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***Common Channel Interoffice Signaling:***

# History and Description of a New Signaling System

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*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

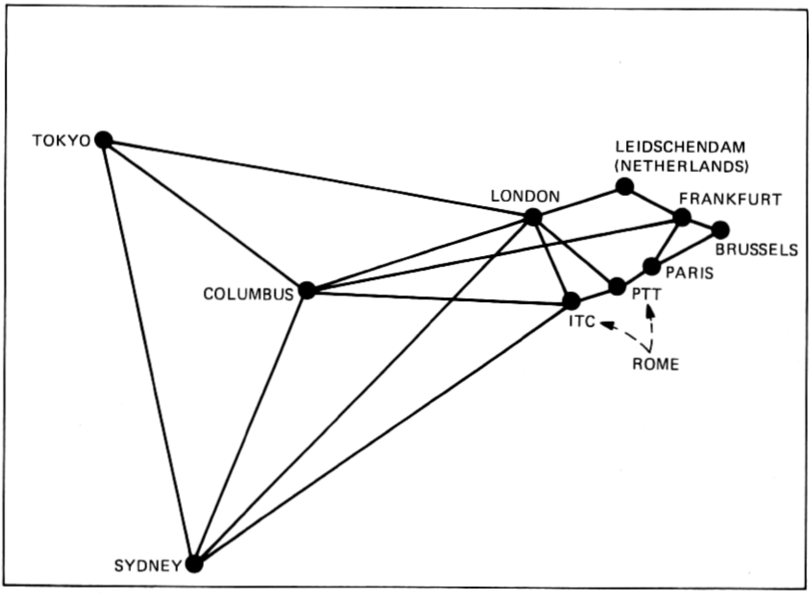

Fig. 1—CCITT system No. 6 total field trial network, phases B and C.

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

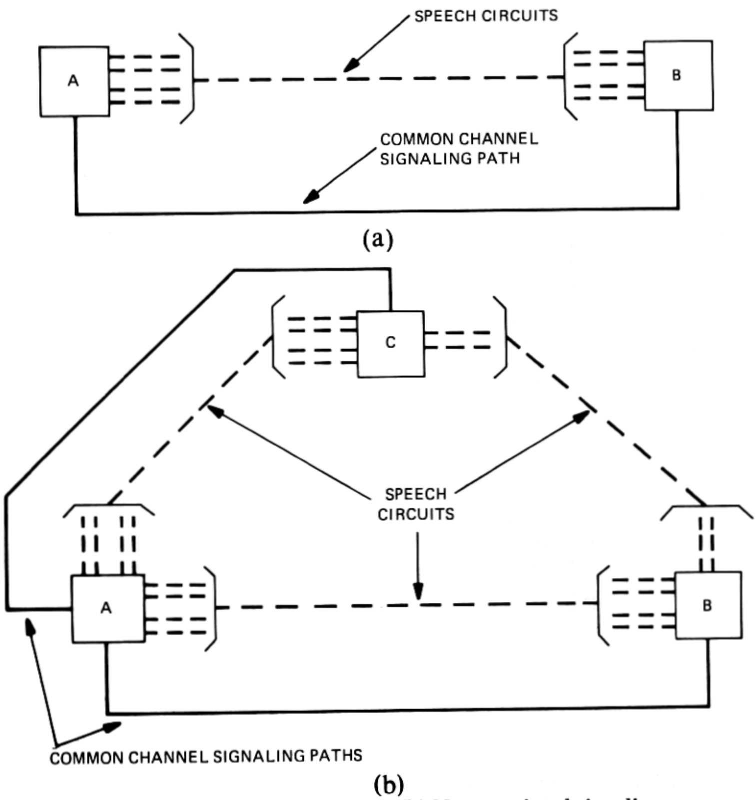


Fig. 2—(a) Associated signaling. (b) Nonassociated signaling.

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-

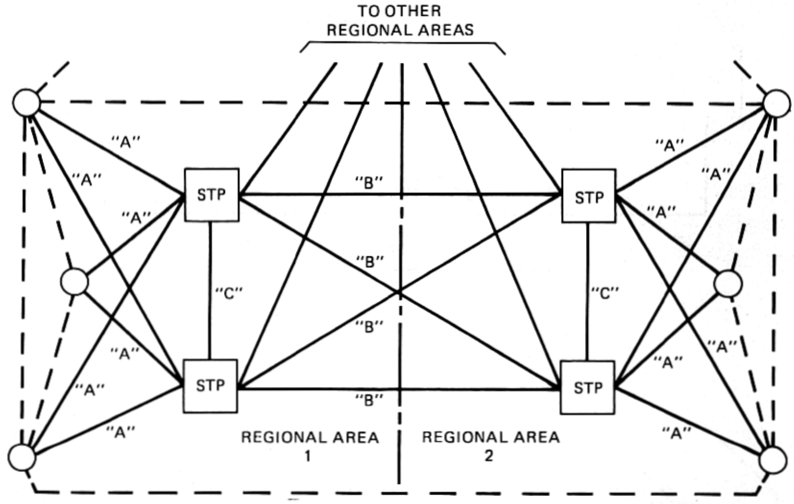


Fig. 3—User offices connected to STP quad.

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

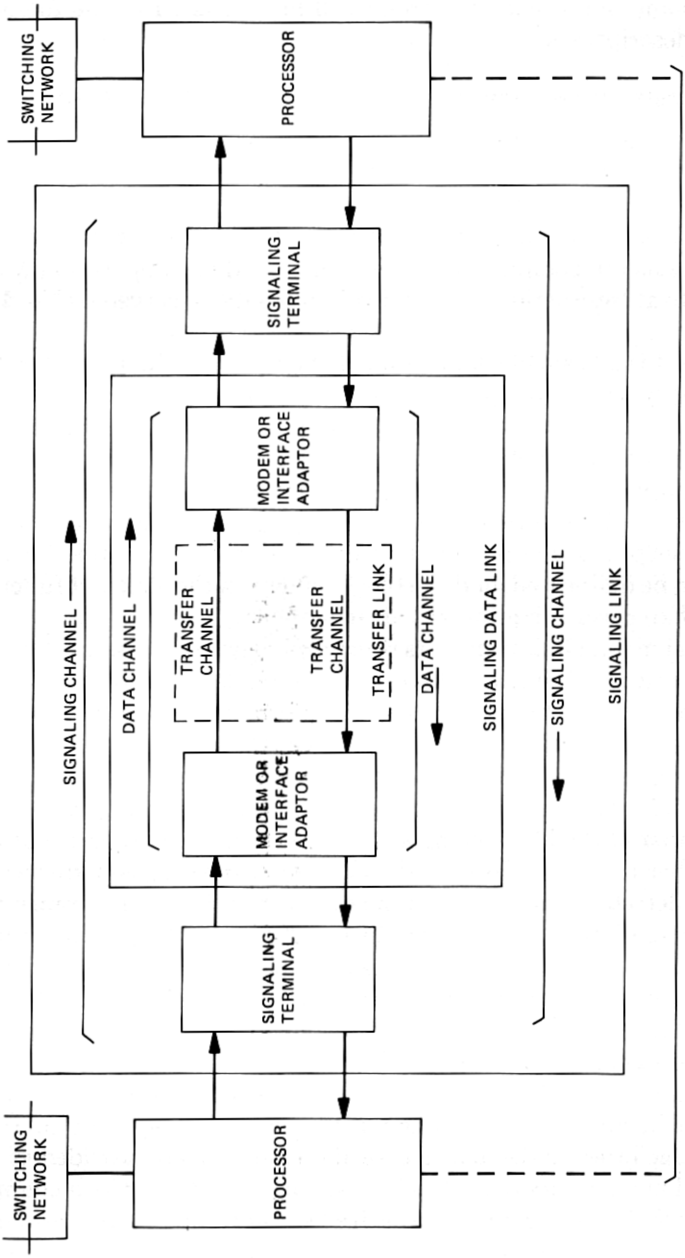


Fig. 4—Basic block diagram of the Common Channel Interoffice Signaling System.

## 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.

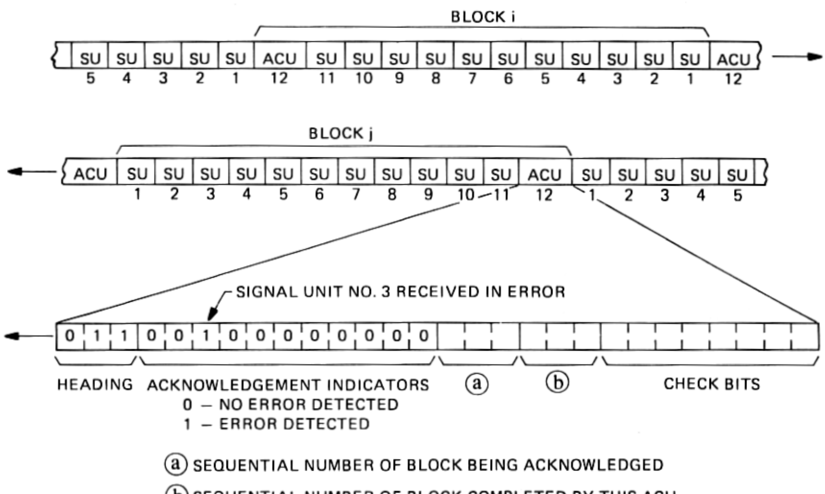


Fig. 5—Block structure, CCIS SUs and ACU.

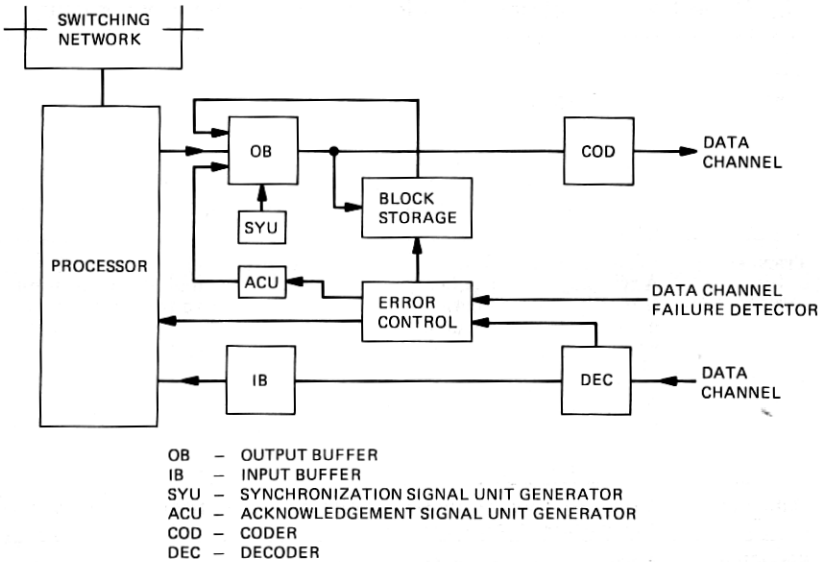


**Fig. 6—Functional block diagram of a CCIS terminal.**

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.

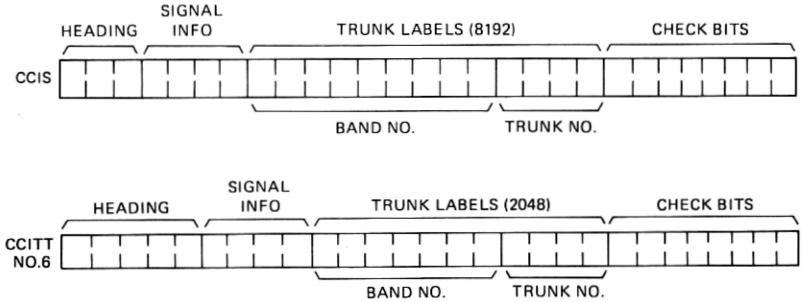


Fig. 7—Lone Signal Unit (LSU) format.

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

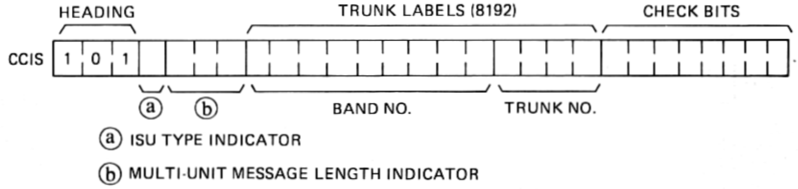


Fig. 8—Initial Signal Unit (ISU) format.

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—<br>Telephone signals<br>Signaling system control signals<br>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<br>01001<br>01010<br>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<br>10010<br>10011<br>10100<br>10101<br>10110<br>10111 | Subsequent address message (one-unit message or multiunit message) |
| 11000<br>111001<br>11010<br>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<br>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.

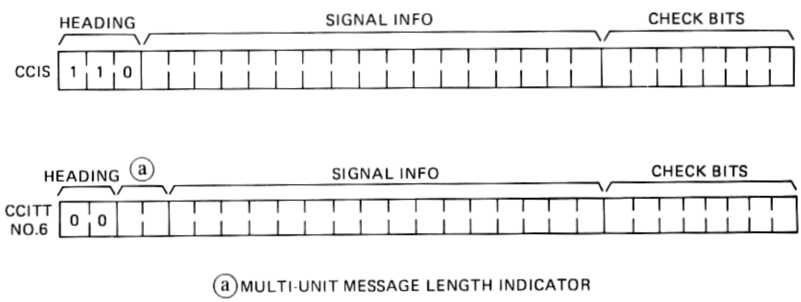


Fig. 9—Subsequent Signal Unit (SSU) format.

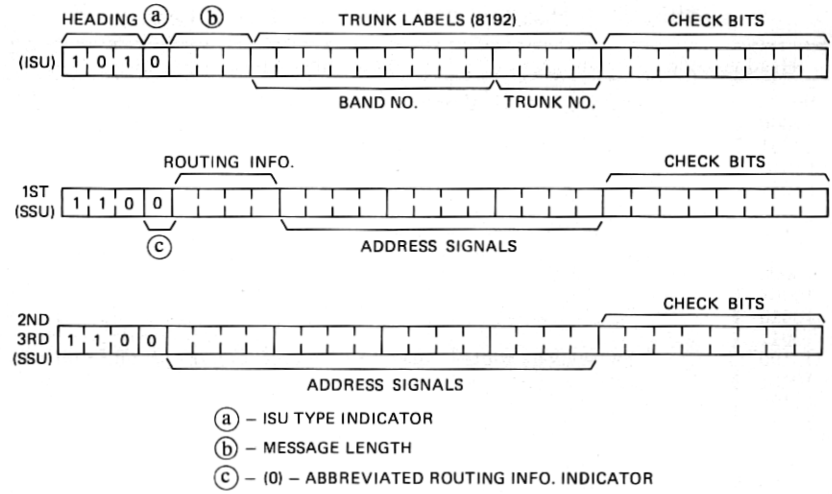


Fig. 10—CCIS Initial Address Message (IAM) with abbreviated routing information.

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

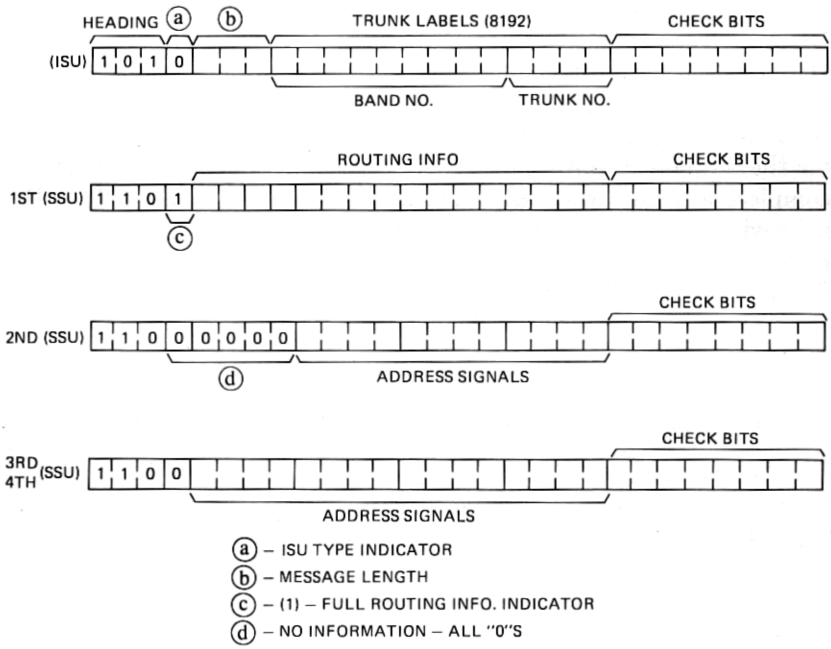


Fig. 11—CCIS Initial Address Message (IAM) with full routing information.

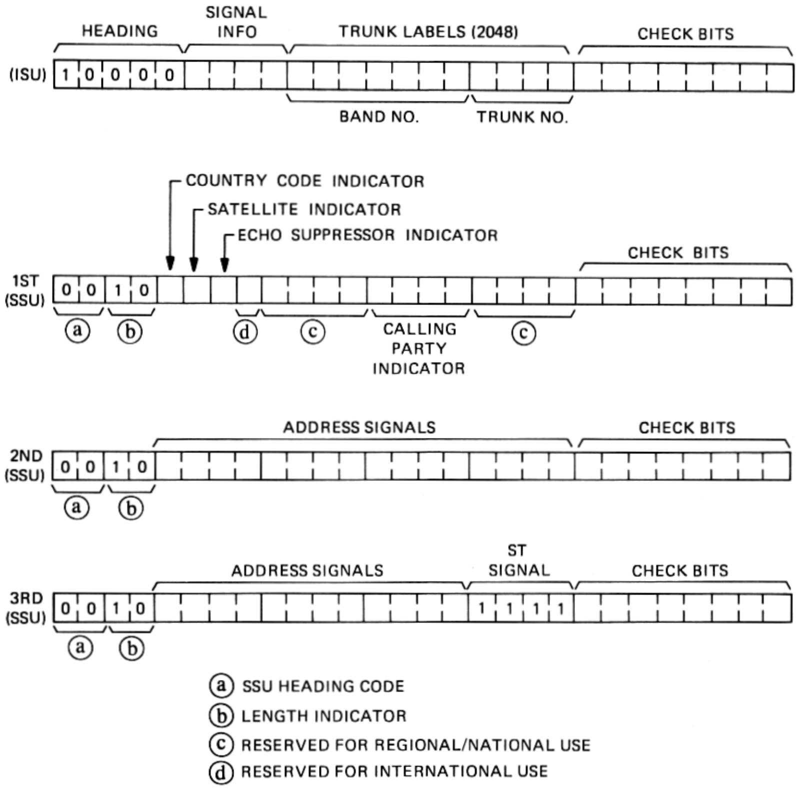


Fig. 12—CCITT-6 Initial Address Message (IAM).

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

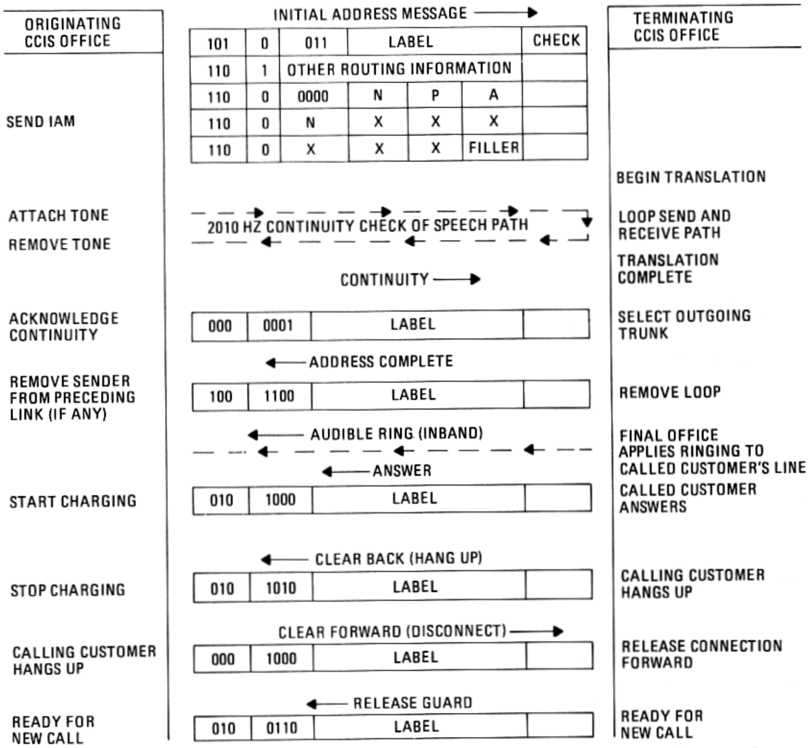


Fig. 13—CCIS signaling for a 10-digit call.

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

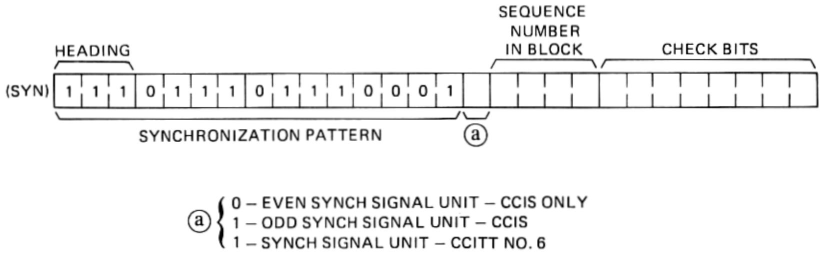


Fig. 14—Synchronization signal unit.

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 $\leq 8$ 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 $\geq 10$ 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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