10.4.3 MAU–DTE Electrical Characteristics. If the AUI is exposed, the electrical characteristics for the driver and receiver components connected between the DTE Physical Layer circuitry and the MAU shall be identical with those as specified in Section 7 of this standard.

10.5 Characteristics of Coaxial Cable System. The trunk cable is of constant impedance, coaxial construction. It is terminated at each of the two ends by a terminator (see 10.6.2), and provides the transmission path for connection of MAU devices. Coaxial cable connectors are used to make the connection from the cable to the terminators and between cable sections. The cable has various electrical and mechanical requirements that shall be met to ensure proper operation.

10.5.1 Coaxial Cable Electrical Parameters. The parameters specified in 10.5.1 are met by cable types RG 58 A/U or RG 58 C/U.

10.5.1.1 Characteristic Impedance. The average characteristic cable impedance shall be 50 ± 2 Ω. Periodic variations in impedance along a single piece of cable may be up to ±3 Ω sinusoidal, centered around the average value, with a period of less than 2 m.

10.5.1.2 Attenuation. The attenuation of a 185 m (600 ft) cable segment shall not exceed 8.5 dB measured at 10 MHz, or 6.0 dB measured at 5 MHz.

10.5.1.3 Velocity of Propagation. The minimum required velocity of propagation is 0.65 c.

10.5.1.4 Edge Jitter; Entire Segment without DTEs Attached. A coaxial cable segment meeting this specification shall exhibit edge jitter of no more than 8.0 ns in either direction at the receiving end when 185 m (600 ft) of the cable is terminated at both ends with terminators meeting the impedance requirements of 10.6.2.1 and is driven at one end with pseudorandom Manchester encoded binary data from a data generator that exhibits no more than 1.0 ns of edge jitter in either direction on half bit cells of exactly $1/2$ BT and whose output meets the specifications of 10.4.1.3, except that the rise time of the signal must be 30 ns + 0, – 2 ns, and no offset component in the output current is required. This test shall be conducted in a noise-free environment. The above specified component is not to introduce more than 7 ns of edge jitter into the system.

10.5.1.5 Transfer Impedance. The coaxial cable medium shall provide sufficient shielding capability to minimize its susceptibility to external noise and also to minimize the generation of interference by the medium and related signals. While the cable construction is not mandated, it is necessary to indicate a measure of performance expected from the cable component. A cable's EMC performance is determined, to a large extent, by the transfer impedance value of the cable.

The transfer impedance of the cable shall not exceed the values shown in Fig 10-6 as a function of frequency.

10.5.1.6 Cable DC Loop Resistance. The sum of the center conductor resistance plus the shield resistance measured at 20 °C shall not exceed 50 mΩ/m.

10.5.2 Coaxial Cable Physical Parameters

10.5.2.1 Mechanical Requirements. The cable used should be suitable for routing in various environments, including but not limited to, dropped ceilings, raised floors, and cable troughs as well as throughout open floor space. The jacket shall provide insulation between the cable sheath and any building structural metal. Also, the cable shall be capable of accepting coaxial cable connectors, described in 10.6. The cable shall conform to the following requirements.

10.5.2.1.1 General Construction

(1) The coaxial cable shall consist of a center conductor, dielectric, shield system, and overall insulating jacket.
(2) The coaxial cable shall be sufficiently flexible to support a bend radius of 5 cm.

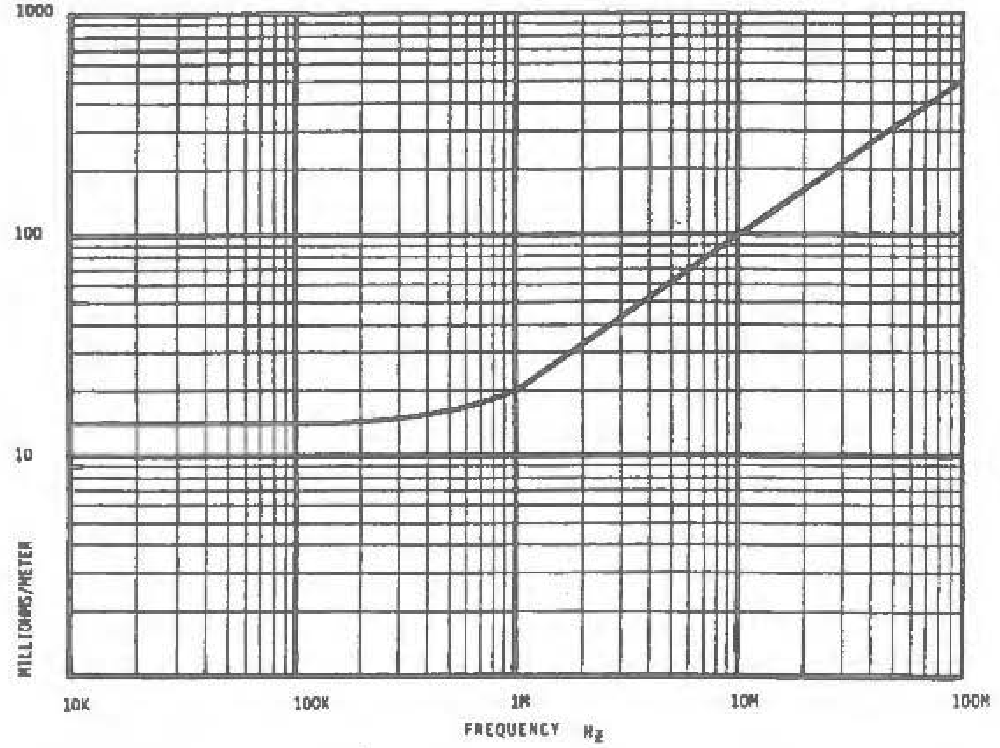


Fig 10-6
Maximum Coaxial Cable Transfer Impedance

10.5.2.1.2 Center Conductor. The center conductor shall be stranded, tinned copper with an overall diameter of 0.89 mm ± 0.05 mm.

10.5.2.1.3 Dielectric Material. The dielectric may be of any type, provided that the conditions of 10.5.1.2 and 10.5.1.3 are met; however, a solid dielectric is preferred.

10.5.2.1.4 Shielding System. The shielding system may contain both braid and foil elements sufficient to meet the transfer impedance of 10.5.1.5 and the EMC specifications of 10.8.2.

The inside diameter of the shielding system shall be 2.95 mm ± 0.15 mm.

The shielding system shall be greater than 95% coverage. The use of tinned copper braid is recommended to meet the contact resistance and shielding requirements.

10.5.2.1.5 Overall Jacket

(1) Any one of several jacket materials shall be used provided the specifications of 10.5.1 and 10.5.2 are met.
(2) Either of two jacket dimensions may be used for the two broad classes of materials provided the specification of 10.5.2.1.1 are met:
  (a) Polyvinyl chloride (for example, PVC) or equivalent having an OD of 4.9 mm ± 0.3 mm.
  (b) Fluoropolymer (for example, FEP, ECTFE) or equivalent having an OD of 4.8 mm ± 0.3 mm.

The cable shall meet applicable flammability and smoke criteria to meet the local and national codes for the installed environment (see 10.8.3).

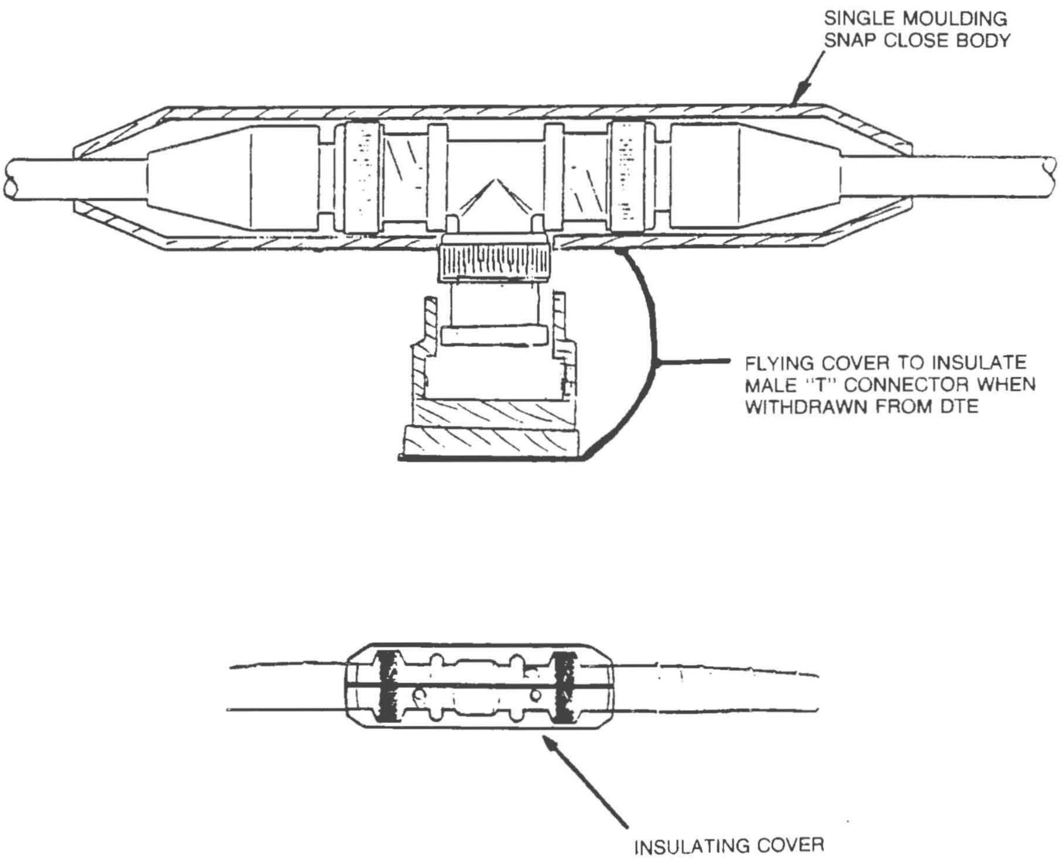
Different types of cable sections (for example, polyvinyl chloride and fluoropolymer dielectric) may be interconnected, while meeting the sectioning requirements of 10.7.2.1.

10.5.2.2 Jacket Marking. It is recommended that the cable jacket be marked with manufacturer and type at a nominal frequency of at least once per meter along the cable.

10.5.3 Total Segment DC Loop Resistance. The sum of the center conductor, connectors, and shield resistance shall not exceed 10 Ω total per segment. Each in-line connector pair or MAU shall contribute no more than 10 mΩ.

As a trunk coaxial cable segment consists of several cable sections, all connectors and internal resistance of the shield and center conductor shall be included in the loop resistance measurement.

10.6 Coaxial Trunk Cable Connectors. The trunk coaxial medium requires termination and is partitioned into sections. Devices to be attached to the medium require a means of connection to the medium. This means is provided by a BNC "T" adapter, as shown in Fig 10-7.



(Tutorial only and not part of the standard.)

Fig 10-7
Examples of Insulated Connector Cover

The BNC connectors shall be of the 50 Ω constant impedance type. High-quality versions of these connectors (per IEC 169-8 [4]) are recommended in order to meet dc loop resistance and reliability considerations. All of the coaxial connectors shall follow the requirements as defined in 10.6.3.

10.6.1 In-Line Coaxial Extension Connector. All coaxial cables shall be terminated with BNC plug connectors. A means shall be provided to ensure that the connector shell (which connects to the cable sheath) does not make contact with any building metal (at ground potential) or other unintended conductor.

An insulating sleeve or boot slipped over the connector at installation time is suitable.

In-line coaxial extensions shall be made with BNC receptacle-to-receptacle connectors joined together to form one "barrel." An insulating sleeve or boot shall also be provided with each barrel assembly.

10.6.2 Coaxial Cable Terminator

10.6.2.1 Coaxial cable terminators are used to provide a termination impedance for the cable equal in value to its characteristic impedance, thereby minimizing reflection from the ends of the cables. Terminators shall be packaged within a male or female connector. The termination impedance shall be 50 $\Omega \pm 1\%$ measured from 0–20 MHz, with the magnitude of the phase angle of the impedance not to exceed 5°. The terminator power rating shall be 0.5 W or greater. A means of insulation shall be provided with each terminator.

10.6.3 MAU-to-Coaxial Cable Connection. A BNC "T" (plug, receptacle, plug) adaptor provides a means of attaching a MAU to the coaxial cable. The connection shall not disturb the transmission line characteristics of the cable significantly; it shall present a low shunt capacitance, and therefore a negligibly short stub length. This is facilitated by the MAU being located as close to its cable connection as possible; the MAU and connector are normally considered to be one assembly. Long (greater than 4 cm) connections between the coaxial cable and the input of the MAU jeopardize this objective.

Overall system performance is dependent largely on the MAU-to-coaxial cable connection being of low shunt capacitance.

The design of the connection shall meet the electrical requirements contained in 10.4.1.1 and the reliability specified in 10.4.2.3. The use of BNC "T" adaptors and connectors satisfies these requirements. Figure 10-7 shows a MAU-to-coaxial cable attachment.

A means shall be provided to ensure that the connector assembly (that is, BNC "T" plus male connectors) does not make contact with any building metalwork (at ground potential) or any other unintended conductors. An insulating cover should therefore be applied after connection. A possible design is depicted in Fig 10-7. The insulating cover should have these characteristics:

(1) It should guard against accidental grounding of the connector assembly.
(2) It should allow ease of attachment and detachment of an assembled "T" connector to the MAU without necessitating the removal of section cable connectors (that is, segment integrity is maintained).
(3) It should be a simple moulding that attaches firmly to a connector assembly.

10.7 System Considerations

10.7.1 Transmission System Model. Certain physical limits have been placed on the physical transmission system. These revolve mostly around maximum cable lengths (or maximum propagation times), as these can affect critical time values for the CSMA/CD access method. These maxima, in terms of propagation times, were derived from the physical configuration model described here. The maximum configuration is as follows:

(1) A trunk coaxial cable, terminated in its characteristic impedance at each end, constitutes a coaxial segment. A coaxial segment may contain a maximum of 185 m (600 ft) of coaxial cable and a maximum of 30 MAUs. The propagation velocity of the coaxial cable is assumed to be 0.65 c minimum (c $= 3 \times 10^8$ m/s). The maximum end-to-end propagation delay for a coaxial segment is 950 ns.
(2) Repeater sets are required for segment interconnection. Repeater sets occupy MAU positions on coaxial segments and count toward the maximum number of MAUs on a coaxial segment. Repeater sets may be located anywhere on a coaxial segment.
(3) The maximum transmission path permitted between any two MAUs is limited by the number of repeater sets that can be connected in series (that is, four). The maximum number of segments connected in series is therefore five (Fig 10-8), which shall consist of no more than three tapped coaxial segments; the remainder shall be link segments as defined in 8.6.1.

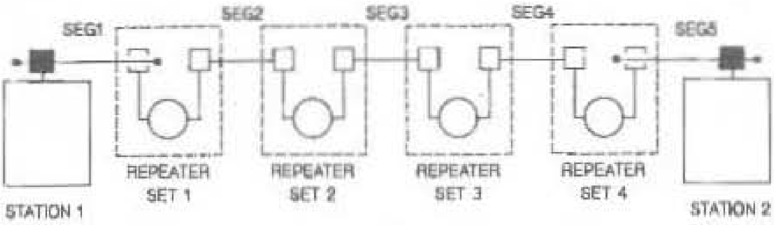


Fig 10-8
Maximum Transmission Path

NOTE: Care should be taken to ensure that the safety requirements are met when extending the trunk cable by the use of repeaters (see 10.7.2.5).

(4) The transmission system may also contain segments comprising trunk coaxial cable specified in Section 8; however, these shall be attached by repeater sets. As such a combination of segments is capable of achieving longer lengths than (3) above, the maximum configuration then becomes limited by propagation delay. Type 10BASE2 segments should not be used to bridge two Type 10BASE5 segments.

Figures 10-9, 10-10, and 10-11 show transmission systems of various types and sizes to illustrate the boundary conditions on topologies generated according to the specifications in this section.

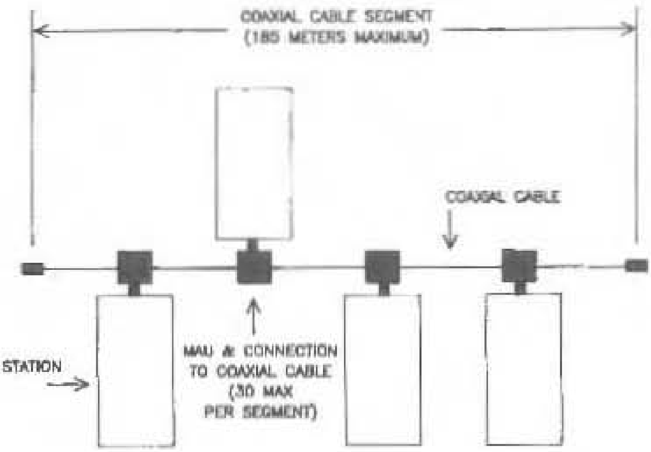


Fig 10-9
The Minimum System Configuration

10.7.2 Transmission System Requirements

10.7.2.1 Cable Sectioning. The 185 m (600 ft) maximum length coaxial cable segment will be made from a number of cable sections. As the variation on cable characteristic impedance is ±2 Ω on 50 Ω, a possible worst-case reflection of 4% may result from the mismatch between two adjacent cable sections. The MAU will add to this reflection by the introduction of its noninfinite bridging impedance.

The accumulation of this reflection can be minimized by observing a minimum distance between MAUs (and between cable sections). In order to maintain reflections at an acceptable level, the minimum length cable section shall be 0.5 m.

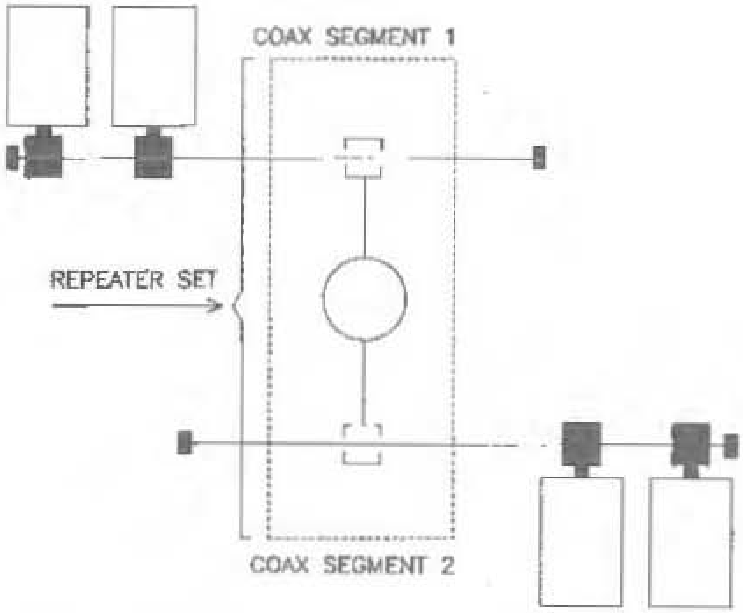


Fig 10-10
The Minimum System Configuration Requiring a Repeater Set

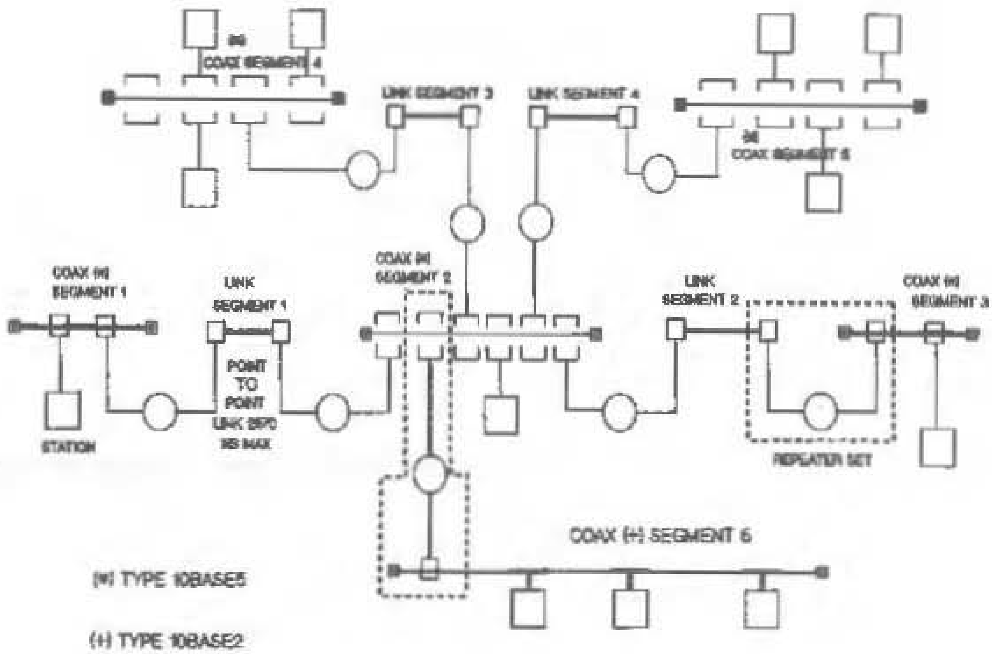


Fig 10-11
An Example of a Large Hybrid System

10.7.2.2 MAU Placement. MAU components and their associated connections to the cable cause signal reflections due to their noninfinite bridging impedance. While this impedance must be implemented as specified in 10.6, the placement of MAUs along the coaxial cable must also be controlled to ensure that reflections from the MAU do not accumulate to a significant degree.

Coaxial cable sections as specified in 10.7.2.1 shall be used to connect MAUs. This guarantees a minimum spacing between MAUs of 0.5 m.

The total number of MAUs on a cable segment shall not exceed 30.

10.7.2.3 Trunk Cable System Earthing. The shield conductor of each coaxial cable segment may make electrical contact with an effective earth reference[13] at one point and shall not make electrical contact with earth elsewhere on such objects as building structural metal, ducting, plumbing fixture, or other unintended conductor. Insulators should be used to cover any coaxial connectors used to join cable sections and terminators, to ensure that this requirement is met. A sleeve or boot attached at installation time is acceptable. (See 10.6.3.)

10.7.2.4 Static Discharge Path. A static discharge path shall be provided. The shield of the trunk coaxial cable is required to be connected to each DTE earth (within the DTE) via a 1 MΩ, 0.25 W resistor that has a voltage rating of at least 750 V dc.

10.7.2.5 Installation Environment. This specification is intended for networks in use within a single building and within an area served by a single low-voltage power distribution system. Applications requiring interplant connections via external (outdoors) means may require special considerations. Repeaters and nonconducting IRL components may provide the means to satisfy these isolation requirements.

NOTE: The reader is advised that devices should not be operated at significantly different frame potentials. The 10BASE2 connection system may not be capable of handling excessive earth currents.

10.8 Environmental Specifications

10.8.1 Safety Requirements. The designer should consult relevant local and national safety regulations to assure compliance with the appropriate standards (for example, see Appendix A for reference material).

10.8.1.1 Installations. If the trunk coaxial cable is to be installed in close proximity to electrical power cables, then installation practice according to local and national code shall be followed (see Annex for resource material).

10.8.1.2 Earthing. Where earthing is mandated by locally or nationally prescribed codes of practice, the shield of the trunk coaxial cable shall be effectively earthed at only one point along the length of the cable. Effectively earthed means permanently connected to earth through an earth connection of sufficiently low impedance and having sufficient ampacity to prevent the building up of voltages that may result in undue hazard to connected equipment or to persons.

10.8.2 Electromagnetic Environment

10.8.2.1 Susceptibility Levels. Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc.

Several sources of interference will contribute to voltage buildup between the coaxial cable and the earth connection of a DTE.

The physical channel hardware shall meet its specifications when operating in either of the following conditions:

(1) Ambient plane wave field of 1 V/m from 10 kHz through 1 GHz.

NOTE: Levels typically >1 km from broadcast stations.

[13] See local or national regulations for guidance on these matters and reference [A12].

(2) Interference source voltage of 15.10 V peak 10 MHz sine wave with a 50 Ω source resistance applied between the coaxial cable shield and the DTE ground connection.

MAUs meeting this standard should provide adequate RF ground return (coaxial cable shield to DTE ground) to satisfy the referenced EMC specifications.

10.8.2.2 Emission Levels. The physical MAU and trunk cable system shall comply with local and national regulations (see Annex for resource material).

10.8.3 Regulatory Requirements. The MAU and medium should consider IEC 435 in addition to local and national regulations. See references [6] and [A12].

11. Broadband Medium Attachment Unit and Broadband Medium Specifications, Type 10BROAD36

11.1 Scope

11.1.1 Overview. This section defines the functional, electrical, and mechanical characteristics of the Broadband Medium Attachment Unit (MAU) and the specific single- and dual-cable broadband media for use with local area networks. The headend frequency translator for single-cable broadband systems is also defined. The relationship of this specification to all of the IEEE Local Area Network standards (IEEE 802) is shown in Fig 11-1. Repeaters as defined in Section 9 are not relevant for 10BROAD36.

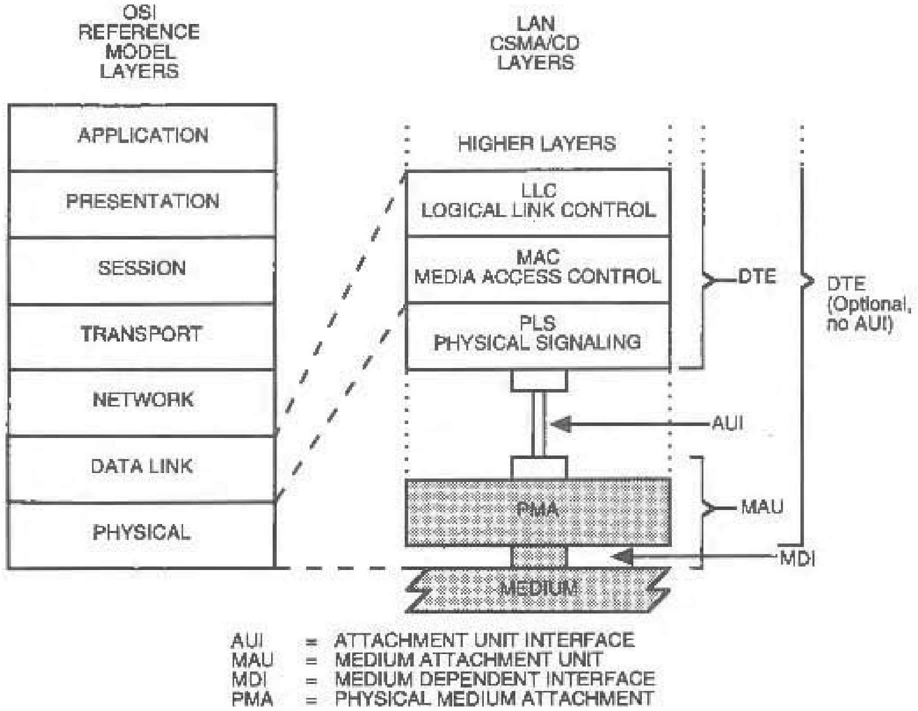


Fig 11-1
Physical Layer Partitioning, Relationship to the ISO Open Systems Interconnection (OSI) Reference Model

The purpose of the MAU is to provide a means of attaching devices to a broadband local network medium. The medium comprises CATV-type cable, taps, connectors, and amplifiers. A coaxial broadband system permits the assignment of different frequency bands to multiple applications. For example, a band in the spectrum can be utilized by local area networks while other bands are used by point-to-point or multidrop links, television, or audio signals.

The physical tap is a passive directional device such that the MAU transmission is directed toward the headend location (reverse direction). On a single-cable system the transmission from the MAU is at a carrier frequency f1. A frequency translator (or remodulator) located at the headend up-converts to a carrier frequency f2, which is sent in the forward direction to the taps (receiver inputs). On a dual-cable system the transmit and receive carrier frequencies are identical (both f1) and the MAU connects to the medium via two taps, one on the receive cable and the other on the transmit cable. The transmit and receive cables are connected to each other at the headend location. Figure 11-2 shows broadband single- and dual-cable systems.

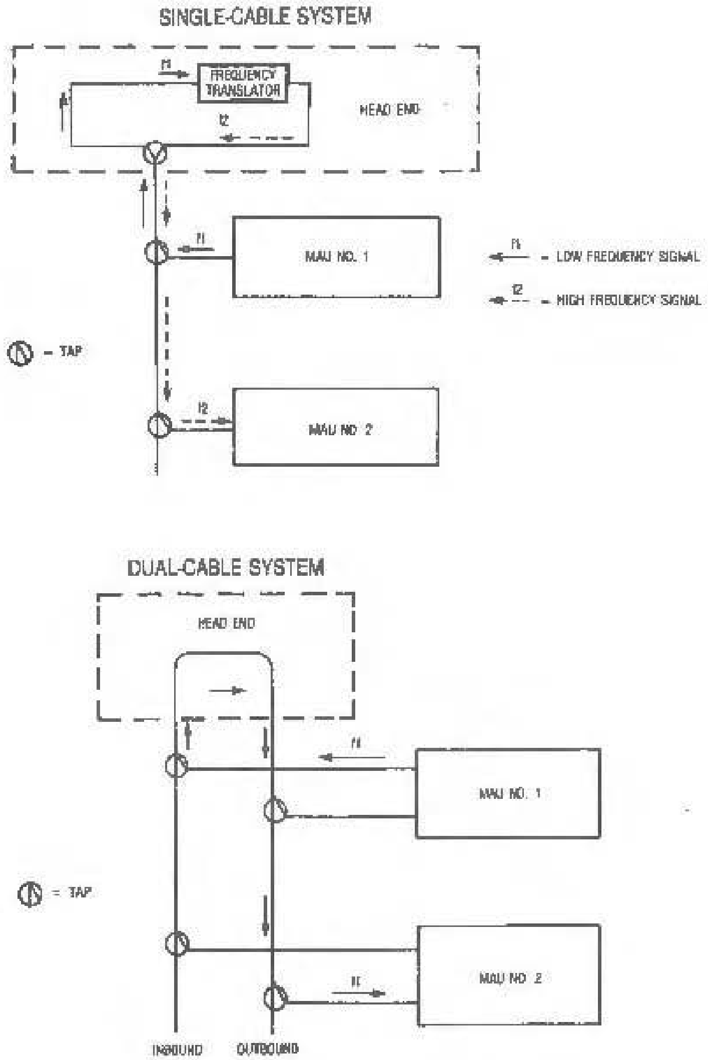


Fig 11-2
Broadband Cable Systems

The broadband MAU operates by accepting data from the attached Data Termination Equipment (DTE) and transmitting a modulated radio frequency (RF) data signal in a data band on the broadband coaxial cable system. All MAUs attached to the cable system receive and demodulate this RF signal and recover the DTE data. The broadband MAU emulates a baseband MAU except for delay between transmission and reception, which is inherent in the broadband cable system.

A transmitting MAU logically compares the beginning of the received data with the data transmitted. Any difference between them, which may be due to errors caused by colliding transmissions, or reception of an earlier transmission from another MAU, or a bit error on the channel, is interpreted as a collision.

When a collision is recognized, the MAU stops transmission in the data band and begins transmission of an RF collision enforcement (CE) signal in a separate CE band adjacent to the data band. The CE signal is detected by all MAUs and informs them that a collision has occurred. All MAUs signal to their attached Medium Access Controllers (MACs) the presence of the collision. The transmitting MACs then begin the collision handling process.

Collision enforcement is necessary because RF data signals from different MAUs on the broadband cable system may be received at different power levels. During a collision between RF data signals at different levels, the MAU with the higher received power level may see no errors in the detected data stream. However, the MAU with the lower RF signal will see a difference between transmitted and received data; this MAU transmits the CE signal to force recognition of the collision by all transmitting MAUs.

11.1.2 Definitions

Attachment Unit Interface (AUI). In a local area network, the interface between the medium attachment unit and the DTE within a data station. Note that the AUI carries encoded signals and provides for duplex data transmission.

Binary Phase Shift Keying (Binary PSK or BPSK). A form of modulation in which binary data are transmitted by changing the carrier phase by 180 degrees.

Broadband LAN. A Local Area Network in which information is transmitted on modulated carriers, allowing coexistence of multiple simultaneous services on a single physical medium by frequency division multiplexing.

CATV-Type Broadband Medium. A broadband system comprising coaxial cables, taps, splitters, amplifiers, and connectors the same as those used in Community Antenna Television (CATV) or cable television installations.

Channel. A band of frequencies dedicated to a certain service transmitted on the broadband medium.

Coaxial Cable. A two conductor, concentric (center conductor and shield), constant impedance transmission line.

Continuous Wave (CW). A carrier that is not modulated or switched.

dBmV. Decibels referenced to 1.0 mV on 75 Ω, used to define signal levels in CATV-type broadband systems.

Drop Cable. The small diameter flexible coaxial cable of the broadband medium that connects to a Medium Access Unit (MAU). See **Trunk Cable.**

Group Delay. The rate of change of total phase shift, with respect to frequency, through a component or system. Group delay variation is the maximum difference in group delay over a band of frequencies.

Headend. The location in a broadband system that serves as the root for the branching tree comprising the physical medium; the point to which all inbound signals converge and the point from which all outbound signals emanate.

Jabber. A condition wherein a station transmits for a period of time longer than the maximum permissible packet length, usually due to a fault condition.

Postamble. In the broadband Medium Attachment Unit specified in this section, the bit pattern appended after the last bit of the Frame Check Sequence; the Broadband End-of-Frame Delimiter (BEOFD).

Return Loss. The ratio in decibels of the power reflected from a port to the power incident to the port. An indicator of impedance matching in a broadband system.

Seed. The twenty-three (23) bits residing in the scrambler shift register prior to the transmission of a packet.

Spectrum Mask. A graphic representation of the required power distribution as a function of frequency for a modulated transmission.

Translation. In a single-cable system, the process by which incoming transmissions at one frequency are converted to another frequency for outgoing transmission. The translation takes place at the headend.

Truncation Loss. In a modulated data waveform, the power difference before and after implementing the filtering necessary to constrain its spectrum to a specified frequency band.

Trunk Cable. The main (large-diameter) cable of a broadband coaxial cable system. See **Drop Cable.**

11.1.3 MAU and Medium Objectives. This subsection states the broad objectives and assumptions underlying the specifications defined throughout this section of the standard.

(1) Provide the physical means for communication among local network Data Link Entities using a broadband coaxial medium.
(2) Provide a broadband Medium Attachment Unit (MAU) that is compatible at the Attachment Unit Interface (AUI) with DTEs used on a baseband medium.
(3) Provide a broadband MAU that emulates the baseband MAU except for the signal delay from Circuit DO to Circuit DI.
(4) Provide a broadband MAU that detects collisions within the timing constraints specified in the baseband case.
(5) Provide a broadband network diameter no less than 2800 m.
(6) Provide a broadband Physical Layer that ensures that no MAU is allowed to capture the medium during a collision due to signal level advantage (that is, ensures fairness of the physical layer).
(7) Provide a broadband MAU that detects collisions in both receive and transmit modes.
(8) Provide a broadband MAU that requires a transmission bandwidth no wider than 18 MHz.
(9) Define a physical interface that can be implemented independently among different manufacturers of hardware and achieve the intended level of compatibility when interconnected in a common broadband local area network.
(10) Provide a communication channel capable of high bandwidth and low bit error rate performance. The resultant mean bit error rate at the physical layer service interface should be less than one part in 10^8 (on the order of one part in 10^9 at the link level) in a worst-case signal-to-noise ratio of 26 dB.
(11) Provide a broadband medium physical layer that allows for implementation in both dual- and single-cable systems.
(12) Provide for ease of installation and service.
(13) Provide a communication channel that coexists with other channels on the same physical medium.

It is not an objective of this broadband MAU to allow its use with the baseband repeater defined in Section 9 of this standard.

11.1.4 Compatibility Considerations. All implementations of the broadband coaxial system shall be compatible at the Medium Dependent Interface (MDI). This standard provides medium specifications for the interconnection of all MAU devices. The medium itself, the functional capability of the MAU and the AU Interface are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided the MDI and AUI specifications are satisfied. Subsystems based on this specification may be implemented in several different ways provided compatibility at the medium is maintained. It is possible, for example, to design an integrated station where the MAU is contained within a physical DTE system component, thereby eliminating the AUI cable.

11.1.5 Relationship to PLS and AUI. The broadband MAU and cable system specifications are closely related to Section 7 (Physical Signaling and Attachment Unit Interface Specifications). The design of a physical MAU component requires the use of both this section and the PLS and AUI specifications in Section 7.

11.1.6 Mode of Operation. In its normal mode of operation, the MAU functions as a direct connection between the DTE and the broadband medium. Data from the DTE are transmitted onto the broadband coaxial system and all inband data on the coaxial cable system is received by the DTE. This mode is the mode of operation for the intended message traffic between stations. Other operating modes, such as a loopback mode or a monitor mode, may be provided but are not defined by this standard.

11.2 MAU Functional Specifications

11.2.1 MAU Functional Requirements. The MAU component provides the means by which signals on the physically separate AUI signal circuits to and from the DTE and their associated interlayer messages are coupled to the broadband coaxial medium. To achieve this basic objective, the MAU component contains the following capabilities to handle message flow between the DTE and the broadband medium:

(1) Transmit Function. The ability to transmit serial data bit streams originating at the local DTE in a band-limited modulated RF carrier form, to one or more remote DTEs on the same network.
(2) Receive Function. The ability to receive a modulated RF data signal in the band of interest from the broadband coaxial medium and demodulate it into a serial bit stream.
(3) Collision Presence Function. The ability to detect the presence of two or more stations' concurrent transmissions.
(4) Jabber Function. The ability of the MAU itself to interrupt the transmit function and inhibit an abnormally long output data stream.

11.2.1.1 Transmit Function Requirements. The transmit function shall include the following capabilities:

(1) Receive Manchester encoded data sent by the local DTE to the attached MAU on Circuit DO (transmit data pair).
(2) Decode the Manchester encoded data received on Circuit DO to produce NRZ (Non-Return to Zero) data and a recovered clock signal.
(3) Scramble the NRZ data using a CCITT V.29-type scrambler with seed changed on each transmitted packet.
(4) Transform the incoming bits (prior to modulation) to provide an unscrambled alternating zero-one pattern terminated by an Unscrambled Mode Delimiter (UMD); scramble the remainder of the incoming preamble, Start Frame Delimiter (SFD), and data frame; and append an unscrambled postamble (Broadband End of Frame Delimiter [BEOFD]).
(5) Differentially encode the packet generated above.
(6) Produce a bandlimited, double sideband suppressed carrier, binary PSK modulated RF signal representing the above generated differentially encoded packet.
(7) Drive the coaxial cable with the modulated RF signal.

Figure 11-3 functionally represents these capabilities. The order of the functional blocks may be altered provided that the result is the same.

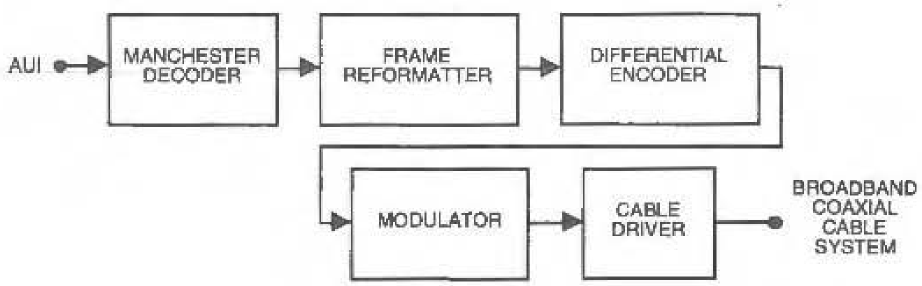


Fig 11-3
Transmit Function Requirements

11.2.1.2 Receive Function Requirements. The receive function shall include the following:

(1) Receive the differentially encoded binary PSK modulated RF signal from the broadband coaxial medium.
(2) Receive the data band RF signals and reject signals in bands other than the data band (rejection of signals in the adjacent collision enforcement band is optional).
(3) Demodulate and differentially decode the incoming RF data signal from the coaxial medium to provide a receive bit stream that represents the scrambled bit stream at the transmitter.
(4) Descramble the receive bit stream using a self-synchronizing descrambler.
(5) Manchester encode the descrambled bit stream.
(6) Send to the DTE, using Circuit DI (receive data pair), an additional, locally-generated, Manchester encoded preamble equal to the number of preamble bits lost in the receive data path (plus or minus one bit), followed by the Manchester encoded bit stream. No more than 6 preamble bits may be lost from the preamble presented to Circuit DO at the transmitting MAU.
(7) Detect end of frame, using the postamble (BEOFD), and ensure that no extraneous bits are sent to the DTE on Circuit DI.
(8) Receive signals in the collision enforcement band and reject signals in the data band and all other bands on the broadband medium.

11.2.1.3 Collision Detection Function Requirements. The MAU shall perform the following functions to meet the collision detection requirements:

(1) Store the scrambled bits (not differentially encoded) in the transmit section through to the last bit in the source address.
(2) Detect the UMD in the transmit and receive paths.
(3) Compare received scrambled bits after the received UMD with transmitted scrambled bits after the transmit UMD through to the last bit in the source address.
(4) A Receive UMD Timer function shall be performed by the MAU. The timer shall be as long as the time required from initial detection of RF data signal presence to detection of a UMD in a normally received (no collision) packet.
(5) Enter a LOCAL COLLISION DETection state if one of the following occurs:
    (a) A bit error is found in the bit compare process through the last bit in the source address.
    (b) The Receive UMD Timer expires before a UMD is detected in the received bit stream.
    (c) The MAU receives the *output* (that is, transmit) signal from the AUI AFTER having received an RF signal from the coaxial cable.
(6) Upon entering the LOCAL COLLISION DET state, cease transmission in the data band and commence transmission in the collision enforcement band for as long as the DTE continues to send data to the MAU.
(7) Upon entering the LOCAL COLLISION DET state send the *signal_quality_error* (SQE) message on Circuit CI (collision presence pair) using the CS0 signal for as long as RF signals are detected on the broadband coaxial medium in either the data or collision enforcement bands.
(8) Detect power in the collision enforcement band and send the SQE message on Circuit CI using the CS0 signal. Send the SQE message for as long as energy is detected in the collision enforcement band.
(9) Ensure that during collisions, due to phase cancellations of the colliding carriers, Circuit DI does not become inactive before Circuit CI becomes active.
(10) Test the collision detection circuitry following every transmission that does not encounter a collision. This test consists of transmitting a burst of collision enforcement RF signal after the end of the postamble transmission and detecting this burst on the receive side. If the burst is detected, the CS0 (BR) signal is sent on Circuit CI of the transmitting MAU.

11.2.1.3.1 Collision Enforcement Transmitter Requirements. The MAU shall provide a collision enforcement (CE) transmitter that generates a constant amplitude RF signal in the CE band at the same power level as the data signal postamble.

11.2.1.3.2 Collision Enforcement Detection Requirements. The MAU shall detect energy in the CE band that is within the specified range of receive levels, irrespective of the signal power level in the data band.

11.2.1.4 Jabber Function Requirements. The MAU shall have a jabber function that inhibits transmission onto the coaxial cable interface if the MAU attempts to transmit an RF signal longer than 150 ms. The MAU shall provide an MTBF of at least 1 million hours of continuous operation without rendering the transmission medium unusable by other transceivers. Transmissions of less then 20 ms shall not be affected. When the jabber circuit is activated, *signal_quality_error* shall be sent on Circuit CI.

Circuit DO shall also be monitored for transmissions in excess of the maximum packet length. If the packet is longer than 20 ms, an attempt shall be made to deactivate the transmitter before the jabber circuit is activated, to avoid locking up the unit due to a non-MAU failure.

State diagrams defining the jabber function may be found in 11.2.3.

11.2.2 DTE PLS to MAU and MAU to DTE PLS Messages

11.2.2.1 DTE Physical Layer to MAU Physical Layer Messages. The following messages can be sent by the DTE Physical Layer Entities to the MAU Physical Layer Entities (refer to 7.3 of this standard for the definitions of the signals):

Message	Circuit	Signal	Meaning
output	DO	CD1, CD0	Output information
output_idle	DO	IDL	No data to be output

11.2.2.2 MAU Physical Layer to DTE Physical Layer Messages. The following messages can be sent by the MAU Physical Layer Entities to the DTE Physical Layer Entities:

Message	Circuit	Signal	Meaning
input	DI	CD1, CD0	Input information
input_idle	DI	IDL	No input information
mau_available	CI	IDL	MAU is available for output
signal_quality_error	CI	CS0 (BR)	Error detected by MAU

11.2.2.2.1 *input* Message. The MAU Physical Layer sends an *input* message to the DTE Physical Layer when the MAU has a bit of data to send to the DTE. The physical realization of the *input* message is a CD0 or CD1 sent by the MAU to the DTE on Circuit DI. The MAU sends CD0 if the input bit is a zero or CD1 if the input bit is a one. The jitter and asymmetry on CD0 and CD1 shall be no more than that specified in 7.5.2.1.

11.2.2.2.2 *input_idle* Message. The MAU Physical Layer sends an *input_idle* message to the DTE Physical Layer when the MAU does not have data to send to the DTE. The physical realization of the *input_idle* message is the IDL signal sent by the MAU to the DTE on Circuit DI.

11.2.2.2.3 *mau_available* Message. The MAU Physical Layer sends a *mau_available* message to the DTE Physical Layer when the MAU is available for output. The *mau_available* message is always sent by an MAU that is prepared to output data. The physical realization of the *mau_available* message is an IDL signal sent by the MAU to the DTE on Circuit CI.

11.2.2.2.4 *signal_quality_error* Message. The *signal_quality_error* message shall be implemented in the following fashion:

(1) The *signal_quality_error* (SQE) message shall not be sent by the MAU if no or only one MAU is transmitting a legal length packet (as specified in this standard) on the coaxial medium, except as a part of the SQE self test.
(2) If the MAU connected to the local node is not transmitting, then the local MAU shall send the *signal_quality_error* message in every instance when it detects power in the collision enforcement band earlier than the time equivalent for reception of a 512 bit data frame plus preamble and SFD.
(3) When the local MAU is transmitting on the coaxial medium, all occurrences of one or more additional MAUs transmitting shall cause the *signal_quality_error* message to be sent by the local MAU to the attached DTE.
(4) When the MAU has completed a successful transmission of a packet it shall perform an SQE Test sequence. In this instance, the collision enforcement RF signal is interpreted as an SQE Test signal.

11.2.3 MAU State Diagrams. The operation of the MAU during normal transmission and reception can be described by a state diagram that relates the functions of transmission, reception, collision detection, and collision detection testing. Figure 11-4, at the end of this subsection, shows the state transitions for normal operation. Abnormal conditions are implementation-specific.

The state diagram in Fig 11-4 does not describe the operation of the MAU in detail. This is found in 11.2 and 11.3.

The operation of the jabber function is described by the state diagram of Fig 11-5. When the MAU Jabber state machine is in the INTERRUPT or JAB state, outputs of the MAU Jabber state machine shall override those of the MAU state machine.

11.2.3.1 MAU State Diagram Messages. The following messages are used in the state diagram:

(1) disable_data_driver. Deactivates the mechanism by which the RF data signal is impressed onto the coaxial cable.
(2) enable_data_driver. Activates the mechanism by which the RF data signal is impressed onto the coaxial cable.
(3) disable_CE_driver. Deactivates the mechanism by which collision enforcement RF signals are impressed onto the coaxial cable.
(4) enable_CE_driver. Activates the mechanism by which collision enforcement RF signals are impressed onto the coaxial cable.
(5) *mau_available*. Signifies that the MAU is available for transmission (that is, there is no SQE active).
(6) *signal_quality_error* (SQE). Signifies that the MAU has detected a collision, it has successfully completed the SQE Test sequence, or the jabber circuit is active.
(7) start_SQE_test_timer. Causes a timer to begin counting so that the SQE Test signal may be sent to the coaxial cable interface.
(8) positive_disable. Prevents any RF signal from being sent onto the coaxial cable.

11.2.3.2 MAU State Diagram Signal Names. The signal names used in the state diagram are as follows:

(1) PowerOn. This signal signifies that power has been applied to the unit.
(2) rx_energy. When this signal is active, an RF signal on the coaxial cable has been detected either in the data band or in the collision enforcement band or in both. The delay in asserting or deasserting this signal is sufficiently short that the delays specified in 11.3.4.5 are met.
(3) output. Signifies that data from the DTE is being presented for transmission at the AUI.
(4) tx_umd (Transmit Unscrambled Mode Delimiter). When the Unscrambled Mode Delimiter has been detected in the transmit data sequence, this signal is asserted.
(5) rx_umd (Receive Unscrambled Mode Delimiter). When the Unscrambled Mode Delimiter has been detected in the receive data sequence as it is conveyed from the coaxial cable interface, this signal is asserted.
(6) SQE_test_timer. This signal is on during the time that the SQE Test Timer is engaged. At the end of the time, this signal is deasserted.
(7) rx (Receive). As long as data is being presented by the MAU to Circuit DI of the AUI, this signal is active. When the last bit of the receive data has been presented to the AUI, this signal is deasserted.

(8) ced (Collision Enforcement Detection). RF signal power in the collision enforcement band causes this signal to be asserted.

(9) ced_window (Collision Enforcement Detection Window). This signal defines a period of time (a "window") during which collisions may occur. Its purpose is to distinguish collision enforcements from SQE Test sequences on the coaxial cable. The window opens when rx_energy goes active and closes a minimum of 365 bit times later. The maximum time the window may be open is the minimum frame length, plus preamble and SFD: 576 bits.

(10) rx_umd_timeout (Receive Unscrambled Mode Delimiter Timeout). It is possible that the Receive Unscrambled Mode Delimiter may be corrupted by a collision such that the bit-by-bit comparison may not begin. This signal forces detection of a collision due to failure to detect the rx_umd within a maximum time. The timeout begins upon receipt of RF signal in the data band and expires 32 bit times later.

(11) tx_#_rx (Transmit Not Equal to Receive). Assertion of this signal occurs when a difference is detected between the received data stream and the transmitted data stream.

(12) bbbw (Bit-by-Bit Window). Bit-by-bit comparison shall be performed only for a time long enough to guarantee that the last bit of the source address has been examined. This signal is asserted after the UMD is received and throughout the bit-by-bit comparison process. To place a bound on the location of the source address relative to the UMD, the maximum preamble length permitted for operation with the broadband MAU is 62 bits. This places the last bit of the source address no later than 143 bits after the UMD.

(13) ced_gate. This signal is a gating function that serves to shape the timing of ced during an SQE Test. It becomes true a minimum of 6 and a maximum of 16 bit times after the last bit has been presented to Circuit DI and stays active 10 ± 5 bit times.

(14) tx_energy. This signal signifies that the MAU is attempting to transmit an RF signal onto the coaxial cable.

(15) frame_timer. This signal is on from the beginning of output until it is reset or until it has been on continuously for timeout1 s. The value of timeout1 shall be greater than 20 ms and less than timeout2.

(16) jab_timer. This signal turns on when tx energy turns on and lasts until it is reset or until it has been on continuously for timeout2 s. The value of timeout2 shall be greater than timeout1 and less than 150 ms.

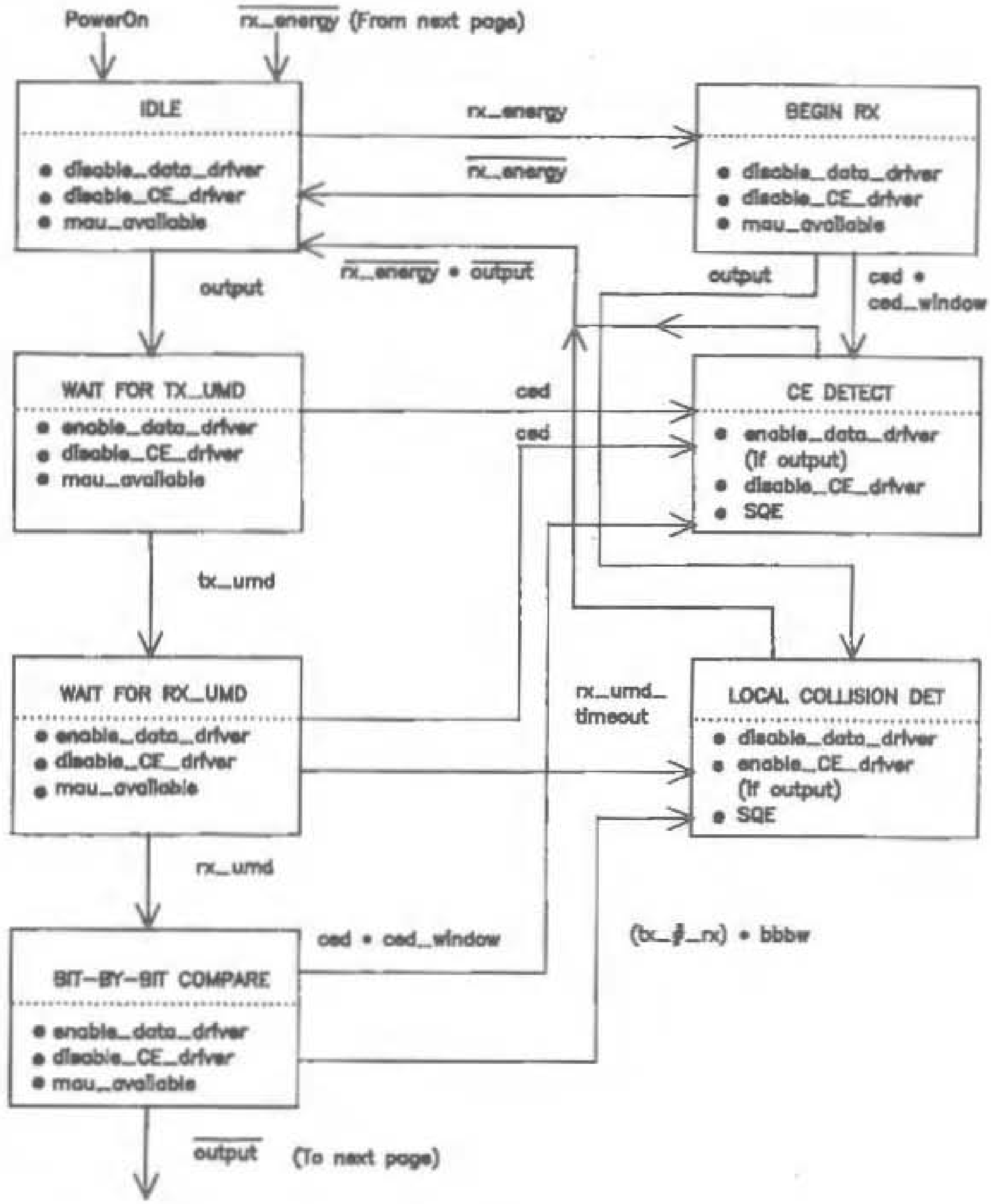


Fig 11-4
MAU State Diagram

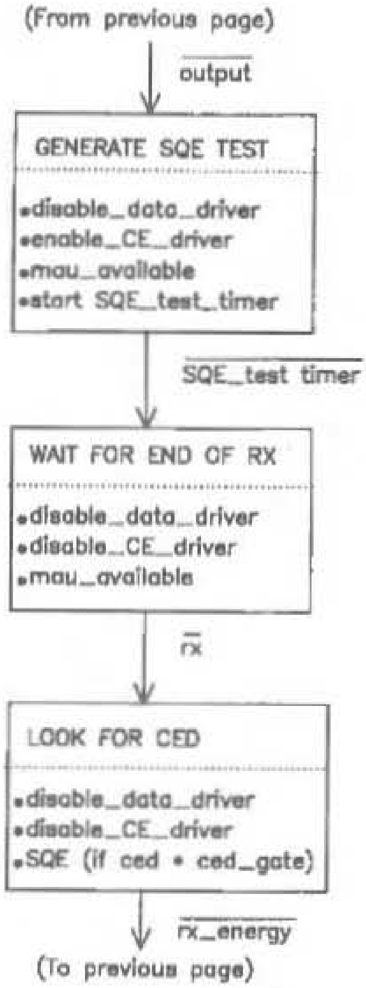


Fig 11-4
MAU State Diagram *(continued)*

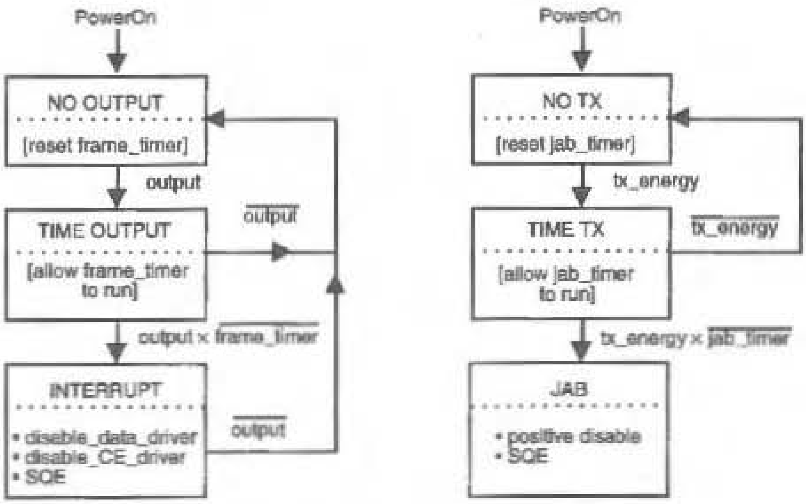


Fig 11-5
MAU Jabber State Diagram

11.3 MAU Characteristics

11.3.1 MAU-to-Coaxial Cable Interface. The following subsections describe the interface between the MAU and the broadband coaxial medium. The medium is a 75 Ω CATV-type broadband cable installation employing a single bidirectional cable with band-split amplifiers and filters, or dual unidirectional cables with line amplifiers.

11.3.1.1 Receive Interface

11.3.1.1.1 Receive Input Impedance. The nominal input impedance at the receive port shall be 75 Ω. The return loss within the data and collision enforcement frequency bands shall be at least 14 dB with power applied to the MAU.

11.3.1.1.2 Receiver Squelch Requirements. There shall be a receiver squelch that inhibits reception of RF signals that are too low in level. This squelch shall permit reception of RF data or collision enforcement signals that are greater than or equal to –7 dBmV rms as measured by the method of 11.3.1.2.5. RF signals (data, collision enforcement, noise, or other signals) of levels lower than –15 dBmV rms shall be ignored.

The receive squelch for CE signals shall be derived from a power detector with noise bandwidth greater than or equal to 1.5 MHz centered at the CE center frequency.

11.3.1.1.3 Receive Level Requirements. The receiver shall operate with RF data and CE signals having levels from –4 dBmV to +16 dBmV rms. The nominal receive level shall be +6 dBmV rms.

11.3.1.1.4 Receiver Selectivity and Linearity Requirements. The MAU shall operate in the presence of single frequency (CW) signals adjacent to the receive band of the MAU and offset from the band edges, received at the following levels:

(1) 0 dBmV rms at 0.25 MHz below and above the band
(2) 10 dBmV rms at 1.25 MHz below and above the band

The receiver shall be capable of operating in a cable environment loaded with TV signals (for example, every 6 MHz in the USA). The TV signals shall be no higher than +10 dBmV peak video at the receiver coaxial cable interface.

11.3.1.1.5 Receive Input Mechanical Requirements. The receiver mechanical interface shall be a 75 Ω female F-series coaxial connector. The connection to the broadband medium shall be through a coaxial drop cable with a mating male F-series connector. For single-cable configurations, the same connector may be used for receive and transmit.

11.3.1.2 Transmit Interface

11.3.1.2.1 Transmit Output Impedance. The nominal output impedance at the transmit port shall be 75 Ω. The return loss within the data and collision enforcement frequency bands shall be at least 14 dB with power applied.

11.3.1.2.2 Transmitted RF Packet Format. Figure 11-6 shows the transmitted RF packet format.

11.3.1.2.3 Transmit Spectrum and Group Delay Characteristics. The transmit RF data signal shall be binary phase-shift-keyed (PSK) modulated and shall have a frequency spectrum equivalent to baseband raised-cosine Nyquist filtering with a rolloff factor (a) of 0.4, and within the limits of Fig 11-7. For rectangular pulses, the filter characteristic is

$$H(jw) = \begin{cases} \dfrac{wT/2}{\sin(wT/2)}; & \left[0 <= w < \dfrac{\pi}{T}(1-a)\right] \\ \dfrac{wT/2}{\sin(wT/2)} \cos^2\left(\dfrac{T}{4a}\left[w - \dfrac{\pi(1-a)}{T}\right]\right); & \\ & \left[\dfrac{\pi}{t}(1-a) <= w < \dfrac{\pi}{T}(1+a)\right] \\ 0; & \left[w >= \dfrac{\pi}{T}(1+a)\right] \end{cases}$$

where T = one symbol time (100 ns for 10 Mb/s) and a = 0.4, and the first term accounts for the sin x/x spectrum of NRZ random data.

The total variation in group delay from Circuit DO to the RF coaxial medium interface shall not exceed 20 ns in the frequency band from the carrier frequency to ± 5 MHz, and 32 ns to ± 5.5 MHz.

The collision enforcement (CE) signal shall be a constant amplitude pulse with controlled turn-on and turn-off times. Random modulation may be added to reduce the probability of cancellation when more than one CE signal is received simultaneously. The modulated signal shall have an instantaneous frequency within 0.75 MHz of the CE band center frequency and shall conform to the spectrum mask specified in 11.3.1.2.4. The random modulation may be derived from the transmit NRZ data stream.

The CE signal rise and fall times shall approximate a Gaussian shape of the form:

$$f(t) = \exp\left(-\frac{1}{2}\left[\frac{t}{T}\right]^2\right)$$

where T = one symbol time and t < 0 for the rise time and t > 0 for the fall time.

The CE and data RF signals shall not be transmitted simultaneously.

11.3.1.2.4 Transmit Out-of-Band Spectrum. The transmitted power outside the specified band shall meet or exceed the relative attenuation (RA) specified below, under the following conditions:

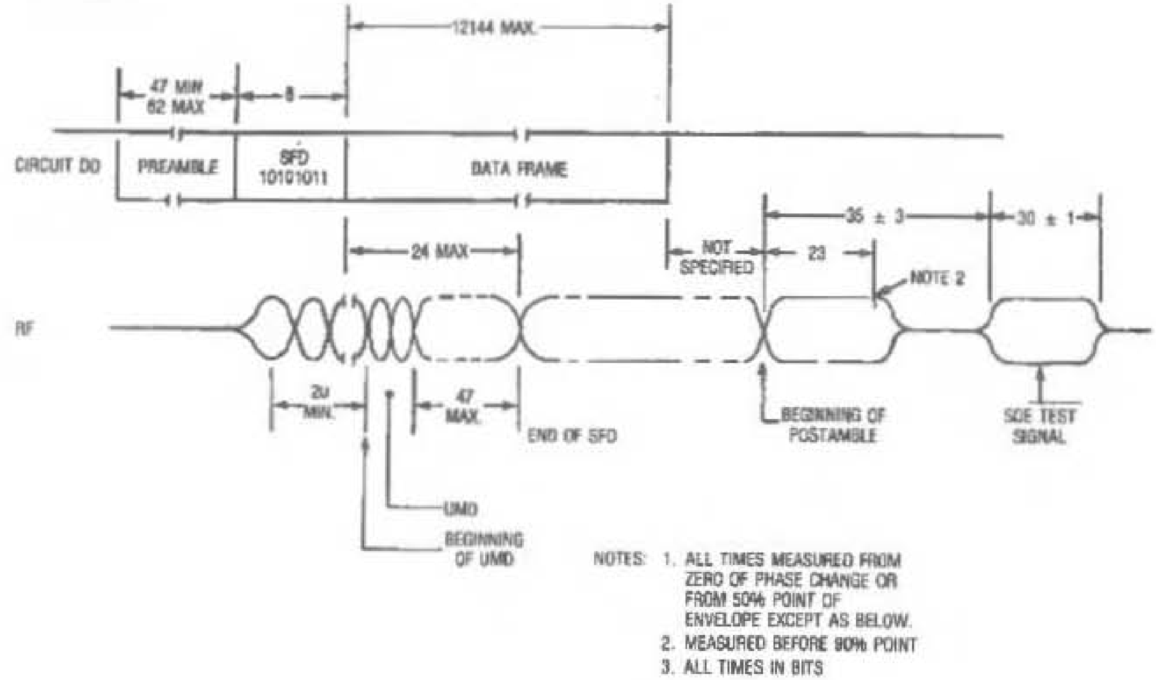


Fig 11-6
Packet Format and Timing Diagram (AUI to Coaxial Cable Interface)

(1) Transmitted packet length is 256 bits with a 25.6 μs interval between packets, for 50% duty cycle on the cable.
(2) Reference level is an unmodulated carrier, equivalent to the postamble transmitted level.
(3) RA is the attenuation in decibels relative to the reference level outside the specified band, measured in a 30 kHz noise bandwidth with a video filter of 300 Hz bandwidth or less.
(4) B is 18 MHz, the width of data plus collision enforcement bands.
(5) MF is the measurement frequency in MHz.
(6) NCEF is the frequency of the nearest edge of the band, in MHz.

$$RA = \min\left(63, 55 + 30 \times \left|(MF - NCEF)/B\right|\right)$$

Figure 11-8 graphically shows the attenuation requirement for out-of-band power.

11.3.1.2.5 Transmit Level Requirements. The transmitter output power during the postamble and during the SQE Test of the collision enforcement signal shall be 1000 mV peak-to-peak into a 75 Ω load (51 dBmV rms). Truncation loss due to the specified data filtering is 1 dB; transmitted RF data signal power is 50 dBmV rms. Transmit output power variations shall not exceed ± 2 dB.

11.3.1.2.6 Nontransmitting Signal Leakage Requirement. The RF data signal and collision enforcement signal leakage to the coaxial cable interface while the MAU is not in its transmission mode shall be less than –20 dBmV rms.

11.3.1.2.7 Transmit Spurious Output Requirement. All spurious signals from the transmitter (inband and out-of-band) while not transmitting shall be less than –20 dBmV rms. All spurious signals from the transmitter while transmitting data or collision enforcement shall be below the spectrum mask specified in 11.3.1.2.4.

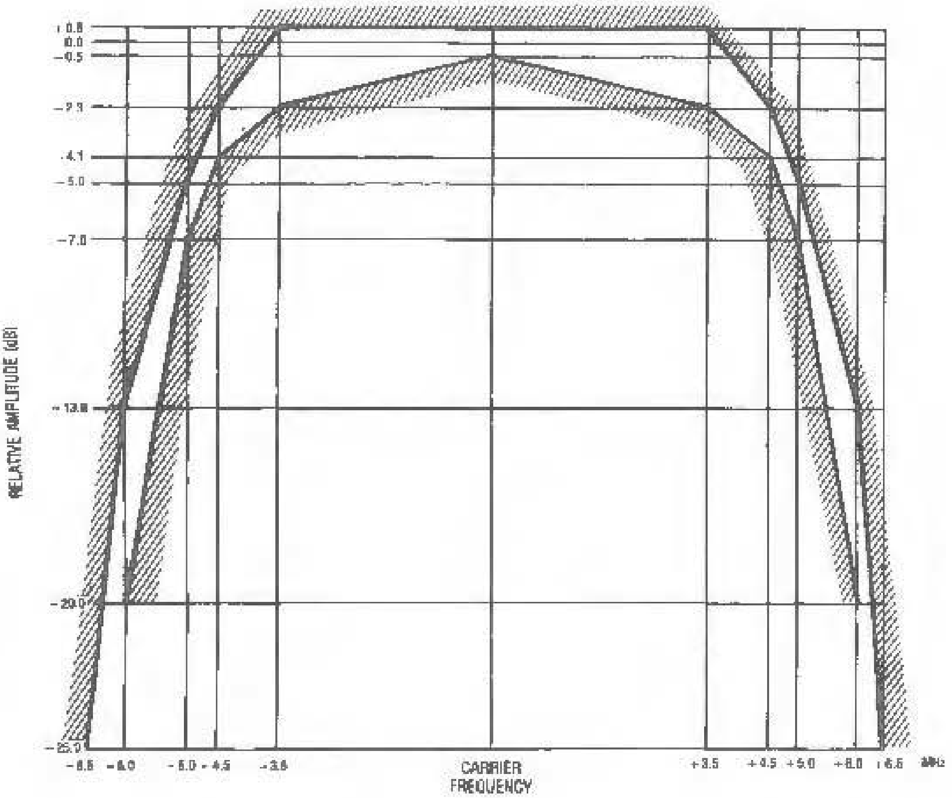


Fig 11-7
Spectrum Mask for RF Data Signal

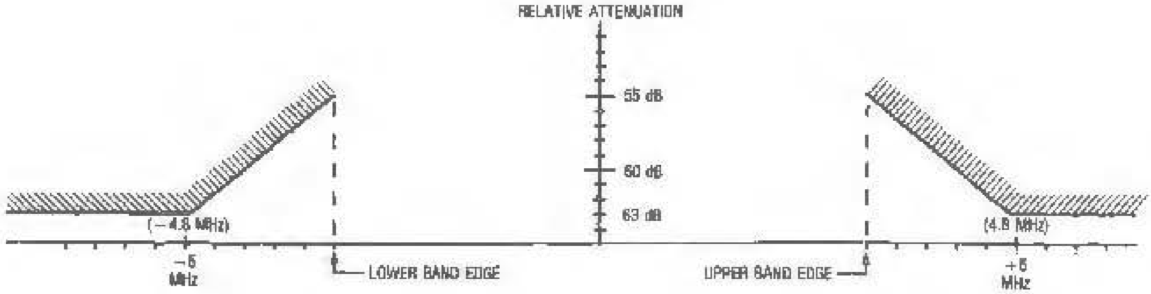


Fig 11-8
Transmit Out-of-Band Power Attenuation

11.3.1.2.8 Collision Enforcement Signal Leakage Requirement. The collision enforcement RF signal leakage to the coaxial cable during data transmission and while the MAU is not enforcing collisions shall be less than 5 dBmV rms. Leakage shall be less than –20 dBmV rms when the MAU is not in the transmission mode.

11.3.1.2.9 Transmit Output Mechanical Requirements. The transmit mechanical interface shall be a 75 Ω female F-series coaxial connector. The connection to the broadband medium shall be through a coaxial drop cable with a mating male F-series connector. For single cable installations, the same connector may be used for transmit and receive.

11.3.2 MAU Frequency Allocations. The broadband MAU uses a data band 14 MHz wide and an adjacent collision enforcement band 4 MHz wide. A single cable midsplit configuration with a frequency offset of 156.25 MHz or 192.25 MHz between forward and reverse channels is recommended. Other configurations, including dual-cable, where forward and reverse channels are on separate unidirectional cables, also are permitted.* The preferred pairing for the usual North American 6 MHz channels is specified in Table 11.2-1 and Table 11.2-2. The tables also specify the data carrier or collision enforcement center frequency for each band, and for single-cable systems, the frequency translation and the headend local oscillator frequency.

11.3.2.1 Single-Cable Systems Frequency Allocations.* Table 11.2-1 lists the permissible frequency band allocations for single-cable systems. The 192.25 MHz translation is recommended for all new designs. The 156.25 MHz translation is allowed for compatibility with some existing systems. The 156.25 MHz translation results in a reversal of the data and collision enforcement bands, as the lower sideband is used.

11.3.2.2 Dual-Cable Systems Frequency Allocations.* In nontranslated dual-cable systems transmit and receive frequencies are identical. Table 11.2-2 lists the permissible frequency band allocations. In some instances translated dual-cable systems are installed. In such cases the single-cable frequency allocations may be used.

Table 11.2-1
Single-Cable Frequency Allocations (Frequencies in MHz)

TRANSMITTER			RECEIVER			
			Translation 156.25 MHz		Translation 192.25 MHz	
Data Carrier	Coll Enf Center Freq	Transmit Band	Headend Local Osc	Receive Band	Headend Local Osc	Receive Band
43	52	35.75–53.75	245.75	192-210	192.25	228-246
49	58	41.75–59.75	257.75	198-216	192.25	234-252
55	64	47.75–65.75	269.75	204-222	192.25	240-258
+61	70	53.75–71.75	281.75	210-228	192.25	246-264
67	76	59.75–77.75	293.75	216-234	192.25	252-270
73	82	65.75-83.75	305.75	222-240	192.25	258-276

NOTES: (1) Some of these optional bands are overlapping.
(2) Frequency tolerance of the data carrier and headend local oscillator shall each be ± 25 kHz.
(3) + denotes the preferred frequency allocation.

11.3.3 AUI Electrical Characteristics

11.3.3.1 Electrical Isolation Requirements. The MAU must provide isolation between the AUI cable and the broadband coaxial medium. The isolation impedance shall be greater than 250 kΩ at 60 Hz, measured between any conductor (including shield) of the AU Interface cable and either the center conductor or shield of the coaxial cable. The isolation means provided shall be able to withstand 500 Vac rms for one minute.

The MAU power supply, if provided, shall meet the appropriate national requirements. See Reference [8] for guidance.

*The remainder of 11.3.2 and all of 11.3.2.1 and 11.3.2.2 are not part of the ISO standard. Frequency allocations are a subject for national standardization.

Table 11.2-2
Dual-Cable Frequency Allocations (Frequencies in MHz)

Data Carrier	Coll Enf Center Freq	Data Band	Coll Enf Band
43	52	36–50	50–54
49	58	42–56	56–60
55	64	48–62	62–66
+61	70	54–68	68–72
67	76	60–74	74–78
73	82	66–80	80–84
235.25	244.25	228–242	242–246
241.25	250.25	234–248	248–252
247.25	256.25	240–254	254–258
253.25	262.25	246–260	260–264
259.25	268.25	252–266	266–270
265.25	274.25	258–272	272–276

NOTES: (1) Some of these optional bands are overlapping.
(2) Frequency tolerance of the data carrier shall be ± 25 kHz.
(3) + denotes the preferred frequency allocations.

11.3.3.2 Current Consumption. The MAU may have its own power supply but is also allowed to use the power supplied by the DTE through the AUI cable. When drawing current from the AUI, the current shall not exceed 0.5 A as provided by the AUI source. The MAU shall be capable of operating from all possible voltage sources as supplied by the DTE through the resistance of all permissible AUI cables. The MAU shall not disrupt the broadband coaxial medium should the DTE power source fall below the minimum operational level under abnormal MAU load conditions. The MAU shall be labeled externally to identify the nominal value of current required by the device at the AUI.

11.3.3.3 Driver and Receiver Requirements. The requirements for AUI cable driver and receiver components within the MAU are identical with those specified in Section 7 of this standard. The drivers shall provide signals that meet the symmetry and jitter requirements of Circuit DI defined in Section 7 and the receivers shall accept signals that have traversed the worst-case lengths of AUI cable.

11.3.3.4 AUI Mechanical Connection. The MAU shall be provided with a 15-pin male connector as specified in detail in the PLS/AUI specifications, in 7.6 of this standard.

11.3.4 MAU Transfer Characteristics. Signals presented on Circuit DO are transformed into signals at the coaxial cable interface by delaying them and by reformatting them. Signals at the coaxial cable interface are transformed into signals on Circuit DI and Circuit CI by a different framing change and by additional delay.

11.3.4.1 AUI to Coaxial Cable Framing Characteristics. Data presented on Circuit DO shall first be received differentially, then Manchester decoded into an NRZ data stream. The framing of the data shall then be transformed into a new packet for presentation to the RF modulator in the following way (see Fig 11-6 and Fig 11-9):

(1) Up to 5 bits of the incoming data stream may be dropped for detection and Manchester decoding purposes.

(2) Beginning with the first zero, 20 bits of zero-one pattern shall be sent for receiver synchronization and clock recovery.

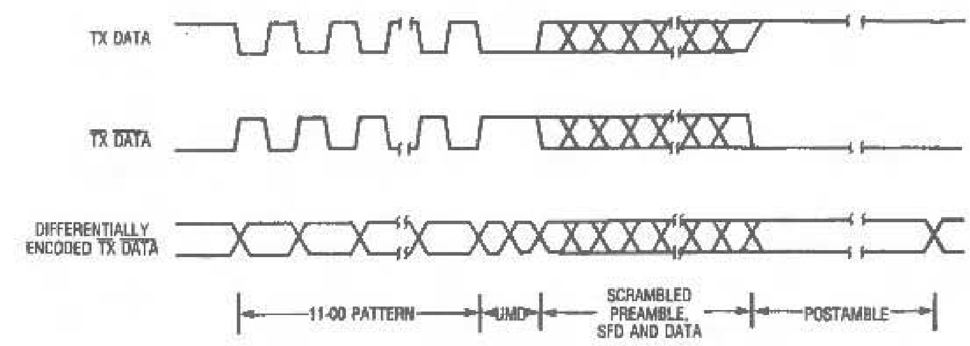


Fig 11-9
Packet Format at Modulator Input

(3) The next two bits (zero-one in the incoming pattern) shall both be set to zero and form the Unscrambled Mode Delimiter (UMD). The UMD shall take the place of the zero-one in the incoming pattern; it shall not be inserted into the data stream.
(4) All remaining bits in the preamble, SFD, and data fields shall be scrambled (using a CCITT V.29 scrambler plus a differential encoder per 11.3.4.1).
(5) A postamble (BEOFD) consisting of a zero followed by 22 ones shall be added immediately after the last scrambled data bit (the postamble is not scrambled). The postamble may be extended to allow controlled turnoff of the transmitted signal, as shown in Fig 11-6.
(6) All bits (unmodified preamble; UMD; scrambled preamble, SFD, and data; and postamble) are inverted.
(7) All bits sent to the RF modulator are differentially encoded. Figure 11-9 shows the appearance of the data before and after the differential encoder.
(8) The SQE Test sequence shall be generated after a successful data transmission by transmitting a collision enforcement RF signal with the timing shown in Fig 11-6.

Because the preamble of the incoming data on Circuit DO is modified, it is assumed that DTEs generate a minimum length preamble of 47 bits. The maximum preamble length is allowed to be 62 bits, as shown in Fig 11-6.

11.3.4.1.1 Scrambler and Differential Encoding Requirements. The NRZ data shall be scrambled (using a CCITT V.29-type scrambler). A new seed shall be used by the scrambler for every new packet presented by the DTE to the MAU. Figure 11-10 is a diagram of a typical scrambler implementation.

The scrambled NRZ data shall be differentially encoded (see Fig 11-11 for a typical implementation).

The entire encoding process comprising the scrambling and differential encoding is essentially equivalent to a division of the polynomial representing the data to be transmitted by the following polynomial:

$$G(x) = 1 + x^{-1} + x^{-18} + x^{-19} + x^{-23} + x^{-24}$$

11.3.4.2 Coaxial Cable to AUI Framing Characteristics. The MAU shall demodulate, differentially decode, and invert the received RF data signal to recover the scrambled and inverted data stream. Clock shall be recovered and a replica of the unfiltered and noninverted transmitted data stream shall be created. The restored data shall be forced to a logic "one" state whenever no RF data signal is detected. This prevents false UMD detection and forces postamble detection when no carrier is present.

The framing information contained in the RF data stream shall be used to reconstruct the received data so that no more than 6 bits are lost and no more than one bit added to the preamble field, and no bits are added to or lost from the end of the transmit data. Detection of the UMD in the receive data shall initiate, after a fixed delay, a locally generated preamble sequence of zero-one pattern. This pattern "fills in" the preamble bits altered due to the framing information at the beginning of the packet: the zero-one synchronization and clock recovery sequence, the UMD, and the descrambler synchronization sequence.

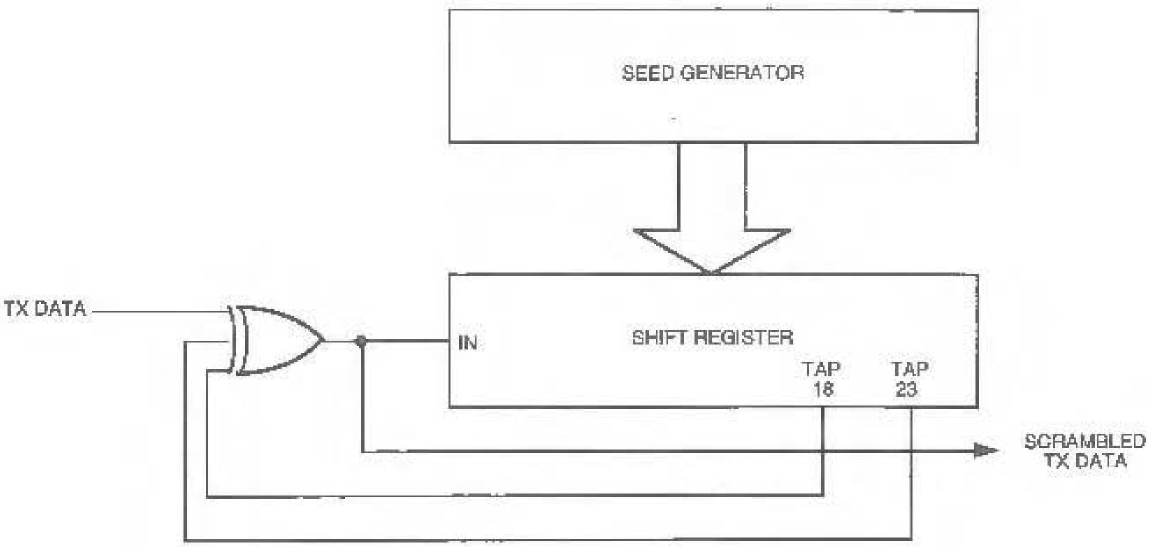


Fig 11-10
Scrambler

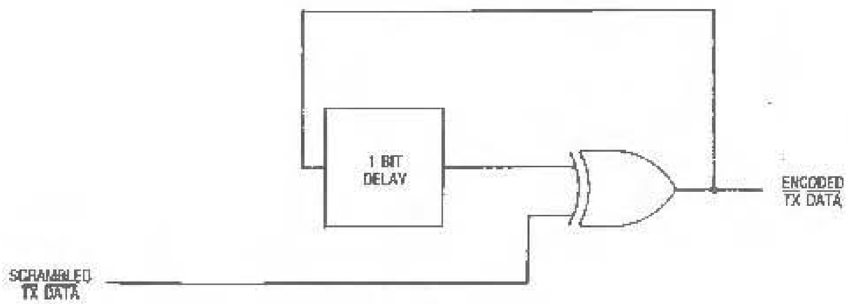


Fig 11-11
Differential Encoder

The MAU shall descramble the received data using a self-synchronizing (CCITT V.29-type) descrambler. No prior knowledge of the seed used by the scrambler shall be assumed by the descrambler circuit. The descrambler shall have valid output no later than 23 bit intervals after the UMD is detected by the receiver. An example of a descrambler is shown in Fig 11-12. The differential decoding performed by the demodulator and the descrambling function are essentially equivalent to multiplying the received polynomial by G(x) as defined in the scrambling and differential encoding requirements subsection above.

After the descrambler is synchronized, 23 bits after the UMD, the correctly descrambled receive data, starting with the 24th bit after the UMD, shall be transferred to the Manchester encoder and therefrom to the AUI. The delay from the detection of the UMD to the beginning of the locally generated zero-one pattern shall be chosen so that no more than 6 bits of preamble are lost, and no more than one bit added, in transmission from Circuit DO to Circuit DI.

The MAU shall detect the "zero" followed by 22 "ones" (the postamble pattern) and, in conjunction with the loss of carrier detection in the data band or the presence of a collision enforcement detection signal, shall ensure that the packet presented to the local DTE has no extraneous bits added by the MAU to the end of the packet.

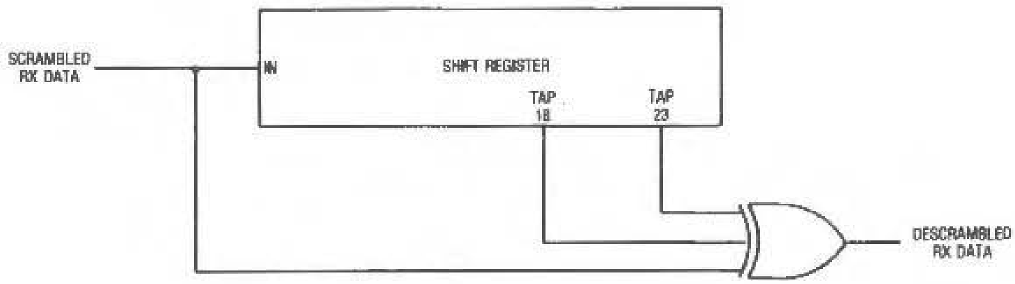


Fig 11-12
Descrambler

The SQE Test signal shall be detected on the RF interface and the SQE signal shall be presented to Circuit CI of the transmitting MAU, subject to the timing restrictions of 11.3.4.5.4. If the signal is not observed at the RF interface due to failure of any element in the transmitter or receiver, no SQE signal may be presented to the AUI. In the event of a collision enforcement, energy will appear in the collision enforcement band within the ced_window time after energy first appears in the data band. Circuit CI shall be asserted when collision enforcement is first detected and shall continue to be active until after the RF signal on the RF port has subsided. Note that an SQE Test signal appended to a packet whose length is less than the ced_window time (less than the minimum allowed packet length) will be indistinguishable from a collision enforcement, except by the MAU transmitting. The transmitting MAU shall take this into account and shall not interpret energy in the collision enforcement band to be a collision when the length of the transmitted packet is less than the ced_window time and the SQE Test sequence has been transmitted. See the discussion in 11.4.2 for more information on ced_window.

11.3.4.3 Circuit DO to Circuit DI Framing Characteristics. In the absence of a collision, the packet format of the receive data at the AUI is identical to that of the transmit data, except that there may be one more preamble bit than was sent at the transmit port and up to 6 bits of the preamble lost. In the presence of a collision, the receive data is undefined, but shall still be properly Manchester encoded.

11.3.4.4 AUI to Coaxial Cable Delay Characteristics. The timing and delays associated with the transmitter of the MAU are identified below. To ensure compatibility with all MAUs the delays identified below cannot be exceeded nor traded off with other delays in the system.

11.3.4.4.1 Circuit DO to RF Data Signal Delay. The delay from a transition on Circuit DO at the end of a bit to the corresponding phase change of the RF data signal (such bit chosen so that an RF burst phase change does exist) shall be no more than 24 bit times. The delay from the first transition on Circuit DO to the first appearance of RF energy, however, is not specified except as it is determined by other timing constraints.

11.3.4.4.2 Circuit DO to CE RF Output Delay. In the event that the MAU begins receiving energy on the coaxial medium just before the DTE presents data to the AUI, a collision shall be detected locally, as described in Fig 11-4. The delay from the first bit at Circuit DO of the AUI to the presentation of collision enforcement at the coaxial cable interface in this circumstance shall be 32 bit times maximum.

11.3.4.4.3 Transmit Postamble to SQE Test Signal Delay. The delay from the initial transition of the first bit of the postamble (Broadband End of Frame Delimiter) measured at the RF port to the 50% point of the rising edge of the SQE Test signal shall be 35 ± 3 bit times.

11.3.4.4.4 SQE Test Signal Length. The SQE Test signal length shall be 30 ± 1 bit times as measured at the 50% points of the RF signal.

11.3.4.5 Coaxial Cable to AUI Delay Characteristics. The MAU receiver timing and delays described below shall not be exceeded or traded off against any other delays in the system.

11.3.4.5.1 Received RF to Circuit DI Delay. When there is no collision in progress, the delay from the end of the SFD in the received RF data signal at the coaxial cable interface to the end of the SFD on Circuit DI, shall be a maximum of 75 bit times (see Fig 11-13). The minimum is not specified, nor is the delay specified at other locations in the packet. The end of the SFD in the received RF data signal (at the coaxial cable interface) is defined as the time at which the envelope of the carrier would pass through the midpoint if the first bit following the SFD was a zero and the scrambler disabled.

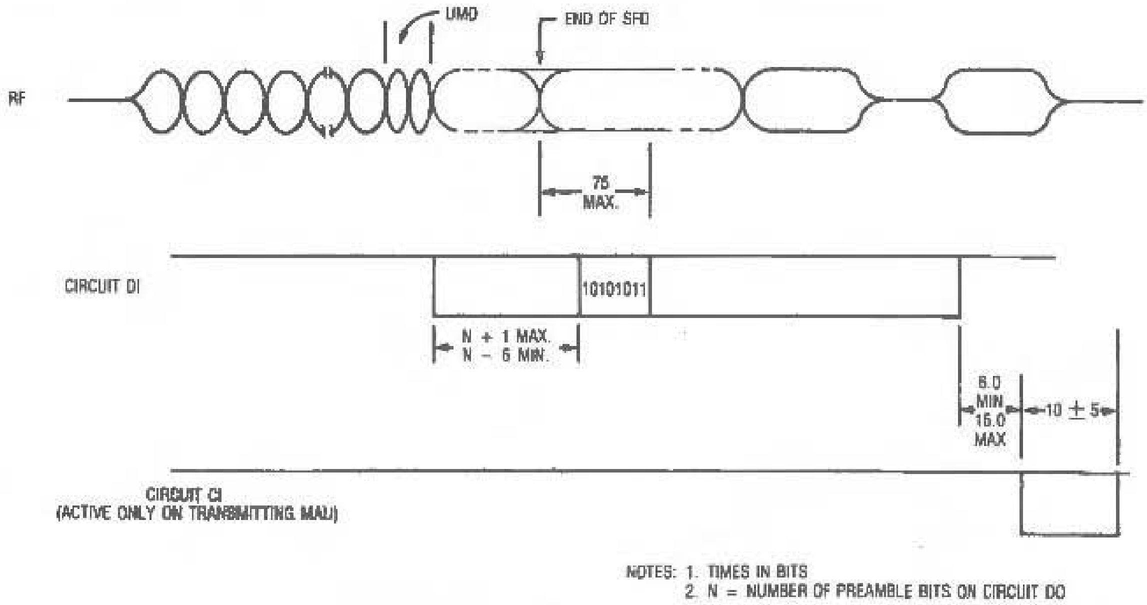


Fig 11-13
No Collision Timing Diagram (Coax to AUI)

11.3.4.5.2 Received RF to CE RF Output and Circuit CI Delay. In the event that a collision is detected via the bit-by-bit comparison, the delay from the end of the bit in which the collision was detected, as represented by the RF signal, to the 50% point on the rising edge of the collision enforcement signal shall not exceed 34 bit times. The delay from the same point to the first transition of Circuit CI shall not exceed 27 bit times. Circuit CI shall cease activity no more than 31 bit times after activity on the RF interface (in both data channel and collision enforcement channel) ceases. See Fig 11-14 and Fig 11-15.

11.3.4.5.3 Collision Enforcement to Circuit CI Delay. In the event of a collision enforcement by another MAU, the delay from the 50% point on the rising edge of the RF collision enforcement signal to the first transition of Circuit CI shall be no more than 31 bit times. Circuit CI shall be active for a minimum of 5 bit times and shall become inactive within 31 bit times of the cessation of activity on the RF coaxial cable interface, as shown in Fig 11-15.

11.3.4.5.4 Receive Data to SQE Test Delay. If a collision enforcement signal is received after the ced_window signal becomes inactive (see (9) in 11.2.3.2), or if the MAU has transmitted an SQE Test sequence, the MAU is to interpret the collision enforcement signal as an SQE Test signal. If the SQE Test sequence is correctly detected (that is, the test passes), then the delay from the last transition of Circuit DI to the first transition of Circuit CI shall be at least 6 but not more than 16 bit times. Circuit CI shall remain active for 10 ± 5 bit times. Only the transmitting MAU shall assert its Circuit CI as a result of successful completion of the SQE Test sequence.

If a collision enforcement signal is received before the ced_window signal becomes inactive, the MAU shall interpret it as a collision enforcement and the timing of 11.3.4.5.3 shall apply.

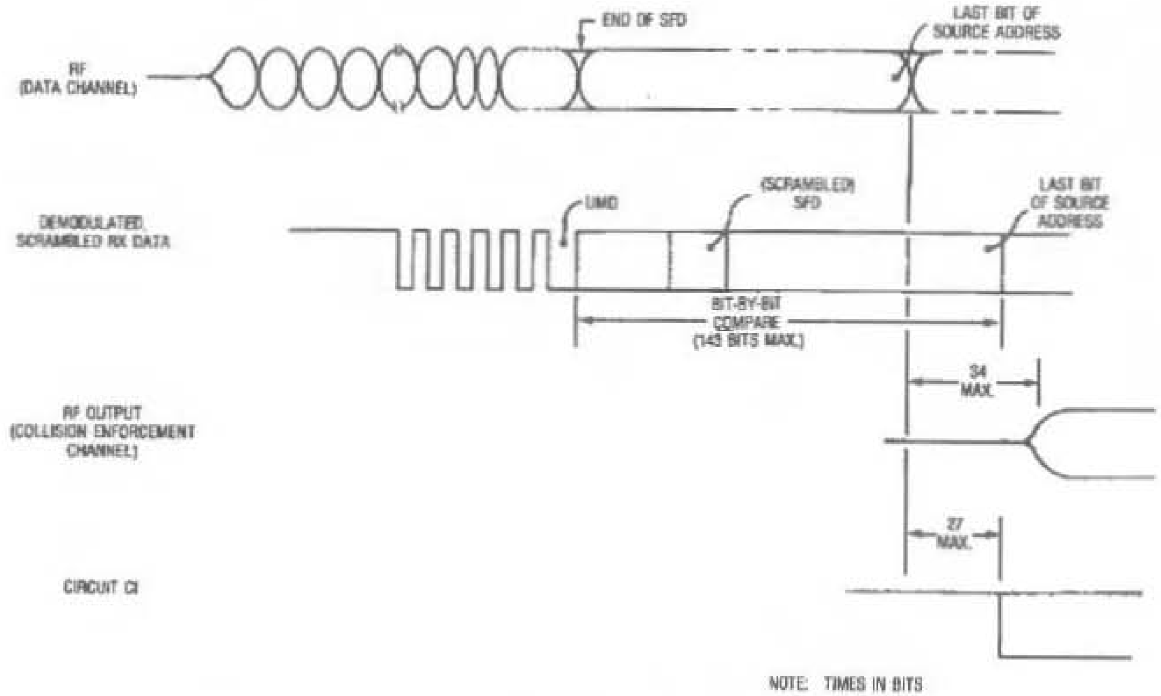


Fig 11-14
Collision Timing Diagram (RF Data to RF Collision Enforcement)

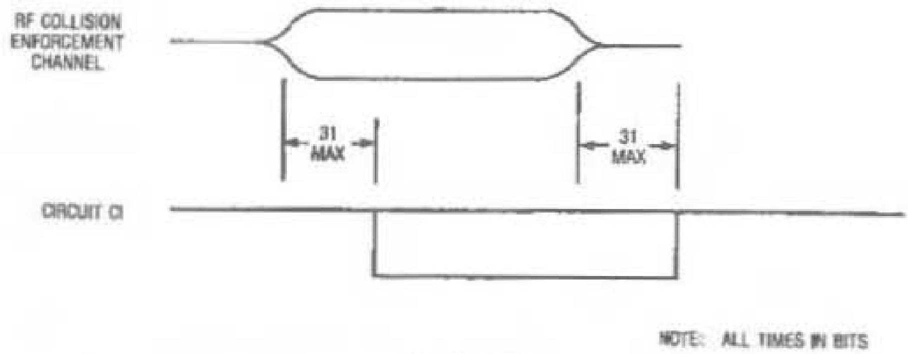


Fig 11-15
Collision Timing Diagram (Coaxial Cable Interface to AUI Circuit CI)

11.3.4.6 Delay from Circuit DO to Circuit DI. The time delay from a bit on Circuit DO at the AU Interface to the corresponding bit on Circuit DI at the AU Interface is equal to the round trip delay of the MAU connected back-to-back with itself (that is, in RF loopback) plus the round trip delay through the cable system at the location of the MAU. Therefore, the delay is a function of the location of the MAU on the cable system. It is never less than the transmitter delay plus the postamble length plus the time to detect loss of carrier or presence of the SQE Test signal. See Fig 11-16 for the timing relationship when the cable has zero length.

When the MAU is transmitting a short packet (less than 576 bits), the timing for Circuit CI during the SQE Test sequence shall be the same as it is for normal length packets. If the MAU transmits a short packet (less than 576 bits) that encounters a collision and if the SQE Test sequence has not been transmitted when the collision is detected by the MAU, then the timing for Circuit CI shall be the same as it is for any normal collision.

11.3.4.7 Interpacket Gap Requirement. The MAU shall be able and ready to transmit data presented to it by the DTE no later than 90 bit times after the last bit of a received packet was presented by the MAU at its AUI.

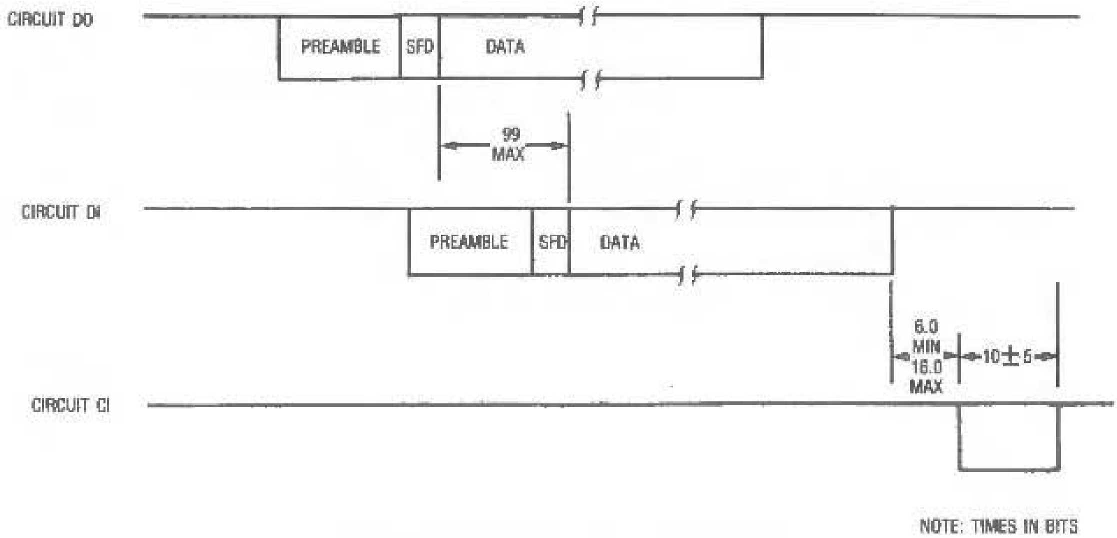


Fig 11-16
Timing at AUI for Zero-Length Coax

11.3.4.8 Bit Error Rate. The MAU shall have a Bit Error Rate (BER) as measured at the AUI lower than one error in 10^8 in a "zero-length coax" test environment (that is, a coaxial cable connection sufficiently short to have negligible delay and transmission impairments). It shall have this BER for receive signal levels in the range specified in 11.3.1.1.3 and in the presence of –28.3 dBmV rms/14 MHz white Gaussian noise. This represents a 24.3 dB signal-to-noise ratio for the specified minimum signal level, –4 dBmV rms. For the same BER in a "system" environment (as opposed to zero-length coax), a 26 dB signal-to-noise ratio is required.

The MAU shall meet the BER requirements specified above when receiving strings of up to 33 consecutive identical bits.

11.3.5 Reliability. Component failures within the MAU electronics should not impede communication among other MAUs on the broadband coaxial cable. Connectors and other passive components comprising the means of connecting the MAU to the coaxial cable shall be designed to minimize the probability of total network failure. The MAU shall be designed to provide an MTBF of at least 1 000 000 hours without causing communication failure among other stations attached to the broadband local network medium.

11.4 System Considerations

11.4.1 Delay Budget and Network Diameter. The delay budget for the broadband MAU and rest of the Physical Layer is tabulated in Table 11.4-1. This table includes allocations for trunk cables (the backbone cables in the system), drop cables (a length of 25 m is assumed), etc. The velocities of propagation assumed are included in the table; use of other types of cables will alter the system diameter accordingly. The types of cables, including the mix of drop and trunk cable lengths, can be altered as long as the total propagation delay from the most distant MAU to the headend does not exceed 70 bit times. The total delay budget of 576 bit times includes allowance for the preamble and SFD (64 bits).

Table 11.4-1 tabulates delay allocations for a dual-cable system with no headend delay. In translated single-cable systems, the headend translator delay reduces the maximum trunk cable distance by [D/(2 × CV)], where D is the delay in nanoseconds, and CV is the cable velocity in nanoseconds per meter. For 3.83 ns/m velocity trunk cable, this reduction is [Delay (ns) / 7.66] m.

Table 11.4-1
Broadband Dual-Cable Systems—Physical Layer Delay Budget

Delay Element	Maximum Allowed Value (Bits)
DTE1 starts to put out first bit	0.00
First bit from DTE1 at AUI	3.00
AUI Cable (50 m at 5.13 ns/m)	2.57
Circuit DO to Tx RF Out	24.00
Tx Drop Cable (25 m at 4.27 ns/m)	1.05
Tx Trunk Cable (1800 m at 3.83 ns/m)	68.95
Rx Trunk Cable (25 m at 4.27 ns/m)	68.95
Rx Drop Cable (25 m at 4.27 ns/m)	1.05
End of Bit Comparison (last bit of source address)	160.00
Rx RF to Collision Enforcement RF Out (from RX bit that is found to be in error to collision enforcement out)	34.00
Tx Drop Cable (25 m at 4.27 ns/m)	1.05
Tx Trunk Cable (1800 m at 3.83 ns/m)	68.95
Rx Trunk Cable (1800 m at 3.83 ns/m)	68.95
Rx Drop Cable (25 m at 4.27 ns/m)	1.05
Rx Collision Enforcement to Circuit Ci	31.00
AUI Cable (50 m at 5.13 ns/m)	2.57
DTE1 Detects Collision Presence	3.00
DTE1 Jams Channel	32.00
Allowance for Traps, Splitters, Amplifiers, and Margin	3.86
Total	576.00

11.4.2 MAU Operation with Packets Shorter than 512 Bits. The MAU transmits an SQE Test sequence onto the RF medium after every transmitted packet. If the frame plus preamble and SFD is less than the ced_window in length, a receiving MAU cannot distinguish the SQE Test signal from a collision enforcement signal due to a collision. Therefore, operation of the MAU with data frames shorter than 512 bits may cause all other receiving MAUs to see a collision. The transmitting MAU, however, recognizes the SQE Test because that MAU was the one that transmitted the test. An MAU transmitting a short packet that encounters a collision can distinguish the resulting collision enforcement from an SQE Test signal by the fact that the transmitting MAU will not have transmitted the SQE Test sequence unless the packet is shorter than the round trip delay on the cable plant. In the latter instance, the transmitting MAU may not detect a collision enforcement.

11.5 Characteristics of the Coaxial Cable System. The cable system upon which the broadband MAU operates shall meet the following electrical and mechanical requirements.

11.5.1 Electrical Requirements. The electrical requirements of the cable system are listed in Table 11.5-1. Each parameter is applicable over the frequency range to be used by the broadband MAU.

Adjacent channel signal levels shall be consistent with the requirements of 11.3.1.1.4.

Table 11.5-1
Cable System Electrical Requirements

Impedance	75 Ω
Return Loss	14 dB min
Transmit Level	+50 dBmV ±2 dB
Receive Level	+6 dBmV ±10 dB
Maximum Receive Noise Level	-30 dBmV/14 MHz
Loss Variation* (per 18 MHz band)	2 dB min, 52 dB max
Path Loss (between any transmit port and receive port, including loss variation)	36 dB min, 52 dB max
Group Delay Variation	
—around data carrier	20 ns/10 MHz max
—over 18 MHz band	34 ns max

* Not including headend.

11.5.2 Mechanical Requirements. The connection of the cable system to the broadband MAU is via a standard F-series screw-on male connector. For the dual-cable case, two such connectors are required: one for transmit and the other for receive.

11.5.3 Delay Requirements. The maximum length of the cable system is constrained by the allowable round trip delay from the farthest transmitting MAU to the farthest receiving MAU. Table 11.4-1 allows 140 bit times round trip delay in the cable system. For trunk cable propagation velocity of 3.83 ns/m, this allows 3600 m of trunk cable (round trip; 1800 m from the farthest point to the headend), and 25 m of 4.27 ns/m velocity drop cable at each MAU. In addition, 50 m of AUI cable is allowed on each MAU, therefore allowing, in this case, a maximum of 3750 m DTE to DTE separation. These lengths will be different if cables of different propagation velocity are used. This is acceptable so long as the maximum delay is not exceeded.

For single-cable systems, the maximum delay of 140 bit times includes the delay through the headend. The maximum cable system length must be reduced appropriately, as described in 11.4.1.

11.6 Frequency Translator Requirements for the Single-Cable Version

11.6.1 Electrical Requirements. The headend frequency translator performance is included in the cable system characteristics specified in 11.5, except as defined in Table 11.6-1.

Table 11.6-1
Frequency Translator Requirements

Group Delay Variation	
—around data carrier frequency	20 ns/10 MHz max
—between data carrier and CE center frequency	60 ns max
Amplitude Variation (from 6 MHz below the input data carrier frequency to 1 MHz above the CE center frequency)	2 dB max
Translation Frequency	per Table 11.3-1

The frequency translator contributes to total cable system delay and shall be labeled by the vendor with the input-to-output delay in the band of operation. The effect on network length can then be computed per 11.4.1.

11.6.2 Mechanical Requirements. The input and output mechanical interface shall be 75 Ω female F-series coaxial connectors. The connection to the broadband medium shall be through a coaxial cable with a mating male F-series connector.

11.7 Environmental Specifications

11.7.1 Safety Requirements. This subsection sets forth a number of recommendations and guidelines related to safety concerns. This list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to assure compliance with the appropriate standards.

Local area network cable systems, as described in this section, are subject to at least four direct electrical safety hazards during their use, and designers of connecting equipment should be aware of these hazards. The hazards are as follows:

(1) Direct contact between local network components and power or lighting circuits
(2) Static charge buildup on local network cables and components
(3) High-energy transients coupled onto the local network cabling system
(4) Potential differences between safety grounds to which various network components are connected

These electrical safety hazards, to which all similar cabling systems are subject, should be alleviated for a local network to perform properly. In addition to provisions for properly handling these faults in an operational system, special measures shall be taken to ensure that the intended safety features are not negated when attaching or detaching equipment from the local area network medium of an existing network.

Sound installation practice, as defined in applicable national and local codes and regulations, shall be followed in every instance in which such practice is applicable.

11.7.2 Electromagnetic Environment

11.7.2.1 Susceptibility Levels. Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc.

The physical MAU hardware shall meet its specifications when operating in an ambient plane wave field of:

(1) 2 V/m from 10 kHz through 30 MHz
(2) 5 V/m from 30 MHz through 1 GHz

MAUs meeting this section should provide adequate RF ground return to satisfy the EMC specification.

11.7.2.2 Emission Levels. The physical MAU hardware shall comply with the applicable national and local regulations for emission levels.

11.7.3 Temperature and Humidity. The MAU and associated cable system are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

12. Physical Signaling, Medium Attachment, and Baseband Medium Specifications, Type 1BASE5

12.1 Introduction

12.1.1 Overview. 1BASE5 is a 1 Mb/s CSMA/CD network based on twisted pair wiring. Each DTE (Data Terminal Equipment) is star-connected to a shared hub through two pairs that function as transmit and receive channels. Hubs can be cascaded, and DTEs can be connected to any hub. Packets transmitted by a DTE are propagated by the hub to a higher-level hub if one exists; otherwise the hub broadcasts the packet back down to all DTEs and lower-level hubs. Packets received by a hub from a higher-level hub are retransmitted to all attached DTEs and lower-level hubs. If two or more DTEs or lower-level hubs transmit concurrently, the hub generates a collision-presence signal that the DTEs detect as a collision. Hubs between a transmitting DTE and the header (highest level) hub propagate data or the collision-presence signal to the header hub; this hub in turn broadcasts the packet or collision signal to all DTEs and lower-level hubs.

12.1.2 Scope. The 1BASE5 specification builds upon the first six major sections of this standard; the remaining major sections (other than this one, of course) do not apply to 1BASE5. That is, the Media Access Control (MAC) and Physical Signaling (PLS) Service Specifications are used in common with the other implementations of this standard, but the Physical Medium Attachment (PMA) sublayer, transmission medium, and hub functions for Type 1BASE5 are specified in this section. The relationship of the 1BASE5 specification to the OSI Reference Model and the IEEE 802.3 CSMA/CD LAN Model is shown in Fig 12-1.

12.1.3 Definitions

bit cell. The time interval used for the transmission of a single data (CD0 or CD1) or control (CVH or CVL) symbol.

bit rate (BR). The rate of data throughput on the medium (in b/s or Hz, whichever is more appropriate to the context). See 12.3.2.4.1.

bit time (BT). The duration (of transmission) of one bit symbol (bit cell) (1/BR). See 12.3.2.4.1.

carrier sense. In a local area network, an ongoing activity of a data station to detect whether another station is transmitting. Note that the signal provided by the PLS to the PMA sublayer indicates that one or more DTEs are currently transmitting.

Clocked Data One (CD1). A Manchester encoded data "1." A CD1 is encoded as a LO for the first half of the bit cell and a HI for the second half of the bit cell.

Clocked Data Zero (CD0). A Manchester encoded data "0." A CD0 is encoded as a HI for the first half of the bit cell and a LO for the second half of the bit cell.

Clocked Violation HI (CVH). A symbol that deliberately violates Manchester encoding rules, used as part of the Collision Presence signal. A CVH is encoded as a transition from LO to HI at the beginning of the bit cell, HI for the entire bit cell, and a transition from HI to LO at the end of the bit cell.

Clocked Violation LO (CVL). A symbol that deliberately violates Manchester encoding rules, used as part of the Collision Presence signal. A CVL is encoded as a transition from HI to LO at the beginning of the bit cell, LO for the entire bit cell, and a transition from LO to HI at the end of the bit cell.

collision. A condition that results from concurrent transmissions on the physical medium.

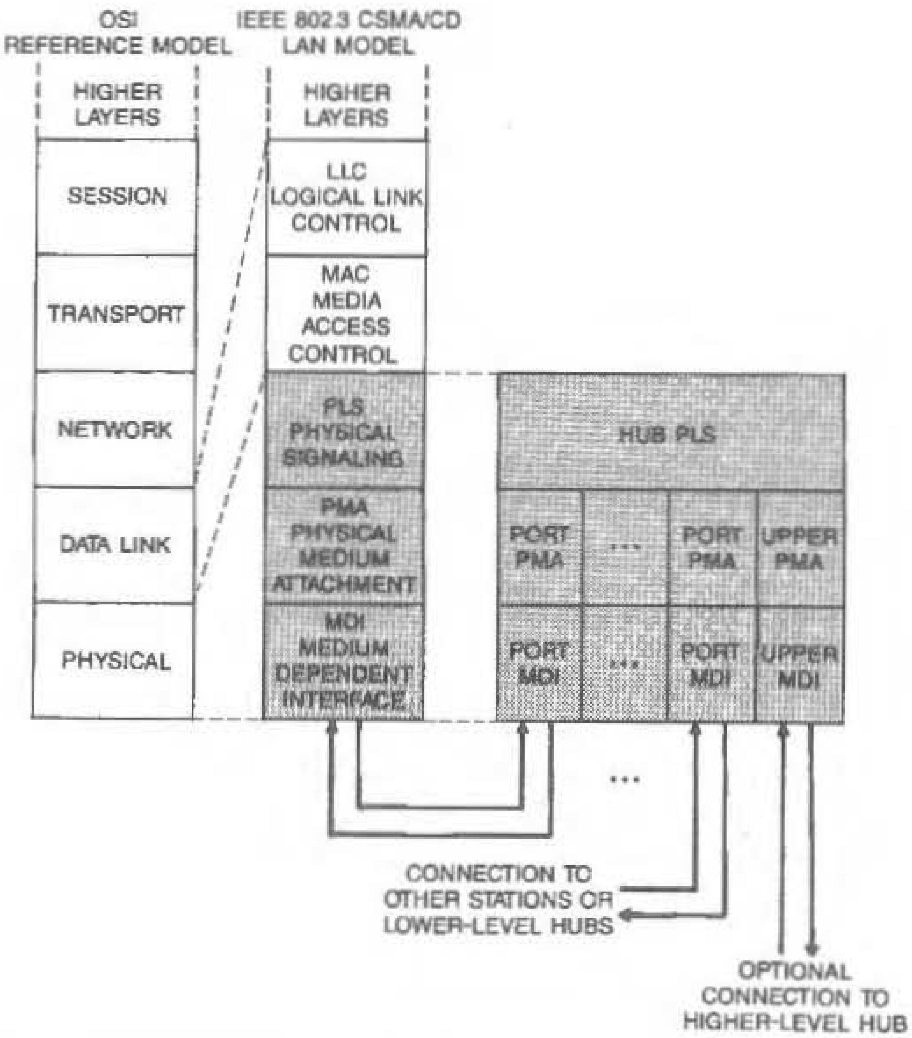


Fig 12-1
1BASE5 Relationship to the ISO Open Systems Interconnection (OSI) Reference Model and the IEEE 802.3 CSMA/CD LAN Model

Collision Presence (CP). The non-Manchester signal generated by hubs to report collisions and some error conditions. See 12.3.2.4.3 for details.

header hub (HH). The highest-level hub in a hierarchy of hubs. The HH broadcasts signals transmitted to it by lower-level hubs or DTEs, such that they can be received by all DTEs that may be connected to it, either directly or through intermediate hubs. See 12.2.1 for details.

hub. A device used to provide connectivity between DTEs. Hubs perform the basic functions of restoring signal amplitude and timing, collision detection and notification, and signal broadcast to lower-level hubs and DTEs.

idle (IDL). A signal condition where no transition occurs on the transmission line. It is used to define the time between packets. See 12.3.2.4.4 for details.

intermediate hub (IH). A hub that occupies any level below the header hub in a hierarchy of hubs. See 12.2.1 for details.

Jabber Function. A mechanism for controlling abnormally long transmissions.

special link (SL). A transmission system that replaces the normal medium. See 12.8 for details.

12.1.4 General Characteristics. Type 1BASE5 has the following general characteristics:

(1) 1 Mb/s signaling rate, Manchester encoded
(2) Twisted pair wiring
(3) Point-to-point interconnection of DTEs to hubs, with one twisted pair serving as the upward link, the other as the downward link
(4) Data pairs can coexist in the same telephone cable bundles as voice pairs
(5) When a hub receives signals from a DTE or lower-level hub, it propagates them to a higher-level hub if one exists; otherwise, the hub broadcasts the signals back down to the DTEs and lower-level hubs
(6) When a hub receives signals concurrently from two or more DTEs or lower-level hubs, it generates a unique collision presence signal, and distributes it as in (5) above
(7) DTE-to-hub and hub-to-hub interfaces are electrically isolated at both ends
(8) Up to five hub levels are allowed
(9) Hubs serve as repeaters
(10) Maximum DTE-to-hub and hub-to-hub distance is approximately 250 m for telephone wiring (cable-type dependent; see 12.7)
(11) Special links may be used to extend some DTE-to-hub or hub-to-hub distances to 4 km

12.1.5 Compatibility. This specification calls out one principal compatibility interface, namely PMA-to-Medium. It is intended that different implementations of DTEs and hubs be able to interoperate in 1BASE5 networks.

12.1.6 Objectives of Type 1BASE5 Specification

(1) Provide for low-cost networks, as related to both equipment and cabling
(2) Make it possible to use telephone-type building wiring, and in particular spare wiring when available
(3) Provide for easy installability, reconfigurability, and service
(4) Ensure interconnectability of independently developed DTEs and hubs
(5) Ensure fairness of DTE access
(6) Provide a communication channel with a resultant mean bit error rate, at the physical layer service interface, of less than one part in 10^8 (on the order of one part in 10^9 at the link level)

12.2 Architecture

12.2.1 Major Concepts. Type 1BASE5 is a 1 Mb/s CSMA/CD network. DTEs are connected to hubs (and hubs to other hubs) by point-to-point wiring, resulting in a star topology network. Data transmissions are Manchester encoded.

An elementary configuration is illustrated in Fig 12-2. In this instance, each DTE is connected to the hub via separate transmit and receive channels (normally two twisted pairs). The hub serves as the point of concentration and performs two major functions: signal regeneration/retiming (repeating) and collision detection. When only one DTE transmits, the hub repeats the signals, compensating for amplitude and phase distortion, and broadcasts to all DTEs. When a hub detects two or more DTEs transmitting concurrently, the hub generates a unique Collision Presence (CP) signal, which it broadcasts instead of the originally transmitted signals. The hub continues to send CP until it receives IDL from all lower-level DTEs. CP has the property that it can be detected by DTEs as a Manchester code violation.

The interconnection architecture does not imply any minimum, typical, or maximum number of DTEs to be connected to a given hub; this is an implementation or installation detail.

Up to five levels of hubs may be cascaded. A two-level configuration is illustrated in Fig 12-3, with a header hub (HH) and intermediate hubs (IH). There can be a number of IHs; there must be one and only one HH. Each DTE or IH is connected to a hub via separate transmit and receive channels (normally two twisted pairs). An IH propagates signals from its DTEs toward the HH; it sends CP toward the HH in the event of

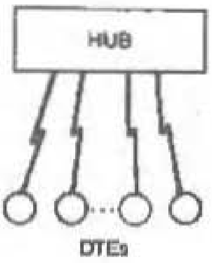


Fig 12-2
Single Hub Network

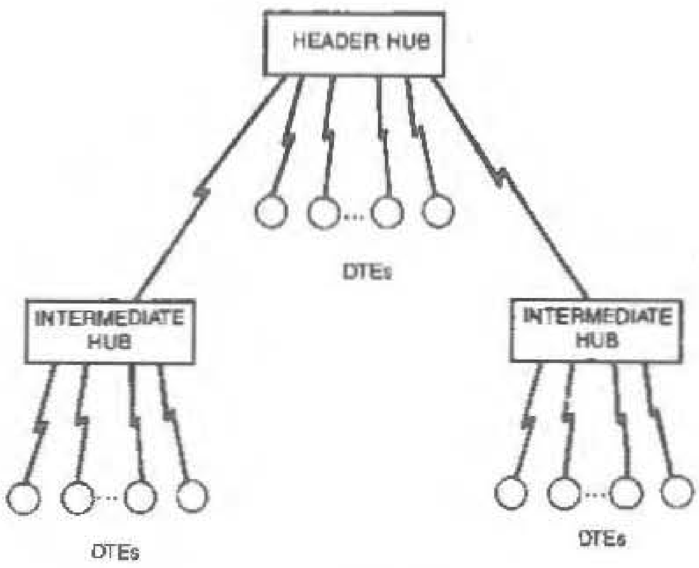


Fig 12-3
Network with Two Levels of Hubs

a collision. The HH repeats the signals it receives from DTEs or IHs back down to all DTEs and IHs. The HH generates CP if more than one of its inputs becomes active. The IHs repeat the signals received from the HH, and broadcast to all the connected DTEs' receivers. Hubs do not distinguish whether input signals along the upward path emanate from DTEs or lower-level IHs. If a single input is active, the hub repeats the signal regardless of its source; if more than one is active, it generates CP.

A configuration involving four hub levels and a special link is illustrated in Fig 12-4. In this example, one IH is used for simple repeating (one connection upward and one connection downward). Other than having one link in and one link out, repeaters are identical to other hubs. Special links are connections, possibly containing active devices, that are used for situations requiring extra propagation delay or special transmission media.

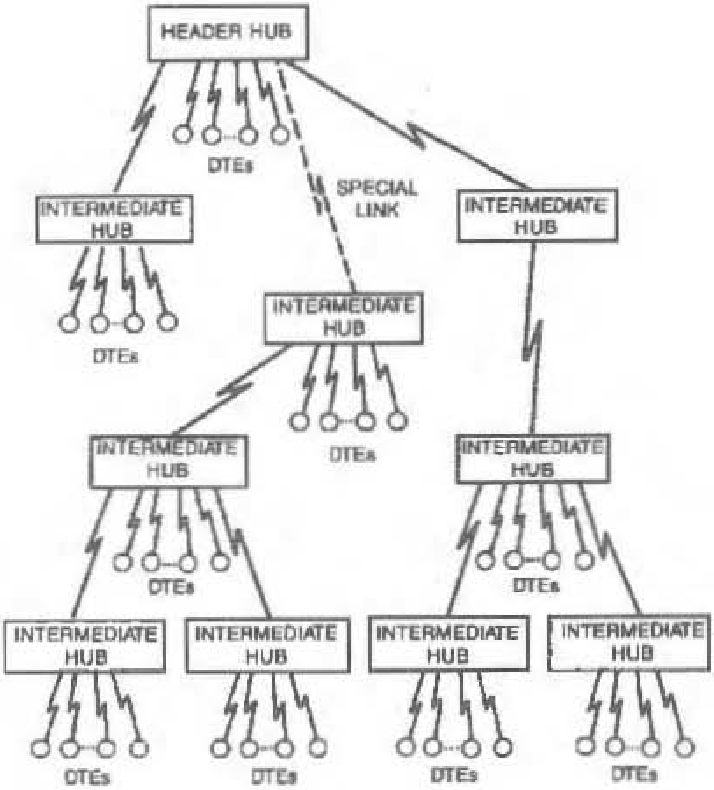


Fig 12-4
Network with Four Levels of Hubs

12.2.2 Application Perspective. The primary application area for type 1BASE5 is expected to be in office environments for networking DTEs such as personal computers or other workstations. In many cases, spare wiring contained in existing telephone wire bundles will be used.

12.2.3 Packet Structure. Packets are transmitted from the PLS to the PMA as follows:

<silence> <preamble> <sfd> <data> <etd> <silence>

The packet elements shall have the following characteristics:

Element	Characteristics
<silence>	No transitions
<preamble>	Alternating CD1 and CD0 for ≥56 bit times (ending in CD0)
<sfd>	CD1 CD0 CD1 CD0 CD1 CD0 CD1 CD1
<data>	8 × N instances of CD0 or CD1
<etd>	First part of IDL

12.2.3.1 Silence. The <silence> delimiter provides an observation window for an unspecified period of time during which no transitions occur. The minimum duration of <etd> followed by <silence> is the interFrameGap defined in 4.4.2.2.

12.2.3.2 Preamble. The <preamble> delimiter begins a packet transmission and provides a signal for receiver synchronization. The signal shall be an alternating pattern of CD1 and CD0. This pattern shall be transmitted by the DTE for a minimum of 56 bit times at the beginning of each packet. The last bit of the preamble (that is, the final bit of preamble before the start-of-frame delimiter) shall be a CD0.

The DTE is required to supply at least 56 bits of preamble in order to satisfy system requirements. System components consume preamble bits in order to perform their functions. The number of preamble bits sourced ensures an adequate number of bits are provided to each system component to correctly implement its function.

12.2.3.3 Start-of-Frame Delimiter. The <sfd> indicates the start of a frame, and follows the preamble.

12.2.3.4 Data. The <data> in a transmission shall be in multiples of eight (8) encoded data bits (CD0s and CD1s).

12.2.3.5 End-of-Transmission Delimiter. The <etd> indicates the end of a transmission and serves to turn off the transmitter. The signal shall be the first part of an IDL.

12.3 DTE Physical Signaling (PLS) Specification

12.3.1 Overview. This section defines logical characteristics of the DTE PLS sublayer for 1BASE5. The relationship of this specification to the entire standard is shown in Fig 12-5. The sublayer and its relationship to the MAC and PMA sublayers are described in an abstract way and do not imply any particular implementation.

12.3.1.1 Summary of Major Concepts

(1) There are two channels between the PLS and PMA sublayers. Output data are passed through the output channel and input data and control (CP) are passed through the input channel.
(2) Each direction of data transfer through the PLS operates independently and simultaneously (that is, the PLS is full duplex).

12.3.1.2 Application Perspective. The DTE PLS sublayer performs the following functions:

(1) Encodes OUTPUT_UNITs from the MAC sublayer into a Manchester encoded waveform that it sends to the PMA sublayer output circuit
(2) Decodes a Manchester encoded waveform from the PMA sublayer input circuit into INPUT_UNITS, CARRIER_STATUS, and SIGNAL_STATUS

12.3.2 Functional Specification. This section provides a detailed model for the DTE PLS sublayer.

Many of the terms used in this section are specific to the interface between this sublayer and the MAC sublayer. These terms are defined in the service specification for the PLS sublayer (see 6.3).

12.3.2.1 PLS-PMA Interface. The PLS and PMA communicate by means of the following messages:

Message	Meaning	Source
output	Output information	PLS
output_idle	No data to be output	PLS
input	Input information	PMA
input_idle	No input information	PMA

12.3.2.1.1 *output* Message. The PLS sublayer sends an *output* message to the PMA sublayer when the PLS sublayer receives an OUTPUT_UNIT from the MAC sublayer.

The physical realization of the *output* message is a CD0 or a CD1 sent by the PLS to the PMA. The PLS sends a CD0 if the OUTPUT_UNIT is a ZERO or a CD1 if the OUTPUT_UNIT is a ONE. This message is time-coded. That is, once this message has been sent, the function is not completed until one bit time later.

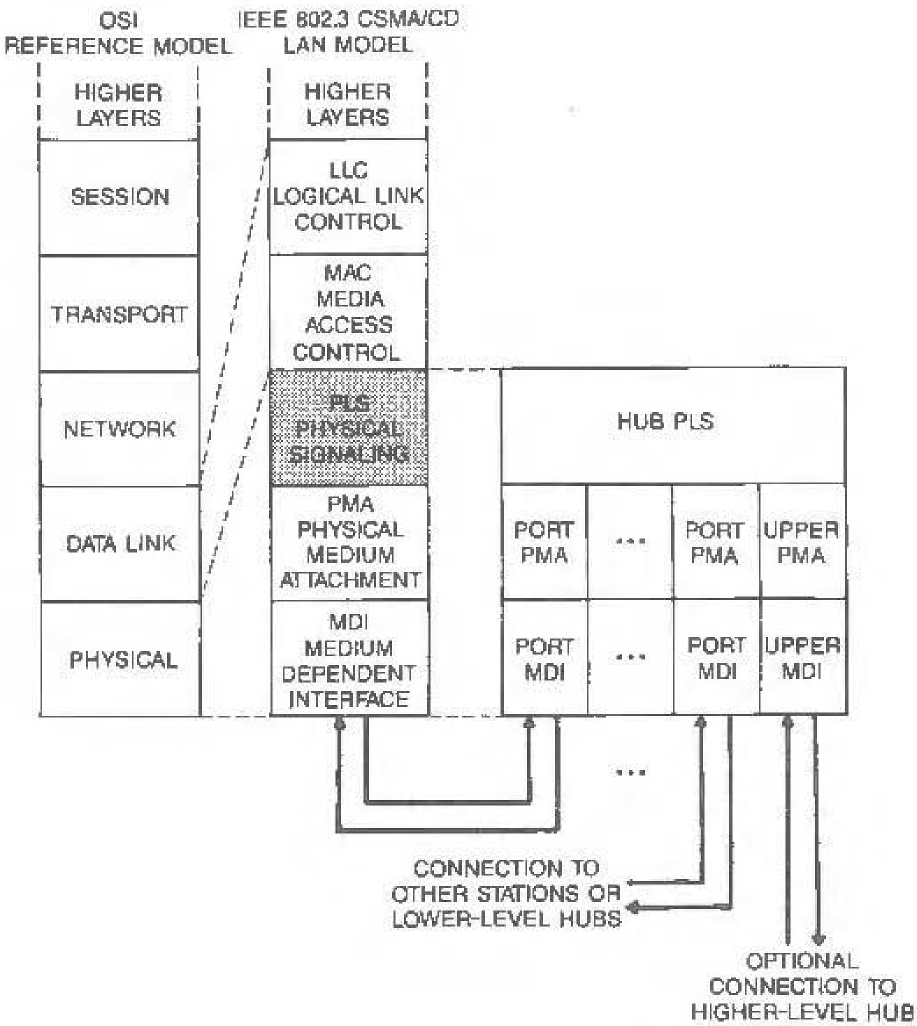


Fig 12-5
Station Physical Signaling, Relationship to the ISO OSI Reference Model and the IEEE 802.3 CSMA/CD LAN Model

The *output* message cannot be sent again until the bit cell being sent as a result of sending the previous *output* message is complete.

12.3.2.1.2 *output_idle* Message. The PLS sublayer sends an *output_idle* message to the PMA sublayer at all times when the MAC sublayer is not in the process of transferring output data across the MAC to PLS interface. The *output_idle* message is no longer sent (and the first OUTPUT_UNIT is sent using the *output* message) when the first OUTPUT_UNIT of a packet is received from the MAC sublayer. The *output_idle* message is again sent to the PMA when DATA_COMPLETE is received from the MAC sublayer.

The physical realization of the *output_idle* message is IDL sent by the PLS to the PMA.

12.3.2.1.3 *input* Message. The PMA sublayer sends an *input* message to the PLS sublayer when the PMA has received a bit from the medium and is prepared to transfer this bit to the PLS.

The physical realization of the *input* message consists of data units, CD0, CD1, CVL, or CVH, derived from the incoming data stream. If ambiguity exists due to excessive noise or jitter, the PMA may send an arbitrary combination of these.

12.3.2.1.4 *input_idle* Message. The PMA sublayer sends an *input_idle* message to the PLS sublayer when the PMA sublayer does not have data to send to the PLS sublayer. This condition exists when carrier is lost or IDL is received.

12.3.2.2 PLS-MAC Interface. The PLS and MAC communicate by means of the following messages:

Message	Meaning	Source
OUTPUT_UNIT	Data sent to the PMA	MAC
OUTPUT_STATUS	Response to OUTPUT_UNIT	PLS
INPUT_UNIT	Data received from the PMA	PLS
CARRIER_STATUS	Indication of input activity	PLS
SIGNAL_STATUS	Indication of error/no error condition	PLS

12.3.2.2.1 OUTPUT_UNIT. The MAC sublayer sends the PLS sublayer an OUTPUT_UNIT every time the MAC sublayer has a bit to send. Once the MAC sublayer has sent an OUTPUT_UNIT to the PLS sublayer, it may not send another OUTPUT_UNIT until it has received an OUTPUT_STATUS message from the PLS sublayer. The OUTPUT_UNIT is a ONE if the MAC sublayer wants the PLS sublayer to send a CD1 to the PMA sublayer, a ZERO if a CD0 is desired, or a DATA_COMPLETE if an IDL is desired.

12.3.2.2.2 OUTPUT_STATUS. The PLS sublayer sends the MAC sublayer an OUTPUT_STATUS in response to every OUTPUT_UNIT received by the PLS sublayer. OUTPUT_STATUS sent is an OUTPUT_NEXT when the PLS sublayer is ready to accept the next OUTPUT_UNIT from the MAC sublayer. (The purpose of OUTPUT_STATUS is to synchronize the MAC sublayer data output with the data rate of the physical medium.)

12.3.2.2.3 INPUT_UNIT. The PLS sublayer sends the MAC sublayer an INPUT_UNIT every time the PLS receives an *input* message from the PMA sublayer. The INPUT_UNIT is a ONE if the PLS sublayer receives a CD1 from the PMA sublayer or a ZERO if the PLS sublayer receives a CD0 from the PMA sublayer. The INPUT_UNIT may be either ZERO or ONE if the PLS sublayer receives a CVL or CVH from the PMA sublayer.

12.3.2.2.4 CARRIER_STATUS. The PLS sublayer sends the MAC sublayer_CARRIER_STATUS whenever there is a change in carrier status, as detected by the PMA. The PLS sublayer sends CARRIER_ON when it receives an *input* message from the PMA and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_OFF. The PLS sublayer sends CARRIER_OFF when it receives an *input_idle* message from the PMA sublayer, and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_ON.

12.3.2.2.5 SIGNAL_STATUS. The PLS sublayer sends the MAC sublayer SIGNAL_STATUS whenever it detects the beginning or end of Collision Presence. The PLS sublayer sends SIGNAL_ERROR when it receives *input* message CVL or CVH from the PMA sublayer and the previous SIGNAL_STATUS the PLS sublayer sent was NO_SIGNAL_ERROR. The PLS sublayer sends NO_SIGNAL_ERROR when it receives an *input_idle* message from the PMA sublayer and the previous SIGNAL_STATUS that the PLS sent to the MAC sublayer was SIGNAL_ERROR. The PLS shall send SIGNAL_ERROR to the MAC sublayer when the Collision Presence pattern is detected; it may send SIGNAL_ERROR any time it receives an *input* message that is neither CD0 nor CD1.

12.3.2.3 PLS Functions. The PLS sublayer functions consist of four simultaneous and asynchronous functions. These functions are Output, Input, Error Sense, and Carrier Sense. All of the four functions are started immediately following PowerOn. These functions are depicted in the state diagrams shown in Fig 12-6 through Fig 12-9, using the notation described in 1.2.1.

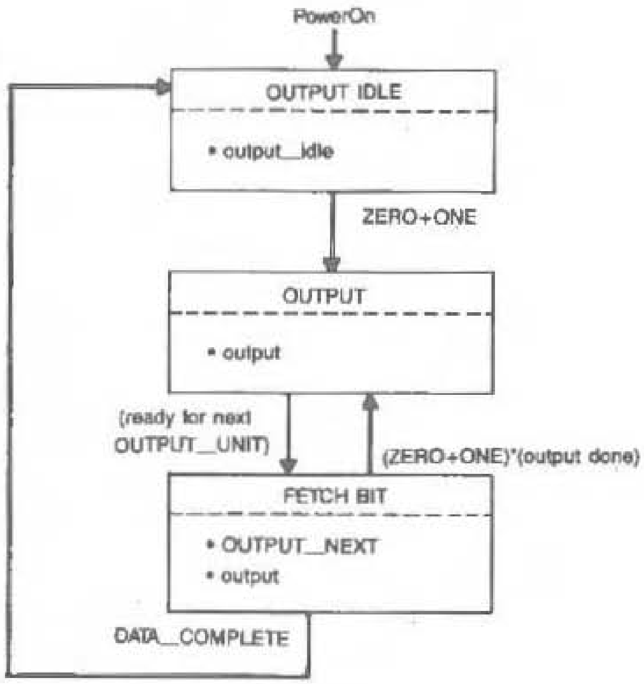


Fig 12-6
DTE PLS Output Function

12.3.2.3.1 State Diagram Variables. The variables used in the state diagrams and the corresponding descriptions are the following:

(1) Inter Process Flags

disable_SIGNAL_ERROR	Used in the state diagrams and functions. It is used by the Input Function to prevent false collision detection by the Error Sense Function during preamble startup.
protectTimer	Used by the Carrier Sense Function to implement the protection period described in 12.5.3.2.3. It is started by "start-protectTimer." "protectTimer_done" is satisfied when the timer has expired.

12.3.2.3.2 Output Function. The Output Function transparently performs the task of data transfer from the MAC sublayer to the PMA sublayer. The state diagram of Fig 12-6 depicts the Output Function operation.

12.3.2.3.3 Input Function. The Input Function transparently performs the task of data transfer from the PMA sublayer to the MAC sublayer. The state diagram of Fig 12-7 depicts the Input Function operation.

12.3.2.3.4 Error Sense Function. The Error Sense Function performs the task of sending SIGNAL_STATUS to the MAC sublayer at the beginning and end of the Collision Presence pattern. The state diagram of Fig 12-8 depicts the Error Sense Function operation.

12.3.2.3.5 Carrier Sense Function. The Carrier Sense Function performs the task of sending CARRIER_STATUS to the MAC sublayer whenever the input becomes active or idle, as detected by the PMA sublayer. The state diagram of Fig 12-9 depicts the Carrier Sense Function operation.

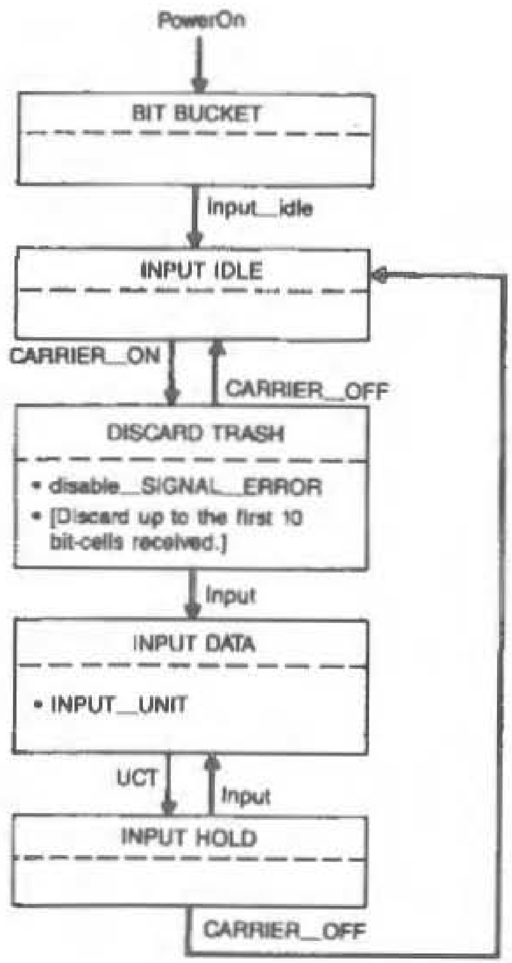


Fig 12-7
DTE PLS Input Function

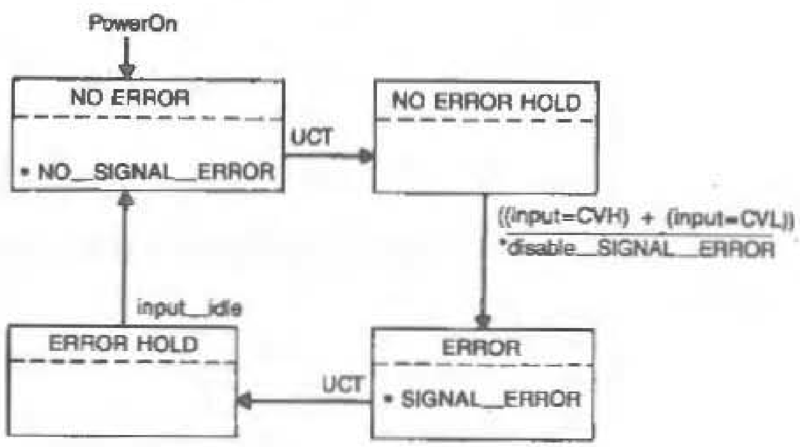


Fig 12-8
DTE PLS Error Sense Function

AMX and Dell, Inc.
Exhibit 1026-00216

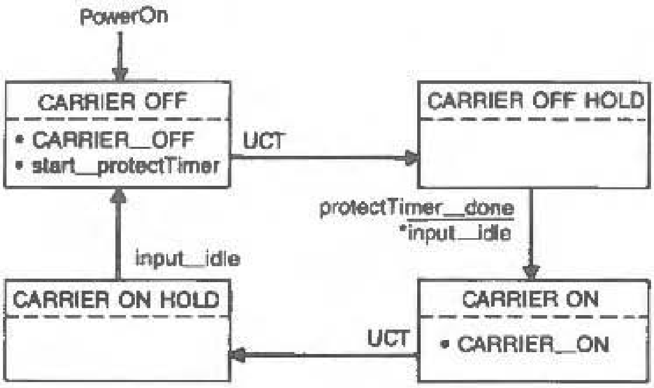


Fig 12-9
DTE PLS Carrier Sense Function

A timer may be used by the Carrier Sense Function to implement the protection period described in 12.5.3.2.3. It is started by "start-protectTimer" and asserts "protectTimer_done" after 0 to 30 μs since starting.

12.3.2.4 Signal Encoding. Five distinct symbols can be transmitted on the line: CD0, CD1, CVL, CVH, and IDL. Of these, CVL and CVH are transmitted only as part of the collision presence reporting pattern CP.

12.3.2.4.1 Data Transmission Rate. The data transmission rate (BR) is 1 Mb/s $\pm$ 0.01%. A bit time (BT) is therefore nominally 1 μs.

12.3.2.4.2 Data Symbol Encoding. Manchester encoding is used for the transmission of packets. Manchester encoding is a binary signaling mechanism that combines data and clock into bit cells. Each bit cell is split into two halves with the second half containing the binary inverse of the first half; a transition always occurs in the middle of each bit cell. During the first half of the bit cell, the encoded signal is the logical complement of the bit value being encoded. During the second half of the bit cell, the encoded signal is the uncomplemented value of the bit being encoded. Thus, a CD0 is encoded as a bit cell in which the first half is HI and the second half is LO. A CD1 is encoded as a bit cell in which the first half is LO and the second half is HI. Examples of Manchester waveforms are shown in Fig 12-10. The zero crossings of an ideal Manchester waveform occur on precise half-bit-cell boundaries. The zero crossings of real waveforms may include timing jitter that causes deviation from these "idealized zero crossings.".

12.3.2.4.3 Collision Presence Encoding. Two signals, CVL and CVH, that are transmitted only as part of the collision presence reporting pattern, CP, violate the normal Manchester encoding rule requiring a transition in the middle of each symbol. A CVH is encoded as a transition from LO to HI at the beginning of the bit cell, HI for the entire bit cell, and transition from HI to LO at the end of the bit cell. A CVL is encoded as a transition from HI to LO at the beginning of the bit cell, LO for the entire bit cell, and transition from LO to HI at the end of the bit cell.

The Collision Presence reporting signal, CP, is a special sequence that differs from any legitimate Manchester-encoded signal. CP is encoded as a repeating sequence of 1 bit time LO, 1/2 bit time HI, 1 bit time LO, 1 bit time HI, 1/2 bit time LO, and 1 bit time HI. This may also be interpreted as repetitions of the five-symbol sequence CVL, CD0, CD1, CD0, CVH. Should a transmitter's or receiver's timing be shifted by 1/2 bit time, then the same sequence will be interpretable as repetitions of CD1, CVL, CVH, CD1, CD0. In either case, the presence of non-Manchester symbols distinguishes the sequence from data. Examples of

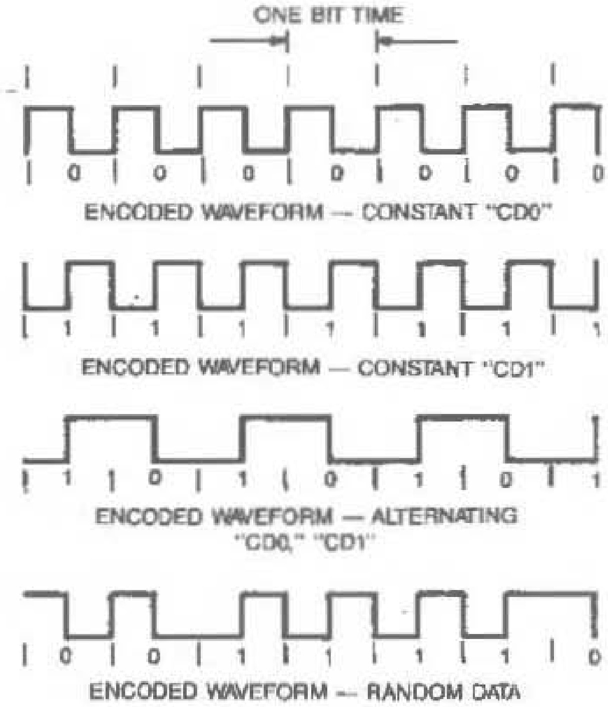


Fig 12-10
Examples of Manchester Waveforms

Collision Presence waveforms are shown in Fig 12-11. See 12.3.2.2.5 and 12.4.3.2 for further details on the detection and generation of CP.

NOTE: CP is the minimal length sequence that meets the following design criteria:

(1) The sequence should not look like legitimate Manchester-encoded data even if the receiver does not lock onto the correct bit-cell boundaries.

(2) The sequence should maintain overall dc balance. That is, it should be HI 50% of the time and LO the other 50%.

(3) The signal should occupy the same part of the frequency spectrum as normal data. That is, transitions should occur every half or whole bit time so that the fundamental signaling frequencies of BR/2 and BR are maintained. Furthermore, allowing more than one bit time to pass without a transition would introduce ambiguity with the idle line condition (IDL).

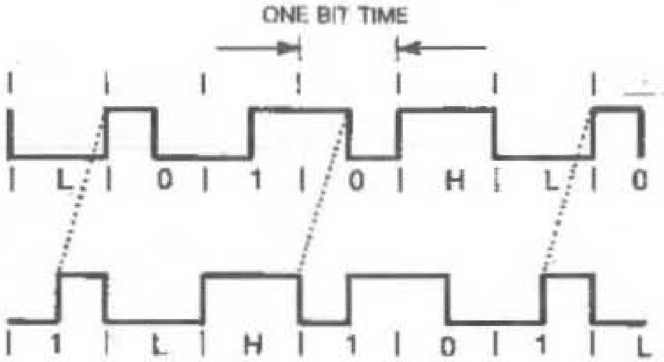


Fig 12-11
Examples of Collision Presence Waveforms

12.3.2.4.4 Idle Line Encoding. The line condition IDL is also used as an encoded signal. An IDL always starts with a HI signal level. Since IDL always starts with a HI signal, an additional transition will be added to the data stream if the last bit sent was a zero. This transition cannot be confused with clocked data (CD0 or CD1) since the transition will occur at the start of a bit cell. There will be no transition in the middle of the bit cell. The HI signal level, as sent by a transmitter, shall be maintained for a minimum of 2 bit times.

12.4 Hub Specification

12.4.1 Overview. This section defines the logical characteristics of the hub used in 1BASE5. The relationship of this specification to the entire standard is shown in Fig 12-12.

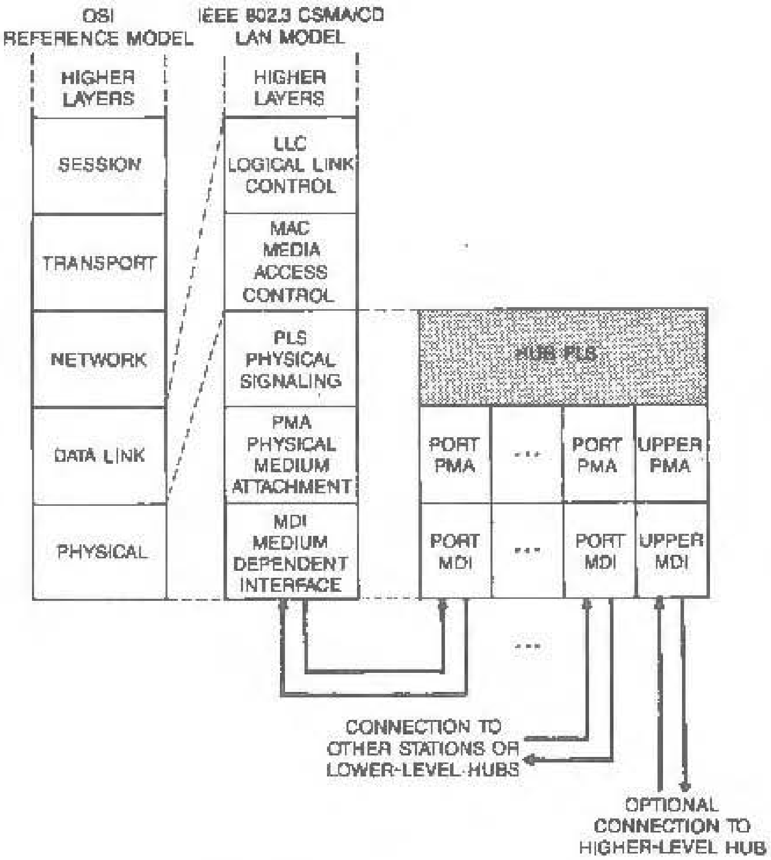


Fig 12-12
Hub Relationship to the OSI Reference Model and the IEEE 802.3 CSMA/CD LAN Model

12.4.1.1 Summary of Major Concepts

(1) A hub consists of a Hub PLS sublayer and a number of instances of the PMA sublayer.
(2) One instance of the PMA sublayer, the "upper PMA," provides a connection to a higher-level hub. This PMA is not required for the header hub.
(3) Each of the remaining instances of the PMA sublayer, called "port PMAs," provides a connection to a DTE or a lower-level hub.

(4) The Hub PLS transfers data in two directions: upward from the port PMAs, to the upper PMA and downward from the upper PMA to the port PMAs.
(5) The upward and downward "sides" of the hub operate independently and simultaneously.

12.4.1.2 Application Perspective. The hub is a physical layer entity that performs two functions:

(1) It retransmits incoming signals with amplitude and timing restored.
(2) It detects collisions between any two or more ports and reports knowledge of the collision by transmitting a special collision presence reporting pattern.

12.4.2 Hub Structure. Each hub is functionally divided into two parts: the upward side and the downward side. The upward side is responsible for combining the transmissions from DTEs and hubs lower in the network into a single transmission to the next level up. The downward side is responsible for distributing the combined signal (which is wrapped around from the upward side of the header hub) to each of the DTEs and hubs below. Except as specified in 12.4.3.2.3 and 12.4.2.6, the two sides function independently.

There is an upward input channel and a corresponding downward output channel for each DTE or hub immediately below the hub. Although there is no electrical connection between the two lines, they do share a connector and cable (see 12.6 and 12.7) and are collectively known as a **hub port**. Each port is accessed through an instance of the PMA sublayer referred to as a "port PMA."

The one output channel from the upward side and the one input channel to the downward side of a hub are similarly paired and, for all but the header hub, are connected to a port of the next-higher-level hub. They are accessed through an instance of the PMA sublayer referred to as the "upper PMA."

NOTE: A hub that includes n hub ports should be called an n-port hub, even though it may have an extra jack for the upper PMA. The latter connection should never be counted as a port, despite common engineering usage, because it does not meet the specific definition of a 10BASE5 hub port given above.

12.4.2.1 Upward Side. The primary function of the upward side of a hub is to propagate signals from each of its inputs to its single output. If more than one input is active, then the Collision Presence signal CP is transmitted instead. In addition, the signals are retimed to restore the transitions to half-bit-time boundaries; see 12.4.3.2.5 for the details of retiming.

12.4.2.2 Downward Side. The primary function of the downward side of a hub is to repeat signals from its one input to each of its outputs. In addition, the signals are retimed to restore the transitions to half-bit-time boundaries; see 12.4.3.2.5 for the details of retiming.

12.4.3 Hub PLS Functional Specification. This section provides a detailed model for the Hub PLS sublayer.

12.4.3.1 Hub PLS to PMA Interface. The interface between the Hub PLS and the PMA is the same as that specified in 12.3.2.1 for use between the DTE PLS and the PMA except that the *output* message from the Hub PLS to the PMA is used to transmit CVL and CVH in addition to CD0 and CD1.

12.4.3.2 Hub PLS Functions. The Hub PLS sublayer functions consist of three asynchronous functions. These functions are Upward Transfer, Jabber, and Downward Transfer. All three functions are started immediately following PowerOn; an independent copy of the Jabber function is started for each port PMA. These functions are depicted in the state diagrams shown in Fig 12-13 through Fig 12-15, using the notation described in 1.2.1.

12.4.3.2.1 State Diagram Variables. The variables used in the state diagrams and the corresponding descriptions are the following:

(1) *Port Designators:* Instances of the PMA sublayer are referred to by index. PMA information is obtained by replacing the X in the desired function with the index of the PMA of interest. Furthermore, PMAs may be referenced by several special designators used as indices:

X	Generic port PMA designator. When X is used in a state diagram its value indicates the particular instance of a generic function.

UPPER	Indicates the upper PMA.
ALLPORTS	Indicates that all port PMAs are to be considered. All port PMAs must meet a test condition in order for that test to pass.
ALLENABLEDPORTS	Indicates that all port PMAs that are not disabled by the Jabber Function are to be considered. All such port PMAs must meet a test condition in order for that test to pass.
ONEPORT	Indicates that all port PMAs that are not disabled by the Jabber Function are to be considered. One, but not more than one, such port PMA must meet a test condition in order for that test to pass.
>ONEPORT	Indicates that all port PMAs that are not disabled by the Jabber Function are to be considered. Two or more such port PMAs must meet a test condition in order for that test to pass.
N	Defined by the PORT function on exiting from the UPWARD IDLE state of Fig 12-13. It indicates which port PMA caused the exit from the UPWARD IDLE state.

(2) *Port Functions*:

PORT(TestCondition)	Returns the index of a port PMA passing the indicated test condition. If multiple port PMAs meet the test condition, the PORT function will return one and only one of the acceptable values.

(3) *Input Variables:*

INPUT(X)	Indicates the state of activity on the designated PMA input channel. It may be either "idle" or "active." The former indicates that *input_idle* is asserted; the latter indicates that it is not asserted.
input(X)	Used to receive an *input* message (see 12.3.2.1) from the designated PMA input channel.
probation_alternative	Used to distinguish between the two allowed alternatives for exiting the JABBER JAM state of Fig 12-14 when an active port becomes idle. The implementor of a hub may treat the variable as either true or false.

(4) *Output Variables:*

output(X)	Used to send an *output* message (see 12.3.2.1 and 12.4.3.1) to the designated PMA output channel.
output_idle(X)	Used to send an *output_idle* message (see 12.3.2.1) on the designated PMA output channel.

(5) *Inter Process Flags:*

send_collision	Used by the Upward Signal Transfer Function to indicate a series of *output* messages to the upper PMA sublayer, the effect of which is to transmit the CP signal, as described in 12.3.2.4.2, 12.3.2.4.3, and 12.4.3.2.7.
jabber_collision	Used by the various instances of the Jabber Function to signal the Upward Signal Transfer Function that CP should be generated.
disable_input(X)	Used to disable the designated PMA input channel. The input is re-enabled when disable-input(X) is no longer asserted. Only the Upward Signal Transfer Function is affected by the disabling of a port (via the ALLENABLEDPORTS, ONEPORT, and >ONEPORT designators).

jabberTime1 — Used by the Jabber Function (see 12.4.3.2.3) to detect excessively long transmissions. It is started by "start_jabberTime1." "jabberTime1_done" is satisfied when the timer has expired.

jabberTime2 — Used by the Jabber Function (see 12.4.3.2.3) to determine when to disable ports due to excessively long transmissions. It is started by "start_jabberTime2." "jabberTime2_done" is satisfied when the timer has expired.

12.4.3.2.2 Upward Signal Transfer Function. The Upward Signal Transfer Function combines signals from the various port inputs and passes them on to the upper output. It also detects and reports collisions as appropriate. The state diagram of Fig 12-13 depicts its operation.

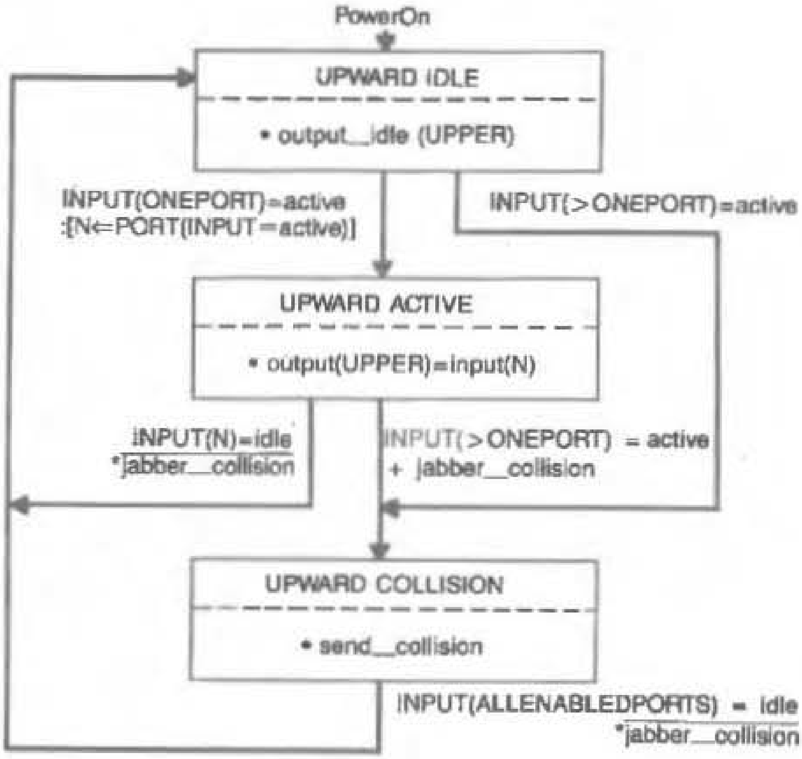


Fig 12-13
Hub PLS Upward Transfer Function

Signals are propagated upward according to the following rules, except as controlled by the Jabber Function (see 12.4.3.2.3):

(1) If IDL is present on all port inputs, then transmit IDL.
(2) If IDL is present on all but one of the port inputs, then repeat the signal received from that one line. If that one signal is CP, then a hub may generate its own CP signal instead of repeating the received CP signal.
(3) If two or more inputs are active (non-IDL) at the same time, then transmit CP and continue transmitting CP until all inputs indicate IDL again.

Whenever the hub finishes transmitting CP, it shall then transmit IDL, including the extended HI period.

12.4.3.2.3 Jabber Function. The Jabber Function detects abnormally long transmissions and takes appropriate action to abort them. The state diagram of Fig 12-14 depicts its operation.

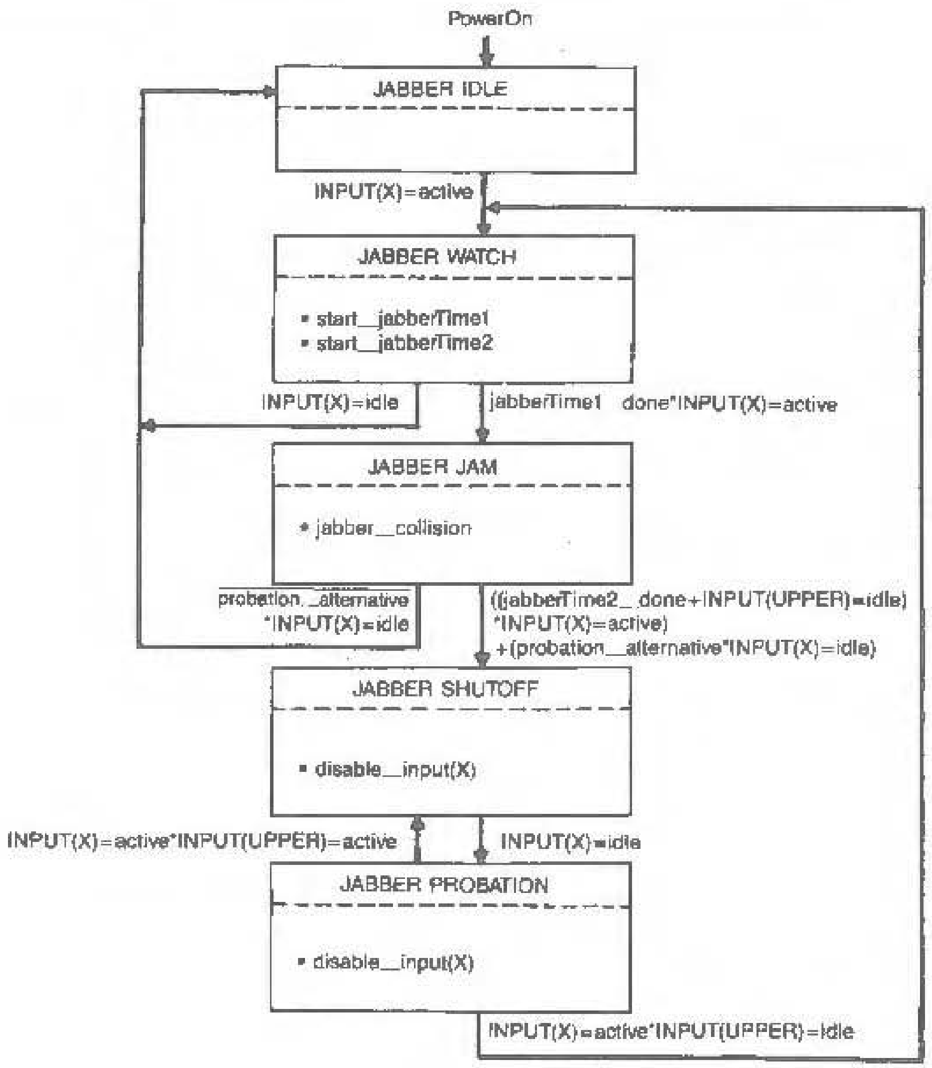


Fig 12-14
Hub PLS Jabber Function for Port X

Two timers are used by the Jabber Function. They may be implemented either as local timers for each instance of the Jabber Function or as global timers shared by all instances. Furthermore, because the two timers are always started concurrently, an implementation may share circuitry between the two.

The first timer is started by "start_jabberTime1" and asserts "jabberTime1_done" after 25 to 50 ms since starting. If implemented as a single global timer, assertion of start_jabberTime1 by any instance of the Jabber Function with any other instance(s) still waiting for that timer shall not restart the timer, thereby shortening the waiting period for the latest instance.

Similarly, the second timer is started by "start_jabberTime2" and asserts "jabberTime2_done" after 51 to 100 ms since starting. If implemented as a single global timer, assertion of start_jabberTime2 by any instance of the Jabber Function with any other instance(s) still waiting for that timer shall not restart the timer, thereby shortening the waiting period for the latest instance. Furthermore, if this second timer is implemented as a single global timer, then assertion of start_jabberTime1 by any instance of the Jabber Function with any other instance(s) still waiting for just the second timer (in the JABBER JAM state) shall be treated as if the first timer expires immediately (asserting jabberTime1_done) for the latest instance, thereby causing that instance to join the other instance(s) waiting for the second timer.

Hardware within the upward side of a hub shall provide a window of 25 to 50 ms, during which time a normal packet or CP sequence may be propagated upward. If any port input (or, as an alternative implementation, the hub's combined upward signal) exceeds this duration without becoming idle, then the hub shall switch to transmitting CP until 51 to 100 ms after the beginning of the window and then, if that input is still active, disable that input (or all nonidle inputs) until it once again becomes active while the downward side is idle.

The "probation_alternative" input variable is used to distinguish between the two allowed alternatives for exiting the JABBER JAM state of Fig 12-14 when an active port becomes idle. The implementor of a hub may treat the variable as either true or false. If true, the port will enter the JABBER PROBATION state (via the JABBER SHUTOFF state); if false, the port will instead return to the JABBER IDLE state.

12.4.3.2.4 Downward Signal Transfer Function. The Downward Signal Function repeats signals from the upper input to the various port outputs. The state diagram of Fig 12-15 depicts its operation.

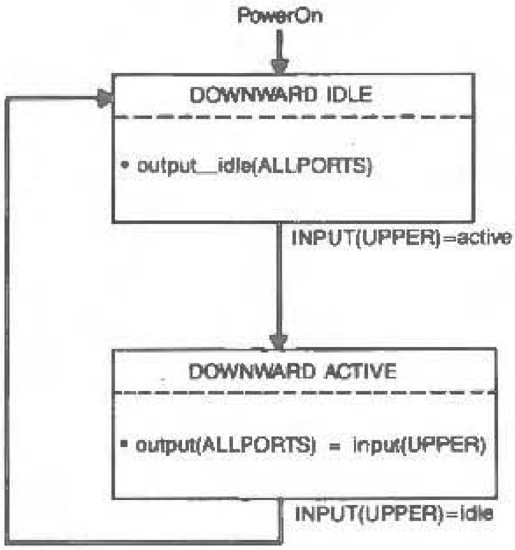


Fig 12-15
Hub PLS Downward Transfer Function

The downward side of a hub may detect the Collision Presence signal at the upper input and generate its own CP signal to be transmitted at the port outputs (in place of repeating the received CP signal).

Whenever the hub finishes transmitting CP, it shall then transmit IDL, including the extended HI period.

12.4.3.2.5 Retiming (Jitter Removal). Each side of each hub shall retime any clocked signals that it propagates so that the transitions occur on half-bit-time boundaries, thereby avoiding accumulation of excessive jitter. Such retiming shall preserve the sequence of CD0, CD1, CVL, and CVH symbols being propagated.

If an ambiguity exists in the incoming bit cells due to excessive noise or jitter, than the appropriate side of the hub may either switch to generating CP or replace the erroneous bit cell with an arbitrary combination of half or whole bit cells.

Retiming also accounts for differences (if any) in clock rates between that used to send bit cells to the hub and that used to send them out from the hub. Excessive differences in clock rates (caused by clocks not meeting 12.3.2.4.1) and excessively long packets (caused by exceeding maxFrameSize) may each cause the capacity of the retiming function to be exceeded. In such circumstances, the appropriate side of the hub may either switch to transmitting CP or add or delete half or whole bit cells as needed.

Whenever bit cells are added, deleted, or replaced, the hub shall maintain synchronization of the outgoing bit cells to a half or whole bit cell boundary. Furthermore, it shall not generate periods of more than one bit time without a transition.

12.4.3.2.6 Header Hub Wrap-Around. For each particular network configuration, one hub operates as the header hub and all others as intermediate hubs. It is suggested, but not required, that hub implementations be capable of being used for either purpose. Methods for switching between these two modes are beyond the scope of this standard.

For an intermediate hub, the upper output shall be connected to a port input of the next higher-level hub and the upper input shall be connected to a port output of a higher-level hub.

For the header hub, the upper output shall be connected to the upper input. This wraparound may appropriately bypass parts of the PMA specification so long as the resulting implementation is functionally equivalent to one with a wired connection. For example, signals internal to the hub need not be translated to the corresponding external levels and then translated back to internal levels. Similarly, it shall not be necessary to retime the wrapped signal twice, once in the upward side and then again in the downward side of the same header hub; a single retiming is permissible.

12.4.3.2.7 Collision Presence Startup. When a hub starts generating CP (as specified in 12.4.3.2.2 through 12.4.3.2.5) it shall synchronize the startup to a half or whole bit-cell boundary of any immediately preceding signal. If it was sending IDL immediately before the CP, no synchronization or preamble is required.

A hub may start transmission of CP at any point in the sequence that does not result in periods of more than one bit time without a transition during the switch from passing on data to sending CP. Depending on the preceding signal, it may start with L010H, 010HL, 10HL0, 0HL01, or HL010. Because startup may be synchronized to any half-bit-cell boundary, a hub may also transmit the shifted version of CP starting with 1LH10, LH101, H101L, 101LH, or 01LH1.

12.4.3.3 Reliability. Hubs shall be designed to provide a mean time between failure (MTBF) of at least 45 000 hours of operation. Hubs, including the associated connectors and other passive components, should be designed to minimize the probability that, a particular failure results in total network failure. Furthermore, the port electronics of each hub should be designed so as to minimize the probability that the failure of one port prevents communication by equipment attached to the other ports.

12.5 Physical Medium Attachment (PMA) Specification

12.5.1 Overview. This section defines the Physical Medium Attachment (PMA) sublayer for 1BASE5. The relationship of this specification to the entire standard is shown in Fig 12-16. The PMA sublayer connects the PLS sublayer to the Medium Dependent Interface (MDI).

12.5.2 PLS–PMA Interface. The interface between the PLS and the PMA sublayers is specified in 12.3.2.1 for DTEs and in 12.4.3.1 for hubs.

12.5.3 Signal Characteristics

12.5.3.1 Transmitter Characteristics. Transmitters should operate properly when loaded with any cable meeting the requirements of 12.7. To approximate the boundary conditions of such loading, two specific test loads are specified. Transmitters shall meet all requirements of this section when connected to both the "light" (115 Ω) load shown in Fig 12-17 and the "heavy" (approximately 80 Ω) load shown in Fig 12-18. It is expected that transmitters that perform correctly with these two loads will also perform acceptably under intermediate loading conditions.

12.5.3.1.1 Differential Output Voltage. For simplicity of explanation, the text and figures of this section describe the differential output voltage in terms of voltage magnitudes. The requirements of this section apply to the negative pulses as well as the positive ones.

Beginning with the second bit of the preamble (or CP, if no preamble is present), pulses of duration BT/2 shall meet the conditions of Fig 12-19. Pulses of duration BT shall meet the conditions of Fig 12-20. After the zero-crossing, the output shall exceed the voltage of a signal rising from the zero-crossing to 2.0 V with

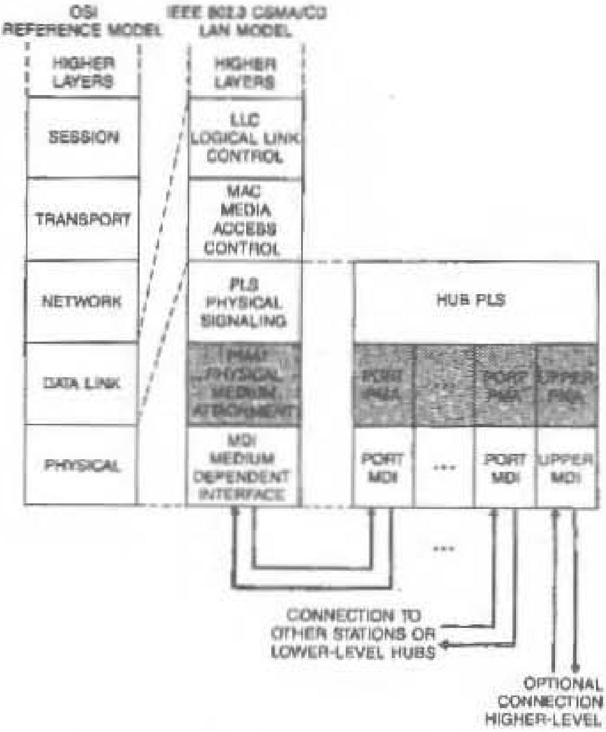


Fig 12-16
Physical Medium Attachment, Relationship to the OSI Reference Model and the IEEE 802.3 CSMA/CD LAN Model

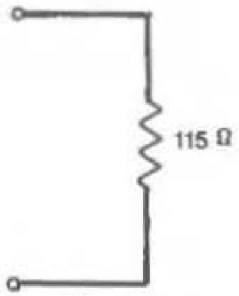


Fig 12-17
Simulated Light Load

a slope of magnitude 20 mV/ns. The output shall remain above 2.0 V until 100 ns before the next, zero-crossing. The peak output voltage shall not exceed 3.65 V. While falling from 2.0 V to the zero-crossing, the signal shall exceed the voltage of a signal falling from 2.0 V to the zero-crossing with a slope of magnitude 20 mV/ns.

For pulses of duration BT, the average voltage that appears from 100 ns after the zero-crossing through BT/2 shall be between 0.95 and 1.8 times the average voltage that appears from time BT/2 through 100 ns before the following zero-crossing. Similarly, for pulses of duration BT, the peak voltage that appears from 100 ns after the zero-crossing through BT/2 shall be between 0.95 and 1.8 times the peak voltage that appears from time BT/2 through 100 ns before the following zero-crossing.

NOTE: The purpose of the above restrictions on average and peak voltages is to avoid transmitter waveforms that peak excessively during the second half of signals of duration BT, resulting in excessive jitter at the receiver. Some equalization to produce slight droop in the second half of signals of duration BT, on the other hand, may help decrease jitter at the far end of long cables.

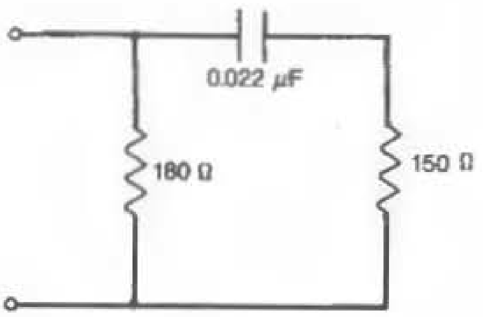


Fig 12-18
Simulated Heavy Load

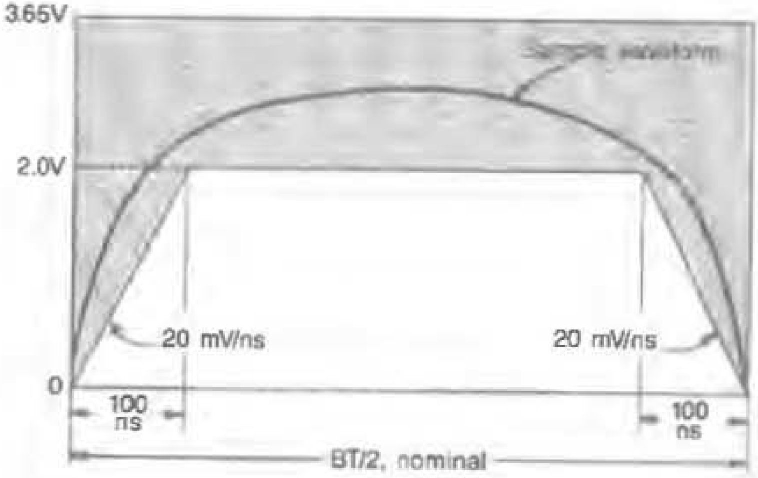


Fig 12-19
Differential Output Voltage, Nominal Duration BT/2

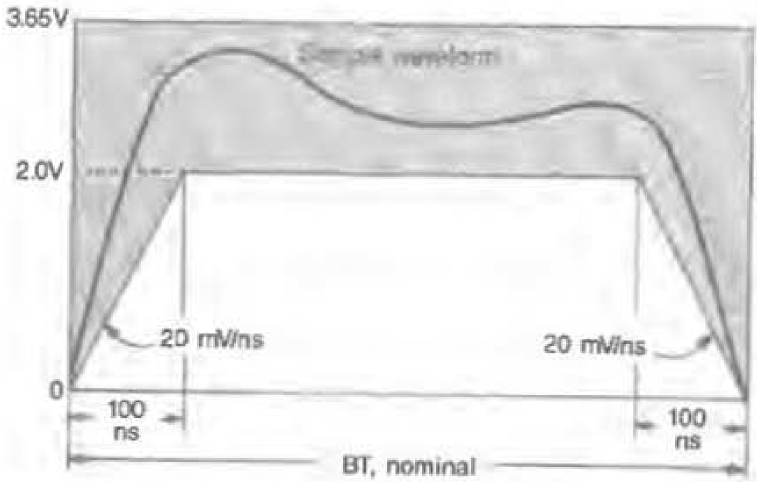


Fig 12-20
Differential Output Voltage, Duration BT

The amplitude of the power spectrum at the output of the transmitter for all possible sequences of signals shall not exceed that produced by an idealized transmitter sending corresponding rectangular waveforms with magnitude 365 V at any frequency.

When a transmitter enters the idle state, it shall maintain a minimum differential output, voltage of 2.0 V from 100 ns through 2BT after the last low-to high transition, as illustrated in Fig 12-21. The differential output voltage shall then fall to 1.1 V within 3BT after that same low-to-high transition. Starting when the differential output voltage first reaches 1.1 V, the magnitude of the output voltage driven into the test loads indicated in Figs 12-22 and 12-23 shall then remain within the limits indicated in Fig 12-21 until the transmitter leaves the idle state.

The transmitter output at the start of idle may exhibit overshoot, ringing, slow voltage decay, or a combination thereof due to the following factors:

(1) Change in transmitter source impedance between the active and idle states
(2) Difference in the magnitudes of the differential output voltage between the high and low output states (ΔV_{OD})
(3) Waveform asymmetry at the transmitter (ΔT)
(4) Transmitter and receiver (transformer) inductance (L)

NOTE: The contribution to the undershoot from each of these can be computed with the following equations:

$$V_{\Delta V_{OD}} = \pm \Delta V_{OD} \cdot R_{OFF} / 2R_{ON}$$

$$V_{\Delta T} = (\pm \Delta T / 1000 \text{ ns}) \cdot V_P \cdot R_{OFF} / R_{ON}$$

$$V_L = V_P \cdot \left(1 - e^{-2.76\ \mu s/(L_P/R_{ON})}\right) \cdot R_{OFF} / R_{ON}$$

where:

$R_{OFF} = R_{SRC\text{-}OFF} \| R_L$

$R_{ON} = R_{SRC\text{-}ON} \| R_L$

$R_{SRC\text{-}OFF}$ = source impedance (Ω) when the driver is off

$R_{SRC\text{-}ON}$ = source impedance (Ω) when the driver is on

R_L = load impedance (Ω)

L_P = combined inductance (μH) of the transmitter and receiver transformers

ΔV_{OD} = difference (V) in magnitude of the HI and LO output voltages

ΔT = asymmetry of the waveform equals the difference between the average HI and average LO pulse widths (ns) at the transmitter

V_P = maximum output voltage (V) during the start of IDL

NOTE: The waveform shown in Fig 12-21 and the equations in the preceding note apply to a transmitter connected to the test loads of Figs 12-22 and 12-23. An actual receiver may present a more complex termination impedance and so the undershoot or overshoot may exceed that encountered with the test loads.

12.5.3.1.2 Output Timing Jitter. The transmitted signal zero-crossings shall deviate from the idealized zero-crossings by no more than ± 10 ns.

12.5.3.1.3 Transmitter Impedance Balance. The longitudinal to metallic impedance balance of the transmitter, defined as 20 $\log_{10}(E_{test}/E_{dif})$, where E_{test} is an externally applied ac voltage, as shown in Fig 12-24, shall exceed 44 dB at all frequencies up to and including 4BR in the idle and nonidle states.

NOTE: It may be difficult to measure the transmitter impedance balance in the nonidle state. A frequency-selective wavemeter or other measurement technique may be required. Furthermore, the balance of the test equipment (such as the matching of the 400 Ω resistors) must exceed that required of the transmitter.

12.5.3.1.4 Common-Mode Output Voltage. The magnitude of the total common-mode output voltage of the transmitter, E_{cm}, measured as shown in Fig 12-25, shall not exceed 300 mV.

NOTE: The implementor should consider any applicable local, national, or international regulations and standards concerning RF emission. Driving unshielded twisted pairs with high-frequency common-mode voltages may result in interference to other equipment.

12.5.3.1.5 Common-Mode Tolerance. Transmitters shall meet the requirements of 12.5.3.1.1 and 12.5.3.1.2 even in the presence of common-mode sinusoidal voltage, E_{cm} (as shown in Fig 12-26), of ± 20 V peak at frequencies from 40 kHz through 6BR.

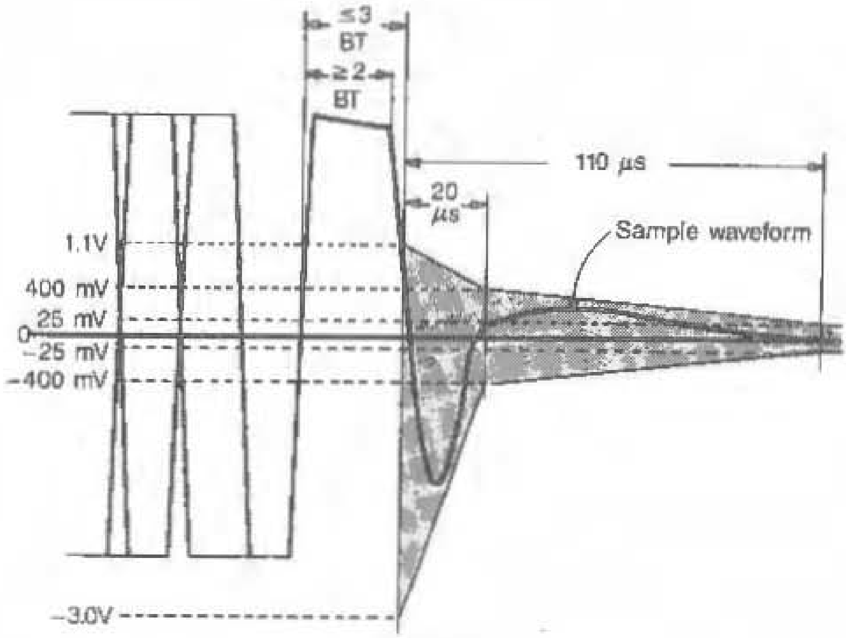


Fig 12-21
Transmitter Waveform for Idle

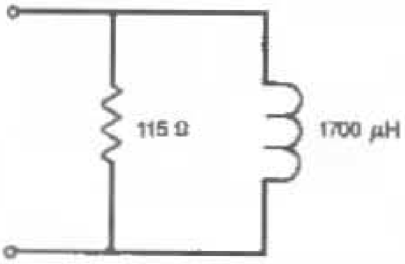


Fig 12-22
Start-of-Idle Test Load #1

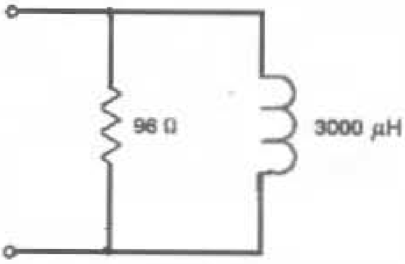


Fig 12-23
Start-of-Idle Test Load #2

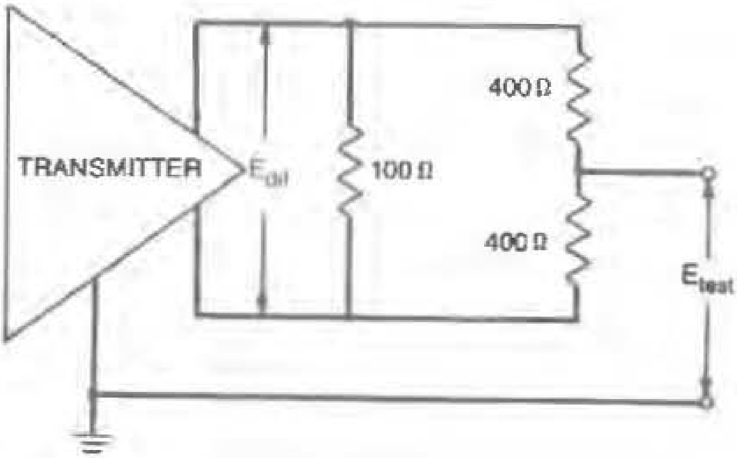


Fig 12-24
Transmitter Impedance Balance

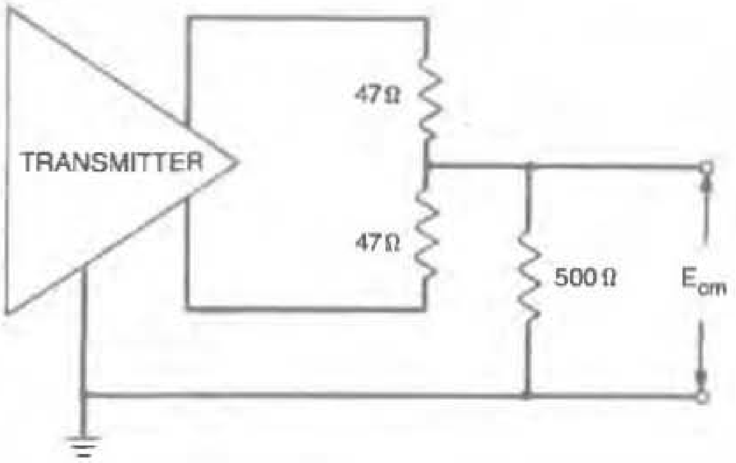


Fig 12-25
Common-Mode Output Voltage

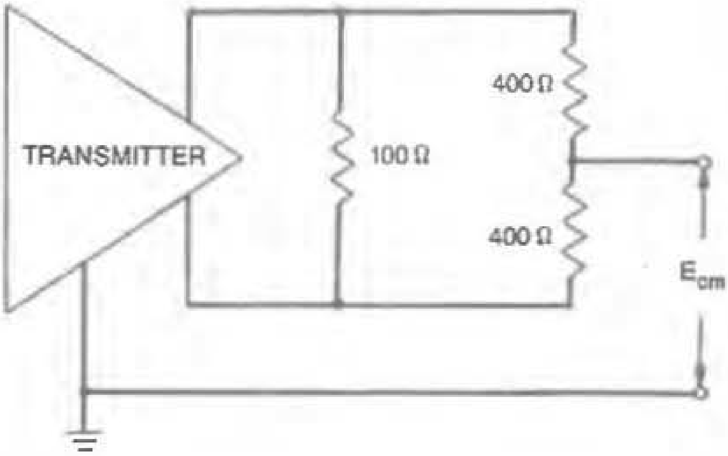


Fig 12-26
Transmitter Common-Mode Tolerance

12.5.3.1.6 Transmitter Fault Tolerance. Transmitters, both when idle and when nonidle, shall tolerate the application of short circuits across their outputs for an indefinite period of time without damage and shall resume normal operation after such faults are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

Transmitters, both when idle and when nonidle, shall withstand, without damage, a 1000 V common-mode impulse of either polarity, applied as indicated in Fig 12-27. The shape of the impulse shall be 0.3/50 μs (300 ns virtual front time, 50 μs virtual time of half value), as defined in IEC Publication 60 (see Reference [11]).

NOTE: Tolerance of, and recovery from, the application of the telephony voltages described in 12.10.2 is optional, but the safety requirements of that section are mandatory.

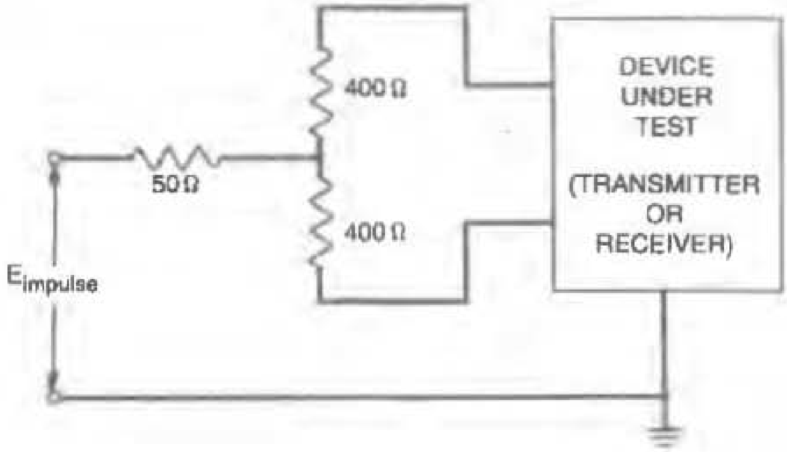


Fig 12-27
Common-Mode Impulse Test

12.5.3.2 Receiver Characteristics

12.5.3.2.1 Differential Input Voltage. The receiver shall operate properly when a signal meeting the minimum magnitude requirements of Fig 12-28 is received. When less than 300 mV, the magnitude of the voltage will exceed that of a straight line through the nearest zero-crossing with slope of magnitude 9 mV/ns. That is, the average slew rate near each zero-crossing will exceed 9 mV/ns. The magnitude of the voltage will also remain at or above 1.0 V for some period lasting at least 150 ns (650 ns for pulses of duration BT) that starts within 250 ns of the preceding zero-crossing and its peak will be at least 1.1 V.

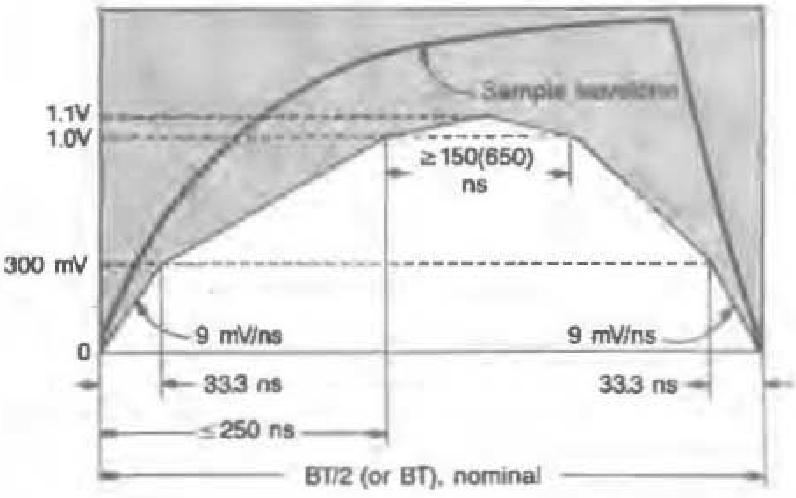


Fig 12-28
Receiver Signal Envelope

12.5.3.2.2 Input Timing Jitter. Receivers shall operate properly with zero-crossing jitter of up to ± 32 ns from the ideal.

12.5.3.2.3 Idle Input Behavior. The IDL condition shall be detected within 1.8 bit times of the last low-to-high transition at the receiver.

NOTES: (1) It is necessary to distinguish CVH from IDL.

(2) System jitter considerations make it impractical to detect IDL (<etd>, end-of-transmission delimiter) any sooner than 1.8 bit times. The specific implementation of the clock recovery mechanism, or equivalent, determines the lower bound on the actual IDL detection time. Adequate margin should be provided between the lower bound and 1.8 bit times.

The receiver shall take precautions to ensure that the HI-to-silence transition of the start of IDL is not falsely interpreted as a silence-to-nonidle transition, even in the presence of signal droop, overshoot, ringing, slow voltage decay, or a combination thereof due to capacitive and inductive effects in the transmitter, cable, and receiver, including those discussed in 12.5.3.1.1.

To this end, a receiver in a hub shall treat its input as if it were idle for between 20 and 30 μs after detecting IDL. The timing of this "protection" period for the port PMAs may use a single timer that is started when all ports have become idle or disabled by the Jabber Function. Receivers in DTEs may include a similar protection period of up to 30 μs.

NOTE: The protection period is required in hubs because erroneously interpreting the start-of-idle as a new transmission will result in propagation of the error to DTEs, despite any precautions taken in those DTEs. The protection period is optional in DTEs because any implementation error in a DTE will affect only that particular DTE.

12.5.3.2.4 Differential Input Impedance. The (complex) differential input impedance of the receiver, $Z_{receiver}$, shall be such that the reflection attenuation, defined as $20 \log_{10} (|Z_{receiver} + Z_{cable}| / |Z_{receiver} - Z_{cable}|)$, where Z_{cable} is the differential characteristic impedance of the attached cable, exceeds 16 dB over the range BR/2 through 2BR for all cables meeting the requirements of 12.7.2.

12.5.3.2.5 Common-Mode Rejection. Receivers shall assume the proper output state for any differential input signal, E_s, that results in a signal, E_{dif}, that meets 12.5.3.2.1 and 12.5.3.2.2, even in the presence of common-mode sinusoidal, voltages, E_{cm} (as shown in Fig 12-29), of ±20 V peak at frequencies from 40 kHz through 6BR.

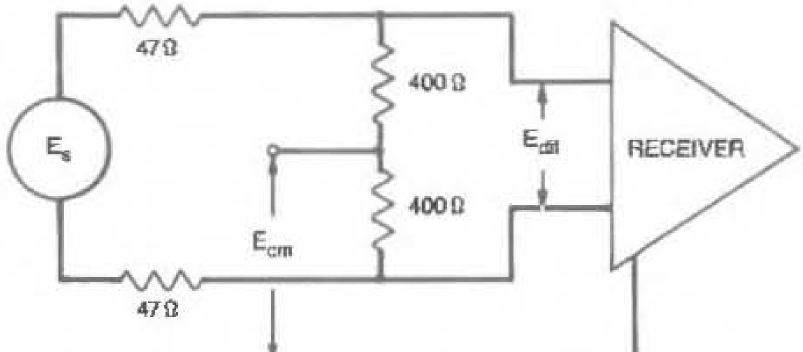


Fig 12-29
Receiver Common-Mode Rejection

12.5.3.2.6 Noise Immunity. Receivers shall meet the following limits on average error, rates when the noise described in 12.7.4 is added to the signals described in 12.5.3.2.1 and 12.5.3.2.2:

(1) When nonidle, the receiver error rate shall not exceed one error in 10^8 bits.
(2) When idle, a receiver used in a DTE shall not falsely detect carrier more than one in 100 s.
(3) When idle, a receiver used in a hub shall not falsely detect carrier more than once in 1500 s.

NOTE: Receivers whose inputs include a 2–4 MHz, 2-pole, low-pass, Butterworth filter and a 560 mV squelch level will meet this last requirement for idle-mode noise immunity yet still perform properly with the weakest signal allowed by 12.5.3.2.1.

12.5.3.2.7 Receiver Fault Tolerance. Receivers shall tolerate the application of short circuits across their inputs for an indefinite period of time without damage and shall resume normal operation after such faults are removed.

Receivers shall withstand, without damage, a 1000 V common-mode impulse of either polarity, applied as indicated in Fig 12-27. The shape of the impulse shall be 0.3/50 μs (300 ns virtual front time, 50 μs virtual time of half value), as defined in IEC Publication 60 (see Reference [11]).

NOTE: Tolerance of, and recovery from, the application of the telephony voltages described in 12.10.2 is optional, but the safety requirements of that section are mandatory.

12.6 Medium Dependent Interface (MDI) Specification

12.6.1 Line Interface Connector. 8-pin connectors meeting the requirements of Section 3 and Figs 1 through 5 of ISO/DIS 8877 (see Reference [16]) shall be used as the compatibility interface between the PMA and the medium. The use of other types of connectors, if any, within a PMA or within the medium, although not explicitly prohibited, is outside the scope of this standard.

12.6.2 Connector Contact Assignments. The contacts of the connectors, as depicted in Figs 12-30 and 12-31, shall correspond to signaling circuits as indicated below:

Contact	Signal
1	Upward Data+ (positive for HI signal)
2	Upward Data– (negative for HI signal)
3	Downward Data+ (positive for HI signal)
4	not used by 1BASE5
5	not used by 1BASE5
6	Downward Data– (negative for HI signal)
7	reserved
8	reserved

For DTEs and the upper MDI of hubs, contacts 1 and 2 are used for transmitting and contacts 3 and 6 are used for receiving. For the port MDIs of hubs, however, contacts 1 and 2 are used for receiving and contacts 3 and 6 are used for transmitting.

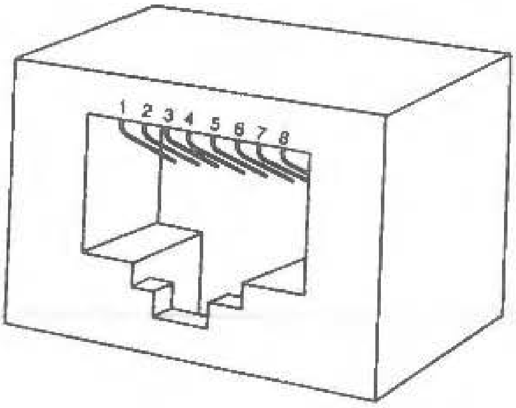


Fig 12-30
DTE and Hub Connector

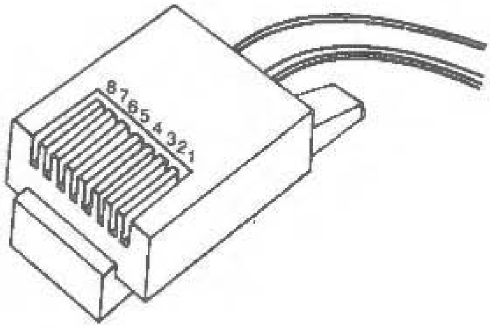


Fig 12-31
Cable Connector

12.6.3 Labeling. To distinguish 1BASE5 connectors from those used for other purposes, it is recommended that appropriate labels be affixed to wall outlets and other connectors. This is particularly important in environments in which the specified 8-contact connectors are used for more than one purpose.

12.7 Cable Medium Characteristics

12.7.1 Overview. A significant number of 1BASE5 networks are expected to utilize in-place building wiring. In this environment, DTEs connect to wall outlets using twisted pair telephone cord. The wall outlets, in turn, connect to wiring closets, where hubs could be located, using standard telephone wiring. This wiring typically consists of 0.4–0.6 mm diameter (26–22 gauge) unshielded twisted pairs.

12.7.2 Transmission Parameters. Each wire pair used to interconnect DTEs and hubs shall meet the requirements of 12.9.3 and also have the following characteristics.

12.7.2.1 Attenuation. Total cable attenuation between a transmitter and the corresponding receiver shall be no more than 6.5 dB at all frequencies between BR/2 and BR, 9.2 dB at frequencies between BR and 2BR, and 13.8 dB at frequencies between 2BR and 4BR.

12.7.2.2 Differential Characteristic Impedance. The magnitude of the differential characteristic impedance at frequency BR, Z_{BR}, of each wire pair used shall be between 80 Ω and 115 Ω. In addition, the magnitude and phase angle of the characteristic impedance at each of the following frequencies shall be within the corresponding ranges indicated:

	Magnitude		Phase Angle	
Frequency	Minimum	Maximum	Minimum	Maximum
BR/4	Z_{BR}	$Z_{BR} + 7\ \Omega$	–10°	0°
BR/2	Z_{BR}	$Z_{BR} + 5\ \Omega$	–8°	0°
BR	Z_{BR}	Z_{BR}	–6°	0°
2BR	$Z_{BR} - 4\ \Omega$	Z_{BR}	–4°	0°
4BR	$Z_{BR} - 5\ \Omega$	Z_{BR}	–3°	0°

12.7.2.3 Medium Timing Jitter. Intersymbol interference and reflections due to impedance mismatches between the sections of a cable segment can introduce jitter in the timing of the zero-crossings. A cable segment terminated in 96 Ω shall add no more than ± 17 ns, referenced to the transmit clock, of edge jitter when driven with a rectangular signal of magnitude 2.5 V through a source impedance 22 Ω. The driving signal shall be a Manchester-encoded pseudo-random sequence of data with a repetition period of at least 511 bits.

NOTES: (1) The reflections caused by splicing two cable sections that have different characteristic impedances (but that each meet the requirements of 12.7.2.2) will not contribute significantly to timing jitter if the splice is within 10 m of either end of the segment.

(2) Branches off a wire pair (often referred to as "bridged taps" or "stubs") will generally cause excessive jitter and so should be avoided.

(3) Jitter can be measured at the receiving end of a segment using an oscilloscope. The oscilloscope is triggered on zero-crossings; the deviation of subsequent zero-crossings from multiples of BT/2 is then observed. The deviation of each zero-crossing must not exceed ± 34 ns.

12.7.2.4 Dispersion. Each wire pair shall produce an output signal that meets the zero-crossing edge rate described in 12.5.3.2.1 when driven with a 1 MHz trapezoidal signal of magnitude 2.0 V (that is, 4.0 V peak-to-peak) with edge rate 20 mV/ns.

12.7.3 Coupling Parameters. To avoid excessive coupling of signals between pairs of a cable, the crosstalk and imbalance must be limited.

Crosstalk attenuation is specified with the far end of both the disturbed and the disturbing pairs and the near end of the disturbed pair terminated in 96 Ω.

12.7.3.1 Pair-to-Pair Crosstalk. The near-end, differential, crosstalk attenuation between each wire pair and each other pair in the same cable shall be at least 45 dB frequencies up to BR and at least $45 - 15 \log_{10} (f/BR)$ dB for each frequency f between BR and 4BR.

12.7.3.2 Multiple-Disturber Crosstalk. The near-end, differential, crosstalk attenuation between multiple disturbing wire pairs and a disturbed pair in the same cable shall be at least 38.5 dB at frequency BR and at least 38.5– 15 $\log_{10}$ (f/BR) dB for each frequency f between BR and 4BR.

When two or more disturbers are present in a common cable sheath, the multiple-disturber, near-end, crosstalk attenuation (MDNEXT) into each pair, measured in dB, may be determined using the following equations:

$$H_j = \sum_{i \neq j} 10^{(-X_{ij}/20)} \cos \theta_{ij}$$

$$V_j = \sum_{i \neq j} 10^{(-X_{ij}/20)} \sin \theta_{ij}$$

$$MDNEXT_j = 10 \log_{10}(H_j^2 + V_j^2)$$

where:

i iterates over each disturbing pair
j is the disturbed pair
X_{ij} is the magnitude of the near-end, differential, crosstalk attenuation from pair i to pair j
θ_{ij} is the phase angle of the near-end, differential, crosstalk attenuation from pair i to pair j

If only the probability distribution of X_{ij} is known, then the distribution of MDNEXT can be determined using Monte Carlo methods with that X_{ij} distribution and a phase angle uniformly distributed between 0 and 2π rad.

NOTE: See Appendix A3 for example computations of MDNEXT distributions.

12.7.3.3 Balance. The longitudinal to metallic balance of the cable, defined as 20 $\log_{10}$ (E_{test}/ $2E_x$), where E_{test} is an externally applied voltage, as shown in Fig 12-32, shall exceed 44 dB at all frequencies up to 4BR.

NOTE: The balance of the test equipment (such as the balance of the transformer and the matching of the 300 Ω resistors) must exceed that required of the cable.

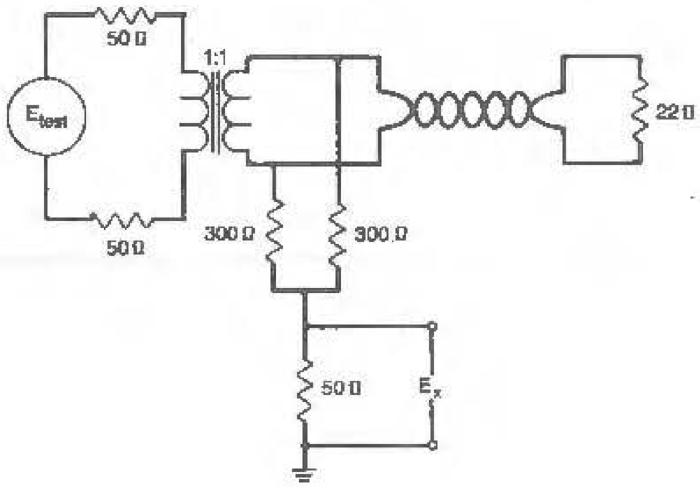


Fig 12-32
Cable Balance Test

12.7.4 Noise Environment. Links used with 1BASE5 shall provide a noise environment no worse than that described below. The total noise environment generally results from two primary contributions: self-crosstalk from other 1BASE5 wire pairs and externally induced impulse noise, typically from telephone ringing and dialing signals, and office machinery. For the purposes of this standard, it can be assumed that the two components contribute independently and so the total error rate can be appropriately split between the two.

12.7.4.1 Impulse Noise. The noise voltage on wire pairs terminated at both ends in 96 Ω, as measured through the following specified filters, shall not exceed the corresponding threshold voltages more than 9 times per 1800 s interval. Following the start of any particular impulse that is counted, any additional impulses shall be ignored (that is, not counted) for a period of 100 μs. Each filter is a 2-pole Butterworth low-pass filter with the indicated cut-off (3 dB point) frequency.

Cut-Off Frequency	Threshold
2 MHz	170 mV
4 MHz	275 mV
10 MHz	560 mV

The impulse noise occurrence rate changes inversely by one decade for each 7 dB change in the threshold voltage. That is, if the noise occurrence rate is 9 counts per 1800 s at a particular threshold voltage, then a rate of 9 counts per 18 000 s will occur at a threshold 7 dB above that voltage. If a count rate of N counts per 1800 s is measured on a specific cable and filter at the specified voltage threshold, the media noise margin is $7 \log_{10} (9/N)$ dB.

12.7.4.2 Crosstalk. The level of crosstalk noise on a pair depends on the level of the disturbing signal(s) and the crosstalk attenuation from the pair(s) carrying the signal(s). With the maximum transmit level specified in 12.5.3.1, the sinusoidal crosstalk attenuations specified in 12.7.3.1 and 12.7.3.2, and multiple, synchronized, random Manchester disturbers, the peak self-crosstalk (that is, crosstalk from other 1BASE5 signals) noise levels, as measured through the following specified filters, shall be less than or equal to the levels indicated below. Each filter is a 2-pole Butterworth low-pass filter with the indicated cut-off (3 dB point) frequency.

Cut-Off-Frequency	Level
2 MHz	105 mV
4 MHz	160 mV

12.8 Special Link Specification

12.8.1 Overview. Some 1BASE5 networks may require extension beyond the limits imposed by 12.7 or, due to the installation environment, may require special media such as optical fiber, high-grade cable, or even free-space transmission. The detailed design of special links that replace standard links for use in such circumstances is beyond the scope of this standard, but the end-to-end characteristics are specified. It shall be the responsibility of the supplier to ensure the proper operation of special links with other 1BASE5 equipment.

12.8.2 Transmission Characteristics. Special links shall meet the overall attenuation, jitter, and dispersion specifications of 12.7.2.1, 12.7.2.3, and 12.7.2.4, respectively. Total noise introduced due to crosstalk or other sources shall not exceed that allowed for standard media, as specified in 12.7.4. To the extent that it affects operability with 1BASE5 transmitters and receivers, special links shall also meet the impedance and balance requirements of 12.7.2.2 and 12.7.3. The delay and preamble loss allowed for special links is specified in 12.9.4.

12.8.3 Permitted Configurations. No more than one special link is permitted in the path between any DTE and the header hub. That is, special links may be installed in parallel but not in series.

NOTE: Special links may be combined with other 1BASE5 components, such as hubs. Such combinations are subject to the performance specifications of this standard only as visible at their external interfaces. For example, explicit MDIs are not required internal to such combinations.