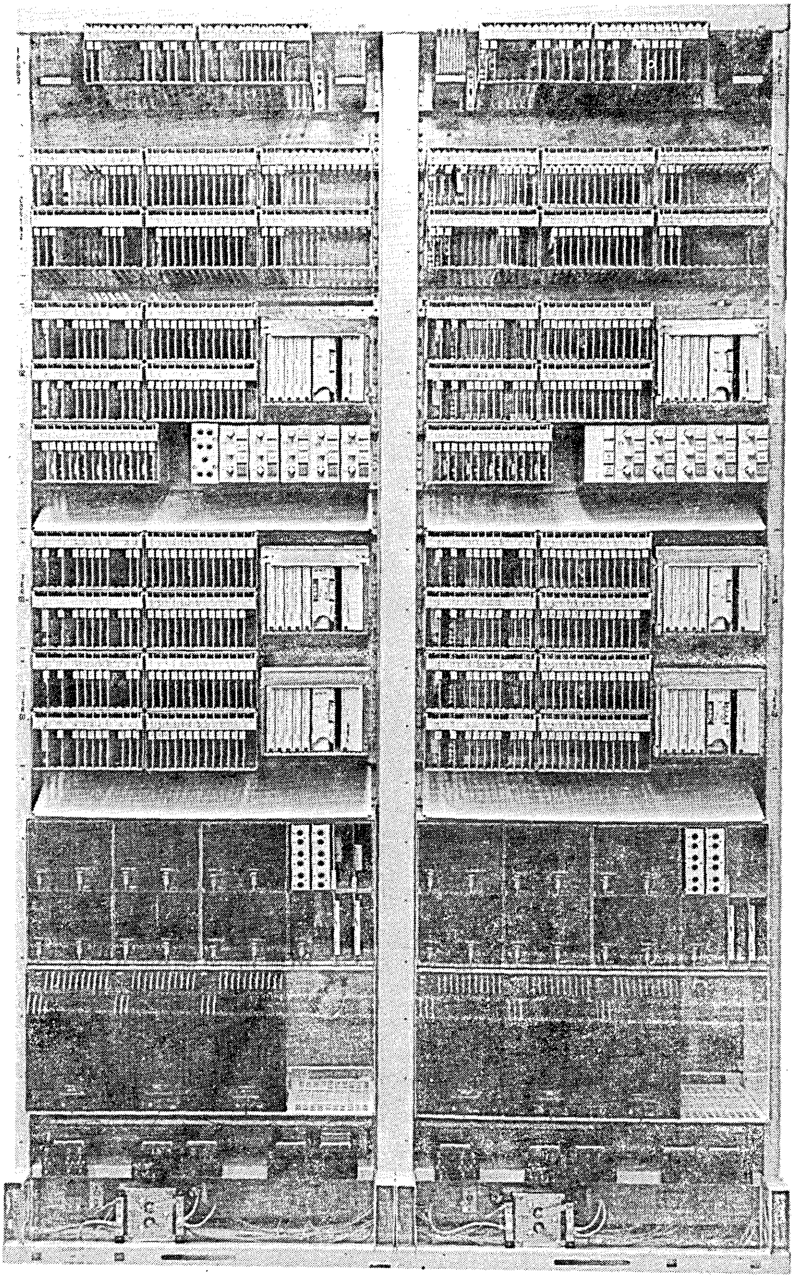

Fig. 17—No. 4 ESS basic terminal frame.

called the K-code, is sent to the CONTR on the Peripheral Unit Enable Address (PUEA) bus, the order containing the operation code, data, and optional terminal number is sent on the Peripheral Unit Write Bus (PUWB), and the CONTR replies on the Peripheral Unit Reply Bus (PURB).

Each CONTR and its mate share a common set of cable drivers and receivers contained in the IPUB units. These units allow either CONTR to be accessed from either bus 0 or bus 1. Both IPUB units are powered from a source independent of the CONTRs.

The sequence of CONTR operations is driven by a 12.5 MHz oscillator, which generates 64 decoded clock pulses, each of 80-nanosecond duration. Initiating the sequence is a synchronization pulse from the CC that precedes the K-code and data. At the beginning of each sequence the K-code is compared with the hard wired code of the CONTR, and if a match occurs, the sequence continues. If no match occurs, the sequencer is initialized and awaits the next synchronization pulse from the CC.

Sequences that follow the activation of the proper CONTR either access a terminal unit or perform the maintenance or control operations internal to the CONTR.

3.3 No. 1 ESS terminal group

The most recent addition to the family of CCIS terminal frames is the No. 1 ESS[5] data terminal group. Since this equipment is intended to be used in a more general data terminal application as well as in CCIS, its design reflects the requirements of both systems and represents a cost-effective solution to the data terminal need.

Basically the terminal group interfaces to the No. 1 ESS Processor Peripheral Unit Address Bus (PUAB) and Scanner Answer Bus (SCAB) and is enabled by the Central Pulse Distributor (CPD). Duplicated terminal access controllers (CONT) are provided which communicate with 16 terminal units. The No. 1 ESS bus system and enabling scheme is similar to that of the No. 4A System, hence the CONT and TAC unit designs are similar. Each of the 16 terminal units can be equipped with up to two modems. Only one modem is equipped in the CCIS application, however. The modem outputs are connected to the Voice Frequency Links (VFL) via Voice Frequency Link Access (VFLA) circuits which provide maintenance access to the link from an office test frame and provide a loopback path for terminal-modem fault diagnosis. A block diagram of the processor to VFL interconnections is shown in Fig. 18.

The No. 1 ESS data terminal group consists of a basic frame and two supplementary frames. The basic frame mounts duplicated CONT units and a maximum of eight data terminal units, along with two power control units and VFLA circuits associated with each terminal.

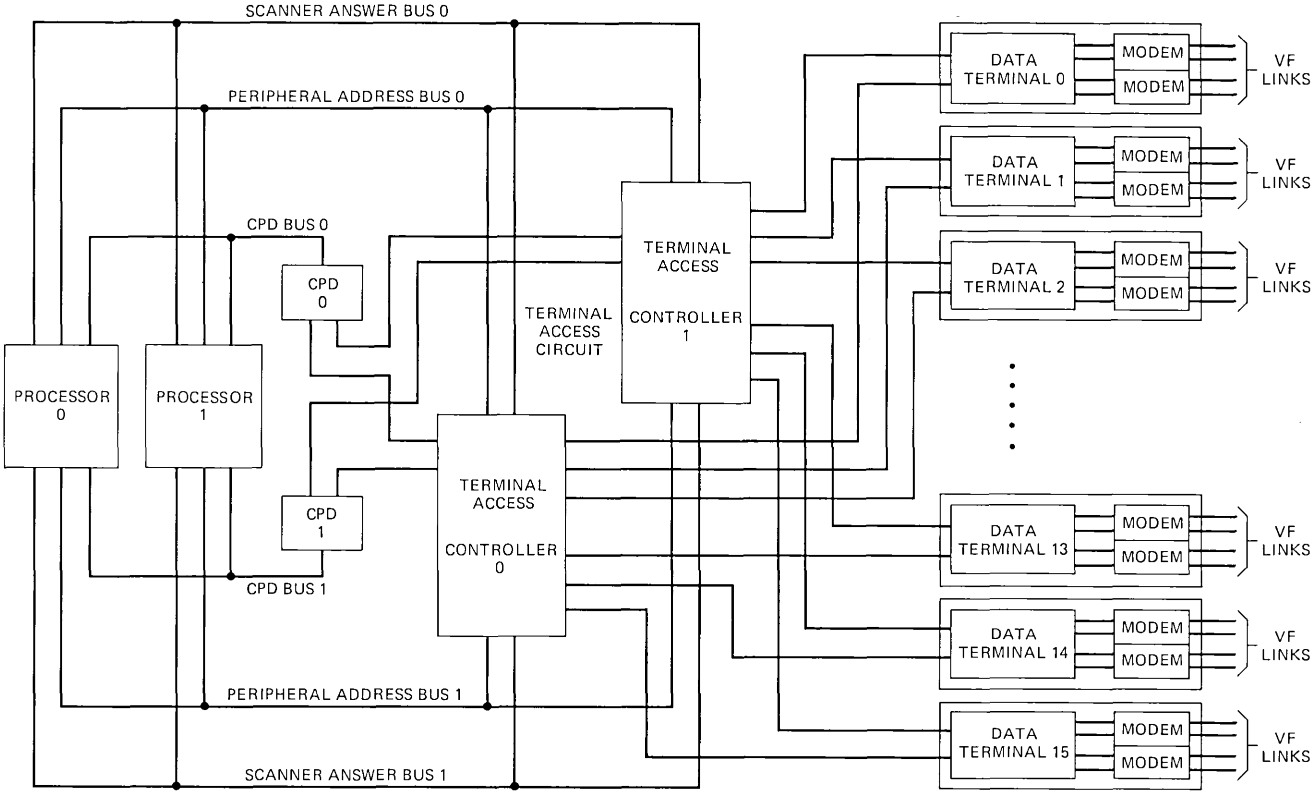

Fig. 18—No. 1 ESS terminal group block diagram.

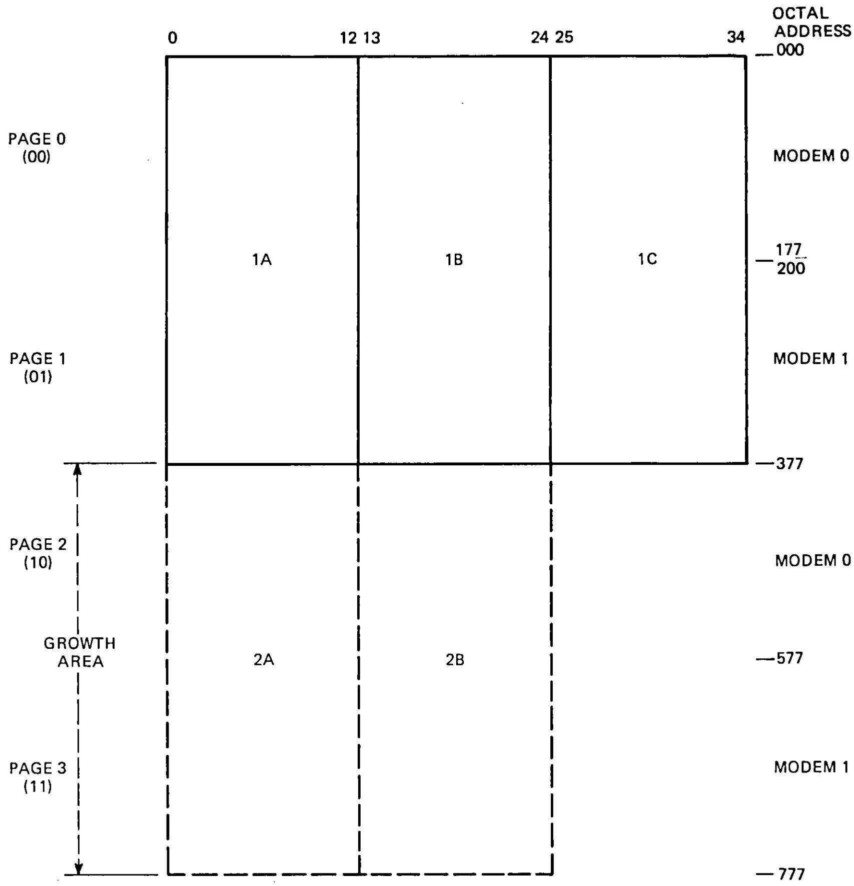

Fig. 19—No. 1 ESS terminal unit data memory organization.

Basic terminal unit architecture is retained in the No. 1 ESS design. Departures from the common No. 4 ESS design are in memory implementation and modem interfacing. The former involves the use of bipolar memory planes, each of which provides storage for 256 twelve-bit words. The resultant data memory organization is shown in Fig. 19. Alternate blocks of 128 words are assigned to each modem. Maintenance access to the VFL from an office test position is provided by the VFLA unit. The modem output can be connected to the VFL or looped back for maintenance purposes. Switched access to the VFL from a test position via the No. 1 ESS Trunk Link Network (TLN) is also allowed for initial alignment and periodic maintenance.

IV. 4A TOLL DISTRIBUTOR AND SCANNER

4.1 Introduction

The Distributor and Scanner (DAS) is a peripheral unit of the Stored Program Controller (SPC) providing autonomous base level scanning and distributing functions which are new and crucial to CCIS in the No. 4A toll application. It is primarily used to interface CCIS trunk circuits with the SPC. Each DAS frame contains 2048 distribute points and 2048 scan points. With connectorized access to the SPC Peripheral Bus System up to nine DAS frames can be provided in a 4A toll office. Each office requires at least two frames for reliability. They control up to 1700 trunks and miscellaneous points. Each additional DAS frame controls up to 2000 trunks. The distribute point is a mercury relay controlled by a flip-flop. The flip-flop is set and checked in one SPC cycle thus allowing a DAS distribute order to be executed in base level programs.

Many fault recognition and diagnostic features are part of the DAS design. Checks are made on each autonomous scan and each directed operation. When a check fails it is stored and an All Seems Well (ASW) failure is sent to the processor. A bit per point and per operation called a pest bit is provided allowing diagnostic and repair work to proceed without continual failure indications. The per point matrix pest also allows partial equipping of the matrix in groups of 512 points.

4.2 General description

A functional block diagram of DAS is shown in Fig. 20. It consists of duplicated controllers and bus access circuits and a simplex matrix. The bus I/O circuits contain the connectorized cable transformers for receiving data from the Peripheral Unit Bus (PUB) and the enable pulses. They also provide connectorized access to drive the Scanner Answer Bus (SCAB) leads and terminal strips for the various scan and distribute points used to control the frame.

The two controllers provide completely duplicated autonomous, directed and maintenance functions. During normal autonomous scanning operation they run in synchronism with matching to detect faulty operation. Most directed operations are also done in synchronism.

The matrix consists of 128 rows with each row containing 16 scan points and 16 distribute points. Access is duplicated down to the circuit packs containing the scan and distribute points.

4.3 Physical design

The Distributor and Scanner frame, Fig. 21, is a conventional ESS double bay frame. The frame is provided fully cabled to a total of 8 matrix unit (256 scan and 256 distribute points each) and is equipped

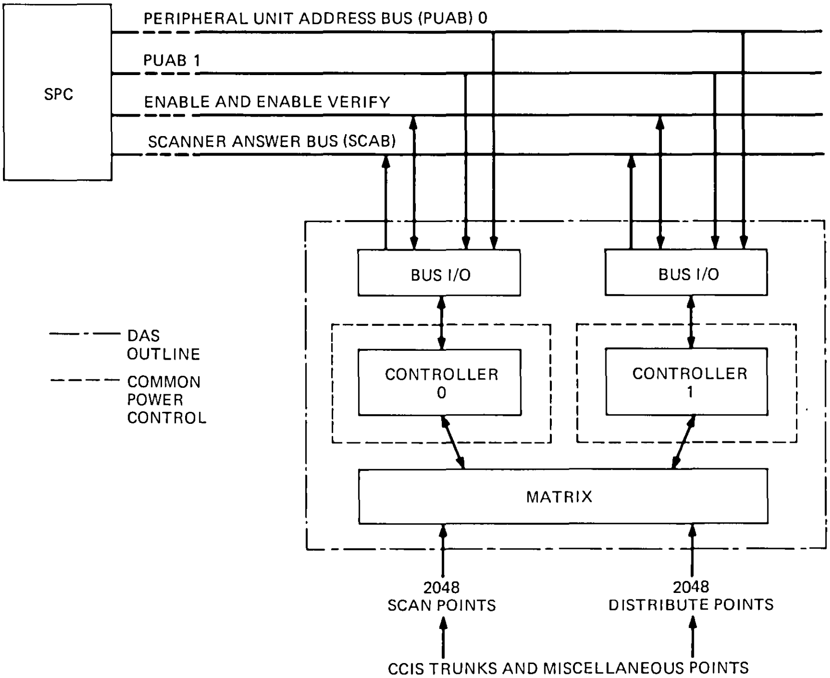

Fig. 20—DAS functional block diagram.

initially with the circuit packs for two matrix units. Growth for other than the first two DAS frames, which must be fully equipped, is to be provided with matrix packs as required for particular installations.

A fully equipped DAS frame requires 362 circuit packs of twenty different codes. The logic family used is the Western Electric Company TTL logic mounted in dual-in-line packages.

Power requirements for the frames' TTL logic are supplied via four dc-dc converters which supply the eight matrix units and two converters which are dedicated to the duplex controllers.

4.4 Matrix

The basic element in the matrix is a pair of circuit packs: the matrix point pack containing 16 distribute flip-flops and 16 scan points and the matrix relay pack containing the 16 mercury relays used as the distribute drivers. The pair is arranged in eight rows with two points per row.

Sixteen of these circuit pack pairs are arranged to make a unit of 32 rows with 8 points/row. The full matrix then consists of eight units in a 128 row by 16 points/row array.

A typical distribute and scan circuit is shown in Fig. 22. For distribute

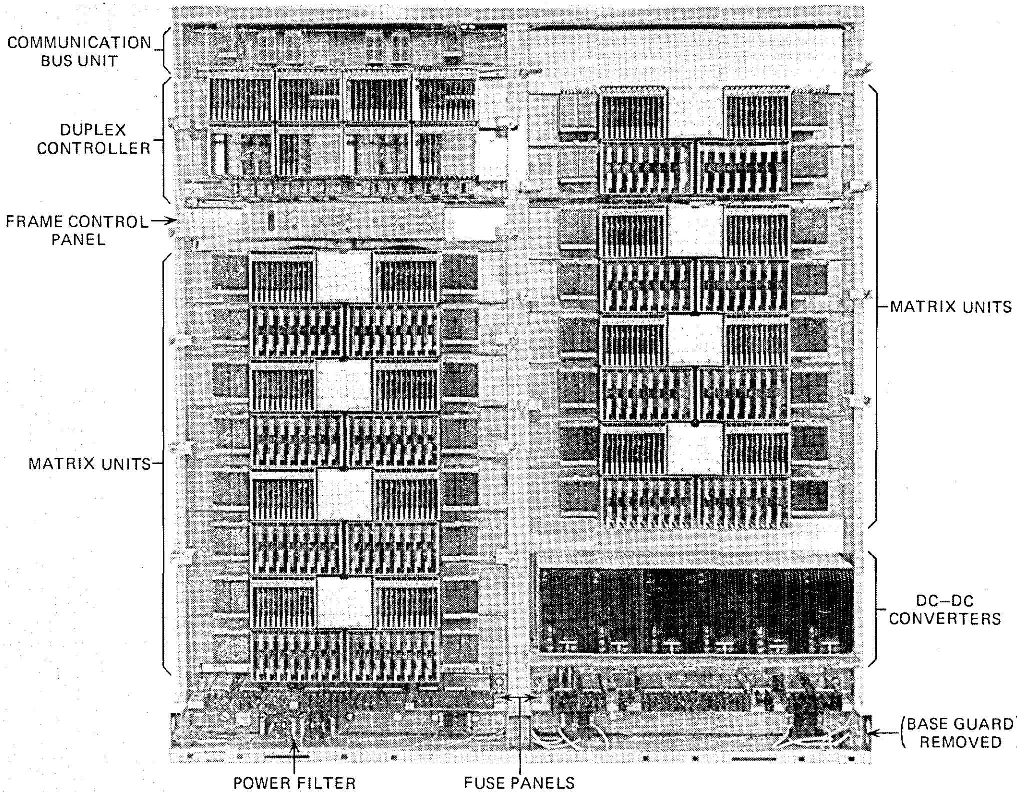

Fig. 21—Distributor and scanner frame.

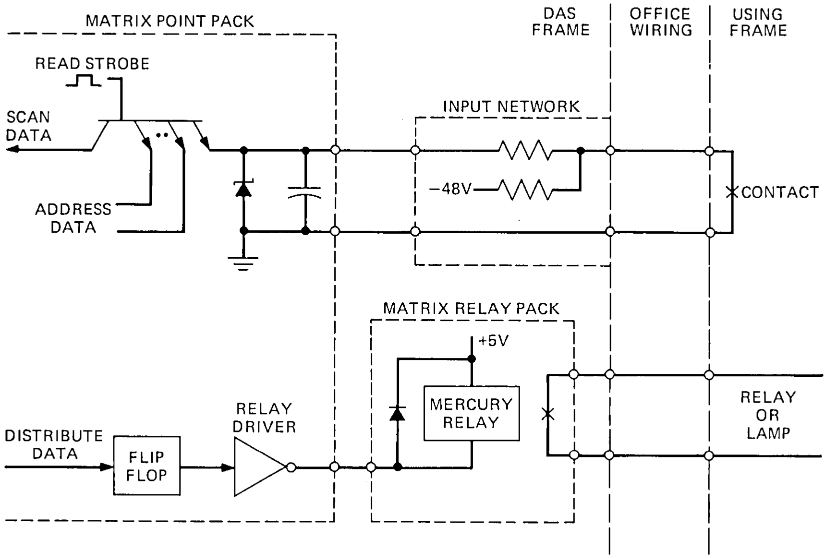

Fig. 22—Distribute and scan circuits.

a flip-flop stores the data and a relay driver is used to buffer its output to a mercury wetted relay.

The scan point consists of a resistor capacitor network which is read by a TTL gate. When the contact is closed the gate input is above 2.81 volts. In the contact open state the gate input is about 0.5 volts negative. Worst case DC noise margins at the contact are 3.8 volts when the contact is closed and 11 volts when it is open. The filter network has a delay time of 1.7 ms open to closed and 1.5 ms closed to open.

4.5 Controller

A block diagram of the DAS controller is shown in Fig. 23. It consists of a memory, a number of registers, change logic and a wired logic sequencer. The sequencer controls all operations of the controller. Normally it autonomously scans every row of the matrix, detecting and buffering any changes. When the SPC initiates a directed operation by sending an enable and data the sequencer returns an enable verify, interprets the desired operation from the data, interrupts autonomous operation, executes the directed operation, and resumes autonomous operation.

The memory is 1024 row by 18 bits/row static random access memory. Each row consists of 16 data bits and two parity bits, one over each half of the data. Memory is divided into 8 sectors, each sector having 128 contiguous rows of data. Five of these sectors (last report, last look,

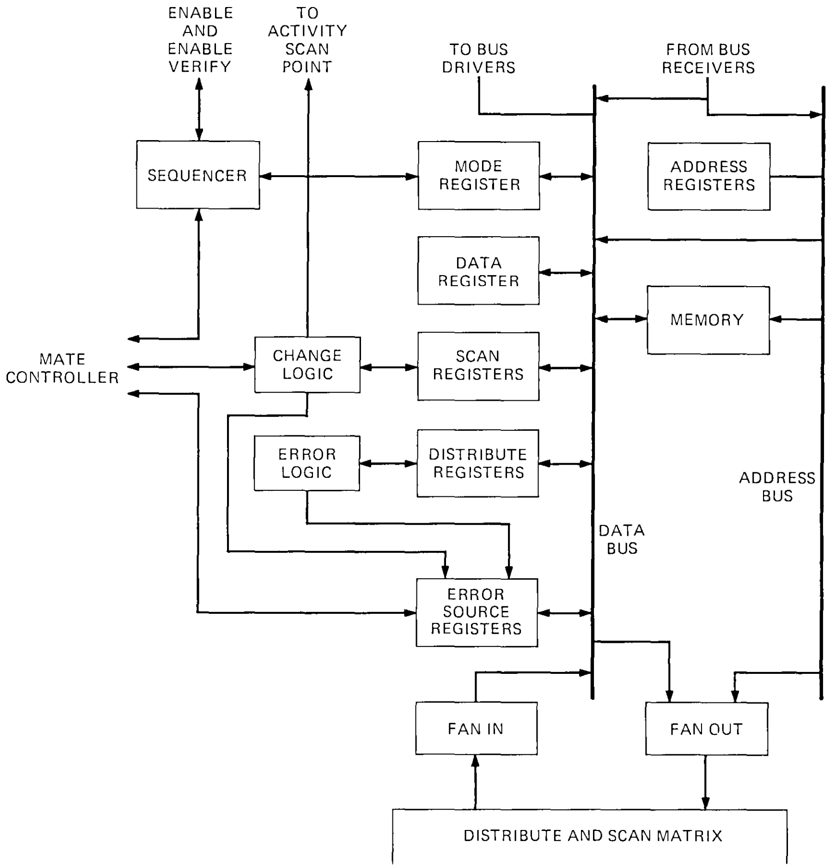

Fig. 23—Controller block diagram.

distribute memory, ignore, and pest) are direct images of the 128 × 16 matrix and are used to store data pertaining to each point in the matrix. The change buffer sector stores a word of data for each scan change detected during autonomous operation. This word contains the 12 bit address of the changed scan point and a change direction bit. Two sectors are unused.

The distribute registers, scan registers and change logic shown in Fig. 23 are used during autonomous scanning. Each register is a 16 bit parallel in, parallel out shift register. The scan registers store data on one scan row at a time. They are loaded in parallel from memory (last report, last look, ignore, pest) and from the matrix. After they are all loaded with data pertaining to the same row, they are shifted a bit at a time into the change logic. In this way the change logic processes one point at a time. If the ignore or pest bits are set, no changes are reported. Otherwise the

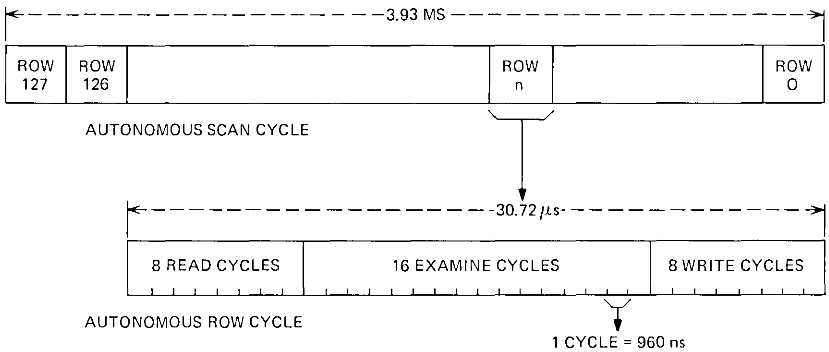

Fig. 24—Autonomous cycle timing.

change logic combines the present look at the scan point, the last look, the last reported state of the scan point and state change data from the mate controller. The result of this combination is new last report data, a change indication to the mate and a change indication for loading its own change buffer.

The distribute registers are used for trouble detection. On each matrix read operation, the state of the distribute flip flops for that row is read into one distribute register and its image read into the other. They are shifted to the error logic and compared one bit at a time. A mismatch causes an ASW failure and halts autonomous operation. This procedure checks all the access and readout circuits on a continual basis.

The mode register is a 11 bit register which controls normal and diagnostic operation of each controller. It is set by a special maintenance instruction. Bits are provided to control both normal and diagnostic operation.

4.6 Operation

The DAS has two modes of operation, autonomous and directed. Fig. 24 shows the timing of the 3.93 microsecond autonomous scan cycle of all 128 rows. For each row there are eight load cycles which load the scan and distribute shift registers from the matrix and from the memory. Then there are 16 examine cycles, one for each point in the row. During each examine cycle the change and error logic combine the data for that point. Finally there are eight write cycles during which the last report and last look memory is written and the row address counter is advanced.

There are 15 directed operations; five reads, eight writes and a autonomous scan start/stop pair. For call processing an interrogate operation returns the address and direction of oldest change in the buffer and a bit indicating if the buffer is not empty. There is also a matrix read which returns the status of all scan (or distribute) points in a row. Four writes allow distributes to a point, a quarter row (four bits), a half row (8 bits) or a complete row. The remaining reads and writes allow the processor to read and write the DAS registers and memory for maintenance.

V. IGFET STORE

Memory for storing CCIS programs and data is provided by a semiconductor store unit using Insulated Gate Field Effect Transistor (IGFET) memory devices. A store frame (Fig. 25) consists of a controller and from one to six memory modules, each having a capacity of 32,768 words by 47 bits. The controller provides external interfaces for its memory modules and generates necessary timing and control signals. Three memory modules are required in a CCIS switching office, and one memory module is needed in a CCIS signal transfer point. Store frames are duplicated for reliability.

The IGFET memory device is 4096 words by one bit, using n-channel technology. The device is dynamic, with refresh provided autonomously by the store controller. Sixteen memory devices are packaged on a memory plane containing 32,768 words by two bits. A memory module consists of 24 memory planes with the controller. Five-volt Transistor-Transistor Logic (TTL) devices are used in the nonmemory portions of the store.

VI. OUTPULSER FRAME

On all incoming CCIS calls served by new trunks, an outpulser must be connected to permit the marker to establish the cross office connection. The outpulser also provides access to circuitry which tests continuity of the CCIS transmission facility. In the case where a conventional outgoing trunk is selected, the outpulser transmits the address digits to the next office.

The outpulser unit is a modified Multi-Frequency (MF) sender with the MF receiver unit and incoming digit registration circuitry removed. The modification also adds the ability to connect to the circuit which tests CCIS trunk continuity and the ability to receive address digit loads from the processor.

Three outpulser units are mounted on an outpulser frame (Fig. 26). These are arranged into groups with up to 48 outpulsers per group. Up to three outpulser groups can be provided per office.

VII. CCIS OUTPULSER LINK—TRUNK COMPLEX

An equipment module consisting of three CCIS trunk frames and one outpulser link frame is designed as a fully connectorized module. This design permits the factory to prepare all cabling between the four frames

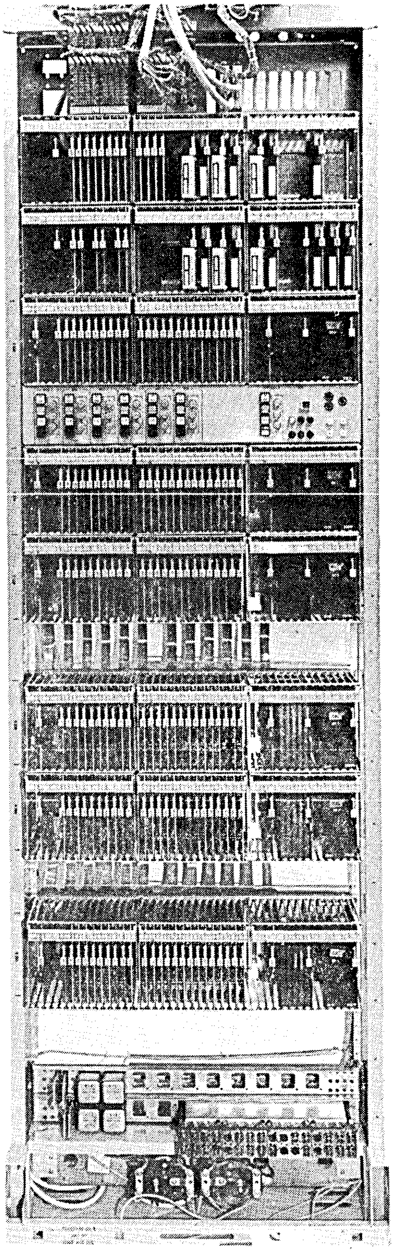

Fig. 25—IGFET store frame.

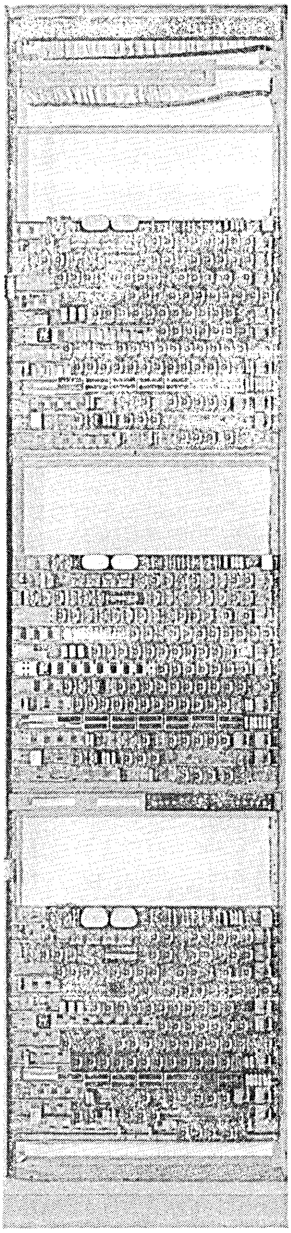

Fig. 26—Outpulser frame.

in module. A total of 360 trunks are attached to their respective outpulser link appearance by connectorized umbilical cables provided on the trunk frames and mated with frame connectors on the link frame at the time of installation. In addition the cabling between 11 outpulser link frames, which form a group, are connectorized. These link frame cables provide the ability for all trunks to access every outpulser in the associated outpulser group. This permits easy rearrangement during growth additions as well as ease of connection during initial installation.

7.1 Outpulser Link Frame

The outpulser link consists essentially of small crossbar switches and functions to connect an incoming CCIS call to an outpulser. The frame, Fig. 27, contains three links, one for each of the associated trunk frames in the module. Each trunk on a link has access to every outpulser in its outpulser group through the connection in the outpulser link.

7.2 CCIS Trunk Frame

The CCIS trunk frame accommodates a total of 120 plug-in trunk units. The trunks consist of epoxy coated steel boards making use of miniature wire spring relays and other low profile components. A typical trunk is shown in Fig. 28. Use of the metal boards takes advantage of the structural and thermal characteristics of these substrates. The connectors for the plug-in trunks are hard wired at the trunk frame to cables which are connectorized at the outpulser link. A test housing, to be equipped in every third trunk frame, provides a convenient station for the manual testing of any of the trunks in the same frame or adjacent frames.

7.3 Outpulser Link Controller Frame

An outpulser link controller frame, Fig. 29, provides the necessary logic to operate the outpulser link when an incoming CCIS call is connected to an outpulser. As part of this operation the controller also passes the identity of the trunk and outpulser to the SPC. In addition the outpulser link controller functions to connect a transceiver to the outpulser when requested by the processor. A single outpulser link controller frame is required for each outpulser group. Each frame provides four controller units to serve the associated outpulser group.

VIII. TRANSCEIVER AND CONNECTOR FRAME

The transceiver and connector frame, Fig. 30, provides the ability to test the voice path when the associated signaling is carried over the CCIS data link. The transceiver generates tones and has a receiver for verifying the integrity of the talking path under test. The connector portion of the

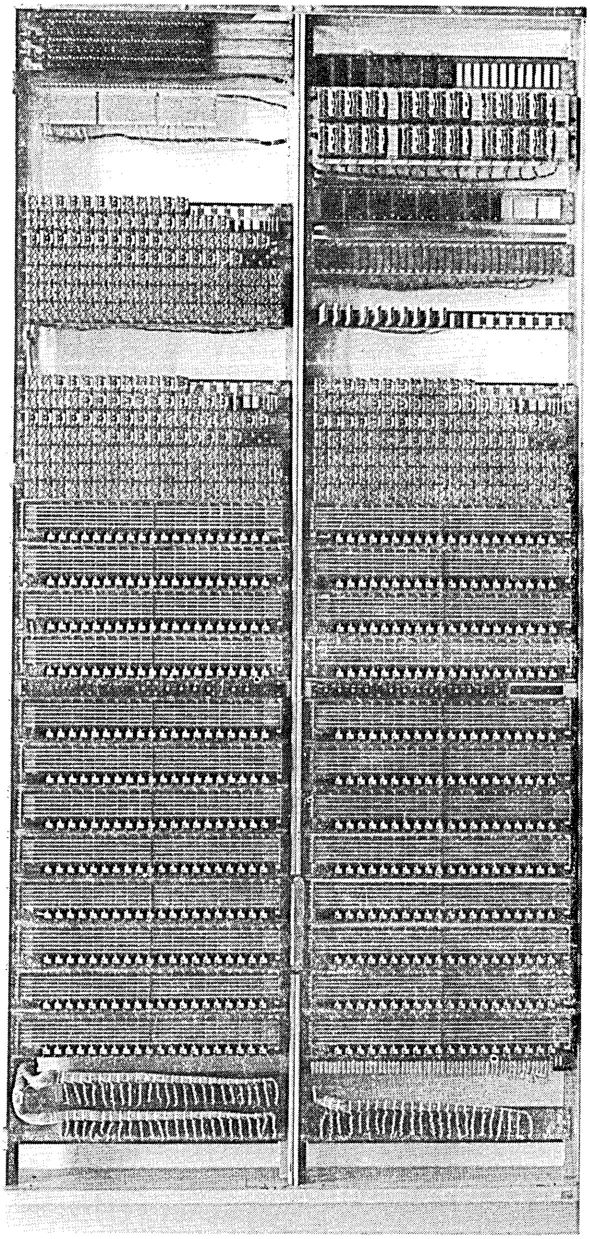

Fig. 27—Outpulser link frame.

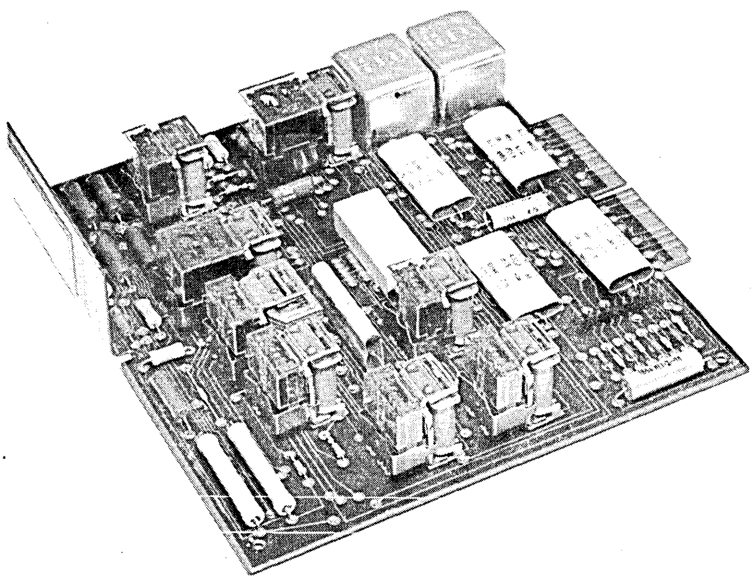

Fig. 28—CCIS plug-in trunk.

frame uses connectorized patch cables to provide multiple appearances of the transceivers which enhance rearrangements during growth.

IX. AUXILIARY DECODER CONNECTOR

The Auxiliary Decoder Connector (ADC), Fig. 31, is provided to increase the capacity of each connector of the basic Decoder Connector (DC). The additional leads provided increase the number of address digits which the DC can handle. These additional digits permit the entire address to be read from the sender or loaded into the outpulser for transmission to the next office.

X. MODIFIED EQUIPMENT

10.1 Options and planning

Most 4A crossbar and ETS circuits require some alteration, either minor or substantial, to operate with CCIS. The majority of the CCIS market in 4A crossbar will be in conversions of existing machines. CCIS features are now provided as standard in all common control circuits so that all subsequent manufacture of common control hardware will be CCIS compatible.

Circuits such as trunks, ETS, Peripheral Bus Computer (PBC) and test frames introduce the CCIS changes as options.

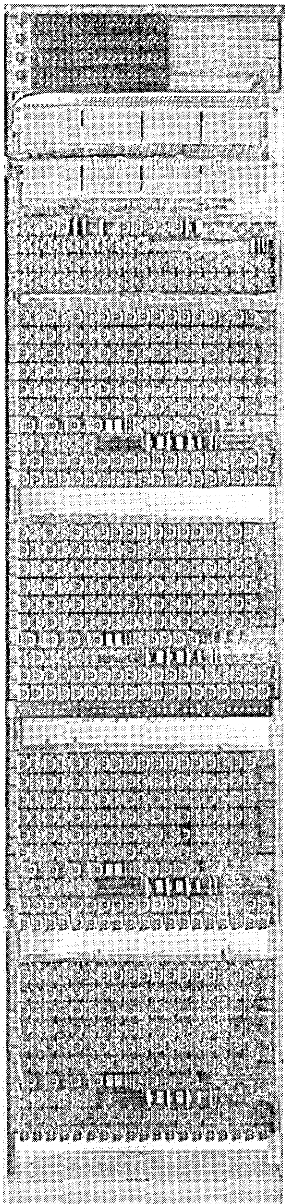

Fig. 29—Outpulser link controller frame.

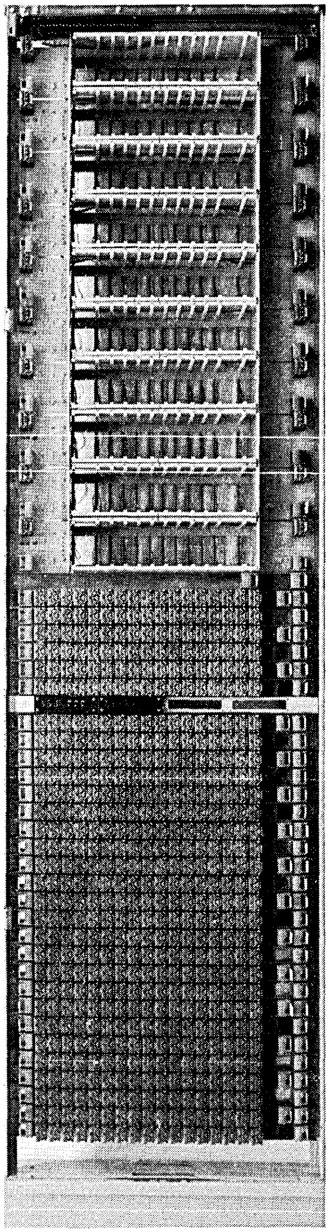

Fig. 30—Transceiver and connector frame.

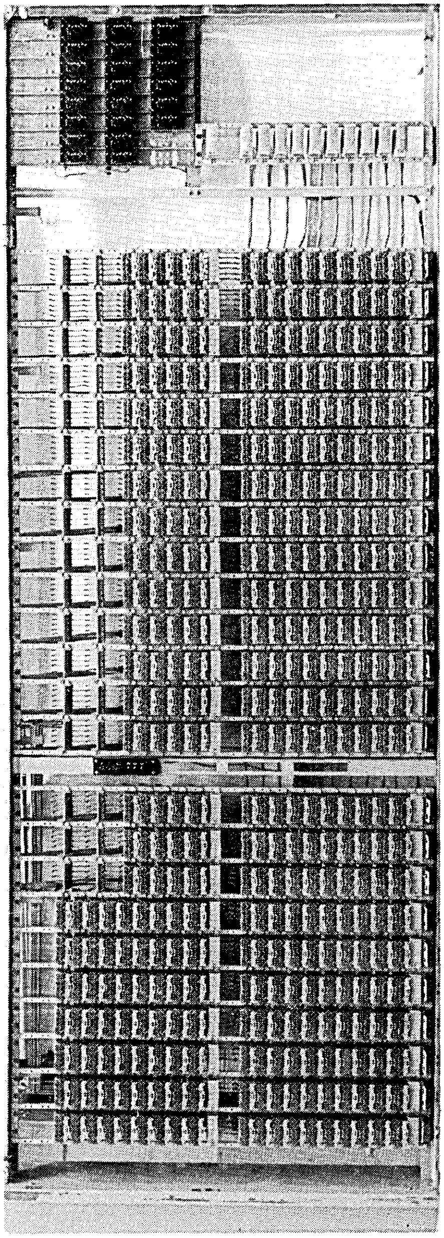

Fig. 31—Auxiliary decoder connector frame.

This permits the customer to acquire the CCIS features only where required.

10.2 Marker

The marker is modified to accept the outgoing link address of a CCIS trunk selected by the processor and to establish a connection between a sender or outpulser and the transceiver. This circuitry is contained in a single unit, added to the standard marker frame. The unit contains a cross connect field to permit the marker to be quickly converted to CCIS operation after the CCIS generic program is loaded.

10.3 Outgoing link frames

Relays are added to this frame through which the marker can seize a CCIS trunk previously selected by the processor. This change is contained in two units per link frame.

10.4 Senders

Senders are modified for CCIS to provide all address digits to the processor. This change is required so that the processor can transmit the entire address field to the next office when an outgoing CCIS trunk is selected. In addition the MF sender must be modified to serve also as an outpulser when the trunks served contain both conventional and CCIS trunks. This requires the capability of accepting the address digits to be outpulsed from the processor via the decoder channel. These changes are accomplished by adding relays to the existing units plus some associated wiring changes.

10.5 Decoder channel

The decoder channel is modified to permit handling all eleven address digits of a call. This change is accomplished by addition of apparatus into existing space on the unit.

10.6 Decoder connector

CCIS requires only wiring changes to associate the Decoder Connector (DC) with the auxiliary DC to increase its data capacity.

10.7 EM trunks

Standard mounting plate versions of the MF intertoll trunks may be field modified for use as CCIS trunks. The modification opens the E&M leads, provides for looping the transmit and receive speech pairs for voice path assurance testing, adds connections to the Distributor and Scanner (DAS) for supervision and control and provides a connector for patching the facility side of the trunk for transmission tests. The modification includes a rotary switch control to permit either MF or CCIS operation.

10.8 Electronic Translator System and Peripheral Bus Computer

Minor changes are required on the Alarm and Display (A&D) and Teletypewriter Buffer (TTYB) frames. The A&D is changed to add lamps and logic associated with new CCIS hardware. Additional TTYBs are required to serve additional teletypewriters used for CCIS.

The PBC modification requires additional core memory to accommodate the increased amount of data for CCIS traffic and an additional disk unit. The expansion requires the addition of one cabinet, some relocation of hardware units among the resulting four cabinets and associated cabling changes.

XI. NEW TEST FRAMES AND INTERFACES

11.1 Outpulser Link Controller Test Frame (OLCTF)

The OLCT frame, Fig. 32, and the CCIS Intra-Office Trunk Test Frame (CIOT) together form a small test center located in the CCIS trunk area of a 4A switching machine. The OLCT performs processor controlled scheduled operational tests of the controller and manually requested tests in conjunction with trouble clearance by the craftspersons.

A single bay contains the logic units, control panel, lamp displays and writing shelf which comprises the OLCT frame.

11.2 CCIS Intra-Office Trunk (CIOT) test frame

This test frame, Fig. 33, performs scheduled operational tests of CCIS trunks under processor control. Manual testing via a TTY associated with this test frame can also be performed to aid trouble clearing and circuit order testing. Test connections may be held to permit manual transmission measurements.

The CIOT consists of a single bay frame. A control and lamp panel, a writing shelf, relay logic units and a telephone handset are component parts of the hardware arrangement. An associated TTY is dedicated to this test frame for I/O functions. This test frame along with the outpulser link controller test frame form a remote test center.

11.3 VFL test frame

The Voice Frequency Link (VFL) test frame, Fig. 34, provides the ability to perform manual transmission tests on CCIS data links. It is intended for use only at the Signal Transfer Point (STP) locations where

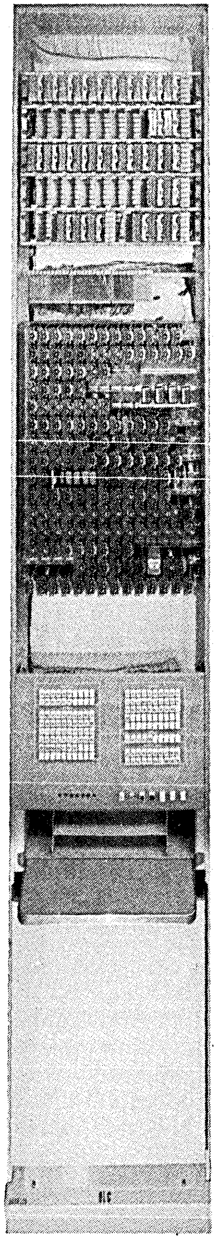

Fig. 32—Outpulser link controller test frame.

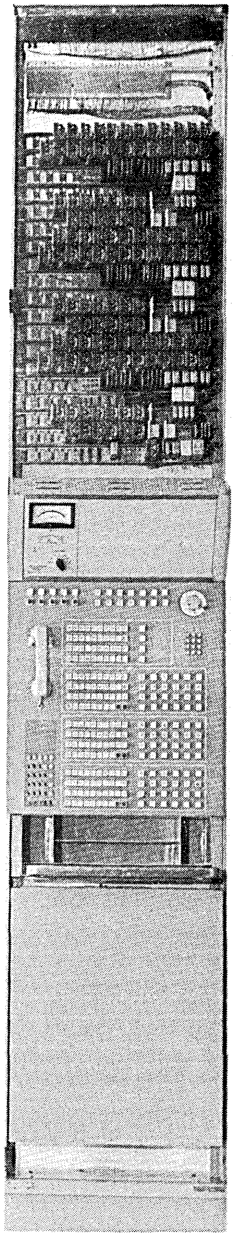

Fig. 33—CCIS intra-office trunk test frame.

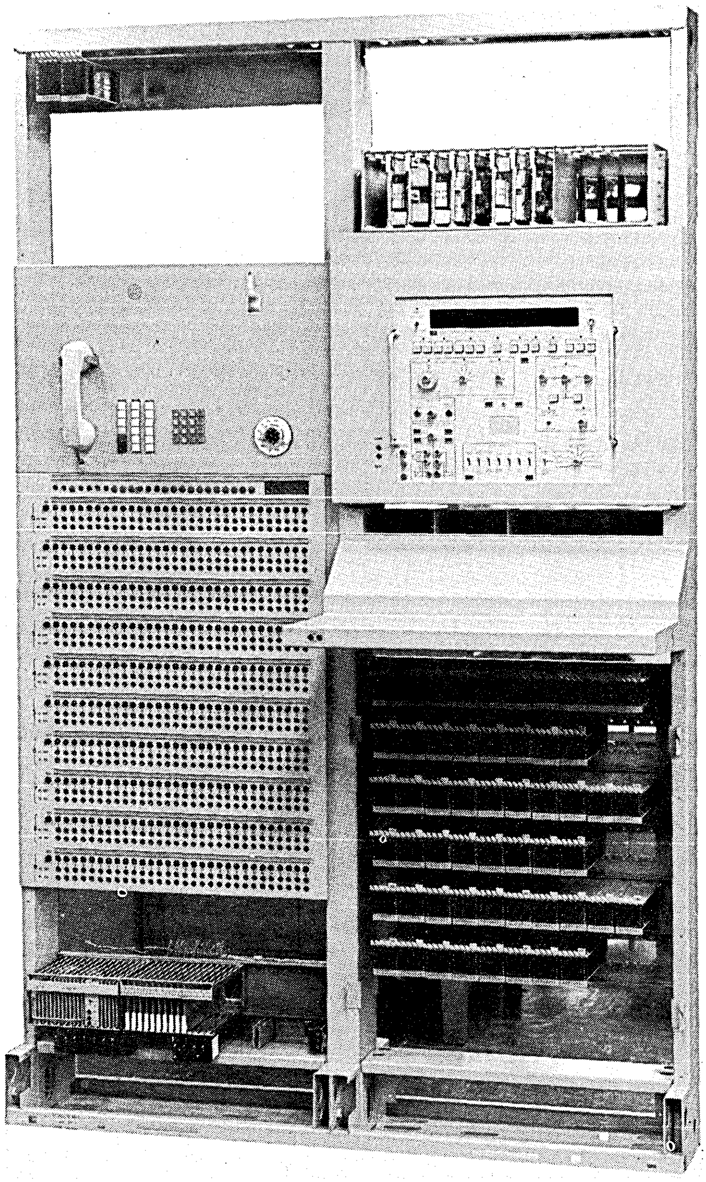

Fig. 34—Voice frequency link test frame.

there are large numbers of VFLs. The test appearance of a VFL is switched to the VFL test frame under processor control. The frame provides a Transmission Impairment Measurement (TIM) test set for manual tests. A telephone set and control logic for connecting to various communication circuits is also provided. An ETS teletypewriter (TTY) provides the I/O function.

The VFL test frame is contained on a double bay framework. Jacks are provided for 300 VFL appearances on the jack bay. A cross connect field is provided to permit regrouping the VFL appearance on the jack bay without office cabling changes.

11.4 Voice Frequency Link Access Unit and Frame

This circuit performs the switching necessary to disconnect a voice frequency link from the CCIS terminal and connect it either to the VFL test frame for manual testing or to the maintenance terminal for automatic testing. As shown in Fig. 35, eight VFL access units are provided in a single bay frame. Each unit serves four CCIS terminal units. This frame is required in an STP, but not in a CCIS switching office, where only a VFL access unit is required.

XII. MODIFIED TEST FRAMES

12.1 Trouble recorder

This frame was modified to add CCIS information to the trouble record card, to add circuitry for testing the operation of CCIS features in the 4A common control hardware and to provide additional alarm and status lamps. It was implemented by adding two new units, some components to existing units and a new trouble record card.

12.2 Incoming Sender Register Test (ISRT) frame

This test frame was modified to perform tests of the CCIS features in senders, outpulsers and sender/outpulsers. In addition the ISRT was altered to test the transceivers which are used by CCIS to test the continuity of voice paths. Output information on hard faults is sent to the maintenance TTY. These changes were incorporated by adding a new unit to the frame plus some component changes on the frame control panel.

12.3 Automatically Directed Outgoing Intertoll Test (ADOIT) frame

The ADOIT frame was modified to perform automatic transmission testing of CCIS trunks. The test connector is not used by the ADOIT to access CCIS trunks; instead ADOIT to processor communication is used to request the processor to reserve the designated trunk for the ADOIT connection. The changes were accomplished by addition of apparatus and wiring to existing units on the ADOIT frame.

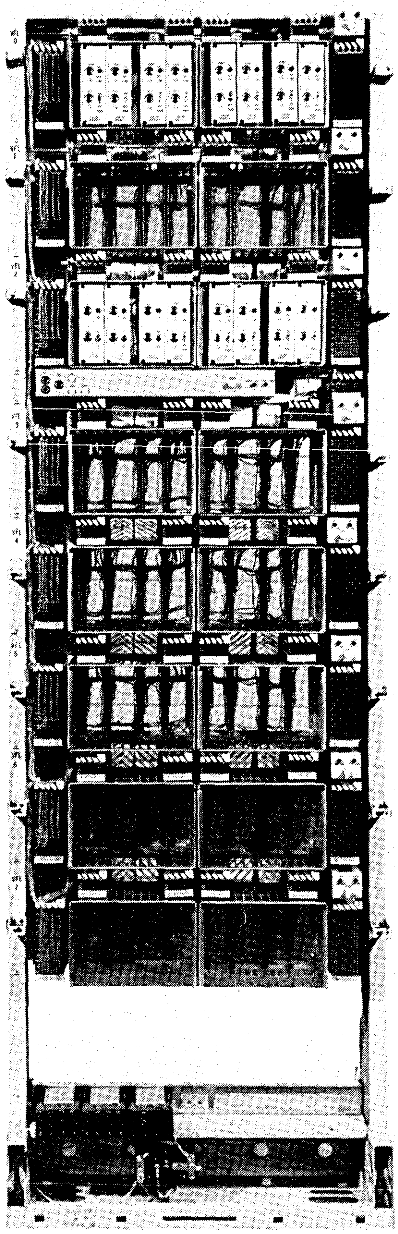

Fig. 35—Voice frequency link access frame.

XIII. TRANSMISSION EQUIPMENT

13.1 Integrated Manual Test Frame (IMTF)

This frame provides for the manual testing of both conventional and CCIS trunks. The frame has two test access appearances on the switching machine and can optionally be equipped for Switched Maintenance System 3B (SMAS) which can gain access to points in the transmission terminal equipment. This arrangement allows the cross office testing to be performed by one person. The test portion of the IMTF is shown in Fig. 36.

For CCIS trunk testing access is made via the Teletype Corporation *DATASPEED* 40 teletypewriter. The *DATASPEED* 40 interfaces the SPC through the Teletypewriter Buffer (TTYB) and can be used by the craftsperson to access a specific trunk, control the state of certain equipments, and to obtain information from other test frames.

Each test access via the switching machine is monitored during the call setup. Certain operational problems which halt call progress are displayed as an aid in trouble isolation. Transmission level and noise measurements can be made from test lines or with a craftsperson in the distant office.

The IMTF is optionally provided with a return loss measuring set and/or an echo suppressor measuring system depending on the assignments of toll connecting and intertoll trunk testing. Jacks are provided for the use of portable equipment.

The Voice Frequency Links (VFL) for the switching offices appear in the Test Trunk and VF Link Jack (TTJ) bay which is adjacent to an IMTF. The test appearance of the VFL is switched to the TTJ bay by the processor. From there it can be patched to the IMTF for transmission measurements. Portable test equipment can be used if required, such as for envelope delay distortion measurements. The TTJ also provides test trunks and lines to other test frames and equipment.

The IMTF has been arranged to group together those functions which are needed to permit one person to isolate trunk and facility problems. The IMTF is part of what is known as a Trunk Operations Center (TOC), which is responsible for pre-cutover and circuit order testing. The general trunk maintenance functions include trouble detection, service protection, sectionalization, verification, and others.

To support these functions SPC channel 6 and PBC channel 26 are available in the TOC to present information such as trunk status.

13.2 Outgoing Trunk Testing System (OTTS)

The Outgoing Trunk Testing System (OTTS), Fig. 37 is a microprocessor centered, minicomputer controlled test frame that operates automatically to test all intertoll and toll connecting message trunks

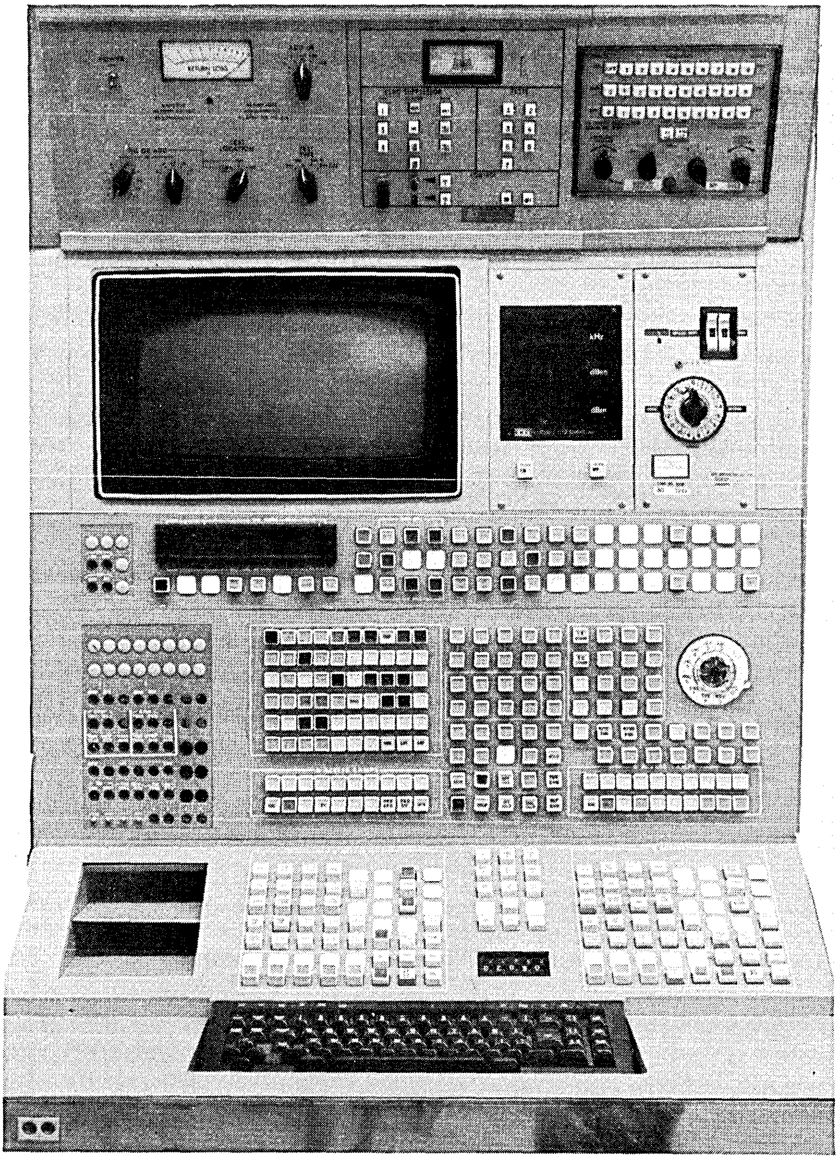

Fig. 36—Close up of integrated manual test frame.

outgoing from a No. 4A switching machine. The minicomputer providing the control can be colocated with and connected directly to the OTTS [the Trunk and Facilities Maintenance System (TFMS) configuration] or may be remote and controlled via a Direct Distance Dialing data link [the Centralized Automated Reporting on Trunks (CAROT) configura-

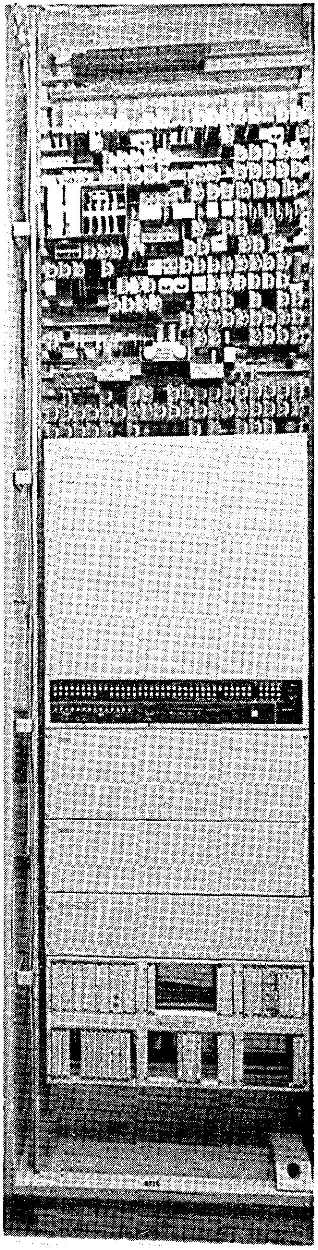

Fig. 37—Outgoing trunk testing system bay.

tion]. In either case, the minicomputer serves to specify a trunk and a test. The microprocessor part of the OTTS equipment serves to control, monitor and report the results of each test.

OTTS is able to conduct tests on two trunks simultaneously via the switching machine and results in sufficient capacity in a single test frame to complete all the trunk testing requirements of even the largest No. 4A offices.

For conventional trunks, OTTS performs tests to all standard operational and transmission test lines. Following any of these, a supplementary trunk identification, trunk verification, disconnect timing (for intertoll trunks) or incoming release (for toll completing trunks) test may be made. Alternatively, any of a variety of special abbreviated trunk tests may be specified. Preceding each test, a set of call process checks is made. Any failure terminates the sequence with a report message to the controlling minicomputer. OTTS may be controlled to complete to a busy trunk, distinguish between service and maintenance busies (without service disruption) and to control the lockout relays of equipped trunks.

For CCIS trunks, OTTS performs tests only to transmission test lines. Before each test, a Voice Path Assurance (VPA) check is made. The results of the VPA check are reported to the controlling minicomputer, but the transmission test line test is continued independent of those results. Following each transmission test a special CCIS release timing check is made.

These tests can be made on CCIS trunks made maintenance busy at the near-end. Trunks may be made maintenance busy or returned to service from a maintenance busy state. A sequence of call progress checks analogous to those for conventional trunks is made. For conventional trunks, OTTS interfaces the No. 4A switch as two incoming trunks. OTTS performs its own sender functions and interfaces with the common control via a single decoder connector appearance. OTTS identifies the trunk to be tested to the marker via the test connector and a dedicated trunk block connector.

Similarly for CCIS trunks, OTTS interfaces the switch as two incoming conventional trunks. The same decoder connector appearance is used as is used for conventional trunks to initiate the switching process, but for CCIS trunks the trunk to be seized and the call destination are identified to the switch via a pair of multi-lead interfaces with the DAS circuit of the SPC.

User interaction with OTTS in the TFMS configuration takes place via two local Trunk Maintenance teletypewriters. One terminal is customarily dedicated to tests on intertoll and the other to tests in toll connecting trunks. The TFMS configuration operates in two distinct modes, routine and demand.

In the routine mode of operation, all trunks are tested by traffic group in a predetermined sequence. Only those tests that fail are reported, and busy trunks are stored for retesting at 30-minute intervals. In the routine testing mode, CCIS and conventional trunk groups may be mixed.

In the demand mode of operation, a formatted request may be entered at a trunk maintenance terminal and cause one or more repetitions of any test sequence in the repertoire to any trunk or group. The results of any test made in the demand mode are reported, whether or not the test results are passing.

User interaction with OTTS in the CAROT configuration can take place in any of three modes, each of which requires that the OTTS be converted to a Remote Office Test Line (ROTL) by application of an optional OTTS/ROTL unit. The OTTS/ROTL unit serves to interpret communications between the CAROT processor and the OTTS sequence controller.

The routine mode for the CAROT configuration is similar to that for the TFMS configuration except in that the processor is remotely located and the output (trouble) reports are prepared on a line printer colocated with the CAROT processor. Similarly, a demand mode exists in the CAROT configuration in which the request is made from and the results are reported to a terminal connected to the CAROT processor either directly or via a direct distance dialing data link.

The third mode of interaction with OTTS consists of direct connection of a Manually Controlled Interrogator (MCI) to the OTTS/ROTL unit in the OTTS bay. Using the MCI, any test sequence in the repertoire can be made repetitively and the results are displayed on panel lights on the MCI.

13.3 Unitized terminal equipment

Modern No. 4A crossbar and No. 4 ESS toll offices utilize Unitized Facility Terminals (UFT) to provide all the termination, signaling and channel bank equipments needed for toll trunks in compact prewired packages. This UFT family has been expanded to include frames for use with CCIS trunks. Four frames sets have been added.

Two sets of frames were designed primarily to be compatible with No. 4A crossbar offices. One, a set of three frames provides a complete terminal for 480 trunks including channel banks, carrier supply and distribution, power supply and distribution, transmission level adjusting attenuators, and maintenance and communications equipment. The second frame set design adds echo suppressors to the unitized terminal. Similar frame sets were designed primarily for ESS offices in arrangements with and without echo suppressors. The frame including echo suppressors will not be needed in No. 4 ESS offices after the introduction of the digital echo suppressor terminal but will be needed in No. 1 and No. 1A ESS offices.

The CCIS frames occupy only one-half the floor space needed for similar UFT equipment which include signaling units.

All frames are arranged for convenient in-aisle maintenance access and communications. Optionally, the frames may be equipped with plug-in maintenance connectors to provide dial-up remote access to all trunks at the carrier interface (+7, −16 TLP) from the IMTF or other test position.

In the transition to CCIS it will be desirable to utilize existing equipment arrangements at least temporarily. Plug-in units interchangeable with SF signaling units have therefore been made available. These units provide only the attenuators for transmission level adjustment.

XIV. SUMMARY

The application of CCIS to the toll network has taken advantage of existing but modern hardware technology in the various switching systems to reduce development time and cost to the network. New units and frames have been required as well as modifications to existing switching equipment. The technology matches exactly that being used in new ESS offices and has been optimized for ease of conversion of existing No. 4A crossbar offices. The design should allow rapid expansion of the CCIS network.

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Common Channel Interoffice Signaling:

Development Tools

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Tools used in the design, development, and testing of various components of the Common Channel Interoffice Signaling (CCIS) feature of No. 4A toll crossbar and No. 4 ESS are described. Included in the discussion are CCIS software design and administration support tools, electronic circuit design, analysis, and test tools, and laboratory support systems for software and hardware testing.

I. INTRODUCTION

A CCIS switching office or Signal Transfer Point (STP) consists of a variety of complex software and hardware systems whose sound design and thorough testing can be aided by effective support and development tools. Such software tools as a text editor, a macro assembler, and a linking loader are indispensable for program development. Managing large data bases of commonly used symbol definitions and large numbers of individual programs is accomplished by sophisticated software administration systems. Several hardware development tools not only aid the design and analysis of complex electronic circuits, but also provide circuit performance data used in the diagnostic software for these circuits. Support for the testing of completed software and hardware designs has also been provided. Laboratory utilities and test systems are available for debugging, function testing, and integration of system programs. The need for testing certain electronic peripheral circuits in an isolated environment has led to the development of off-line test systems that simulate the appropriate central control processors and their peripheral busses. The operation and application of each of these systems in the development of CCIS are detailed below.

II. SOFTWARE DEVELOPMENT TOOLS

The software development tools described below are programs and systems utilized in the design, development and maintenance of the CCIS real-time application software. Most of the tools are similar to those needed for any software development effort, and are representative of the major tools used during the development of CCIS. They are used for both the Stored Program Control (SPC) and Peripheral Bus Computer (PBC) developments and include a development and maintenance administration system, an editor, an assembler, a loader, and two special aids. One special aid is used for the development and maintenance of common pools of information, called COMPOOLS, which are used by the assembler. The other aid is a special purpose assembler for the CCIS terminal hardware unit to aid in assembling its language.

If we look at the development of a typical CCIS program module, called a pident, we can see how these tools are utilized. First, the name of the pident and its associated administrative information are entered into the Interactive Program Administration System (IPAS) data base. The user may then create the new pident through the use of an interactive editor within IPAS. The created pident, along with Advanced Processor Editor (APE) control cards, is submitted by IPAS for assembly by the appropriate version of the Switching Assembler Program (SWAP) as a batch job. Once the assembly is flag-free, the object module created by SWAP is linked to other modules of the system by the loader, which creates a load tape of the CCIS or PBC programs. This program tape is directly readable by the SPC or PBC machines, to initialize their memories with the real-time application programs.

For the CCIS development, these tools are designed to run on a general-purpose computer-center machine rather than on the application processor. The time-sharing and batch facilities of a large-scale, general-purpose computer are required to accommodate the heavy demand for these tools by the members of the development team; because the application processor is specially designed to control a switching machine, its instruction set and operating system are not suitable for general-purpose programming or time-shared use. Furthermore, to maximize the effective utilization of machine time, functions such as program editing and assembling, which can be carried out off line, are supported on the computer center processor, leaving the laboratory switching processor available for program debugging and system testing.

2.1 IPAS—the Interactive Program Administration System

IPAS is at the heart of the program development process. It executes interactively under the computer center's time-sharing facility. Before IPAS was available, programmers used card edit decks to define the changes required in a pident source file. Job Control Language (JCL) statements were generated by hand to run program assemblies under SWAP in a batch mode. IPAS replaced card edit decks with disk files of editor statements, and it replaced manual submission of assemblies with automatic generation and submission of required JCL. A programmer can now log onto IPAS, interactively create or modify a set of edit statements for a specified version of a pident, and schedule a batch assembly of the modified source without an intimate knowledge of the computer center operating system. Thus, more efficient use is made of program development time.

IPAS utilizes a central data base to control user access to IPAS, to control user access to particular functions and data files, and to record the existence and status of a pident's related edit files. The people in the Program Administration Group use the IPAS data base to control permanent changes to program source files, to check dates and times of assemblies, to generate official program listings for field distribution, and to set up loader input to produce a new generic tape.

2.2 Editing, assembling, and linking pidents

As with all Bell System stored program switching developments, such as No. 1 ESS, No. 2 ESS, and No. 3 ESS, an editor, assembler and loader are the basic tools for program system development. The APE editor used to edit the program source is that used by the No. 2 ESS and No. 3 ESS developments. The SWAP assembler used is similar to those used for other developments. The loaders which perform the linking functions for each machine are unique.

2.2.1 APE—the Advanced Processor Editor

A subject file data base is edited by the APE editor through the use of control cards and new input lines to produce a temporary updated file which is passed to the assembly step, and optionally, to a new, permanently altered and renumbered subject file. By using the APE editor, temporary changes can be made to the source files, and incorrect edits can be easily removed. In addition, the accumulation of these edits provides a history of changes to each pident, allowing programmers, testers, and administrators to determine the changes from one issue of a pident to the next very simply and efficiently.

2.2.2 SWAP—the Switching Assembler Program

SWAP is a powerful macro assembler, which reads symbolically coded machine instructions, pseudo-operations, and macros and converts them into object machine code.[1,2] Its normal outputs include an assembly listing and a disk data set containing the Object Program Module (OPM).

The OPM contains the assembled machine code plus linkage and administrative information needed by the loaders. Separate but similar versions of SWAP exist to assemble SPC and PBC code.

The SWAP assembler, developed concurrently with the SPC No. 1A processor[10] in the 1960s was intended for use by all electronic switching system software developments. In the next decade, when the use of high-level languages for SPC machines was investigated, the potential improvements in the program development process and in software maintainability did not appear to offset the penalty of greater real-time consumption and memory usage characteristic of most high-level languages. As a result, traditional methods using macros and assembly-language programming were employed in the development of 4A/CCIS software.

2.2.3 LDR—the Loader

Separate loaders exist for the SPC and PBC systems. Each loader takes any number of OPMs produced by SWAP (Section 2.2.2) and resolves the linkages between them. It also assigns each pident to a "real" piece of memory (address) or disk space and converts all relative addresses to absolute addresses. Each loader produces a listing consisting of the free and occupied areas of memory, the linkages resolved and outstanding, and any error messages. The ultimate product is the load tape, which is an application-machine-readable image of the linked real-time programs.

2.2.4 COMPAS—the COMPOOL Administration System

References to common data, formats, and locations are resolved not only in the loader stage, but also in the SWAP assembly stage using an entity known as a COMPOOL or DATAPOOL. COMPOOL is a collection of commonly used symbolic names, addresses, layouts (patterns) for locations, and registers, which are assembled and saved on a disk data set. A number of these preassembled disk data sets may then be used in subsequent SWAP assemblies to resolve references to symbols.

When used to refer to memory locations, the symbols contain certain special attributes, such as the address of a table, the address of a word or structure within a table, or a particular portion of a single word. To facilitate describing these symbols in a meaningful fashion, a special language was developed. This language, its compiler, editor, and data base are collectively known as the COMPOOL Administration System (COMPAS). The high-level language of COMPAS is used to describe the entities comprising a COMPOOL, such as tables, words, items, registers, constants, memory blocks, and holes in a hierarchical and sequentially

```
:SYSTEM         BUILD (CCIS)
:MOVEBEFORE     TABLEC, TABLEB
:INSERTAFTER    MYTABLE

    MEMBLK          addr1, addr2, PROTECTED, OFFICE_DATA,,,
                    'space for trunk tables and headcells'
    TABLE           TRKTABLE
    PROGRAMMER      'name room extension'
    SYSTEM          CCIS
    ORIGIN          ABSOLUTE, EVEN, 'used as list of headcells'
    MEMORY          PROTECTED, OFFICE_DATA
    LENGTH          16, 32, 'one word per trunk headcell'
    QUANTITY        1, 4, 'one table per trunk group — min=1, max=4'
    DOCUMENT        TTBL, 68009
    DESCRIPTION     'these tables are indexed by trunk group number'

        WORD            NAME=WORD1. TTBL, WRDTYP=DATA, WRDNUM=0
        PLACEMENT       'these headcells require immediate access'
        DESCRIPTION     'headcell is used to point to array of trunks'

            ITEM TTBL_EQUIP, 3, 17, N, 'eqpd=001, uneqpd=000, maint=100'
            ITEM TTBL_PTR, 17, 0, N, 'ptr to trunk tbl'

        WORD            NAME=TYPE_TTBL, WRDTYP=DATA, WRDNUM=1
        PLACEMENT       'corresponds to ttbl_ptr'
        DESCRIPTION     'used for trunk group type'

            ITEM TTBL_TYPE, 3, 0, N, 'see document PR-68003.I4 for
                 bit types'
            ITEM FILL, 17, 3,, 'unused bits', DEFAULT=0

    TCONST          TTBL_EQUIP_CHK, 1, 'constant used to check
                    equipped status'
    END_TABLE
    REGD            TTBL_REG_CHK, E (3), 0,, 'register definition used
                    to check trk tbl'
    HOLE            128, 'leave hole 128 words long in memory'

:RENAME         TRK_TBL, NEWTRK_TBL
:DELETE         HOLE. 17744
:PRINTAFTER     *ALL     #print formatted list of compool
:END
```

Fig. 1—Sample table definition and input commands for a COMPAS run.

ordered structure. Figure 1 shows a typical table definition in COMPAS format, with examples of the editing and layout commands.

The entities are entered into the data base, and the existing data base is manipulated by using the COMPAS command language. Thus, COMPAS provides the COMPOOL administrator with an entity-based editor and command structure. This feature facilitates the manipulation of complete entities such as tables, which have an arbitrarily complex structure and length, by using a single command.

COMPAS provides other special advantages over conventional COMPOOL defining techniques such as SWAP macros. It provides for the checking of the entity data for consistency. For instance, when the layout of a particular word is defined, the items can be checked to verify that all bits are defined once, unless declared otherwise. This provides a level of checking not possible using conventional SWAP declarations. COMPAS also provides for the complete description of each entity and its parts. This helps document the entities and provides for reference to the individuals responsible for controlling the entities.

In addition to the features already described, the COMPAS high-level language definition of a COMPOOL is transmitted to Western Electric, where it is used to build a data compiler automatically. This is done using a system developed jointly by Bell Laboratories and Western Electric known as the Integrated Data Management System (IDMS). This system facilitates the automatic updating of the data compiler needed to support changes to COMPOOL often required with issuance of new generics of the CCIS programs.

2.2.5 *TASM—the Terminal Assembler*

The terminal hardware unit,[3] which is a special purpose computer used as an interface between data transmission facilities and an application processor, is used in several switching systems. Currently, the terminal is able to communicate with the No. 1 ESS, No. 1A ESS, and SPC No. 1A processors. The terminal does not contain a peripheral unit such as a tape unit from which it is capable of loading its application program. Therefore, the terminal application program must be assembled by the respective SWAP assembler (Section 2.2.2) into the format of the application processor (SPC No. 1A, No. 1 ESS, or No. 1A ESS). That processor then can transmit the terminal application program to the terminal over its own communication paths.

The terminal has its own assembly language, so a terminal assembler (TASM) was written using SWAP macros and pseudo-operations. Thus, the terminal assembler is imbedded within SWAP in much the same way as was the CENTRAN (SNX360) assembler for the Safeguard project.[4] It is a one-pass data handling, two-pass program handling assembler.

The assembler consists of two parts: a common portion and an application portion. The common portion consists of approximately 1200 lines of macros and is used without change by all SWAP assemblers required to assemble terminal programs. The application portion is unique to each application (system) using a terminal. It consists of approximately 300 lines of macros which perform the job of packing the assembled data passed to it by the common section into the format necessary for the particular application.

Using this technique, the assembly listing produced contains the terminal source code lines, the assembled values and addresses in terminal format, and the packed application format, cross-referenced to the terminal format, in one listing. Also, as a result of this technique, a single SWAP assembly produces an OPM which can be linked by any one of the application-processor loaders.

III. HARDWARE DEVELOPMENT TOOLS

There were two software tools of major importance used in the development and testing of the hardware for CCIS. By far the largest and most complex tool was the Logic Analyzer for Maintenance Planning (LAMP).

3.1 LAMP—Logic Analyzer for Maintenance Planning

LAMP is a large and complex system which runs under several general-purpose computer operating systems. It is a circuit simulator capable of logic, fault, race, and timing analysis of circuits.[5,6] It was used to help design the CCIS circuits through provisioning for diagnostics and maintenance. It was also used to verify the logic and timing within the circuits prior to building laboratory models.

LAMP can produce outputs which link it to many other tools, such as the Diagnostic Language (DIAL) (Section 4.1) and the frame and circuit pack testing tools (Section VI). In particular, one of its outputs is used in the production of the Trouble Locating Manual (TLM), as described below.

3.2 TLM—the Trouble Location Manual Program

In order to locate and diagnose hardware problems in the new electronic circuits added for CCIS, a printed TLM using a first-failing test algorithm was provided. Production of such a TLM begins with one or more LAMP simulations of the circuit; one simulation may be run for each diagnostic phase. The input to each simulation is the data from the SPC-resident diagnostic programs. Results from multiple LAMP simulations are combined to form one "results" data base. These results, however, cannot be used directly to generate trouble numbers. Packing algorithms must first be applied to simulate the packing of results done within the SPC. The SPC diagnostic programs pack the results because of the limited SPC memory available for storage of the raw data. Different packing rules may be applied for each CCIS circuit.

A fault data base is constructed from the LAMP circuit model and from physical circuit data contained in circuit-pack device files. This data base associates the fault numbers used in the various processing algorithms (e.g., in LAMP), with physical locations and fault descriptions, and it defines the classes of equivalent (logically identical) faults.

The final step in TLM generation is the application of the trouble number calculation algorithm to the packed simulation results. The trouble number data is combined with the physical fault information to produce the printed behavioral TLM.

IV. COMBINATION HARDWARE-SOFTWARE DEVELOPMENT TOOL

DIAL is a macro language used to generate diagnostic tables for CCIS peripheral units. These tables are stored in SPC memory and in conjunction with a DIAL table executor, compose a diagnostic program. A typical DIAL statement may specify a peripheral order to the circuit under test and the corresponding expected reply to that order. The generation of the diagnostic tables is done using a DIAL-SPC compiler. The DIAL macros are also compiled using a DIAL-LAMP compiler to produce LAMP input vectors (Section 3.1). These input vectors are used to drive a LAMP simulation of the circuit to verify circuit operation during initial circuit design stages, to design and evaluate diagnostic tests, and to produce a TLM for the circuit through fault simulation. A third application of DIAL macros is to generate factory tests. The DIAL statements generate a data base which is released to Western Electric to be used to test the peripheral units before shipment.

Among the advantages of using the DIAL language are:

(*i*) The same set of source statements may be used during initial circuit design, in diagnostic generation, and in manufacturing test generation by inputting them to different DIAL compilers.

(*ii*) Functions are easier to code and understand because DIAL statements are macro calls.

(*iii*) The language is common to several peripheral units.

(*iv*) DIAL table-driven diagnostics require less SPC memory than machine-language code of the same tests.

In addition, because the DIAL compilers are actually a set of SWAP macros, functions coded in the DIAL language are portable and can be used in several machines and systems which use the SWAP assembler.

V. LABORATORY SUPPORT SYSTEM

The demand for increased reliability of software systems, coupled with the high degree of complexity which is characteristic of many modern software designs, has resulted in the need for effective and efficient testing methods and sophisticated laboratory support tools. The development of CCIS software for 4A crossbar and for No. 4 ESS—systems where the reliable performance of the software is essential to the continuity of telephone service—was supported by a number of such tools. (A discussion of No. 4 ESS support systems may be found in Ref. 7.)

5.1 Utilities for debugging and testing

When a program module is first introduced into the host processor in a laboratory environment, the software designer requires special tools which enable him to execute specific sections of his program, monitor its operation, detect and analyze performance anomalies, and rapidly make corrections and modifications. As system integration progresses, function testing causes increased program interaction, and additional testing aids are needed which provide for less disruptive collection of large amounts of performance data and rapid resolution of detected errors. Two independent laboratory utility systems, a host-processor-resident utility system and a minicomputer-resident noninteracting utility system, provide the program control and monitoring facilities required during the early stages of testing.

5.1.1 Resident Utility

Program testing at its most basic level is accomplished with the Resident Utility system, which is illustrated in Fig. 2. In this mode, the user is provided with the greatest degree of control over the execution of a program. By the use of the Noninteracting Utility Program Interface Console (NUPIC), which is used as a manual test console or "T-cart," program execution in the SPC processor may be stopped, instructions may be executed one at a time, or "matchers" may be used to detect the execution, reading, or writing of a specified memory location.

In addition to these manually controlled functions, the Resident Utility provides a variety of software-controlled features through a system of utility programs which "reside" in SPC memory. In either a batch mode using punched-card input, or interactively with teletypewriter (TTY) commands, the user is able to establish his test environment, control the execution of the program sections under test, and collect the desired run-time data. With the SPC system under the control of the utility system, the user may initialize internal registers and scratch memory, and cause execution to begin and end at given locations. By inserting special instructions at user-specified addresses, the utility system can monitor program progress at that address, dynamically modify run-time program parameters, or divert execution to special test routines. The transfer trace facility of the Resident Utility allows the printing of program addresses and internal registers each time a transfer instruction causes a break in sequential instruction execution.

A flexible program modification facility is an essential component of a laboratory utility system. The Resident Utility Overwrite Assembler is the means by which corrected program errors and modifications are incorporated into the machine-language version of the programs as they are being tested in the laboratory. Input statements to the Overwrite Assembler are compatible with the SWAP assembler (Section 2.2.2); once all additions and modifications have been tested in the laboratory to the satisfaction of the programmer, the overwrites may then be incorporated into the permanent version of the program using SWAP and its associated editing programs.

A variety of miscellaneous testing tools and laboratory aids are also part of the Resident Utility feature repertory. Memory may be dumped to magnetic tape or to the line printer, memory may be loaded from tape,

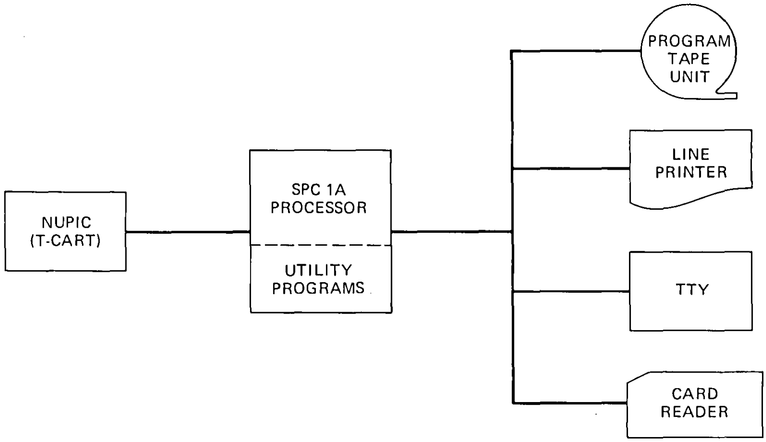

Fig. 2—Resident Utility system.

or data on a magnetic tape may be compared with that in memory. System software and hardware may be reinitialized in varying degrees under utility control.

However, a major drawback to the operation of the Resident Utility is the high degree of direct interaction between the utility and the programs under test. Execution of programs under test at their normal speed, without periodic interruption, is sacrificed for the fine control of program execution and the simplicity of the hardware structure characteristic of the Resident Utility.

5.1.2 Nonresident Utility

The ability to collect program execution and performance data without interaction by the utility system becomes essential in the program integration phase of testing. In a system such as 4A/CCIS, many call set-up functions are performed by electromechanical common-control hardware; the real-time software which controls and monitors this equipment executes essentially instantaneously relative to the much slower hardware. Interruptions to normal program flow, such as those caused by the Resident Utility to collect and print program data, could delay the initiation or execution of these programs, thereby distorting normal hardware-software sequences and corrupting test results. This inadequacy of the Resident Utility is overcome with the Nonresident Utility, whose noninterfering monitoring and off-line data processing are better suited to the more rigid environment of the latter phases of testing.

The nerve center of the Nonresident Utility system is a minicomputer

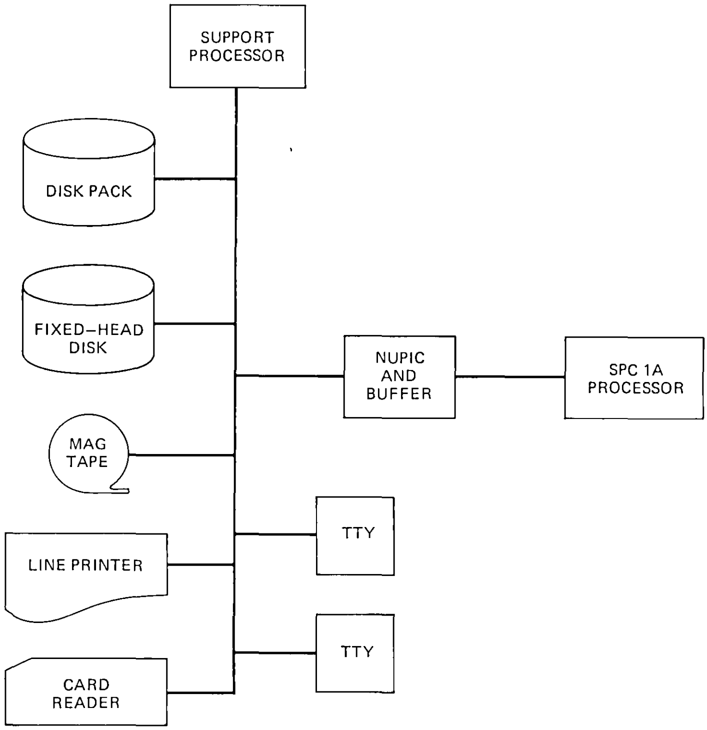

Fig. 3—Nonresident Utility system.

support processor (Fig. 3), one of whose peripherals is the NUPIC with its associated buffer. Under control of the Nonresident Utility software, the NUPIC is programmed to collect selected SPC program execution information when one or more of a variety of matchers detects a user-specified condition in the SPC processor. Among the conditions which these hardware matchers may be armed to detect are the execution of a specified SPC program address, the reading or writing of a given bit pattern at a specified address, and the accessing of a given SPC peripheral unit. In each case, the user may establish the particular conditions under which a match should occur either by composing Nonresident Utility statements interactively at a TTY keyboard or by identifying a previously created disk file containing images of the desired statements. Once these commands have been executed and the appropriate matchers armed, the NUPIC continuously monitors the operation of the SPC processor until a match occurs. At that instant, without interruption to the operation of the SPC, the NUPIC gates the information previously specified by the user's commands to a buffer which is unloaded by the support processor. An additional feature may be enabled or disabled when a match occurs:

noninteracting transfer trace, which provides a snap of critical SPC operational data each time a program transfer takes place. The autonomous matching and data collecting processes performed by the NUPIC allow for the gathering of a large amount of program execution data without disrupting the normal, full-speed operation of the system under test.

An important component of the Nonresident Utility system is the off-line data processing capability provided in the support processor software. While data being collected by the NUPIC is loaded into the hardware buffer, utility programs are unloading the data in its raw form onto a disk file. At the user's option, this data may be immediately translated into a readable form and printed at high speed, or may be stored on the disk for later off-line processing. A circular-file feature allows the automatic, continuous overlaying of the oldest collected data with new data. In this mode, the unneeded data from passed tests is automatically discarded, and only after a test failure or other irregularity is data collection stopped and the current file contents examined. The printed output of any data collection file may take a number of forms, including raw octal output, conversion to symbolic program names plus offsets, or printout only of data collected from a particular selected program.

Because of its rapid data handling and output capability, and its bulk storage facilities, the Nonresident Utility provides a number of other valuable tools and debugging aids. High-speed loading of SPC memory may be achieved either from magnetic tape or from a support processor disk file. SPC program and office data information may be rapidly dumped to tape, disk, or line printer. The noninterfering accumulation of large amounts of data, together with rapid and efficient off-line processing, have made the Nonresident Utility system an extremely effective testing tool.

5.2 4CAST—automated system testing

With the application of Common Channel Interoffice Signaling to the basic No. 4A toll crossbar system, the size and complexity of the software system has increased significantly. The architecture of the 4A/CCIS[8] and STP[9] machines, indeed, the structure of the entire signaling network, suggests that traditional testing techniques, while adequate for earlier switching systems, must yield to more flexible and powerful tools to keep pace with this advancing technology. The requirements for such a testing tool are that it be capable of communicating with a 4A/CCIS or STP machine over any of its various man-machine and machine-machine interfaces; that it be a convenient vehicle for the development, application, and administration of function and system tests; and that it provide sufficient flexibility and speed of operation to allow rapid execution of a large number of tests with a minimum of user intervention. These needs are met with the 4A/CCIS Automated Support and Test System (4CAST), an implement with which the testing of the large and complex CCIS software structure can be effectively managed. The 4CAST system consists of a compiler, which converts stimulus-response commands written in a high-level language into a command-table load module, and a laboratory run-time system, which executes the load module commands.

5.2.1 Compiler

The 4CAST language, consisting of keywords and structures similar to those in PL/1, enables the test designer to convert test specifications into sequences of action directives or response monitors in a form that is easy to generate and understand. A single 4CAST "procedure," or compilation entity, is typically produced for each test definition and compiled by the 4CAST compiler, which runs on a general-purpose computer center processor. As shown in Fig. 4, the generation of a procedure begins with the user's coding of the procedure text in the 4CAST

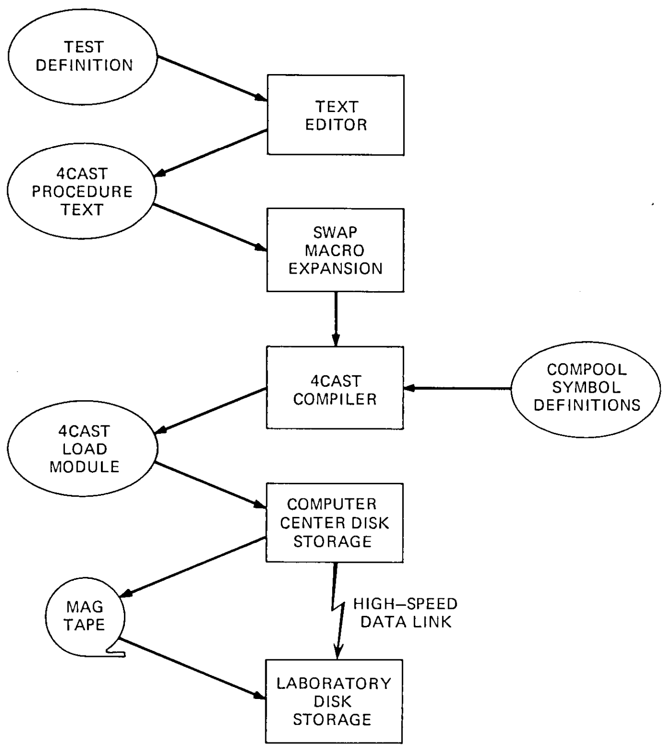

Fig. 4—Generation of 4CAST procedures.

```
PROCEDURE   TESTX. CONTROL;

DECLARE
  INTEGER   X = 25, Y = B (110100);
  INTEGER   SPC_ADDR;                  # definition in COMPOOL;
  TEXT      ERR1 = "INVALID DIGITS";
  TIMER     T1 = S (15), T2 = MS (200);
  SU        ANSWER, HANGUP;            # supervisory signals;
  IAM       ADDR_DIGITS = C (5551212); # telephone number;
                 .
                 .
                 .

END;

START:
  RUN INIT (PARAM1, PARAM2);           # initialize;
  DELAY T2;
  SENDSU  ADDR_DIGITS . trunk_number;  # initiate call;
                 .
                 .
                 .
  ON  ANSWER . trunk_number
    DO;
      PRINT "CALL ANSWERED";
      IF READSPC (SPC_ADDR) = Y
        THEN GO TO RESTART;
        ELSE CONTINUE;
    END;
  WAIT;
                 .
                 .
                 .

RESTART:
  SENDSU  HANGUP . trunk_number;       # disconnect call;
  PARAM1 = PARAM1 + X;
  GO TO START;
END TESTX;
```

Fig. 5—Sample 4CAST test.

language. For added flexibility and convenience, user-defined macros for repetitive or complex functions may be expanded by the SWAP assembler's macro facility. The 4CAST compiler then converts the text commands, definitions, and directives into a 4CAST load module containing tables which drive the laboratory Run-Time System. The compilation process also provides access to the common pool (COMPOOL) of symbol definitions used in the assembly of SPC and CCIS programs. Figure 5 is a sample of the text of a simple 4CAST procedure. Once compiled, a procedure's load module is transported to the laboratory either on a magnetic tape or directly from a computer center disk file to the laboratory support processor disk via a high-speed intermachine data link.

5.2.2 Run-Time System

Once the 4CAST load modules have been transferred to the 4CAST processor's disk, they may be executed by the 4CAST Run-Time System. In the unattended mode of operation, a list of "master procedure" names is entered by keyboard command to the Run-Time System. Each master procedure contains 4CAST directives which load, start, and exit individual tests, or "control procedures," each of which is a 4CAST load

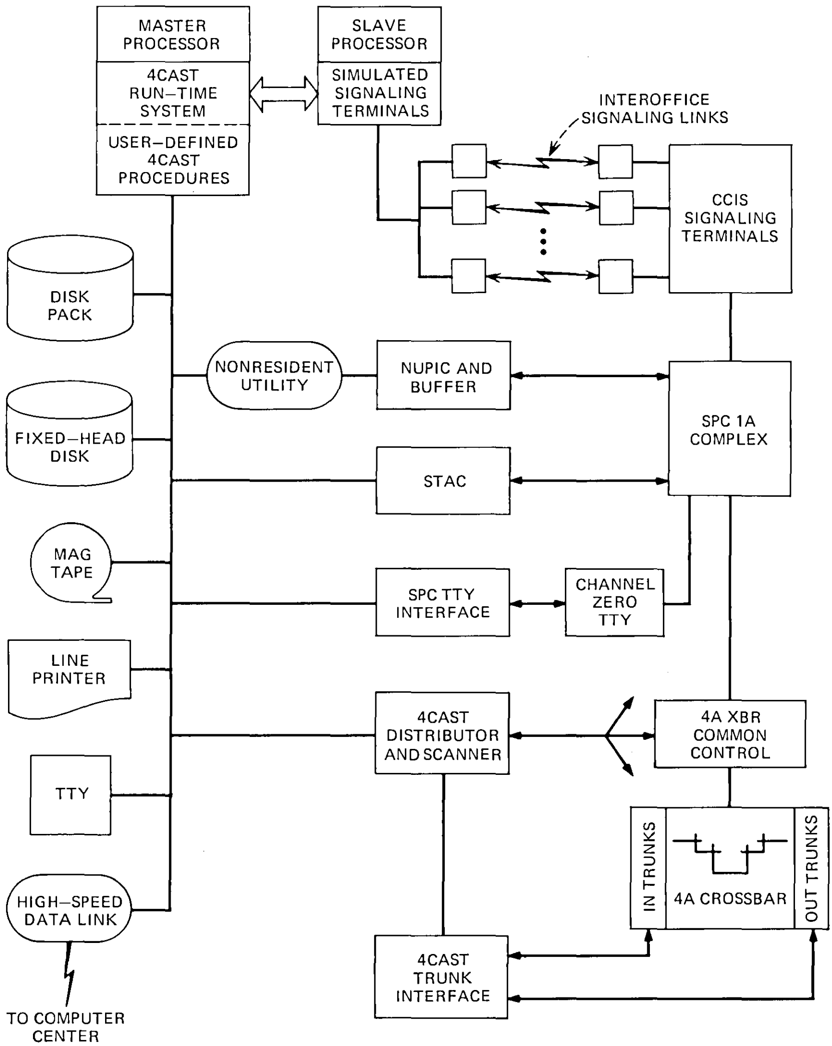

Fig. 6—4CAST system in switching office configuration.

module which performs the initialization, defines the required actions, and monitors the results of a given test. Control procedures are capable of initiating "subprocedures" to perform basic, repeated tasks, such as the set-up of a particular type of call, or the removal from service of a given signaling link. Communication between procedures is accomplished either with parameters passed from a calling procedure (master or control) to a subordinate procedure, or through a common scratch area accessible by all executing procedures.

As seen in Fig. 6, 4CAST can access the CCIS switching office or STP systems in a variety of ways. The most fundamental communication channel is through the CCIS signaling links from the 4CAST Simulated Terminal Interface. It is through this link that nearly all interoffice signaling is simulated. CCIS call set-up and disconnect, signaling network maintenance and control, and other interoffice communication can be initiated and monitored automatically by sequences of user-specified commands in 4CAST procedures. Conventional call origination and termination is accomplished through the 4CAST Trunk Interface, which controls signaling to a variety of conventional 4A trunks. The Distributor/Scanner Circuit, in addition to driving the Trunk Interface, provides direct access to and control over functions in the 4A hardware and in the SPC complex. The primary man-machine interface, the SPC maintenance TTY, is controllable through the TTY Interface using a number of text-handling commands and options in the 4CAST language. Using run-time processing of text variables, the user's procedure may simulate a TTY dialogue with the SPC. Under special circumstances, a test sequence may require that the 4CAST procedure have access to SPC memory or to internal SPC processes. For this reason, two channels are provided which allow direct interaction between 4CAST and the SPC processor: the Nonresident Utility interface using the NUPIC, for performing such utility functions as setting matchers, and the Simulated Terminal Access Circuit (STAC), which allows 4CAST to momentarily halt the SPC, allowing the gathering of internal status or progress data, or the reinitialization of large blocks of memory. Additional features of the 4CAST language and Run-Time System provide for arithmetic functions, command execution control, timing facilities, and data gathering and handling control.

Because of the programmable nature of 4CAST test procedures, changes may be made quickly and easily, allowing test designers to keep pace with the often rapid evolution of the software system under test. An easily manageable administration system for 4CAST tests permits the reapplication of all, or certain subsets, of the existing tests to subsequent issues or generics of the software. For function testing, system integration testing, and regression testing of CCIS software, 4CAST provides an important facility for the generation and application of tests.

VI. OFF-LINE HARDWARE TEST TOOLS

Three categories of testing necessitated the development of off-line test systems for the new electronic peripherals developed for CCIS. These categories are:

(*i*) Laboratory testing of prototype hardware by the circuit designer.

(*ii*) Preliminary testing of diagnostic software against prototype hardware.

(*iii*) Manufacturing testing of standard production hardware.

The peripherals for which this capability was developed are the No. 4A, No. 4 ESS, and No. 1 ESS Terminal Groups, the No. 4A Distributor and Scanner, and the No. 4A/No. 4 ESS and No. 1 ESS terminal units.[3] With the exception of the latter two units, these peripherals share a common characteristic—they are controlled by commands from stored program processors via well-defined bus structures. This characteristic, plus the need for interactive testing and access to large, computer-generated data bases, indicated a computer-controlled system with input media compatible with the LAMP-generated data bases and output interfaces that simulate either the SPC No. 1A,[10] the No. 1A ESS,[11] or the No. 1 ESS[12] processor peripheral bus structures.

In general, each test system is configured as shown in Fig. 7. A minicomputer controls the application of tests to the peripheral under test and compares the peripheral's response with the expected response. The bus interface, or simulator, generates signals of the level and duration defined for the processor bus structure being simulated. Manual control is provided to allow the test engineer to generate special tests which may not exist in the computer-generated test file.

Test files for each peripheral are typically derived from the LAMP simulation data base created during the development of diagnostic programs. As a consequence, the diagnostic information is subjected to an early test against prototype hardware. Once they are generated and resident in the minicomputer, a test monitor program allows access to single tests, groups of tests, or phases, allows repetitive application of a single test or phase in a loop, and provides for on-line editing of the test

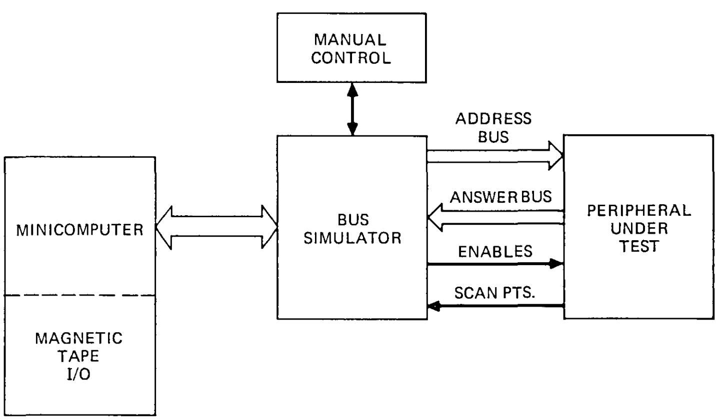

Fig. 7—Test system general configuration.

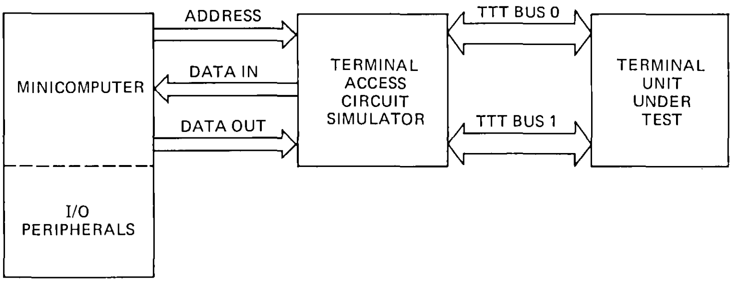

Fig. 8—Terminal unit test system configuration.

file. Tests for circuits not simulated or tests written for the manufacturing testing environment may be run under control of the monitor in conjunction with the computer-generated file.

In the case of the terminal unit test systems, rather than the processor bus structure being simulated, the Terminal Access Controller (CONT)[3] or Terminal Access Circuit (TAC)[3] interface is modeled. Figure 8 illustrates the general test system configuration for these units. The simulation data bases in this case are translated into TAC- or CONT-to-terminal operation codes and data, and the terminal responses are compared by the minicomputer with those predicted by the simulation.

The off-line test system hardware and software designs also provide flexible and efficient tools with which Western Electric is able to conduct manufacturing tests on the respective peripheral frames.

Off-line facilities are also provided for the test and evaluation of individual circuit pack designs, and for testing frames and units at extremes of temperature and humidity.

VII. CONCLUSION

From early design analysis through system integration and manufacturing tests, support tools provided an environment for the efficient and productive development of each of the components comprising the toll CCIS switching and signaling systems. As the development of new features is undertaken to exploit the flexibility and potential of the CCIS network, support systems will be relied upon more heavily to assist in the administration and testing of new designs. Advancing technology in the field of hardware and software support systems, as well as experience gained during initial CCIS development, will enable us to keep pace with this demand for increased development support capability.

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Common Channel Interoffice Signaling:

Field Implementation

By R. S. LITTLE

(Manuscript received May 7, 1977)

This article reviews the Bell System domestic toll CCIS *introduction plan and summarizes the early stages of this field implementation. Establishment of the first two signaling regions, installation and cutover of the first two new* CCIS *toll switching offices, and the first retrofit of* CCIS *to an existing office are each described. Emphasis is placed on discussion of the installation sequence and special test methods developed for adding the* CCIS *feature to in-service switching offices in an efficient and reliable manner.*

I. INTRODUCTION

Domestic CCIS will extend eventually to most SPC-type switching offices in the DDD network. The implementation plan[1] concentrates first on the toll portion of the network in order to realize the benefits of CCIS as soon as possible. Quasi-associated signaling is being used to form the initial domestic CCIS network.[2] This is a simple dual-level signaling network with ten regions corresponding geographically to the ten regions of the DDD message network. Each region has a Signal Transfer Point (STP), duplicated for reliability, which has signaling links to every other STP and to every CCIS-equipped Switching Office (SO) in its region.

Since the basic topological element of this signaling network is a "quad" consisting of the two (mate) STPs in one region fully interconnected with the STP pair of another signaling region, and since construction of a full quad of laboratory STP entities would be impractical, the first two pairs of field STPs were scheduled to serve also as a test vehicle for system design verification. This initial quad consists of STPs at Indianapolis and Omaha for the Norway region and at Dallas and Oklahoma City for the Dallas region. As noted in Ref. 2, these STPs were derived from existing toll crossbar Electronic Translator System (ETS) offices which must remain in service switching conventional SF/MF traffic while the STP feature was being installed and tested. Therefore, this initial quad served also to verify the engineering, data compilation, installation and test methods developed jointly by AT&T, Bell Labs and Western Electric.

Whereas the signal transfer function of an STP is entirely unrelated to any trunk switching activity that the host SPC processor[3] may also be directing, the signal processing function in every CCIS SO is quite intimately related to its trunk switching function. For this reason the first two CCIS SO implementation sites were both new office installations where the basic system design could be verified without risk to other (nonexistent) service on the system. Both available major Bell System toll switching system types were represented: No. 4A toll crossbar (4A) ETS[4] at Madison, Wisconsin, and No. 4 ESS[5] at Chicago. These offices are in the Norway region, so each has signaling links to the Indianapolis and Omaha STPs.

While the Chicago entity was the first No. 4 ESS (4ESS) in service and all such new offices will have the CCIS feature, the Madison entity is likely to be the last new toll crossbar installation and all subsequent toll crossbar CCIS applications will consequently involve retrofit of the CCIS feature to live offices. Therefore it was necessary in the toll crossbar application to also verify proposed retrofit procedures at some existing ETS site. Waukesha, Wisconsin was that site, which is also in the Norway region.

Starting with inaugural CCIS service between Madison and Chicago on May 15, 1976, the CCIS network had grown in six months to include six STPs and six SOs shown in Fig. 1, and reached triple this size within the first full year of CCIS service.

The following sections of this article describe the initial STP quad and SO implementations, with emphasis on the installation sequence and special test methods developed to assure smooth introduction of CCIS service to the domestic toll network.

II. INITIAL STP QUAD IMPLEMENTATION

2.1 Overall description

Indianapolis was selected as the initial application site for STP implementation. The other three members of the initial quad were scheduled to follow the lead set at Indianapolis, but to lag by three weeks in order to facilitate incorporation of any minor procedural modifications deemed advisable from the Indianapolis experience. The major sequential steps in the modification of an ETS office to become an STP are summarized in Fig. 2. Unlike most commercial data processing systems which can be temporarily shut down for periodic maintenance and al-

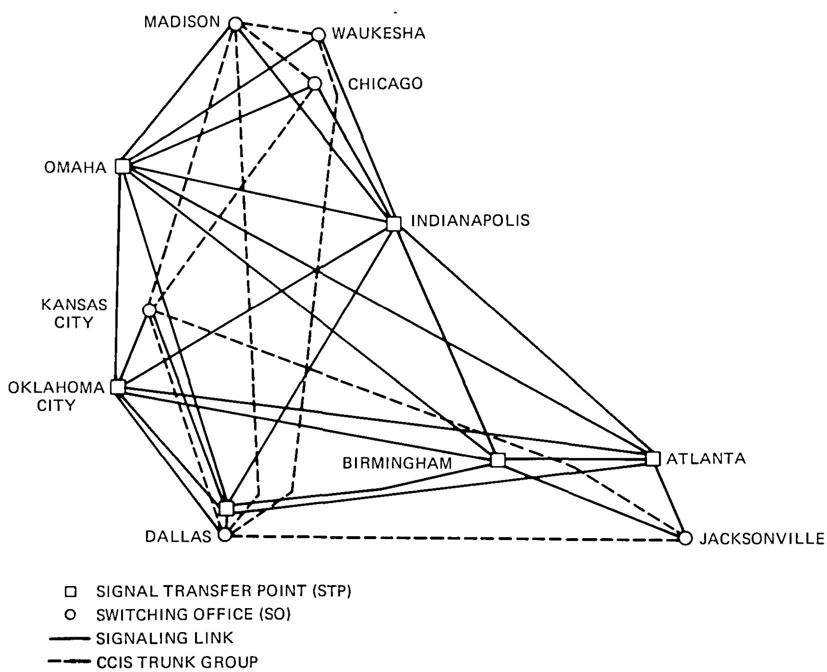

Fig. 1—CCIS network at year-end 1976.

teration, the toll switching systems of the DDD network are required to provide continuous real-time service. Therefore, special conversion and growth procedures are developed to facilitate system modification and to reduce the risk of service impairment to a practicable minimum.

2.1.1 STP candidate selection

An important consideration in STP selection is signaling network security. An STP candidate should be served by at least four physically independent transmission routes for most reliable interconnection of the signaling network, and an STP should be geographically remote enough from its mate that the likelihood of any single catastrophe affecting both STPs is very small.

Each of the ten regions has at least two ETS offices which meet these criteria. Each of the twenty initial STP sites is therefore already equipped with the necessary basic SPC processing system, specifically an ETS. To this nucleus must be added a number of significant features.

2.1.2 PBC retrofit

The first step beyond the basic ETS is addition of a feature known as Peripheral Bus Computer (PBC)[6] to enhance the plant and traffic

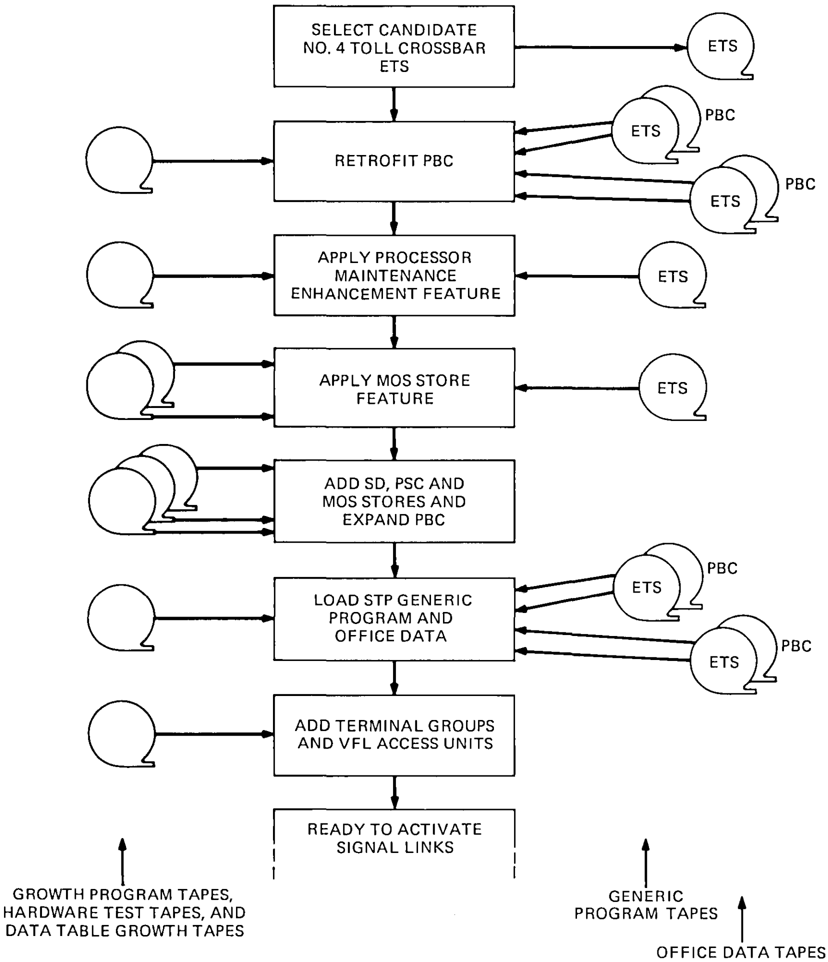

Fig. 2—STP implementation sequence.

measurement and administration functions of the office. This minicomputer adjunct communicates with the SPC processing system by means of an electronic interface known as the ac bus repeater, and obtains measurements from the toll crossbar equipment via two additional electromechanical interfaces called the traffic data converter and the traffic usage interface. Connections between the PBC and the electromechanical equipment of the toll crossbar system do not require any unusual installation treatment and will not be discussed further here. Two other aspects of the PBC retrofit operation are relevant and will be mentioned.

First, the connections between the PBC and the electronic nucleus of the ETS do require special care and are necessary to the STP and CCIS SO functions. These connections, consisting of insertion into the common duplicated peripheral unit address and answer busses and provision of certain dedicated control and status connections, are effected and verified with the aid of a peripheral unit growth program. This program is loaded as a temporary overlay during the PBC retrofit procedure and responds to input commands at the maintenance teletypewriter (TTY) to provide special time-shared test access to the new equipment while the original system continues to process calls in a simplex configuration. When the new connections and equipment have all been verified the growth program facilitates activation of this equipment by setting the appropriate system parameters and establishing the necessary software linkages. The growth program is removed by reloading the generic program.

The other significant aspect of PBC retrofit is the creation of the PBC data base and coordinated modification of the ETS data base to reflect the relocation of several plant and traffic functions from the ETS into the PBC. The normal "recent change" procedures for updating small amounts of ETS office data are not intended to handle such massive data reorganizations as are required during PBC retrofit. Instead an Office Data Recompile System (ODRS) is used to decompile the original ETS office data, merge this with new data owing to the PBC addition and recompile this in the new format appropriate to the ETS/PBC package. The ODRS operation is executed at a centralized data processing location on a general-purpose computer. The ODRS produces as output both printed documents for office record keeping purposes and magnetic tapes for conveying the recompiled data to the ETS/PBC site.

When the PBC equipment connections have been verified, the PBC is loaded with its program and data and the ETS is forced into simplex operation on the active store bus while the new ETS program and data are loaded into the standby store bus. After successfully comparing the newly loaded contents against a second magnetic tape copy, the ETS is forced into simplex operation on the new load and is subjected to a series of tests to verify basic system sanity. Upon satisfactory completion of these tests the ETS is returned to duplex operation on the new load.

2.1.3 Processor modifications

Processor modifications are required to improve system recovery capability and to permit addition of more economical Metal Oxide Semiconductor (MOS) program and data storage. After the processor modifications have been completed, actual store growth is possible. Since the system requires unique data tables for each store frame controller and for each store module, a special growth program is used to create these tables and to support the connection and verification of the new controllers to the existing store/processor subsystem.

Complete controller verification requires the presence of at least one memory module served by that controller, so growth of the first module on each frame is always part of the frame growth process. Up to five more modules can be added if more memory is required.

As with the peripheral unit address and answer busses, the store address and answer busses use parallel ac pulse communication over balanced and terminated pairs. A very important function of growth programs is the generation of bus pulse test patterns which facilitate oscilloscopic verification of bus connections since shorts, opens, misterminations, crosses, transpositions and reversals may occur during installation.

After all connections have been verified and the added store equipment has passed all diagnostic tests, the store growth program serves two additional functions. First, the contents of each store module are initialized to the values pertinent to spare memory. Up to this point all store growth activities have been performed on only one unit at a time. Final activation, however, is done on a duplex pair of modules by directing the growth program to set the equippage bits in active system memory for this new pair of stores.

2.1.4 Additional STP equipment

The STP also requires growth of another Signal Distributor (SD1) frame and another Peripheral Scanner (PSC4) frame to augment the distribute and scan capability of the basic ETS configuration. An extension of the same peripheral unit growth program that is used during the PBC retrofit is used to support SD1 and PSC4 connection, verification and activation.

Growth of the signaling terminal equipment is predicated upon first having loaded the STP generic program. Each group of signaling terminals is served by a pair of Terminal Access Circuits (TACs) which must be connected into the peripheral address and answer busses. A further extension of the peripheral unit growth program supports TAC growth and provides a means to check installation of each terminal unit and each associated Voice Frequency Link (VFL) access circuit. Equipped signaling terminals are left in the diagnostic state for future activation under the STP generic program whenever a signaling link is to be placed into service.

2.1.5 STP generic program activation

Upon completion of store, PSC4 and SD1 growth, the system is ready to receive the STP generic program and office data. The STP program supercedes the ETS program and the STP office data tape is loaded to augment existing office data. Since the STP function is an addition to the regular ETS trunk switching function, rather than an integral part of it, the STP software is designed to permit retention of the existing ETS office data intact, thereby avoiding a decompile/recompile operation.

Introduction of the STP function also entails a coordinated load of a new generic program and additional data into the PBC; however, no extraordinary procedures are necessary.

2.2 VFL layout and characterization

Careful selection of transmission facilities for VFLs is essential to the reliability of the signaling network. Circuit layouts for the initial signaling links were provided by the CCIS Network Administration Center (CNAC) several months earlier than normal so that these VFLs could be characterized prior to signaling link activation. Normal analog measurements of loss and noise parameters were recorded periodically for possible future correlation with signaling link performance. Experience shows the circuit layout procedures are effective in securing diverse routes, and that the transmission characteristics are comfortably within the system design objectives.

2.3 Signaling link activation

A signaling link consists of a VFL and terminal equipment at each end of the VFL. This terminal equipment can, under program control, be operated in a self-looped mode which does not include the VFL, a remote-looped mode which does not include the distant terminal, or a fully duplex synchronized mode which is the normal service configuration. The signaling link activation procedure requires that each end of the link pass a series of local tests in the self-looped mode. The office which has been assigned maintenance control of the link advances the link through the remote-looped mode into the normal duplex signaling configuration, whereupon the two terminals automatically achieve synchronization and the signaling link activation is complete.

2.4 Quad security verification

The first signaling links activated at the Indianapolis STP were temporarily connected to the development laboratory equipment[7] in Columbus, Ohio. During this phase of CCIS implementation the laboratory served many roles, simulating the remainder of the CCIS network in support of basic tests at Indianapolis. As the Omaha, Dallas, and Oklahoma City STPs became available the temporary VFLs from Indianapolis to Columbus were replaced by the standard VFLs from Indianapolis to those other STPs.

Prior to activating any links to the first CCIS switching offices this signaling quad was deliberately faulted to verify signaling security. Link failures as well as complete STP failures were simulated and signaling integrity was continuously maintained by virtue of network redundancy. Access links to the Chicago and Madison CCIS switching offices from the Indianapolis and Omaha STPs were then activated and proper responses to access link troubles and to simulated switching office failures were verified.

2.5 Signaling network growth

Signaling link activation for any new CCIS SO should precede CCIS service to permit pre-cutover interoffice testing of CCIS trunks. When a CCIS SO is the first in its region, as is the Jacksonville 4ESS, the pair of STPs for that region must first be added to the signaling network. This in turn means activating a new quad of signaling links from the new STP pair to every existing STP pair. The installation and activation methods are the same as proven during implementation of the initial signaling quad.

When the tenth and final pair of STPs are activated in late 1977, each STP will require at least twenty CCIS terminals to establish the basic interregional signaling network. When the signaling capacity of one signaling link quad is reached, corresponding roughly to six thousand CCIS trunks between the switching offices in those two regions, it becomes necessary to activate another quad of signaling links between the associated STPs.

III. INITIAL SWITCHING OFFICE IMPLEMENTATION

3.1 "Chicago 7" first 4ESS installation

The first 4ESS installation, known as Chicago 7, entered regular service on January 17, 1976. As discussed in Ref. 5, the CCIS SO feature is an inherent part of every 4ESS, so no retrofit procedure is required.

The initial STP network was not available in January, so Chicago 7 cut over with its signaling terminals in the self-looped mode. During the next three months the VFLs to Indianapolis and Omaha and the CCIS trunk facilities to Madison were aligned and tested. In March, when the STPs were ready to begin access link tests, the VFL-to-terminal connections were completed and these signaling links were activated. In April, when the Madison CCIS SO was ready to begin interoffice CCIS trunk tests, the trunk facility-to-trunk unit connections were completed and preservice tests were performed.

3.2 "Madison 2" 4A installation

As mentioned in the introduction and further discussed in Ref. 4, the installation of the new 4A toll crossbar office, known as Madison 2, provided the last "nonpenalty" environment in which to prove the integrity of the 4A CCIS SO design.

Although many new 4A/ETS installations have been initially equipped with the PBC, none other than Madison had the prerequisite processor maintenance improvements included in the equipment as shipped from the factory. With the prerequisite generic program in the system, the MOS memory feature was introduced and the transition generic program was loaded to support store growth.

Actual store growth at Madison 2 was completed without the security and assistance of formal store growth procedures. This successful departure from standard practice permitted an early version of the 4A CCIS SO generic program and preliminary office data to be loaded into Madison 2. As the SO generic program development progressed, successively more complete versions were loaded and verified.

Since new peripheral equipment, consisting of a Terminal Group (TG) and a pair of Distributor and Scanner (DAS)[8] frames, must be added to the peripheral address and answer busses of each 4A CCIS SO, and since standard growth procedures were not available in time to meet the Madison 2 schedule, special arrangements were made to pretest this equipment extensively prior to its connection into the peripheral busses. The existing PBC system was used to exercise the DAS and TG frames for off-system verification of these frames at Madison 2.

With the DAS frames on line, CCIS feature tests can get into full swing. At Madison 2 this phase of the installation allowed discovery of latent problems and permitted early determination of the root cause of these problems.

3.3 "Waukesha 2" 4A retrofit

The Waukesha 2 4A/ETS entered regular service in 1973. It is therefore a relatively new office with recent vintages of equipment. Its PBC has been in service since early 1975. These factors, plus its position as a sectional center in the Norway region, made it an excellent candidate as the initial 4A CCIS SO retrofit site. However, unlike Madison 2, the existing equipment did not already contain apparatus and wiring for the CCIS feature, nor did the basic SPC contain the improved maintenance feature. The most significant difference is that Waukesha 2 was in service. Therefore, whereas the Madison 2 experience had proven in most of the 4A CCIS SO design and manufacture, the role of Waukesha 2 was to prove in the retrofit procedures.

3.3.1 PBC retrofit and 4A CCIS modifications

The major sequential steps in the modification of an ETS machine to become a CCIS SO are summarized in Fig. 3. Most 4A/ETS offices which

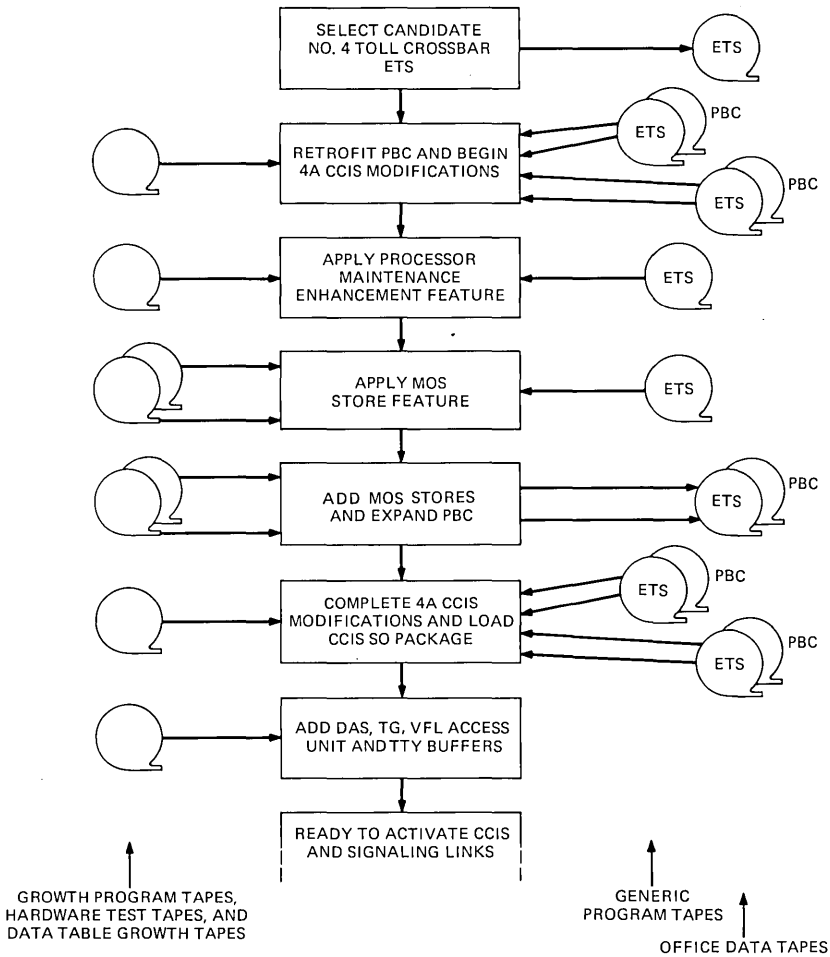

Fig. 3—No. 4A CCIS SO implementation sequence.

are candidates for the CCIS SO feature are also independently candidates for the PBC and maintenance enhancement features by virtue of their expected service longevity. Several of these offices have already been retrofitted with the PBC. Many of the same 4A equipment frames which must be modified for the PBC feature will receive additional modification for the CCIS SO feature. Therefore, recent and future PBC retrofit jobs at CCIS SO sites include many of the 4A CCIS modifications in the same operation, which reduces the overall time required to implement the two features. In either case it is not feasible to verify the CCIS capability of the modified 4A equipment until later in the retrofit sequence. Instead it is only practical to verify that the CCIS modifications do not interfere with conventional 4A/ETS operation before returning each modified equipment unit to service.

Of all the equipment requiring modification during retrofit of the CCIS feature, the quantity and vintage of senders is most critical in determining the overall time required for a given CCIS SO retrofit job, and the moderate number and recent manufacture of senders in the Waukesha 2 office served to minimize the modification interval.

3.3.2 Maintenance enhancement and MOS store features

Application of the processor modifications, growth of the stores and expansion of the PBC configuration in each CCIS SO retrofit situation are nearly identical to those steps of the STP retrofit operation (see Section 2.1.3). The only difference is in the greater number of store modules and the greater amount of PBC core storage added for the CCIS SO application.

3.3.3 CCIS SO data compilation

Once the store modules are activated, a substantial divergence occurs between the SO and STP retrofit sequences. The 4A/ETS office data additions and modifications needed to support the CCIS SO feature are so extensive as to require a decompile/recompile operation analogous to that provided by ODRS for PBC retrofit (see Section 2.1.2). An entirely new and more powerful Integrated Data Management System (IDMS) has been developed to provide this function. IDMS is able to decompile existing office data, merge these data with new CCIS SO information and create a recompiled set of data pertinent to the ultimate retrofitted configuration of the office equipment and traffic routing. Since Madison 2 was an entirely new office with no existing data to decompile, Waukesha 2 was the first IDMS application.

New information is provided to IDMS via a questionnaire containing a series of formcodes which are filled out by the telephone company planners in conjunction with the Western Electric line engineers. These formcodes are similar to, but much more extensive than, the formcodes which are filled out to specify the additional CCIS data required for an STP office. Preplanning is an important aspect of any office data compilation, to reduce or preclude the need for recent change activity as trunking to other switching offices is added or reassigned during the foreseeable future. Therefore, formcodes are filled out to include data for at least two years, as an objective, of preplanned trunk additions and rearrangements.

Existing office data are provided to IDMS via a magnetic tape copy of those areas of system memory containing office data. A preliminary audit dump of existing office data is submitted to IDMS in order to obtain an indication of any incompatibilities between the formcode entries and the existing office data. Any such problems are resolved while the store modifications are being made. As soon as the new stores are activated, the final dump is made and final IDMS processing is performed. This final processing typically requires several iterations to resolve data errors, many of which are detected by IDMS itself through a series of reasonableness tests. The new office data tapes and documentation are delivered to the CCIS SO job site for further checking. This final checking is the opportunity to prepare recent changes to correct minor errors in the recompiled data, and to reprepare any recent changes which have been entered into the existing office data base after the final dump was taken. These recent changes are arranged for entry into the machine in decreasing order of importance to proper service.

3.3.4 CCIS SO software load

With all of the 4A common control modifications completed, the recompiled "ETS" and PBC data tapes ready to load and the most critical recent changes ready to be entered upon this new load, consider for a moment the matter of program compatibility. Whereas ETS call progress is controlled mainly in hardware, CCIS SO call progress is controlled largely in software, even for calls not involving CCIS trunks. The DAS equipment (mentioned in Section 3.2 and described more completely in Refs. 4 and 8), which provides the interface necessary to obtain software control of the 4A call processing hardware, is as alien to the pre-CCIS generic programs as it is vital to the CCIS SO generic program. This apparent dilemma is solved by transcending through a series of four intermediate program versions which support gradual metamorphosis of the critical hardware from ETS operation to CCIS operation.

The first intermediate program introduced at Waukesha allowed call processing to continue in the hardware-controlled ETS manner, but using the CCIS SO data base. The main function of this program version was to maintain the integrity of switching service while the new "ETS" and PBC data bases were brought up to date and verified. It also allowed, via a compatible growth overlay program, controlled connection, verification and activation of the new CCIS SO peripheral units. These are the DAS frames, the TG with typically two terminal units and one VFL access unit, and an additional TTY buffer frame or two for I/O channels associated with CCIS-equipped Integrated Manual Test Frames (IMTFs) for interoffice CCIS trunk testing and status reporting.

Upon activation of DAS frames 0 and 1, which terminate the scan and distribute leads for all common control equipment, the second intermediate program was loaded. This version allowed 4A senders to be tested on a demand basis to verify their ability to properly report seizure and release to the processor via the DAS. These were the first of many tests to verify that the CCIS modifications previously installed in the 4A hardware actually provided the CCIS function. This step afforded an important opportunity not only to correct any problems affecting DAS scanning of senders prior to committing service calls to such control, but also a further chance for office personnel to become accustomed to operation and maintenance of this new DAS equipment.

Successful completion of the above tests allowed advancement to the third intermediate program, which expected sender DAS reports for all calls, not just test calls. Thereafter, DAS frames 0 and 1 were an integral and vital part of the system for all call processing. Their activation also allowed subsequent activation of the TG equipment and of any additional DAS frames which might have been needed to serve CCIS trunks beyond the capacity of the first two frames. The modest size, recent vintage and careful installation of the Waukesha 2 system permitted rapid progress to be made through the first three versions of intermediate program. Activation of the TG equipment was deferred until closer to the time that signaling links to the home STPs were due for service in support of interoffice CCIS trunk testing.

The Decoder-Marker Test (DMT) frame and associated trouble recorder were retrofitted with the CCIS feature. At this point the fourth intermediate program was loaded; then it was only necessary to rearrange a few cross-connections in order to activate the CCIS mode of testing. This rearrangement then permitted verification of CCIS capability previously installed in the decoder channels. These manual tests performed at the DMT frame paved the way for activation of the CCIS feature in the markers. The first intertoll marker was removed from service, its cross-connections were rearranged for CCIS operation, it was subjected to a series of tests from the DMT frame and it was returned to service. Upon similar conversion of the remaining intertoll and toll completing markers, the transformation of an ETS office into a CCIS SO is virtually complete as far as conventional trunk call processing is concerned. What remains to be proven before any CCIS trunks may be activated is that all senders, transceivers and outpulsers or modified sender/outpulsers are capable of serving CCIS trunks.

3.3.5 Sender test automation

Key to CCIS testing of senders, outpulsers, sender/outpulsers and transceivers is automation of the Incoming Sender and Register Test (ISRT) frame. With the automated ISRT frame, referred to as the ASRT frame, under program control it becomes possible to finish the verification of sender CCIS modifications and to begin the outpulser and transceiver tests. Completion of these tests is necessary prior to allowing any CCIS traffic into the office, although pre-cutover CCIS trunk tests can be performed as soon as a few of the outpulsers and transceivers have been verified.

3.3.6 CCIS trunk testing

All CCIS trunks terminating on the Waukesha 2 system are new plug-in trunk relay units served by a new outpulser group. Access to these outpulsers is provided by the outpulser link and outpulser link controller. The link controllers are tested with the new Outpulser Link Controller Test (OLCT) frame. These tests are performed soon after marker tests are completed. Thus, when the ASRT frame is ready for CCIS testing and a few outpulsers and transceivers have been verified, the CCIS Intraoffice Trunk Test (CIOT) frame can be verified and used to exercise the CCIS trunk equipment. CIOT tests can be performed on the entire "drop" if the trunk relay unit is actually equipped, or simply on the cabling to the empty socket and associated outpulser link termination on the trunk frame if plug-in equippage has been deferred. These CIOT tests can verify the incoming and outgoing modes of trunk seizure, including both hardware and software in the process.

When circuit orders for the CCIS trunk circuits have been worked, the IMTF is utilized to complete the interoffice trunk lineup, verification and activation. An initial trunk query entered at the IMTF will verify compatibility of assignment data at both CCIS SOs interconnected by a given trunk. Transmission characteristics are measured and final adjustments are made to assure standard levels throughout each trunk circuit. The office which has maintenance control of a given trunk group has the final pleasure of activating each trunk via an IMTF keyboard message. Periodically thereafter these trunks are routinely tested for proper operational and transmission characteristics by either the new Outgoing Trunk Testing System (OTTS) as at Madison 2 or the CCIS-modified Automatic Directed Outgoing Intertoll Trunk Test (ADOIT) frame as at Waukesha 2. Additionally the CIOT is scheduled under system program control to perform a quick continuity check on CCIS trunks immediately prior to periods of expected heavy traffic and to check the operational features of CCIS trunks during light traffic periods.

Thus has the Waukesha 2 4A/ETS office been retrofitted with the CCIS SO feature. Not only was this accomplished without disruption to its continuous message switching service, but also it was done concurrently with the completion of design development of such major items as IDMS and ASRT. Most importantly the procedures for applying CCIS to a working 4A/ETS have been demonstrated and refined into standards which will permit rapid deployment of CCIS into the DDD toll network.

3.4 Other early CCIS sites

Beyond the initial STP quad and the three CCIS offices which have just been discussed, Fig. 1 shows another pair of STPs and three more switching offices entering CCIS service in 1976. The three SOs are each new 4ESS installations in Kansas City, Jacksonville, and Dallas. Each of these new entities is capable of CCIS operation, but only Dallas lies in a region with STPs already available. The Rockdale region STPs at Atlanta and Birmingham were added to the signaling network to serve the Jacksonville CCIS SO in 1976 and several more new 4ESS and retrofit 4A/ETS offices in 1977 and following years. However, the St. Louis region STPs would have only the Kansas City 4ESS to serve until 1978, so signaling for the Kansas City SO is being temporarily handled by the Dallas region STPs. When the St. Louis region STPs at St. Louis and Kansas City are placed in service and connected to a new pair of terminals in the Kansas City SO, translation instructions at all other STPs will be changed to direct Kansas City SO signals to the St. Louis region STPs in normal fashion. The existing signaling links between the Kansas City SO and the Dallas region STPs will then be deactivated and the associated terminals held for future reassignment.

In Section 3.3.4 it was noted that the 4A/ETS CCIS retrofit at Waukesha utilized a series of four program load steps to achieve the transition from non-CCIS to CCIS operation, and that automation of the ISRT was perhaps the fifth step of this process. It is desirable to have ASRT available much earlier in the retrofit sequence in order to expedite pre- and post-modification testing of senders. A non-CCIS software package capable of driving the ASRT frame is being developed. Later CCIS SO retrofit jobs will utilize this approach to support ISRT automation prior to application of the MOS store feature.

The other significant difference in procedure at later 4A/ETS CCIS SO retrofit jobs is in the transition software. The Anaheim and Gardena offices in California (which provided initial CCIS service in February, 1977) have superimposed a transition overlay program upon the CCIS SO generic program at the time of initial load. This overlay program causes the main program to function as the first version in the Waukesha sequence. It also contains a small control routine which responds to TTY commands to advance the mode of operation to the next version, and so forth, without requiring a reload at each step. This procedural improvement not only speeds the transition and lessens the risk of trouble, but also materially reduces the number of magnetic tapes that must be delivered to the job, kept properly in sequence during the transition, and maintained as future issues of the system are developed.

IV. INITIAL CCIS SERVICE

4.1 Chicago 7—Madison 2 trunk service

On May 15, 1976, the traffic routing instructions at Chicago 7 and Madison 2 were altered to offer regular traffic to the CCIS trunks between these offices. Overflow traffic would be offered to the regular existing routes for calls between these two areas. Since Chicago 7 is a high volume tandem switching office not normally involved in traffic with the Madison area, these conditions were artificially induced for test purposes.

Throughout the initial months of CCIS service the signaling network performance has been excellent. No CCIS traffic has been affected by any signaling link outages, nor by an entire STP outage which occurred when the host Indianapolis switching office failed, leaving the mate STP at Omaha to carry the full signaling load. Moreover, the rate and extent of signaling link interruptions due to all causes is comfortably below the level for which the signaling network has been designed.

4.2 Expansion to other switching offices

At least two aspects of extending CCIS to other switching offices which should be mentioned are signaling and trunking. Since CNAC has been able to preplan the assignment of terminals and bands for two years from the date of service, the STPs already contain the data and most of the terminal hardware necessary to serve all needs into 1978. In such cases it is merely necessary to work the circuit orders for the new VFLs and activate the terminals associated with signaling links for each new switching office as that office prepares for CCIS service.

Provision of CCIS trunks for expansion of the CCIS network has more alternatives. The simplest of these, conceptually, is through completely new "drops" at each switching office and new voice transmission channels to interconnect them. This approach is most likely to be used in growth situations. At the opposite extreme, existing SF/MF trunks may be modified for CCIS operation in place while the traffic group remains in service. Various combinations of these approaches are most likely to be used in nongrowth situations. A special routing change technique has been developed to permit concurrent access to both the "old" SF/MF route and the "new" CCIS route during conversion. Upon completion of the conversion, only the CCIS route remains linked into the routing patterns, and the memory space previously occupied by SF/MF trunk data may be reused.

V. CONCLUSION

The initial CCIS network is successfully in service. The basic CCIS system design and new office installation methods have been verified. Retrofit procedures for STPs and 4A CCIS switching offices are practicable. The domestic CCIS design meets its objectives and additional installations of 4ESS and retrofits of 4A offices are in progress. The rapid deployment necessary for effectively realizing the potential of CCIS presents a real logistics challenge. At the same time, CCIS implementation opens vast new horizons which help assure a healthy entry into the second century of telecommunications service.

VI. ACKNOWLEDGMENTS

The design and development reported in this article are a result of combined effort by many people of the Bell System working toward a joint goal of introducing and deploying CCIS in the DDD network at the earliest practical time. To single out individuals would unintentionally lessen the contributions of others; to omit recognition of the teamwork would be to deny the achievement of CCIS.

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