

Both the transmitter and the receiver shall be ac-coupled to the center conductor of the drop cable of the  $75\ \Omega$  single-channel phase-coherent-FSK bus coaxial cable medium, and the breakdown voltage of that ac coupling means shall be at least 500 V ac rms at 50/60 Hz. In addition to this coupling, the shield of the coaxial cable medium shall be connected to chassis ground, and the dc impedance of that connection shall be less than  $0.1\ \Omega$ .

#### 12.7.6 Receiver Characteristics

**12.7.6.1 Receiver Sensitivity and Selectivity.** The PLE shall be capable of providing an undetected equivalent bit error rate of  $10^{-9}$  or lower, and a detected bit error rate of  $10^{-8}$  or lower, when

- (1) The received signals are transmitted according to 12.7.3.

NOTE: This implies that a preamble following silence may be as short as 22 MAC-symbols.

- (2) The received signals are conveyed by the medium defined in Section 13, with the signal characteristics defined in 13.5.3, the maximum noise specified in 13.5.5, and the maximum reflections specified in 13.5.4.
- (3) The receiver shall report the presence of received signalling, perhaps as *bad\_signal*, and shall not report silence to the MAC sublayer when the received signal level is greater than +10 dBmV.

In summary, the specified signal range is +10 dBmV to +66 dBmV and maximum noise is -10 dBmV in the operating frequency range for both 5 Mb/s and 10 Mb/s receivers.

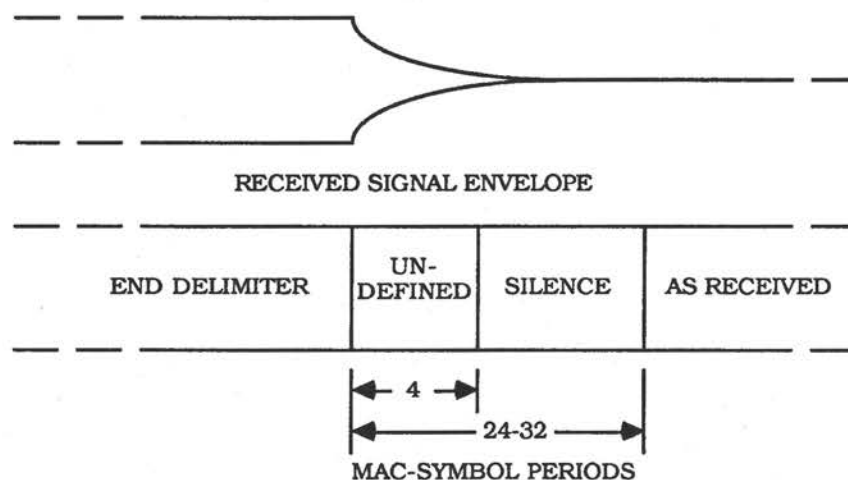
NOTE: When measuring bit error rate, multiple errors in a frame may be counted as a single error.

**12.7.6.2 Minimum Receiver Off Level.** The receiver shall report silence within 2 MAC-symbol\_times of the receiver going below +4 dBmV. The intention of this specification is to prevent the PLE from reporting reflections on the medium as non-silence to the MAC sublayer entity.

**12.7.6.3 Receiver Blanking.** The PLE receiver function shall recognize the end of each transmission and report silence to the MAC sublayer entity for a period thereafter. This period of silence, or blanking, shall begin no later than 4 MAC-symbol\_times after reporting the last MAC-symbol of the last end delimiter of the transmission. This period of silence shall continue to a point at least 24 but no more than 32 MAC-symbol\_times after the reporting of the last MAC-symbol of the end delimiter. Subsequent to this blanking period, silence or non-silence, corresponding to the received signal, shall be reported to the MAC sublayer entity. Figure 12-5 shows the receiver blanking function pictorially.

Therefore the minimum slot time of a network is four octets.

**12.7.7 Symbol Timing.** During the recovery of *pad\_idle* and *silence* symbols, it is permissible to vary the MAC-symbol reporting period by up to one nominal MAC-symbol\_time. The period of each reported MAC-symbol shall nonetheless be within 90–210% of the nominal MAC-symbol\_time at all times. Further, the period of each reported MAC-symbol after *pad\_idle* symbol recovery and until either silence or *bad\_signal* is reported shall be within 90–110% of the nominal MAC-symbol\_time.



**Fig 12-5**  
**Receiver Blanking**

**12.7.8 Symbol Decoding.** After demodulation and determination of each received PHY-symbol, MAC-symbols shall be decoded by the process inverse to that described in 12.7.2, and the decoded MAC-symbols shall be reported at the MAC interface. (As stated in 12.5.1.1, receivers are permitted to decode the transmitted representation of *pad\_idle* symbol as an alternating sequence of *ones* and *zeros*.) Whenever a PHY-symbol sequence is received for which the encoding process has no inverse, those PHY-symbols shall be decoded as an appropriate number of *bad\_signal* MAC-symbols and reported as such at the MAC interface. In such cases, the receiving PLE should resynchronize the decoding process as rapidly as possible.

The polarity of the carrier signal at the start of the frame does not imply specific information about the signal. The PLE shall be able to receive signals of either initial polarity.

**12.7.9 Transmitter Enable/Disable and Received Signal Source Selection (OPTIONAL).** The ability to enable and disable transmission onto the single-channel phase-coherent-FSK bus medium as directed by management is recommended but optional.

The ability to select the source of received signaling, either a loopback point within the PLE or one of the possibly redundant media, as directed by management, is recommended but optional. When such an option is invoked and the selected source is not one of the media, transmission to all connected single-channel phase-coherent-FSK bus media shall be disabled automatically while such selection is in force.

**12.7.10 Redundant Media Considerations (OPTIONAL).** Embodiments of this standard that can function with redundant media are not precluded, provided that the embodiment as *delivered* functions correctly in a nonredundant, single-cable environment. Where redundant media are employed, the provisions of 12.7.4 and 12.7.9 apply separately and independently to each single medium interface, and much of 12.7.9 shall be mandatory. Specifically, separate jabber-inhibit monitoring shall exist for each medium (although common inhibition is permissible), receiver signal source selection shall be provided and it shall be capable of selecting any one of the redundant media, and it shall be possible to enable or disable each single transmitter independently of all other redundant transmitters when the source of received signaling is one of the redundant media.

**12.7.11 Reliability.** The PLE shall be designed so that its probability of causing a communication failure among other stations connected to the medium is less than  $10^{-6}$  per hour of continuous (or discontinuous) operation. For regenerative repeaters this requirement is relaxed to a probability of  $10^{-5}$  per hour of operation. Connectors and other passive components comprising the means of connecting the station to the coaxial cable medium shall be designed to minimize the probability of total network failure.

**12.7.12 Regenerative Repeater Considerations.** The PLE of a regenerative repeater can be considered to be a composite entity, with separate electrical and mechanical transmit and receive functions for each connected trunk segment (that is, each port), that all work under a common encoding, decoding, timing-recovery and control function.

In performing its repeating functions, the regenerative repeater serves as a relay station. When a PHY-symbol other than *off* is received, the composite PLE determines which trunk carried the PHY-symbol, and it then selects that trunk as the source of reported PHY-symbols. Concurrently, the MAC entity begins to retransmit onto the other trunks all MAC-symbols reported. When a collision or noise is detected (for example *bad\_signal* is reported), the repeater's MAC entity sends an abort sequence (see 4.1.8) in lieu of the received MAC-symbols.

The basic mode of operation, originating or repeating, shall be determined by the superior MAC entity and conveyed by the PHY-MODE invoke primitive (see 8.2.3).

When originating, the repeater PLE shall originate the symbol timing provided to the MAC entity and transmit the encoded MAC-symbols onto all connected trunk segments. The repeater PLE shall use either loopback or any one of the attached trunks as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When repeating and when switching to repeating, the repeater PLE shall delay for the equivalent of the receiver blanking period (see 12.7.6.3) from the end of the most recent transmission to prevent repeating the reflection of the just-prior transmission, and shall then scan the connected ports for one on which signaling is being received. During the delay period, and while this scan for signal is unsuccessful, the repeater PLE shall indicate *silence* symbols to its MAC-entity using its locally originated symbol timing. Upon detecting signaling at one or more ports, the repeater entity shall select one of those active ports as the

source of its received signaling. It shall then temporarily disable that selected port's transmitter function, decode the received signaling, retime that signaling before or after decoding, and indicate the decoded MAC-symbols to its associated MAC entity. It should then vary the frequency of the MAC-symbol timing, within the bounds of this subsection (12.7), as necessary to maintain the proper relationship with the frequency of the received PHY-symbol timing.

Regenerative repeaters also prefix enough *pad\_idle* symbols to a transmission to provide a minimum of 3 octets of preamble following its receiver blanking period. In summary, when the MAC entity is originating

- (1) The PLE alone shall determine the MAC-symbol timing
- (2) Transmission occurs on all attached trunks (unless disabled by the provisions of 12.7.9)
- (3) Loopback or any one of the attached trunks can be used as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When the MAC entity is repeating

- (a) The PLE first delays for the receiver blanking period (i.e., long enough to ensure that the prior transmission is not repeated), then scans all attached trunks for signaling and selects one of those trunks with signaling as the source of received signaling.
- (b) Transmission to the selected trunk is temporarily inhibited.
- (c) The received signaling from the selected trunk is decoded and indicated to the MAC entity.
- (d) The frequency of MAC-symbol timing is varied as necessary (at most,  $\pm 0.015\%$ ) to track the frequency of the peer transmitter's MAC-symbol timing until the MAC entity requests transmission of *silence*, and then repeats the whole procedure.

## 12.8 Environmental Specifications

**12.8.1 Electromagnetic Emanation.** Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**12.8.2 Safety Requirements.** All stations meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [7].

**12.8.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The PLE embodiment 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.



**12.9 Labeling.** It is recommended that each embodiment (and supporting documentation) of a PLE conformant to this standard be labeled in a manner visible to the user with at least these parameters:

- (1) Data rate capabilities in Mb/s.
- (2) Worst-case, round-trip delay (for nonrepeaters) or one-way delay (for repeaters) that this equipment induces on a two-way transmission exchange between stations, as specified in 6.1.9.
- (3) Operating modes and selection capabilities as defined in 12.7.9 and 12.7.10.

Additionally, when the station has multiple connectors (for example, redundant media), the role of each such connector shall be designated clearly by markings on the station in the vicinity of that connector.

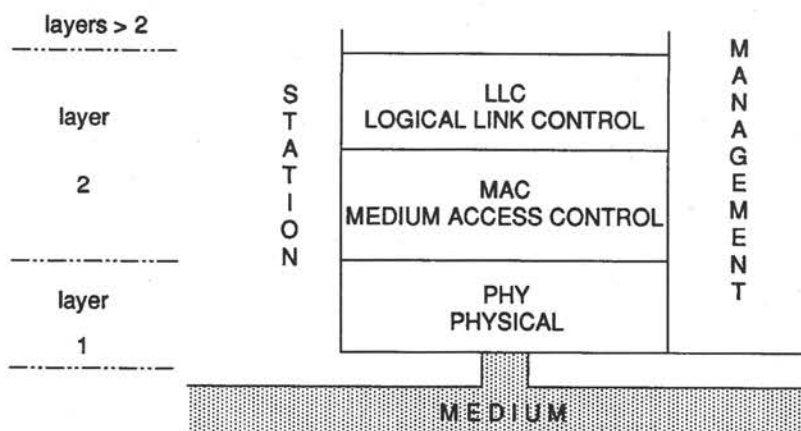
### 13. Single-Channel Phase-Coherent-FSK Bus Medium

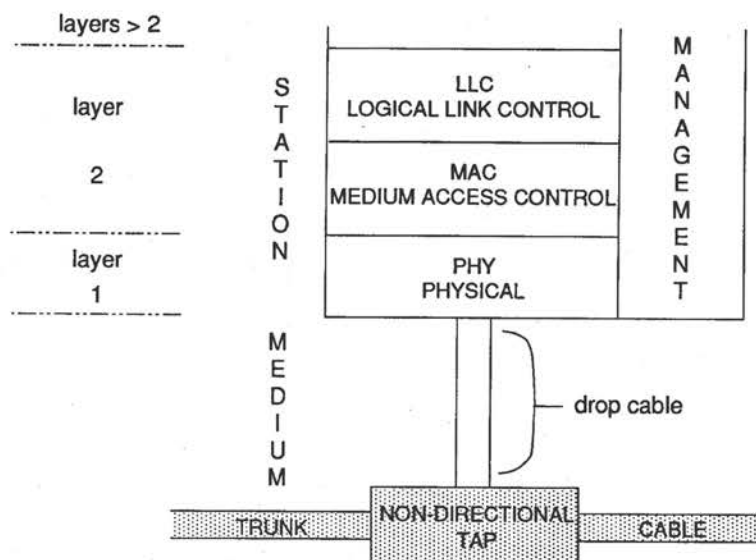
The functional, electrical, and mechanical characteristics of one specific form of medium are specified in this section. This specification includes the medium embodiments of a single-channel phase-coherent-FSK bus medium for a Local Area Network (LAN). The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 13-1. The relationship of this section to the single-channel phase-coherent-FSK bus PLE and medium is illustrated in Fig 13-2.

This standard specifies the medium only insofar as necessary to ensure

- (1) The interoperability of PLEs conforming to Section 12 when connected to a medium conformant to this section, and
- (2) The protection of the LAN medium itself and those using it.

**Fig 13-1**  
**Relation to LAN Model**





**Fig 13-2**  
**Physical Hardware Partitioning**

**13.1 Nomenclature.** Terms used in this section whose meanings within the section are more specific than indicated in the glossary of IEEE P802.1B [10] are as follows:

**dBmV.** A measure of rms signal level on a 75  $\Omega$  cable compared to 1 mV. In terms of SI units, dBmV is defined as dB (1 mV, 75  $\Omega$ ) rms.

**drop cable.** The cable of the medium which connects a tap to a station.

**F-connector.** A 75  $\Omega$  F-series coaxial cable connector such as those used for television and video equipment.

**frequency shift keying (FSK).** A modulation technique whereby information is impressed upon a carrier by shifting the frequency of the transmitted signal to one of a small set of frequencies.

**medium.** The cable system of a LAN including the trunk cable, taps, drop cables, and splitters.

**operating frequency range.** The operating frequency range is defined as 2–15 MHz for a 5 Mb/s data rate and 4–30 MHz for a 10 Mb/s data rate.

**phase-coherent FSK.** A particular form of FSK where the two signaling frequencies are integrally related to the data rate and transitions between the two signaling frequencies are made at zero crossings of the carrier waveform.

**regenerative repeater.** A device used to extend the length or topology of the medium beyond the limits imposed by signal degradation on a single segment of the medium.

**single-channel system.** A system where at any point on the medium, only one information signal at a time can be present without disruption.

**splitter.** A module that electrically and mechanically couples one trunk cable to other trunk cables, providing a branching topology for the single-channel phase-coherent-FSK trunk. A splitter combines signals received at its ports and splits any signal energy received from a trunk symmetrically among the other trunks. It contains only passive electrical components (R, L, C).

**tap, nondirectional.** A module that electrically and mechanically couples the trunk cable to one or more drop cables. It splits the signal received from each trunk cable very asymmetrically, with the bulk of the signal passed to the other trunk cable and only a small percentage passed to the drop cable(s). A small portion of the signal received by the drop cables from the station is split equally among the trunk cables. The tap contains only passive electrical components (R, L, C).

**trunk cable.** The main cable of the medium, interconnecting the taps.

**13.2 Object.** The object of this specification is to

- (1) Provide the physical medium necessary for communication between local network stations employing the token-passing bus access method and the single-channel phase-coherent-FSK bus PLE defined in this standard.
- (2) Provide for high network availability.
- (3) Provide for ease of installation and service in a wide range of environments.
- (4) Permit use of components and installation practices similar or identical with those used in the cable TV industry.

**13.3 Compatibility Considerations.** This standard applies to media that are designed to operate as CATV-like, but nondirectional, single-channel phase-coherent-FSK bus coaxial cable systems. Such systems use nondirectional taps in standard CATV tap housings, and standard CATV connectors and coaxial cable. This specification applies to a single trunk system in which two-way alternate communication is accomplished through the use of nondirectional taps and splitters and, in large systems, multidirectional regenerative repeaters.

All implementations of media conformant to this standard shall be compatible at their drop cable station interfaces. Specific implementations based on this standard may be conceived in different ways provided compatibility at the station interfaces is maintained.

### 13.4 Overview

**13.4.1 General Description of Functions.** The functions performed by the single-channel phase-coherent-FSK bus medium entity are described informally here. Jointly, these functions provide a means for signals generated by a station at the medium interface to be conveyed to all of the other stations on the medium. Thus, stations connected to these drop cables can communicate with each other.

**13.4.1.1 Operational Overview.** Stations are connected to the *trunk* coaxial cable(s) of a single-channel phase-coherent-FSK bus system by *drop* cables and impedance-matching taps. These taps are passive devices that are nondirectional (that is, omnidirectional) with regard to signal propagation. The nondirectional characteristics of the taps permit the signals from a station to propagate in both directions along the trunk cable.

The topology of the single-channel phase-coherent-FSK bus system is that of a highly-branched tree without a root, with the stations connected as leaves to the tree's branches. Branching is accomplished in the trunk itself by way of *regenerative repeaters* (described below) and *splitters*, which provide nondirectional coupling of the signaling carried on the trunk cables similar to that of the just described taps. Like the taps, the splitters also employ only passive electrical components (R, L, C, only).

**13.4.1.2 Regenerative Repeater Functions.** In a single-channel phase-coherent-FSK bus system, regenerative repeaters may be used to connect trunk segments into a highly branched topology, or to extend the length of the medium, or to increase the number of taps on a trunk. The regenerative repeater is connected to the trunks by way of taps and drop cables. Regenerative repeaters are discussed in detail in 12.7.12.

**13.4.2 Basic Characteristics and Options.** All signal-conveyance characteristics and station-interface characteristics are mandatory. All other characteristics are optional.

**13.5 Functional, Electrical, and Mechanical Specifications.** The single-channel phase-coherent-FSK bus medium is an entity whose sole function is signal transport between the stations of a single-channel phase-coherent-FSK bus network. Consequently, only those characteristics of the medium that impinge on station-to-station, signal transport, or on human and equipment safety, are specified in this standard.

An implementation of the medium shall be deemed conformant to this standard if it provides the specified signal transport services and characteristics for the stations of a single-channel phase-coherent-FSK bus medium, and if it meets the relevant safety and environmental codes.

Unless otherwise specified, all measurements in 13.5 are to be made at the point of station or regenerative repeater connection to the medium. Unless otherwise stated, all voltage and power levels specified are in rms and dBmV, respectively, based on measuring the fundamental signal content of continuous transmissions of either all *one* or all *zero* symbols (dBmV is defined as dB [1 mV, 75  $\Omega$ ] rms in 13.1).

**13.5.1 Connection to the Station.** The connection of the single-channel phase-coherent-FSK bus medium to the station shall be by way of a  $75\ \Omega$  drop cable not to exceed 50 m in length. At the station, the drop cable shall have a male F-series  $75\ \Omega$  connector. This connector shall mate with a female F-series  $75\ \Omega$  connector mounted on the station.

In addition to this coupling, the shield(s) of the coaxial drop cable medium shall be connected to the shell of the terminating male F-series connector and the dc impedance of that connection shall be less than  $0.001\ \Omega$ . Also, the dc impedance of a connection between the shell of that male F-series connector and the outer barrel of a mated female F-series connector shall be less than  $0.001\ \Omega$ .

NOTES: (1) At the time this standard was written, there were no recognized standards for F-connectors. A standard for F-connector mating interface dimensions was being drafted by the IEC as Publication 169: (to be determined), Radio-frequency connectors (Type F). A comprehensive Type FD connector standard (intermateable with Type F) was being drafted by the Electronic Industries Association to be published as EIA 550. F-connectors vary greatly in quality. It is suggested that high quality F-connectors be used. Further, since the center conductor of the cable in some F-connectors becomes the male part of the connector, caution should be used in mixing different types of cables with F-connectors. Where possible, the use of connectors with captive center conductors is recommended.

(2) Under certain environmental conditions F-connectors may be unsuitable. Although not part of this standard, the use of  $50\ \Omega$  N-connectors will meet the electrical and performance requirements of Sections 12 and 13.

### 13.5.2 Cable Characteristic

**13.5.2.1 Characteristic Impedance.** The characteristic impedance of the single-channel phase-coherent-FSK bus medium shall be  $75 \pm 3\ \Omega$ .

**13.5.2.2 Trunk Return Loss Requirements.** Unidirectional reflected signal energy, that reflected from one direction on the trunk cable, shall be less than  $-22$  dB below the incident energy level at any point on the trunk cable over the operating frequency range. This reflection is the sum of the reflections caused by the structural return loss of the cable itself and all the taps and other components on the trunk cable.

**13.5.2.3 Medium Interface Return Loss.** The medium as seen at any drop cable to station connection point shall present an impedance resulting in less than  $-14$  dB return loss (VSWR of 1.5:1) when driven from a  $75\ \Omega$  resistive source as measured over the operating frequency range.

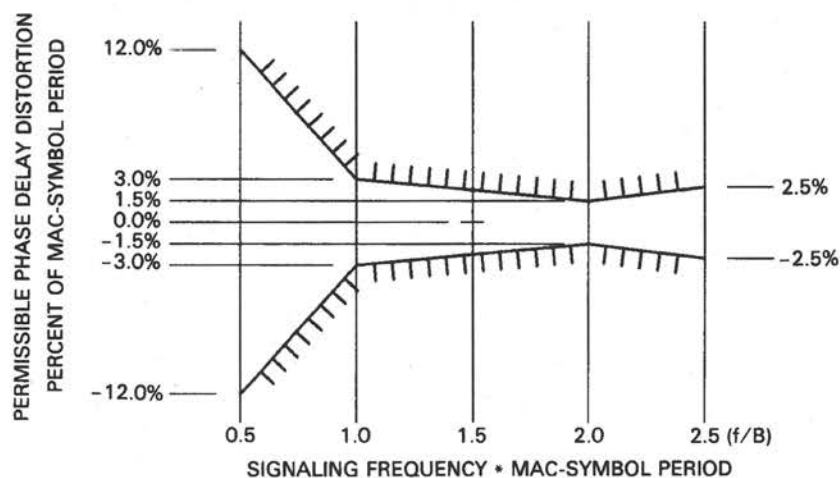
### 13.5.3 Signal Characteristics

**13.5.3.1 Amplitude.** When conveying the signal of a single station or regenerative repeater whose transmit level is as specified in 12.7.3.3, the single-channel phase-coherent-FSK bus medium shall present that signal to any connected station or regenerative repeater at an amplitude of between  $+10$  and  $+66$  dBmV for either a 5 Mb/s data rate or a 10 Mb/s data rate system.

**13.5.3.2 Tilt.** The signal amplitude of the two fundamental signaling frequencies due to media attenuation (corresponding to the data rate and to twice the data rate) at any receiving station shall differ by no more than 3.5 dB.

**13.5.3.3 Distortion.** The maximum percent phase delay distortion (PDD) shall fall within the mask specified in Fig 13-3, which consists of a straight line mask defined by the break points.





$f/B$	Maximum PDD
0.5	$\pm 12\%$
1.0	$\pm 3.0\%$
2.0	$\pm 1.5\%$
2.5	$\pm 2.5\%$

NOTE: The 0% reference is defined at  $1.5 f/B$ .

where

$f$  = signaling frequency (Hz)

$B$  = MAC-symbol data rate (symbols/second)

PDD = the maximum permissible phase delay distortion as a percent of  $1/B$  seconds, which is the MAC-symbol time

**Fig 13-3**  
**Limits for Percent PDD**

**13.5.4 Received Signal Reflection Component.** Excluding noise, the signal received by any station is composed of two parts: the nonreflected component of the signal, and the reflected component. The nonreflected component is that part of the signal that would be received from a perfect medium. The reflected component is due to impedance mismatches in the medium, both on the trunk cable and the drop cable. The transmitting station and the receiving stations are expected to operate as required in Section 12 in the presence of these reflections. As a consequence of the station and medium impedance mismatch characteris-

tics defined in this section and in Section 12, the maximum reflected signal components are as follows:

At a transmitting station, the reflected component of the signal from the medium, during transmission and 1  $\mu$ s subsequent to the end of a transmission, will be at least 14 dB below the transmit level. From 1–2  $\mu$ s following a transmission, the reflected component of a signal will be at least 42 dB below the end of transmission transmit level. After 2  $\mu$ s, the reflection will be below +4 dBmV. These reflection levels are a consequence of the 14 dB return loss permitted for the interface to the medium (13.5.2.3) and the 50 meter maximum length of the drop cable (13.5.1).

If a receiving station shares the same tap as a transmitting station and the isolation between the drop cable ports to the stations is less than 40 dB, then the reflected signal level at the receiving station approaches that of the transmitting station.

**13.5.5 Noise Power.** The in-band noise power shall be –10 dBmV or less in the operating frequency range as measured at any point a station or regenerative repeater is connected to the medium.

**13.5.6 Power Handling Capability.** The total power over the entire cable spectrum, as presented to the station or regenerative repeater, shall be less than 0.25 W.

**13.5.7 Tap Requirements.** The loss between any trunk port and any drop cable port shall be  $20 \pm 0.5$  dB.

For taps with multiple drop cable ports, the isolation between drop ports on the same tap may be between 0 and 41 dB.

**13.5.8 Compatibility with the Stations and Regenerative Repeaters.** An embodiment of a single-channel phase-coherent-FSK bus medium entity is deemed to support a specific single-channel phase-coherent-FSK bus LAN if the requirements of 13.5.1 through 13.5.7 (inclusive) are met when measured from each point of station connection to the medium, independent of which one of the points of station connection is chosen for test signal origination.

**13.5.9 Redundancy Considerations.** As stated in 12.7.10, redundant single-channel phase-coherent-FSK bus media are not precluded by this standard. Where redundant media are employed, the provisions of 13.5.1 through 13.5.7 shall apply separately and independently to each medium interface.

**13.5.10 Reliability.** Connectors and other passive components connecting the station to the coaxial cable medium shall be designed to minimize the probability of total network failure.

### 13.6 Environmental Specifications

**13.6.1 Electromagnetic Emanation.** LAN cable systems shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**13.6.2 Safety Requirements.** All media meeting this standard shall comply with relevant local, national, and international safety codes and standards.

**13.6.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The medium embodiment 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.

NOTE: Operating in this environment implies that quad-shield cable or comparable shielding measures may be required.

**13.7 Transmission\_path\_delay Considerations.** When specifying an embodiment of a medium that conforms to the specifications of this section, a vendor shall state the transmission\_path\_delay as the maximum *one-way* delay that the single-channel phase-coherent-FSK bus medium could be expected to induce on a transmission from any connected station through any intervening regenerative repeaters to any other station. The delays induced by the transmitting and receiving stations should not be included in the transmission\_path\_delay.

For each potentially worst-case path through the medium, a path delay is computed as the sum of the medium-induced delay and repeater-induced delay, if any, in propagating a signal from one station to another. The transmission\_path\_delay used for determining the network's slot\_time (see 6.1.9) shall be the largest of these path delays for the cable system.

These path delay computations shall take into account all circuitry delays in all relevant regenerative repeaters and medium splitters, etc., and all signal propagation delays within the cable segments. The regenerative repeater delays shall be determined as specified in 12.9 and 6.1.9.

The transmission\_path\_delay shall be expressed in terms of the network's symbol signaling rate on the medium. When not an integral number of signaled symbols, it shall be rounded up to such an integral number. When uncertain of the exact value of the delay, vendors shall state an upper bound for the value.

**13.8 Documentation.** It is recommended that each vendor of an embodiment of a medium entity conformant to this standard provide to the user supporting documentation with at least the transmission\_path\_delay, as specified in 13.7 and 6.1.9.

### 13.9 Network Sizing

**13.9.1 Topology Considerations.** Very small systems can be constructed using only flexible coaxial cable and passive impedance-matching networks. Larger systems require semirigid trunk cable and flexible drop cables, or regenerative repeaters, or both. Highly-branched topologies are achieved in this medium using CATV-like components.

**13.9.2 Signal Loss Budget Considerations.** The placement of phase-coherent-FSK regenerative repeaters and taps should take into account

- (1) Each station's minimum transmit level and receive level specifications,

- (2) The desired current and anticipated future placement of stations and regenerative repeaters, and
- (3) The presented signal level and signal-to-noise specifications.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

### 13.10 Appendix—Guidelines for Configuring the Medium

**13.10.1 Network Size.** Both overall length of cable and number of taps should be explicitly combined in the system signal loss budget. Each tap is matched at all ports, and the attenuation between all ports is specified. Thus each tap makes a known contribution to the network loss budget, as does each length of the trunk cable. In addition, each tap includes a definite tap loss between the trunk and the drop, which should also be included in the loss budget.

The tap trunk to drop loss value specified in this standard is  $20 \pm 0.5$  dB. Typical values for commercially available two-drop taps conforming to this specification are 0.3 dB insertion loss over a frequency range of 1–30 MHz. An example calculation of the signal loss budget for a simple, unbranched network, including 20 such two-drop taps, might look like this:

Drop loss at first tap:	20.5 dB
Insertion loss of 18 intervening taps:	5.4 dB
Drop loss at 20th tap:	20.5 dB
Total lumped losses:	46.4 dB

The minimum transmit level and receive sensitivity specified in Section 12 are +63 dBmV and +10 dBmV, respectively. Thus, the cable loss in this example network should not exceed  $63 - 10 - 46.4 = 6.6$  dB. Given the actual intended length of the installed trunk cable, one should select a suitable cable based on attenuation at the highest frequency component for the particular data rate planned or anticipated. For a 5 Mb/s data rate, an RG-11 type cable with an attenuation of 1.5 dB/100 meters at 10 MHz limits the cable length to 440 meters. A longer cable length would be possible if semirigid cable were to be used.

If fewer taps were used, the cable length could be longer. In this case, phase delay distortion rather than cable attenuation might be the limiting factor. A typical phase delay distortion limitation for RG-11 type cable is 700 meters. The cable manufacturer should specify the least cable length at which

- (1) The cable attenuation equals 12 dB at a frequency of 10 MHz (for 5 Mb/s systems) or 20 MHz (for 10 Mb/s systems), or
- (2) The cable tilt equals the maximum permitted by 13.5.3.2, or

- (3) The cable phase delay distortion equals the maximum permitted by 13.5.3.3.

**13.10.2 Network Topology.** The simplest network topology is a long unbranched trunk, requiring the trunk cable to be routed to each station site in turn. Branched topologies may be implemented by impedance-matched nondirectional splitters, which are three-port passive networks that divide the signal incident at one port into two equal parts that are transmitted to the other two ports. The insertion loss between any two ports of a typical, commercially available, nondirectional splitter is 6.5 dB. When branches are implemented by way of such splitters, a separate loss budget should be calculated for each possible end-to-end path, so that the highest loss path can be used to select the trunk cable.

**13.10.3 Repeaters.** Regenerative repeaters are specified in Section 12 for the purposes of branching and the extension of the network beyond the basic signal loss budget.

NOTE: Simply cascading 45 taps in an unbranched trunk configuration (at 0.3 dB insertion loss for each of 43 taps, and 20 dB drop loss for each of the other two) consumes the entire dynamic range of 53 dB. Repeaters may be necessary on larger networks even when end-to-end cable lengths are relatively short.

**13.10.4 Drop Cables.** The drop cables specified in this section are 75  $\Omega$  cables that do not exceed 50 m in length, so that loss in the drop cable is less than 1 dB. This length of cable permits relative freedom in routing the trunk cable and locating the station. Since the drop cable length is not negligible, the drop cable should be terminated in its characteristic impedance of 75  $\Omega$  to preserve the impedance-matched conditions at the tap. This 75  $\Omega$  termination is provided by the stations connected to the drop cable. When no station is connected to a drop cable, or when no drop cable is attached to a drop cable port of a tap, the 75  $\Omega$  termination should be provided by other means. See NOTES in 13.5.1.

**13.10.5 Trunk Connection.** The drop cable is coupled to the trunk cable through the tap, a passive, nondirectional, coupling network that is impedance matched to the 75  $\Omega$  cables at all ports. A fixed small fraction of the signal traveling in either direction on the trunk cable is transferred to the drop cable. A signal from a station on the drop cable is attenuated at the tap and then propagates out in both directions on the trunk.

Multi-port taps return a portion of the signal to other drops as well.

Tap insertion losses essentially represent the way the incident power is divided between the ports, they are not due to dissipation in the tap. Typical values, mentioned earlier in connection with network sizing, are 0.3 dB insertion loss between the trunk ports for a two-port tap, and 20 dB drop loss between the trunk and drop ports. In every case, all ports should be matched for proper operation. This means that a 75  $\Omega$  termination should be connected to every unused port, and that the cable attached to any port should be properly terminated.

The coupling networks consist only of passive R, L and C elements. Power connections are not permitted.

The coupling networks are enclosed by sealed housings to provide both environmental protection and electrical shielding. The housings, typically metal cast-

ings, include integral connectors for the trunk cable and drop cable(s). Housings designed for flexible trunk cables typically use Type F connectors for all ports, while those designed for semirigid trunk cables use Type F connectors for the drop cable, and special connectors that mate directly with properly prepared ends of the trunk cable. If F-connectors are planned, see NOTES in 13.5.1.

**13.10.5.1 Tap Placement.** It is recommended that the taps and cable splices should not be placed at regular  $1/2$  wavelength intervals of the higher signaling frequency.

NOTE: It is the ultimate responsibility of the system installer to assure the specifications of this section are met.

**13.10.6 Earthing.** The trunk cable shield may be floating, single-point, or multiple-point grounded as far as signal transmission is concerned. Earths thus may be installed to eliminate electromagnetic interference (EMI) and comply with safety codes and other regulations applicable to the particular installation. This usually means earthing where the cable enters or leaves a building, and at intervals not exceeding approximately 100 m within the building. Earths should be applied carefully by a clamp that does not crush or damage the cable, because such cable damage causes serious reflections. Suitable clamps are available from suppliers of CATV system hardware.

**13.10.7 Surge Protection.** It is good practice to protect the cable against ground surges due to lightning. Suitable surge protectors that meet the requirements of IEEE C37.90.1-1989 [8] should be used at each end of the cable. The capacitive loading of surge protectors should be small to avoid affecting PLE (modem) performance, and should not exceed values permitted for a standard tap. For maximum surge protection, a low-impedance, heavy-duty earth connection is required.

**13.10.8 Termination.** The trunk cable should be terminated in  $75\ \Omega$  (resistive) at all ends. All drop cables should be properly terminated at the station end. All unused tap ports should be terminated in  $75\ \Omega$ . Shielded  $75\ \Omega$  coaxial terminations with good broadband characteristics are commercially available for most coaxial cables. Since maximum transmit levels are +66 dBmV, power ratings of 0.25 W are sufficient.

**13.10.9 Joining Cable Sections.** In general, the trunk cable will consist of a number of separate sections of coaxial cable. Some sections may be joined by connections to tap housings, while others may be joined by splicing connectors (for semirigid cable) or straight-through connectors (for flexible cable). Flexible cables will be fitted with matched connectors at each end, while semirigid cables will simply have their ends properly prepared to mate with corresponding connectors.

A good engineering practice is to maintain constant impedance between cable sections by using one cable type from one manufacturer for the entire trunk. This practice avoids significant reflections where cables are joined. When dissimilar types are to be joined, it is suggested that a lossy (attenuating) impedance-matched connector be employed to reduce repeated reflections. In order to minimize discontinuities, cable should be obtained from the same lot (same extruder



at about the same time of manufacture). It is the extruder-to-extruder differences that contribute to the mismatch. A minimal-loss splice should only be used between two pieces of cable from the same roll, or at worst from the same lot.

**13.10.10 Pretested Cable.** It is a good practice to pretest all trunk cable before installation. The objective is to ensure that the attenuation does not exceed the expected values at frequencies of interest, and to ensure that concealed (that is, internal) discontinuities that can cause reflections do not exist. For a nominal charge, most cable suppliers will pretest or certify all cable before shipment.

On-site testing after installation is also recommended, since any damage may degrade operating margins or cause outright failure. A recommended method for testing the installed cable for damage, improper termination, shorts, or discontinuities is to use a time domain reflectometer or a return loss meter.

#### 14. Broadband Bus Physical Layer Entity (PLE)

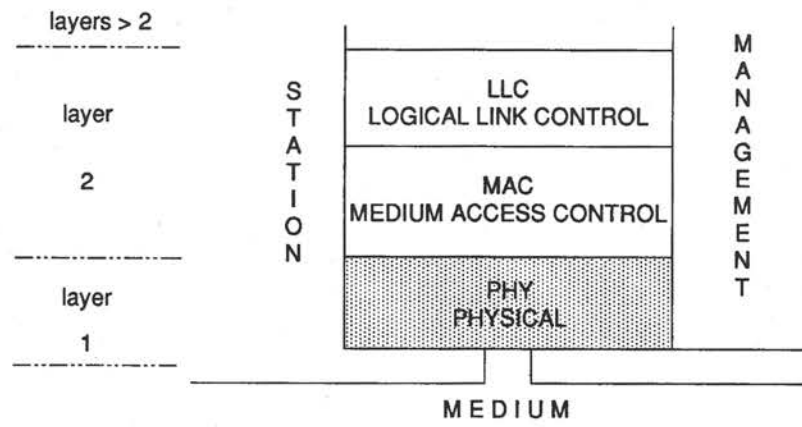
The functional, electrical, and mechanical characteristics of one specific form of PLE (broadband bus) of this standard are specified in this section. This specification includes

- (1) The PLEs found in stations that could attach to the broadband bus local area network (LAN),
- (2) The PLEs of remodulators that are part of the broadband bus LAN.

The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 14-1. The relationship of this section to the broadband bus PLE and medium is illustrated in Fig 14-2. This standard specifies these PLEs only in so far as necessary to ensure

- (1) The interoperability of implementations conforming to this specification,
- (2) The protection of the LAN and those using it.

**Fig 14-1**  
**Relation to LAN Model**



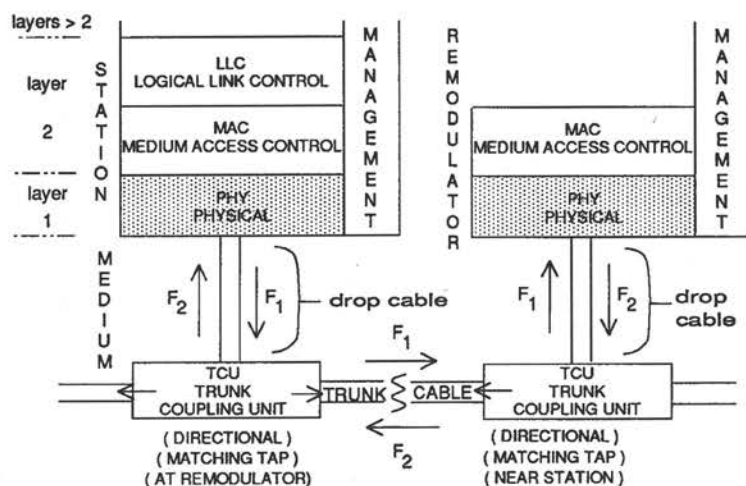


Fig 14-2  
Physical Hardware Partitioning

**14.1 Nomenclature.** Terms used in this section whose meanings, within the section, are more specific than indicated by glossaries referred to in 1.2 are as follows:

**AM/PSK modulation.** A form of modulation in which an RF carrier is both amplitude modulated (AM) and phase-shifted (PSK, phase shift keyed)

NOTE: On single (bidirectional) cable systems,  $F_1 < F_2$  and both  $F_1$  and  $F_2$  are carried on common trunk and drop cables. On dual (unidirectional) cable systems,  $F_1$  and  $F_2$  are carried on separate trunk and drop cables.

**broadband coaxial system.** A system whereby information is encoded, modulated onto a carrier, and band-pass filtered or otherwise constrained to occupy only a limited frequency spectrum on the coaxial transmission medium. Many information signals can be present on the medium at the same time without disruption provided that they all occupy nonoverlapping frequency regions within the cable system's range of frequency transport.

**dBmV.** A measure of rms signal on a 75  $\Omega$  cable compared to 1 mV. In terms of SI units (International System of Units), dBmV is defined as dB (1 mV, 75  $\Omega$ ) rms.

**detected bit error.** An error which is reported as *bad signal*. *Bad signal* reported during the preamble or during the four symbols following the last end delimiter of a transmission is not included.

**drop cable.** The smaller diameter flexible coaxial cable of the broadband medium which connects to a station.

**duobinary signaling.** A method of representing information to be transmitted by pulses shaped so as to reduce the frequency spectrum required to signal the information. Also known as Class 1 Partial Response coding.

**duobinary AM/PSK modulation.** As used in this section, a form of modulation in which data is precoded and signaled as duobinary pulses AM/PSK-modulated onto an RF carrier. The particular precoding used is such that receivers can demodulate the modulated signal without having to recover the phase of that signal. In essence, the PSK component of the modulation is used to reduce the RF signal bandwidth, not to carry additional data.

**remodulator.** As depicted in Fig 14-2, the unit located at the logical root of a broadband bus LAN which demodulates the  $F_1$  frequency signals transmitted by other network stations and rebroadcasts them as  $F_2$  frequency signals back to those stations. In this standard, it transmits continuously and in doing so specifies the precise data rate at which all stations shall transmit.

**multilevel duobinary AM/PSK.** A form of duobinary AM/PSK modulation which uses more than two distinct amplitude levels (in this specification, independent of phase) to represent information. This section specifies a three-level duobinary AM/PSK system capable of signaling at one Medium Access Control (MAC)-symbol/PHY-symbol; Appendix 14.11 discusses an extension capable of signaling at two MAC-symbols/PHY-symbol.

**trunk cable.** The main (larger diameter) cable of a broadband coaxial cable system.

**undetected bit error.** An error that is not reported as *bad\_signal* by the PLE.

**14.2 Object.** The object of this specification is to

- (1) Provide the physical means necessary for communication between local network stations employing the token-passing bus access method defined in this standard and a broadband bus medium,
- (2) Define a physical interface that can be implemented independently among different manufacturers of hardware, and achieve the intended level of compatibility when interconnected to a common broadband bus local area network medium,
- (3) Provide a communication channel capable of high bandwidth and low bit error rate,
- (4) Provide for ease of installation and service in a wide range of environments,
- (5) Provide for high network availability,
- (6) Use a medium that can be shared by totally unrelated applications (such as voice, data, and analog video), and conserve the capacity of that medium where reasonable.

**14.3 Compatibility Considerations.** This standard applies to PLEs that are designed to operate on conventional bidirectional (split frequency) community antenna television (CATV)-like broadband coaxial cable systems, or on similar

unidirectional (split cable) dual-cable systems, or both. Such networks use standard CATV taps, connectors, amplifiers, power supplies, and coaxial cable.

The use of a coaxial broadband system permits the assignment of different frequency bands to multiple simultaneous applications. For example, a portion of the cable spectrum can be used by LANs while other portions are used for point-to-point or multipoint data links, and others are used to convey television and audio signals. With the proper selection of signal levels and proper equipment design, all of the applications can be supported simultaneously.

Compatibility with this medium is determined at the medium interface. Compatible PLEs shall use the same signaling rate, the same frequency allocations, and the same number of cables.

NOTE: CATV-like media typically provide separate coupling points for the remodulator transmit and receive functions due to the location of this station in the topology. A remodulator configured in this way is compatible with other stations having single connections to the medium.

**14.4 Operational Overview of Single-Cable Medium.** The use of a coaxial cable operating as a broadband medium introduces special system considerations that are not encountered in single-channel transmission systems. A conventional CATV-like system uses bidirectional amplifiers to achieve two-way transmission on a single coaxial cable. The amplifier actually consists of two independent unidirectional amplifiers, together with the appropriate crossover filters, so that one amplifier transmits the upper portion of the cable spectrum in the *forward* direction, outbound from the remodulator, while the other amplifier transmits the lower portion in the *reverse* direction, toward the remodulator. Therefore the PLE requires an RF transmitter and receiver each operating in a different portion of the cable spectrum.

At the remodulator, where forward direction signals originate and reverse direction signals converge, a remodulator receives the lower-frequency reverse channel signal and retransmits it as the higher-frequency forward channel signal to the “downstream” stations.

Stations are connected to the *trunk* coaxial cable in such systems by smaller-diameter *drop* cables and impedance-matching *taps*. These taps are passive devices that are highly directional with regard to signal propagation, as shown in Fig 14-2. The directional characteristics of the taps improve the impedance matching at the *ports* of the tap and minimize the effects of reflections due to any impedance mismatches along the trunk or on other drop cables.

The directionality of the tap is such that the transmission loss between the station and the reverse direction trunk. Hence, communication between devices connected to different taps along the coax occurs through the transmission of a frequency  $F_1$  in the low-band toward the remodulator, reception at the remodulator and retransmission in the forward direction at a high-band frequency  $F_2$ , and reception by the “listening” stations.

**14.5 Operational Overview of a Dual-Cable Medium.** Dual-cable systems are similar to single-cable systems except that bidirectionality is provided by separate cables rather than by separate portions of the frequency spectrum on

the same cable. Consequently, amplifiers need be only unidirectional and, with respect to Fig 14-2,  $F_1$  need not be a lower frequency than  $F_2$ .

#### 14.6 General Overview

**14.6.1 General Description of Functions.** The functions performed by the broadband bus PLE are described informally here. Some of these functions are common to all stations of a broadband bus LAN; others are found only in the remodulator station. Jointly they provide a means whereby symbols presented at the MAC interface of one PLE can be conveyed to all of the PLEs on the bus for presentation to their respective MAC interfaces.

**14.6.1.1 Symbol Transmission and Reception Functions.** Successive MAC-symbols presented to the PLEs at its MAC service interface are applied to an encoder that produces as output PHY-symbols from the set: {0} {2} {4}. The encoder includes a scrambler that is applied to consecutive *zero* and *one* input MAC-symbols to reduce the autocorrelation of the encoder's output. The output is then applied to a modulator that uses a duobinary signal shaping process to produce a multilevel AM/PSK signal within the designated RF channel, where the amplitude of each output pulse corresponds directly with the relative numeric value of the associated PHY-symbol. This RF signal is then ac-coupled to the broadband bus medium and conveyed by the medium to one or more receivers.

NOTE: Except for the remodulator, sequences of the MAC-symbol *silence* are conveyed by turning off the transmitter.

Each receiver is also ac-coupled to the broadband bus. It bandpass filters the received signal to eliminate noise from other channels and then infers the transmitted PHY-symbol from the amplitude of the received signal. It decodes the inferred PHY-symbols by an approximate inverse of the encoding process and presents the resultant decoded MAC-symbols at its MAC service interface.

For all MAC-symbols except *pad\_idle*, this decoding process is an exact inverse of the encoding process in the absence of errors. The *pad\_idle* symbols, which are referred to collectively as *preamble*, are transmitted at the start of each MAC frame, both to provide a training signal for receivers and to provide a nonzero minimum separation between consecutive frames. Since each transmission begins with *pad\_idle* symbols, it is expected that some of these initial symbols may be "lost in transit" between the transmitter and the remodulator. Additionally, in broadband bus systems, the encoding for the sequence of *pad\_idle* MAC-symbols is identical to the encoding for a particular sequence of *one* and *zero* MAC-symbols, and receivers are permitted to decode the transmitted representation of *pad\_idle* as a *one* or *zero* MAC-symbol, descramble it if desired, and report it as such to the MAC entity.

As stated above, the remodulator actively transmits sequences of the MAC-symbol *silence* as a specific repeating signaling sequence known as pseudo-silence. This sequence is used to provide a continuous signal for the automatic gain control (AGC) and carrier and data recovery circuitry of the LAN's other stations, and to indicate the signaling type (one MAC-symbol/PHY-symbol, or the



extended type defined in 14.11) currently in use on the LAN. When received by the other stations in the network, pseudo-silence is decoded and reported to their local MAC entities as the MAC-symbol *silence*.

**14.6.1.2 Remodulator Functions.** In an actual single-cable broadband bus system, stations do not transmit and receive on the same frequency channel. One central station, known as a remodulator, receives on a low-frequency channel and transmits on a high-frequency channel. All of the other stations transmit on the low-frequency channel and receive on the high-frequency channel. Thus, the system really consists of a pair of directional channels, with the low-frequency (reverse) channel having many transmitters and one receiver, and the high-frequency (forward) channel having one transmitter and many receivers.

NOTE: The remodulator may also function like any other station and source transmissions of its own.

To allow stations to communicate, the remodulator (see 14.8.18) serves as a relay station; when not transmitting for itself, its MAC sublayer entity interprets the symbols received in the reverse channel and retransmits them (in some form) in the forward channel. When a collision or noise is detected (for example, *bad\_signal* reported), the remodulator's medium access entity sends an abort sequence (see 4.1.8) in lieu of the received symbols. When *silence* is detected, the remodulator sends a pseudo-silence pattern which the other stations report to their medium access entities as *silence*. Thus, during normal operation the remodulator transmits continuously. The other stations in the LAN determine the exact transmit and receive data rate from that continuously on, forward-channel signal and the type of signaling (one MAC-symbol/PHY-symbol, or the extended type as defined in 14.11) from the transmitted pseudo-silence pattern.

In a dual-cable system, the forward channel is carried by the forward-direction cable, the reverse channel by the reverse-direction cable, and the reverse channel frequency does not need to be less than the forward channel frequency. In other respects, dual-cable operation is similar to single-cable operation.

**14.6.1.3 Jabber-Inhibit Function.** To protect the LAN from most faults in a station, each station other than the remodulator contains a jabber-inhibit function. This function serves as a "watchdog" on the transmitter; if the station does not turn off its transmitter after a prolonged time (roughly one-half second), then the transmitter output shall be disabled automatically for at least the remainder of the transmission.

**14.6.1.4 Local Administrative Functions (OPTIONAL).** These functions are activated either manually, or by way of the PLE's management interface, or both. They can include

- (1) Selecting the transmit and receive channels (frequencies and bandwidth).
- (2) Enabling or disabling each transmitter output. (A redundant media configuration would have two or more transmitter outputs.)
- (3) Adjusting the transmitted power level of each transmitter output.
- (4) Selecting the received signal source: any medium (if redundant media are present), or any available loopback point.

NOTE: If a loopback point is selected, then all transmitter output to the medium shall be inhibited.

- (5) Reporting the level of the received RF signal.
- (6) Selecting the signaling type (one MAC-symbol/PHY-symbol or the extended type defined in 14.11) at the remodulator.

**14.6.2 Basic Functions and Options.** Symbol transmission and reception functions and jabber-inhibit functions are required in all implementations. Within the symbol transmission and reception functions, three-symbol signaling (one MAC-symbol/PHY-symbol) capability is mandatory. All other functions are optional.

**14.7 Application of Management.** The following constraints are imposed on the parameters and actions specified in Section 9:

- (1) In the capabilities group the dataRates parameter sequence shall specify one or more of the values 1, 5, and 10.
- (2) In the relativePowerLevel type, the values *tooLow* and *tooHigh* shall be used to indicate signal levels outside the appropriate range as specified in Table 14-1, whereas the values *low* and *high* shall be used to indicate signal levels within that range but deviating by more than 1 dB from a value 7 dB less than the maximum level specified in Table 14-6. The accuracy of this assessment need be no greater than  $\pm 2$  dB.
- (3) In the local management information, the value of minPostSilencePreambleLength shall be 4.

**14.8 Functional, Electrical, and Mechanical Specifications.** Unless otherwise stated, all voltage and power level specifications are in rms and dBmV, respectively, based on transmissions of random data patterns (dBmV is defined as dB (1 mV, 75  $\Omega$ ) rms in 14.1). Measurements for voltage levels and power ratios may be made using a data pattern of unscrambled ones, with a correction factor of +3 dB over equivalent measurements using random data.

**14.8.1 Data Signaling Rates.** The standard data signaling rates are 1 Mb/s, 5 Mb/s, and 10 Mb/s. The permitted tolerance for each signaling rate is  $\pm 0.005\%$ . The exact rate in any given LAN shall be determined by that network's remodulator.

**14.8.2 Symbol Encoding.** The PLE transmits symbols presented to it at its MAC interface by the MAC sublayer entity. The possible MAC-symbols are *zero*, *one*, *non\_data*, *pad\_idle*, and *silence*. Each of these MAC-symbols is encoded into a different code of PHY-symbols {0} {2} {4} and then transmitted.

**Table 14-1**  
**Relative Power Level Reporting**

Channel Bandwidth (MHz)	tooLow	low	OK	high	tooHigh
1.5	<-13	-13 to -4	-4 to -2	-2 to 4	>4
6.0	<-7	-7 to 2	2 to 4	4 to 10	>10
12.0	<-4	-4 to 5	5 to 7	7 to 13	>13

NOTE: All values in dBmV.

**14.8.2.1 Three-Symbol Encoder.** The encoding action to be taken for each of the input MAC-symbols when three-symbol (one MAC-symbol/PHY-symbol) encoding is employed is

(1) **Silence**—

- (a) The remodulator shall encode successive *silence* symbols as successive PHY-symbols of the repeating sequence {2} {2} {0} {4}, always restarting with the first {2} of the sequence for each new period of transmitted pseudo-silence. (It is permissible to terminate the sequence after any PHY-symbol.)
- (b) All stations other than the remodulator shall encode the first MAC-symbol of *silence* after non-*silence*, and the last MAC-symbol of *silence* before non-*silence*, as the PHY-symbol {2}. Such stations shall encode all other MAC-symbols of *silence* as the PHY-symbol {0} and shall cease transmission while transmitting only such {0} symbols representing *silence*.

- (2) **Pad\_idle**—Consecutive *pad\_idle* symbols shall be encoded as successive PHY-symbols of the repeating sequence {4}{0}, always restarting the sequence with the {4} for each new period of *pad\_idle*. When sending *pad\_idle* MAC-symbols immediately after sending *silence* MAC-symbols, the MAC sublayer entity shall send at least as many octets of *pad\_idle* MAC-symbols as are required to result in a minimum of 32 PHY-symbols.

NOTE: For this basic signaling, this minimum is four octets of *pad\_idle* MAC-symbols.

- (3) **Non\_data**—The scrambler described in 14.8.2.3 shall be reinitialized (preset to all ones) at each *non\_data* symbol. Each *non\_data* symbol shall be encoded as a {2}, and the eight-symbol (frame delimiter) sequence of 8.2.1 shall be encoded as follows: each

*non\_data non\_data data<sub>1</sub> non\_data non\_data data<sub>2</sub> data<sub>3</sub> data<sub>4</sub>*

sequence shall be encoded as the sequence

{2} {2} {*d*<sub>1</sub>} {2} {2} {*d*<sub>2</sub>} {*d*<sub>3</sub>} {*d*<sub>4</sub>},

where each *data<sub>i</sub>* is either a *zero* or a *one*, and each *d<sub>i</sub>* is the corresponding encoding of the *data<sub>i</sub>*, either a {0} or a {4} as described below.

After each such eight-symbol (frame delimiter) sequence, as defined in 8.2.1, the encoder shall start to maintain a sense of PHY-octet alignment, with the next output PHY-symbol considered to be the first of a new PHY-octet.

NOTE: This PLE sense of PHY-octet alignment is identical to the MAC entity's sense of MAC-octet alignment.

- (4) **Zero and one**—Each *zero* and *one* symbol shall be encoded as follows:

- (a) The MAC-symbol shall be applied as input to the scrambler described in 14.8.2.3, resulting in a “scrambled” *zero* or *one* MAC-symbol;
- (b) The scrambled MAC-symbol shall be converted to one of the PHY-symbol output codes as follows:

zero  $\rightarrow \{0\}$

one  $\rightarrow \{4\}$

This is the  $data_i$  to  $\{d_i\}$  mapping referred to in 14.8.2.1(3).

- (c) The following procedure shall be performed on each resultant PHY-octet of  $\{0\}$  and  $\{4\}$  PHY-symbol codes. Each such octet of these PHY-symbol codes shall be compared with the immediately prior octet of PHY-symbols as *transmitted* (that is, after execution of this procedure on that prior octet, if applicable). If both PHY-octets consist solely of the identical PHY-symbol code (that is, either sixteen  $\{0\}$ s or sixteen  $\{4\}$ s), then the last three codes in the PHY-octet under examination shall be altered before transmission as follows:

$\{0\} \{0\} \{0\}$  shall be replaced by  $\{4\} \{2\} \{2\}$

$\{4\} \{4\} \{4\}$  shall be replaced by  $\{0\} \{2\} \{2\}$

NOTES: (1) This procedure can alter at most every other octet of PHY-symbols, and the second octet after the encoded (frame delimiter) sequence of 8.2.1 is the first such octet that can be altered. This procedure has no effect on the scrambler described in 14.8.2.3 and in the previous subsection.

(2) The constraints on the occurrence of *non\_data* and *pad\_idle* MAC-symbols imposed by 8.2.1 and 8.2.2, and the resulting constraints on the occurrence of  $\{2\}$  PHY-symbols imposed by 14.8.2.1, may be used in post-detection processing to decrease the error rate of the receiving PLE's PHY-symbol to MAC-symbol decoding process.

**14.8.2.2 Pseudo-Silence Provision for the Enhanced Encoder.** One additional pseudo-silence sequence (other than that of 14.8.2.1) has been reserved for a two MAC-symbol/PHY-symbol enhancement to the basic signaling method. The enhancement itself is described in 14.11, and is for further study.

The pseudo-silence sequence of 14.8.2.1 is

$\{2\} \{2\} \{0\} \{4\}$ —one MAC-symbol/PHY-symbol three-symbol signaling.

The reserved pseudo-silence sequence is

$\{2\} \{2\} \{4\} \{0\}$ —two MAC-symbol/PHY-symbol three-symbol quadrature signaling.

**14.8.2.3 Data Scrambler.** In order to reduce the probability of long transmitted sequences of identical PHY-symbol codes and to randomize spectral components of the transmitted modulation, the symbolic binary data transmitted as *zero* and *one* MAC-symbols for the MAC entity shall be pseudo-randomized by dividing the equivalent message polynomial by the generating polynomial  $1+X^{-6}+X^{-7}$ . The coefficients of the quotient of this division are taken in descending order as the MAC-symbol sequence to be coded in 14.8.2.1 (4). The logical arrangement of such a scrambler and corresponding descrambler is described in 14.12.

As specified in 14.8.2.1, this scrambler (or the corresponding descrambler) is reinitialized at each *non\_data* symbol requested by (or indicated to, respectively) the associated MAC entity. After reinitialization, which is presetting to all *ones*, the scrambler polynomial guarantees that the next six MAC-symbols output will be unaffected by the scrambling process. Thus, the *zeros* and *ones* within the frame delimiter octets of 8.2.1 are unaffected by the scrambling process, even though, in a technical sense, they have been scrambled.

The alteration in the transmitted PHY-symbol codes described in the last paragraphs of 14.8.2.1 has no effect on this scrambler or the corresponding descrambler, as the alteration is made subsequent to scrambling and is reversed prior to descrambling.

NOTE: The scrambler function shall only be applied to data (*one* and *zero*) symbols. *Pad\_idle*, *silence*, and *non\_data* symbols shall not be scrambled.

**14.8.3 Baseband Modulation.** The PHY-symbol coded signal shall be converted to an appropriately shaped pulse whose phase and amplitude are chosen from the set of pulses of phase and relative amplitude  $-2$ ,  $0$ , and  $+2$  as determined by the output PHY-symbol code and by the phase and amplitude of the immediately prior one or two pulses, as specified by Table 14-2.

The equivalent baseband signal shaping function shall be based upon the partial response pulse often referred to as duobinary or Class I partial response, of which time and spectral functions are defined by Eq 14-1, Eq 14-2, and Eq 14-3.

This shaping process shall be effected in such a way that the decoding can be achieved by full wave rectification of the demodulated line signal (that is, without recovery or reconstruction of the phase of the transmitted equivalent baseband signal).

NOTE: The pulse-coding rules of Table 14-2, when combined with the above duobinary signal-shaping function, give rise to a combined signal whose amplitude, when sampled at the correct intervals, corresponds directly to the coded PHY-symbol as follows (where MAX is the maximum such amplitude):

- {0}  $\rightarrow$  0/4 of MAX (= 0)
- {2}  $\rightarrow$  2/4 of MAX (= MAX/2)
- {4}  $\rightarrow$  4/4 of MAX (= MAX)

**Table 14-2**  
**Baseband Pulse Coding Rules**

2nd Prior Pulse	Prior Pulse	Desired PHY-Symbol	Required Pulse	MAC-Symbol Usage (post-scrambler)
—	+2	{0}	-2	<i>zero</i> or
—	-2	{0}	+2	second <i>pad_idle</i> (of pair)
—	0	{0}	0	other <i>silence</i> or (transmitter off)
—	+2	{2}	0	first <i>non_data</i> (of pair)
—	-2	{2}	0	or first <i>silence</i>
+2	0	{2}	+2	second <i>non_data</i>
-2	0	{2}	-2	(of pair)
—	0	{2}	+2	last <i>silence</i>
—	0	{2}	-2	
—	+2	{4}	+2	<i>one</i> or first
—	-2	{4}	-2	<i>pad_idle</i> (of pair)

$$g(t) = \frac{4}{\pi} \cdot \frac{\cos\left(\pi \frac{t}{T}\right)}{1 - \left(2 \frac{t}{T}\right)^2} \quad (\text{Eq 14-1})$$

$$\left| G(f) \right| = \begin{cases} 2T \cos(\pi f T), & |f| \leq \frac{1}{2T} \\ 0, & |f| > \frac{1}{2T} \end{cases} \quad (\text{Eq 14-2})$$

$$\left| G(f) \right| = \begin{cases} -\pi f T, & |f| \leq \frac{1}{2T} \\ 0, & |f| > \frac{1}{2T} \end{cases} \quad (\text{Eq 14-3})$$

respectively, where

$f$  = denotes the frequency (Hz)

$\frac{1}{T}$  = denotes the PHY-symbol signaling rate (symbols/second)

The reference to equivalent baseband signals recognizes that the Physical Layer implementation may be such that the MAC-symbols encoded as in 14.8.2 are converted to and from the line signals without appearing as actual baseband signals.

#### 14.8.4 Recommended Frequency Allocation/Channel Spacing

- (1) This standard recommends a communication medium configuration that is known in the CATV industry as a single-cable, mid-split configuration. In this configuration, the unidirectional forward and reverse channels are paired to provide bidirectional channels. This standard recommends a frequency offset of 192.25 MHz between paired forward and reverse channels in both mid-split and high-split configurations. Other configurations, including dual-cable where forward and reverse channels are on separate unidirectional cables, also are permitted.
- (2) The relationship between data signaling rate and minimum channel bandwidth is

A data rate of 1 Mb/s requires 1.5 MHz of channel bandwidth. A data rate of 5 Mb/s requires 6 MHz of channel bandwidth. A data rate of 10 Mb/s requires 12 MHz of channel bandwidth. Higher data rates for a given channel bandwidth are for future study.

NOTE: The remainder of 14.8.4 is not part of this International Standard. Frequency allocations are a subject for national standardization.

- (3) Table 14-3 shows the preferred pairing for the usual North American 6 MHz channels. The conventional North American CATV nomenclature has been used for the channel names.



The 1.5 MHz channels are formed by equally subdividing any given 6 MHz channel. The 12 MHz channels are composed of adjacent 6 MHz channels, paired as indicated by the lines in the center column of Table 14-3.

The preferred channel assignments for dual-frequency, mid-split and high-split North American system configurations are

- (a) For a 10 Mb/s data rate, a 12 MHz channel pair should be used, with reverse channels 3' and 4' paired with forward channels P and Q.
- (b) For a 5 Mb/s data rate, a 6 MHz channel pair should be used, with reverse channel 3' paired with forward channel P, or reverse channel 4' paired with forward channel Q.
- (c) For a 1 Mb/s data rate, a 1.5 MHz channel pair should be used, chosen from one of the eight equally spaced 1.5 MHz subchannels of reverse channels 3' and 4', paired with corresponding forward channels P and Q.

For dual-cable, single-frequency systems, either the forward channel frequencies or the reverse channel frequencies specified can be used on both forward-direction and reverse-direction cables.

Where multiple channel assignments are needed for multiple LANs on a single shared broadband medium, it is suggested that they be assigned different channel pairs in accordance with these recommendations.

**Table 14-3**  
**Usual North American Mid-split Channels—**  
**Nomenclature and Pairing**

Reverse Channel	Frequency* (MHz)		Forward Channel	Frequency* (MHz)
T10	23.75		J	216
T11	29.75		K	222
T12	35.75		L	228
T13	41.75		M	234
T14	47.75		N	240
2'	53.75		O	246
3'	59.75	†	P	252
4'	65.75	†	Q	258
4A'	71.75	†	R	264
5'	77.75	†	S	270
6'	83.75	†	T	276
FM1'	89.75	†	U	282
FM2'	95.75		U	282
FM3'	101.75		W	294

\* The frequency specified is that of the lower band-edge.

' The primed reverse-direction channels are offset from the conventional forward-direction channels of the same (unprimed) name.

† These channel pairings are recommended for use with this standard.

**14.8.5 Line Signal in RF Band (at the line output of the station).** The equivalent baseband modulation of 14.8.3 shall be applied to an RF carrier centered in the assigned channel (for example, 3 MHz from each channel edge of a 6 MHz channel), and the resultant modulated carrier shall be coupled to the broadband bus medium as specified in 14.8.7.

**14.8.5.1** In the appropriate 1.5 MHz wide, 6 MHz wide, or 12 MHz wide RF channel, the line signal shall correspond to a double-sideband signal with its carrier frequency at the channel mid-point frequency  $\pm 0.01\%$ .

**14.8.5.2** The relationship between the multilevel signals at the real or hypothetical output of the multisymbol signal coder and the transmitted line signal shall be such that the amplitude of the modulated signal at the proper sampling intervals is directly proportional to the numeric symbol of the coded signal.

In a practical case this means that the voltage that results from the full wave rectification of the demodulated line signal corresponds at the proper sampling intervals with the numeric value of the coded signal symbol, with the maximum amplitude corresponding to a coded {4}, a zero amplitude corresponding to a coded {0}, and intermediate amplitudes corresponding proportionately.

**14.8.5.3** The amplitude of the theoretical line signal pulse spectrum, corresponding to an isolated maximum-amplitude pulse appearing at the output of the multisymbol signal coder, is to be cosine-shaped in the frequency domain, as indicated in Eq 14-2, with maxima at the carrier frequency and zeros at  $\pm 0.5$  MHz,  $\pm 2.5$  MHz, or  $\pm 5.0$  MHz from that carrier frequency for 1.5 MHz, 6 MHz, and 12 MHz channel bandwidths, respectively.

**14.8.5.4** The output level of the transmitted signal into a 75  $\Omega$  resistive load shall be set at the value specified in Table 14-4. Once set, the permissible power variance from this level due to all factors shall be at most  $\pm 2$  dB. The maximum variance of the transmitter amplitude for any coded symbol, measured over one transmission, shall be at most 0.5 dB. Embodiments with adjustable transmitter output power shall be able to provide these power and stability figures within the range of such adjustment.

**14.8.5.5** In the 1 MHz, 5 MHz, or 10 MHz signaling band centered at the actual RF carrier frequency, the amplitude distortion of the real spectrum relative to the theoretic spectrum as defined under 14.8.3 shall fall within the limits specified by Table 14-5 and Fig 14-3, and the group-delay distortion relative to

**Table 14-4**  
**Required Transmit Level**

Channel Bandwidth (MHz)	Required Transmit Level (dBmV)
1.5	+41
6.0	+47
12.0	+50

**Table 14-5**  
**Breakpoints of Amplitude Distortion Limits**

Distance from Band Center (% of HBW)	Permissible Distortion from Theoretic Spectrum (in frequency domain (dB))
± 20%	±0.5
± 50%	±1.0
± 80%	±2.0
± 90%	±3.0
±100%	(at least 20 dB attenuation)

where

HBW = 1/2 signaling bandwidth, that is, 0.5, 2.5, or 5 MHz

$$\text{PGD} = \pm 90 \log_{10} \cos(\pi f T), f \leq \frac{1}{2T} \quad (\text{Eq 14-4})$$

where

PGD denotes the permissible group delay distortion relative to the center of the signaling band, measured as a percent of  $T$

$f$  denotes the frequency (Hz)

$1/T$  denotes the PHY-symbol signaling rate (symbols/second)

$$\text{RA} = \min \left( 55, 30 + 10 \log_{10} B + 80 \frac{\text{MF} \cdot \text{NCEF}}{B} \right) \quad (\text{Eq 14-5})$$

where

RA is the attenuation relative to total transmitted power in dB measured in any 30 kHz band

$B$  is the channel bandwidth (MHz)

MF is the measurement frequency (MHz)

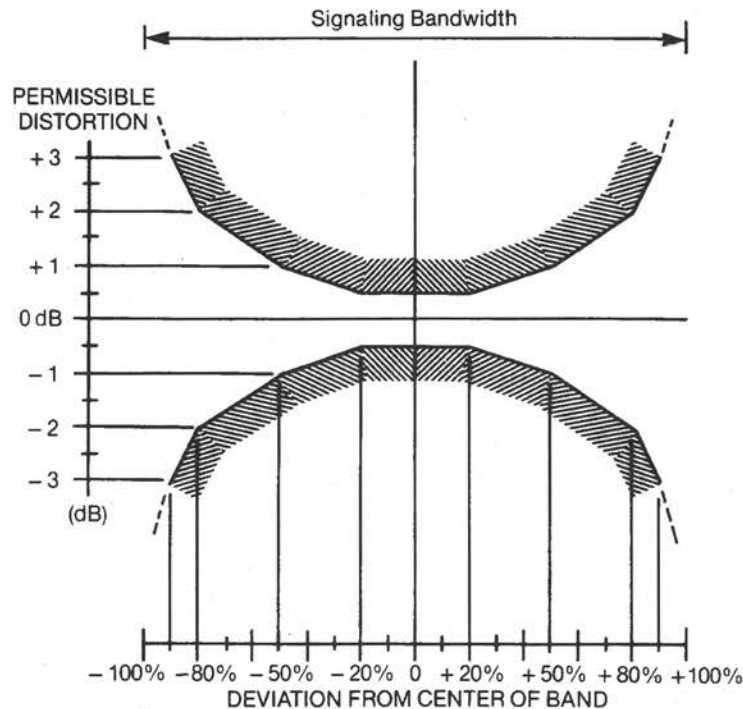
NCEF is the frequency (MHz) of the nearest edge of the channel

the center of the band shall fall within the limits specified by Eq 14-4. At the signaling band edges, where the theoretic spectrum has zeros (infinite attenuation), the actual signal amplitude shall be attenuated at least 20 dB with respect to the signal amplitude at the center of the band.

**14.8.5.6** The transmitted power outside the channel bandwidth shall meet or exceed the attenuation specified in Fig 14-4 and Eq 14-5 relative to total transmitted power independent of the data transmitted.

**14.8.5.7** When a transmitter ceases generating and sending the equivalent baseband pulses described in 14.8.3, either through receiving the MAC-symbol *silence*, or through a management command to cease transmitting, it shall take the following actions:

- (1) It shall send the PHY-symbol {2} as the first symbol of the "silent" period (see 14.8.3),
- (2) It shall continue to transmit the decaying energy of all previously generated equivalent baseband pulses until the power represented by the sum



**Fig 14-3**  
**Limits for Amplitude Distortion**

of these pulses, averaged over one symbol time, is less than a level 26 dB below the power level set by 14.8.5.4,

- (3) After this time, but before 10 symbol times have elapsed from the last transmitted pulse, the total transmitted power, in the transmit channel bandwidth, shall be less than a level 70 dB below the set power level.

When a transmitter begins sending PHY-symbols requiring the generation of pulses, it shall take the following actions:

- (a) It shall remain at a total power output less than a level 70 dB below the set transmit power until not more than 10 symbol times before the first transmitted pulse,
- (b) It shall begin transmitting the energy contained in the pulses before the power represented by the sum of these pulses, averaged over one symbol time, has reached a level 26 dB below the set power level,
- (c) It shall send the PHY-symbol {2} as the last symbol of the "silent" period.

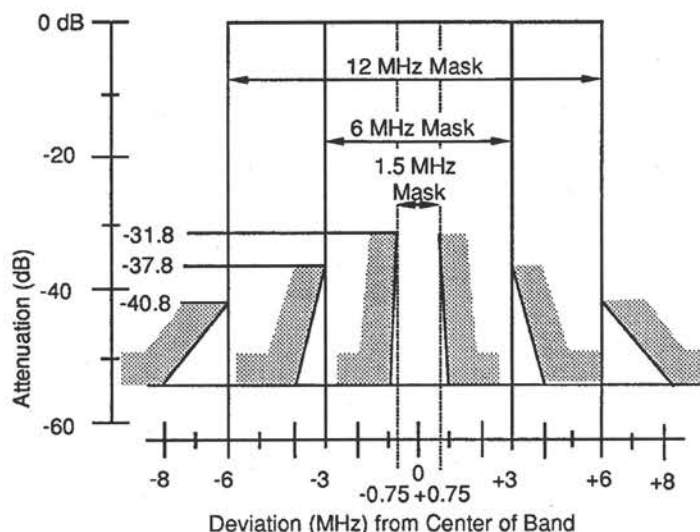


Fig 14-4  
Transmit Spectrum Mask

This does not apply to transmissions terminated through jabber-inhibit.

**14.8.5.8** When the transmitter is disabled or is transmitting only the MAC-symbol *silence*, the transmitted power in the transmit portion of the medium spectrum that is outside the channel bandwidth shall not exceed -25 dBmV measured in any 30 kHz band. When the transmitter is disabled or is transmitting only the MAC-symbol *silence*, the transmitted power in the receive portion of the medium spectrum that is outside the channel bandwidth shall not exceed -10 dBmV measured in any 30 kHz band.

**14.8.5.9** Where separate input and output physical couplings to the medium exist (for example, in dual-cable systems), the leakage output into the input coupling

- (1) During transmitter-off periods shall be the same as that specified for the output coupling in 14.8.5.7.
- (2) During transmitter-on periods shall be the same as the maximum out-of-band attenuation specified for the output coupling in 14.8.5.6.

**14.8.5.10** The residual power level of the suppressed carrier at the transmitter output shall be at least 32 dB below the total transmitted power.

**14.8.6 Jabber-Inhibit.** Each PLE other than a remodulator (which transmits continuously) shall have a self-interrupt capability to inhibit modulation from reaching the LAN medium. Hardware within the PLE (with no external message other than the prolonged detection of an output-on condition within the trans-

mitter) shall provide a nominal window of one-half second  $\pm 25\%$  during which time a normal data link transmission may occur. If a transmission is in excess of this duration, the jabber-inhibit function shall operate to inhibit any further output from reaching the medium. Reset of this jabber-inhibit function is implementation-dependent.

**14.8.7 Coupling to the Medium.** The PLE functions are intended to operate satisfactorily over 75  $\Omega$  CATV-like bidirectional broadband cable installations employing mid-split, sub-split, or high-split line amplifiers and filters, or dual unidirectional cables employing (no-split) line amplifiers.

Both the transmitter and the receiver shall be ac-coupled to the center conductor of the 75  $\Omega$  broadband medium, and the breakdown voltage of that ac coupling means shall be at least 500 V ac rms at 50/60 Hz. In addition to this coupling, the shield of the coaxial cable medium shall be connected to chassis ground, and the impedance of that connection shall be less than 0.1  $\Omega$ .

The mechanical coupling of the station to the medium shall be to a drop cable by way of a female F-series connector on the station, as specified in Section 15. The maximum voltage standing wave ratio (VSWR) at that F-connector shall be 1.5:1 or less when that F-connector is terminated with a 75  $\Omega$  resistive load, as measured over the transmit and receive channel bandwidth when power is applied to the station. This is only applicable to the transmit channel when the station is transmitting.

**14.8.8 Alternate Broadband Media (OPTIONAL).** Sections 14 and 15 specify the standard (preferred) broadband medium configuration as a single trunk cable and single drop cable, bidirectional by frequency, mid-split CATV-like configuration with channel pairings as indicated in 14.8.4. Other configurations are possible that meet the intent of this standard, including alternate channel pairings, sub-split, high-split, or dual-cable media, and redundant media.

Any channel pairing or range of channel pairings compatible with any of mid-split, sub-split, or high-split single-cable operation, or with dual-cable operation, or both, is permissible, provided that the pairing(s) is (are) clearly labeled both on the embodiment and in accompanying literature.

Embodiments of this standard that can be configured to function with either single-cable or dual-cable systems, or with redundant media, or both, are not precluded, provided that the embodiment *as delivered* functions correctly in a minimal (that is, nonredundant, single-cable, or both) environment.

**14.8.9 Receiver Sensitivity and Selectivity.** The PLE shall be capable of providing an undetected bit error rate of  $10^{-9}$  or lower, and a detected bit error rate of  $10^{-8}$  or lower, while

- (1) Receiving in-band signals in the range specified by Table 14-6, transmitted by a PLE conforming to the requirements of Section 14, and
- (2) The in-band signal-to-noise ratio of the medium is 30 dB (V rms/(V rms)) or greater, as measured at the F-connector, and
- (3) The adjacent channels on both sides of the in-band signal contain signals conforming to Section 14 of this standard and whose levels are 14 dB greater than the in-band signal, yet not exceeding +4 dB above the maximum received signal power specified in Table 14-6.

**14.8.10 Minimum Length of Preamble.** The *pad\_idle* sequence is used by PLEs to accurately access the received signal levels. In the remodulator, this initial assessment shall be completed at least four PHY-symbols before the end of this *pad\_idle* sequence (see 8.2.2.5). The minimum length of that *pad\_idle* sequence is a function of both the data rate and whether that *pad\_idle* sequence follows *silence* or other non-*silence* symbols. Table 14-7 expresses that relationship in both microseconds and signaled MAC-symbols for three-symbol (one MAC-symbol/PHY-symbol) signaling.

**Table 14-6**  
**Required Noise Floor and In-band Signal Power**

Channel Bandwidth (MHz)	Max In-band Noise Floor (for remodulators only) (dBmV)	Received Signal Power (dBmV)	
		Min	Max
1.5	-40	-13	+ 4
6.0	-34	- 7	+10
12.0	-31	- 4	+13

NOTES: (1) Specifications of signal power, both out-of-band and in-band due to adjacent channels, are for future study. It is anticipated that the specification format will be to include an unweighted signal power over the total bandwidth (5–450 MHz), and a weighted signal power over the same bandwidth. The specification of unweighted power is to constrain the maximum power presented to a receiver. The specification of weighted power is to constrain the noise power contribution by all other signal sources as presented to a receiver's demodulator.

(2) When measuring bit error rate, multiple errors in a frame may be counted as a single error.

**Table 14-7**  
**Minimum Length of *Pad\_idle* Preamble**

Data Rate (Mb/s)	At Start of Transmission		Between Frames	
	Minimum # of MAC- Symbols	Minimum Time ( $\mu$ s)	Minimum # of MAC- Symbols	Minimum Time ( $\mu$ s)
1	32	32.0	8	8.0
5	32	6.4	16	3.2
10	32	3.2	24	2.4



**14.8.11 Symbol Timing.** Each PLE whose receiver is connected to the forward channel shall recover the PHY-symbol timing information contained within the received signaling, and shall use this recovered timing information to determine the precise rate of symbol transmission. The instantaneous transmit and receive data rates of each such entity shall be identical, with exactly one MAC-symbol (possibly *silence*) transmitted for each MAC-symbol received. (This relationship usually is termed *loopback timing*.) There shall be an implementation-dependent constant-phase relationship between the transmitted PHY-symbol timing and the received PHY-symbol timing. The jitter of the transmitted PHY-symbol timing relative to the PHY-symbol timing within the received signaling shall not exceed a total excursion of 5% of the period of one PHY-symbol.

The remodulator shall originate its own transmit symbol timing. The jitter of the transmitted symbol timing shall not exceed 0.1% of the period of one PHY-symbol. The remodulator may use the known loopback timing arrangement of the other stations in the LAN (as specified in the preceding paragraph) in determining the PHY-symbol timing of any received signaling. In a practical case this means that the remodulator may determine the phase difference between its transmitted and received PHY-symbol timings upon first receipt of a transmission, and then use its self-generated transmit timing plus that measured phase delay to infer the PHY-symbol timing of the received signaling.

**14.8.12 Signaling Type Determination.** The remodulator shall determine the type of signaling (one MAC-symbol/PHY-symbol, or the extended type as defined in 14.11) to be employed in the LAN before commencing transmission in the forward channel and shall convey that determination to all connected stations by means of the pseudo-silence signaling sequence used in lieu of "transmitted" silence as specified in 14.8.2.1 and 14.8.2.2. The remodulator may change this determination at any time, either due to manually invoked command, or through a management interface, or both; when so doing it shall cease all transmissions for a minimum period of 5 ms before making such a redetermination. (As a practical case, this may be used to fallback from extended signaling to one MAC-symbol/PHY-symbol signaling in an extended-capability system that is experiencing unusually high noise, as inferred from error rates.)

**14.8.13 Symbol Decoding.** After demodulation and determination of each received signaled PHY-symbol, that PHY-symbol shall be decoded to a corresponding MAC-symbol by the process inverse to that described in 14.8.2, and the decoded MAC-symbols shall be reported at the MAC interface at a data rate determined jointly by the provisions of 14.8.11 and 14.8.12.

All PLEs except the remodulator shall decode the pseudo-silence sequence as an appropriate number of *silence* MAC-symbols and shall report them at the MAC-PHY interface. True silence on the forward channel (an abnormal condition) shall be decoded as an appropriate number of *bad\_signal* MAC-symbols and shall be reported as such at the MAC-PHY interface.

Whenever a signaled PHY-symbol sequence is received for which the encoding process has no inverse, those PHY-symbols shall be decoded as an appropriate number of *bad\_signal* MAC-symbols and reported as such at the MAC interface.

In such cases, the receiving entity shall resynchronize the decoding process as rapidly as possible.

NOTE: Receivers are permitted to decode each transmitted *pad\_idle* MAC-symbol, which was encoded as a {0} or a {4} PHY-symbol, as a *zero* or a *one* MAC-symbol.

**14.8.14 Transmitter Enable/Disable and Received Signal Source Selection.** The ability to enable and disable the transmission of modulation onto the broadband medium as directed by the management entity is mandatory in remodulators, where signaled *silence* does not turn off the transmitter, and recommended but optional in all other equipment.

The ability to select the source of received signaling, either a loopback point within the PLE or one of the possibly redundant media, as directed by the management entity, is recommended but optional. When such an option is invoked and the selected source is not one of the media, transmission to all connected media shall be disabled automatically while such selection is in force.

**14.8.15 Transmit and Receive Channel Selection (OPTIONAL).** The determination of a PLE's transmit and receive channels, either channel center frequencies or channel bandwidth or both, may be alterable. In such cases the alteration may be accomplished either manually, or upon command through the PLE's management interface, or both. All transmissions to the medium shall be inhibited while such changes are being effected, and any signaling received during such a period of change shall be discarded and not reported to the MAC interface.

**14.8.16 Redundant Media Considerations.** As implied by 14.8.8, redundant broadband media are not precluded from this standard. Where redundant media are employed, the provisions of 14.8.5.4, 14.8.6, and 14.8.14 shall apply separately and independently to each single medium interface, and much of 14.8.14 shall be mandatory. Specifically, the transmitted signal level adjustment of 14.8.5.4 shall be made separately and independently for each connected medium, separate jabber-inhibit monitoring shall exist for each medium (although common inhibition is permissible).

**14.8.17 Reliability.** The PLE shall be designed so that its probability of causing a communication failure among other stations connected to the medium is less than  $10^{-6}$  per hour of continuous (or discontinuous) operation. For remodulators this requirement is relaxed to a probability of  $2 \times 10^{-5}$  per hour of operation. Connectors and other passive components comprising the means of connecting the station to the coaxial cable medium shall be designed to minimize the probability of total network failure.

**14.8.18 Remodulator Considerations.** A remodulator can be considered to be a specialized form of regenerative repeater, which either repeats signaling from the reverse channel on the forward channel or originates signaling of its own on the forward channel. In either case, the remodulator originates the symbol timing provided to its local MAC entity and to all the other stations on the LAN.

The basic mode of operation, originating or repeating, shall be determined by the remodulator's associated MAC entity and conveyed by the PHY-MODE

invoke primitive (see 8.2.3). When originating, the remodulator's PLE shall use internal loopback as the source of the PHY-symbols which it reports to its associated MAC entity by way of the PHY-UNITDATA indicate primitive.

When repeating, the remodulator shall decode the signaling received on the reverse channel and indicate the decoded MAC-symbols to its associated MAC entity.

In summary, when the MAC entity is originating, internal loopback is used as the source of PHY-symbols which are reported by way of the PHY-UNITDATA indicate primitive. When the MAC entity is repeating, the received signaling from the reverse channel is decoded and reported by way of the PHY-UNITDATA indicate primitive.

In either case, the following apply:

- (1) The remodulator determines its own MAC-symbol timing and the exact PHY-symbol signaling rate for itself and for all other stations on the local network (see 14.8.1 and 14.8.11.).
- (2) The remodulator determines the signaling type (one MAC-symbol/PHY-symbol, or the extended type as defined in 14.11) for the entire network, and may optionally change that signaling type after disabling its transmitter(s) for a period of at least 5 ms (see 14.8.12).
- (3) The remodulator transmits a specific repeating sequence (pseudo-silence) during periods when its MAC entity requests the repeated transmission of the MAC-symbol *silence* (see 14.8.2 and 14.8.12). This pseudo-silence sequence is used
  - (a) To provide a continuous signal for the AGC and carrier and data recovery circuitry of the LAN's other stations.
  - (b) To indicate the signaling type (one MAC-symbol/PHY-symbol, or the extended type as defined in 14.11) currently in use on the LAN (see 14.8.2.2).
- (4) The remodulator can use the known exact signaling rate of the other stations (that is, its own exact signaling rate as retransmitted by those other stations, see 14.8.11) to minimize the time required to train on a new transmission and be able to report the received signaling at the specified bit error rates (see 14.8.9).

NOTE: Designers are cautioned that the remodulator shall be designed to achieve these bit error rates at least four MAC-symbol\_times (see 8.2.2) before the end of reception of a minimum-length preamble (see 14.8.10) when the transmission originates from a station whose transmitter output, as measurable at the station's F-connector, falls within the bounds of Table 14-6.

- (5) The receive levels may be exceeded during periods when the distributed token bus protocol has more than one station transmitting. A remodulator should be designed to tolerate at least a 30 dB increase in the received signal level over the maximum specified in Table 14-6 minus the path loss (see 15.5.3). Furthermore, the remodulator shall report the presence of received signaling, perhaps as *bad\_signal*, and shall not report silence to the MAC sublayer during such periods of overload.

The same phenomenon may occur in any other channel that employs a distributed protocol with potential collisions. Thus, a remodulator should be designed to sharply reject signaling in other channels.

#### 14.9 Environmental Specifications

**14.9.1 Electromagnetic Emanation.** Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**14.9.2 Safety Requirements.** All stations meeting this standard shall comply with relevant local, national, and international safety codes and standards, such as IEC Publication 950 (1986) [7].

**14.9.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The PLE embodiment shall meet its specifications when operating in an ambient continuous wave plane wave field of

- (1) 80 mV/m within the operational channel bandwidth.
- (2) 2 V/m for other frequencies from 10 kHz through 30 MHz.
- (3) 5 V/m for other frequencies from 30 MHz through 1 GHz outside the operational channel bandwidth.

**14.10 Labeling.** It is recommended that each embodiment (and supporting documentation) of a PLE conformant to this standard be labeled in a manner visible to the user with at least these parameters:

- (1) Data rate capabilities in Mb/s.
- (2) Types of signaling—one MAC-symbol/PHY-symbol only, or one MAC-symbol/PHY-symbol plus the extended type, as described in 14.11.
- (3) Transmit and receive channel assignments, both frequency and bandwidth.
- (4) Worst-case, one-way repeater delay (for remodulators) or round-trip delay (for other stations) which this equipment induces on a two-way transmission exchange between stations, as specified in 6.1.9.
- (5) Operating modes and selection capabilities as defined in 14.8.14 through 14.8.16.

Additionally, when the station has multiple F-connectors (for example, for dual cables, redundant media, or both), the role of each F-connector shall be designated clearly by markings on the station in the vicinity of that F-connector.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

### 14.11 Appendix—Provisions for Two MAC-Symbol/PHY-Symbol Signaling.

This Appendix gives preliminary considerations for a method of enhancing the basic three-symbol multilevel duobinary AM/PSK signaling to double the data rate within the same signaling bandwidth. The method transmits two three-symbol channels in quadrature (that is, on carriers that are in phase-quadrature to each other) at a theoretic signal-to-noise ratio (S/N) penalty of about 5 dB, but with a requirement for coherent or quasi-coherent detection within receivers.

Standardization of this method is for further study; other methods may be considered as well.

In systems where the remodulators and other stations support this extended signaling method (in addition to the required one MAC-symbol/PHY-symbol method of 14.8.2.1 and 14.8.3), additional requirements for interoperability may be needed. The following requirements, each for further study, are proposed:

- (1) Each PLE (including a remodulator) conforming to the provisions of 14.11 should be able to fall back to half-speed under the provisions of 14.8.2.1 and 14.8.3. Such fallback should be under management control.
- (2) Each PLE (other than a remodulator) capable of signaling by the extended method of 14.11 should be able to recognize and differentiate between the pseudo-silence sequences (see 14.8.2) of its supported signaling methods.
- (3) When the signaling method of the network, as determined by the active remodulator, is of a type supported by the PLE, then that entity should infer the type of signaling then being employed in the LAN from the pseudo-silence signaling sequence used in lieu of “transmitted” silence in the forward channel, as specified in 14.8.1 and 14.8.2. This determination should be remade after any period in which continuous silence (lack of modulation) has been detected in the forward channel for at least 2 ms, or after any loopback mode has been deselected and the broadband medium reselected as the source of received symbols (as described in 14.8.14).

If the inferred network signaling type differs from the current signaling type of the PLE, then that entity should report the new signaling type to management (see 9.2.7) and should inhibit transmission while those types differ.

**14.11.1 Symbol Encoding.** For the enhanced encoding, two separate base-band signals are formed and independently modulated onto in-phase and quadrature carriers for transmission. These are referred to in the following discussion as the in-phase and quadrature subchannels, respectively. Successively encoded MAC-symbols are transmitted alternately in the in-phase and quadrature subchannels.

The encoding action to be taken for each of the input MAC-symbols when three-symbol quadrature (two MAC-symbol/PHY-symbol) encoding is employed is as follows:

(1) **Silence**—

- (a) The remodulator shall encode successive *silence* symbols as successive PHY-symbols of the repeating sequence {2} {0} {2} {0} {4} {0} {0} {0}, always restarting with the first {2} of the sequence for each new period of transmitted pseudo-silence. (Thus, the in-phase subchannel transmission sequence is {2} {2} {4} {0}, and the quadrature subchannel transmission sequence is {0} {0} {0} {0}. Also, it is permissible to terminate the sequence after any even number of PHY-symbols.)
- (b) All stations other than the remodulator shall encode the first two MAC-symbols of *silence* after non-*silence*, and the last two MAC-symbols of *silence* before non-*silence* as the PHY-symbol {2}. Such stations shall encode all other MAC-symbols of *silence* as the PHY-symbol {0} and shall cease transmission while transmitting only such {0} symbols representing silence.

- (2) **Pad\_idle**—Consecutive *pad\_idle* symbols shall be encoded as successive PHY-symbols of the repeating sequence {4} {0} {0} {0}, always restarting the sequence with the {4} for each new period of *pad\_idle*, and always with the {4} transmitted in the in-phase subchannel. (Thus, the in-phase subchannel transmission sequence is {4} {0}, and the quadrature subchannel transmission sequence is {0} {0}.)

When sending *pad\_idle* MAC-symbols immediately after sending *silence* MAC-symbols, the MAC-sublayer entity shall send at least as many octets of *pad\_idle* MAC-symbols as are required to result in a minimum of 64 PHY-symbols.

NOTE: For this enhanced signaling, this minimum is eight octets of *pad\_idle* MAC-symbols (that is, 32 baud).

- (3) **Non\_data**—The scrambler described in 14.8.2.3 shall be reinitialized (preset to all ones) at each *non\_data* symbol. Each *non\_data* symbol shall be encoded as a {2}, and the eight-symbol (frame delimiter) sequence of 8.2.1 shall be encoded as follows: each

*non\_data non\_data data<sub>1</sub> non\_data non\_data data<sub>2</sub> data<sub>3</sub> data<sub>4</sub>*

sequence shall be encoded as the sequence

{2} {2} {2} {2} {*d*<sub>1</sub>} {*d*<sub>2</sub>} {*d*<sub>3</sub>} {*d*<sub>4</sub>} ,

where each *data<sub>i</sub>* is either a zero or a one and each *d<sub>i</sub>* is the corresponding encoding of the MAC-symbol *data<sub>i</sub>*, either a {0} or a {4} as described below, and always with the first {2} transmitted in the primary channel. (Thus, the in-phase subchannel transmission sequence is

{2} {2} {*d*<sub>1</sub>} {*d*<sub>3</sub>} ,

and the quadrature subchannel transmission sequence is

{2} {2} {*d*<sub>2</sub>} {*d*<sub>4</sub>} .)



After each such eight-symbol (frame delimiter) sequence, as defined in 8.2.1, the encoder shall start to maintain a sense of PHY-octet alignment, with the next output PHY-symbol considered to be the first of a new PHY-octet.

NOTES: (1) This PLE sense of PHY-octet alignment is identical to the MAC entity's sense of MAC-octet alignment.

(2) Since *non\_data* symbols occur only in frame delimiters (see 8.2.1), the PLE may infer that the MAC sublayer is outputting a frame delimiter sequence upon receipt of its first *non\_data* symbol.

- (4) **Zero and one**—Each *zero* and *one* symbol shall be encoded as follows:
- (a) The MAC-symbol shall be applied as input to the scrambler described in 14.8.2.3, resulting in a “scrambled” *zero* or *one* MAC-symbol;
  - (b) The scrambled MAC-symbol shall be converted to one of the PHY-symbol output codes as follows:

*zero* → {0}

*one* → {4}

This is the  $data_i$  to  $\{d_i\}$  mapping referred to in 14.11.1(3).

- (c) The following procedure shall be performed on each resultant PHY-octet of {0} and {4} PHY-symbol codes. Each such octet of these PHY-symbol codes shall be compared with the immediately prior octet of PHY-symbols *as transmitted* (that is, after execution of this procedure on that prior octet, if applicable). If the pair of PHY-octets is identical to a single ordered pair of PHY-symbol codes repeated eight times (that is,  $(\{0\} \{0\})^8$ ,  $(\{0\} \{4\})^8$ ,  $(\{4\} \{0\})^8$ , or  $(\{4\} \{4\})^8$ ), so that the in-phase and quadrature subchannel transmission sequences each consist of a single PHY-symbol code, possibly different in each subchannel, repeated eight times, then the last three codes in the PHY-octet under examination shall be altered as follows:

{0} {0} {0} shall be replaced by {2} {4} {2}

{0} {4} {0} shall be replaced by {2} {0} {2}

{0} {0} {4} shall be replaced by {2} {4} {2}

{4} {4} {4} shall be replaced by {2} {0} {2}

In other words, the last code of the in-phase subchannel transmission sequence is altered before transmission as follows:

{0} is replaced by {4}

{4} is replaced by {0}

and the last two codes of the quadrature subchannel transmission sequence are changed to {2} {2} before transmissions.

NOTE: This procedure can alter, at most, every other octet of PHY-symbols; and the second octet after the encoded (frame delimiter) sequence of 8.2.1 is the first such octet that can be altered. This procedure has no effect on the scrambler described in 14.8.2.3 and in the previous subsection.



**14.11.2 Baseband Modulation.** The PHY-symbol coded signals shall be converted to appropriately shaped pulses whose amplitude at the correct sampling intervals is determined by the output PHY-symbol codes as follows (where MAX is the amplitude of the largest pulse):

- {0} → 0/4 of MAX ( = 0 )
- {2} → 2/4 of MAX
- {4} → 4/4 of MAX ( = MAX )

The sequence of pulses corresponding to the first, third, and so forth (odd numbered) PHY-symbols of each transmission sequence shall be shaped for transmission in the in-phase subchannel, as described in 14.8.3, so that their decoding can be achieved by full-wave rectification of the demodulated in-phase component of the line signal. This sequence is known as the baseband in-phase modulation.

The sequence of pulses corresponding to the second, fourth, and so forth (even numbered) PHY-symbols of each transmission sequence shall be shaped for transmission in the quadrature subchannel, as described in 14.8.3, so that their decoding can be achieved by full-wave rectification of the demodulated quadrature component of the line signal. This sequence is known as the baseband quadrature modulation.

**14.11.3 Line Signal in RF Band (at the line output of the station).** The equivalent baseband in-phase modulation of 14.11.2 shall be applied to an (in-phase) RF carrier centered in the assigned channel, the equivalent baseband quadrature modulation of 14.11.2 shall be applied to an RF carrier in phase-quadrature with the preceding (in-phase) RF carrier, and the resultant modulated carriers shall be combined and coupled to the broadband bus medium as specified in 14.8.7.

NOTE: Any equivalent method of impressing in-phase and quadrature components on the RF carrier is acceptable.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

### 14.12 Appendix—Detailed Scrambling and Descrambling Process

**14.12.1 Scrambling.** The message polynomial is divided by the generating polynomial  $1 + X^{-6} + X^{-7}$ . (See Fig 14-5.) The coefficients of the quotient of this division are taken in descending order from the data sequence to be transmitted.

**14.12.2 Descrambling.** At the receiver the incoming bit sequence is multiplied by the generating polynomial  $1 + X^{-6} + X^{-7}$  to form the recovered message polynomial. The coefficients of the recovered polynomial, taken in descending order, form the output data sequence.

**14.12.3 Elements of the Scrambling Process.** The factor  $1 + X^{-6} + X^{-7}$  randomizes the transmitted data over a sequence length of 127 bits. Figure 14-6 is given as an indication only, since with another technique the logical arrangement might take another form.

Fig 14-5  
 $1 + X^{-6} + X^{-7}$  Scrambler

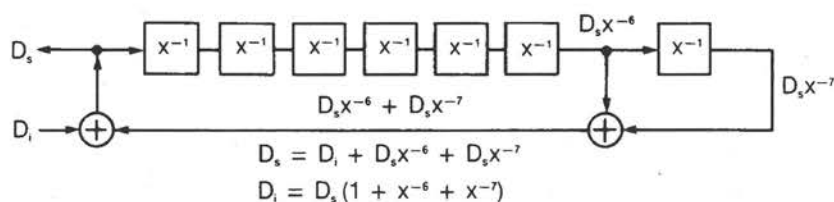
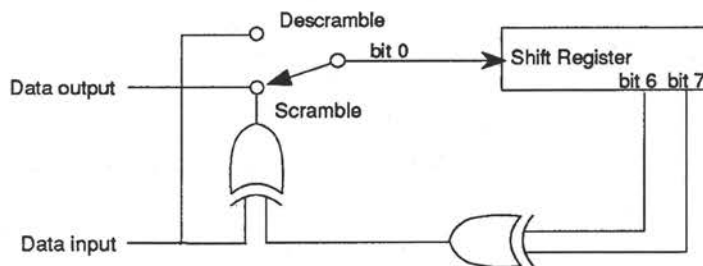


Fig 14-6  
Exemplary Scrambler/Descrambler Circuitry





## 15. Broadband Bus Medium

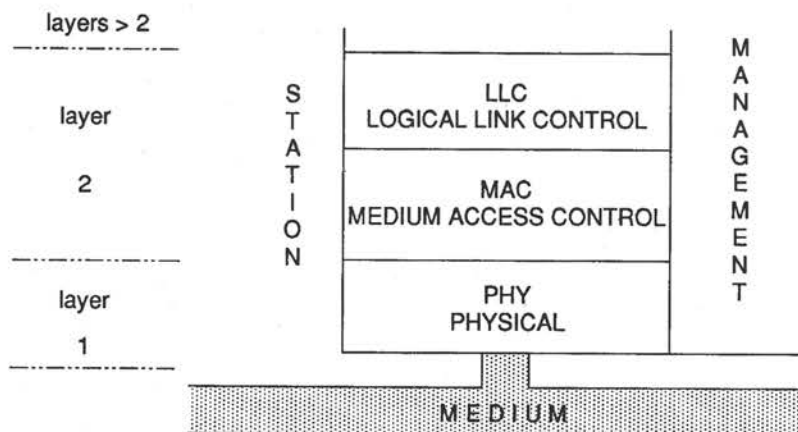
The functional, electrical, and mechanical characteristics of one specific form of broadband bus medium of this standard are specified in this section. This specification includes the medium embodiments of a broadband bus Local Area Network (LAN). The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 15-1. The relationship between this specification and the broadband bus Physical Layer and the medium is illustrated in Fig 15-2.

This standard specifies the medium only insofar as necessary to ensure

- (1) The interoperability of PLEs conforming to Section 14 when connected to a medium conformant to this section, and
- (2) The protection of the LAN and those using it.

IEEE Std 802.7-1989 [11] gives additional guidance on the use of broadband cable systems for LAN data communications.

**Fig 15-1**  
**Relation to LAN Model**



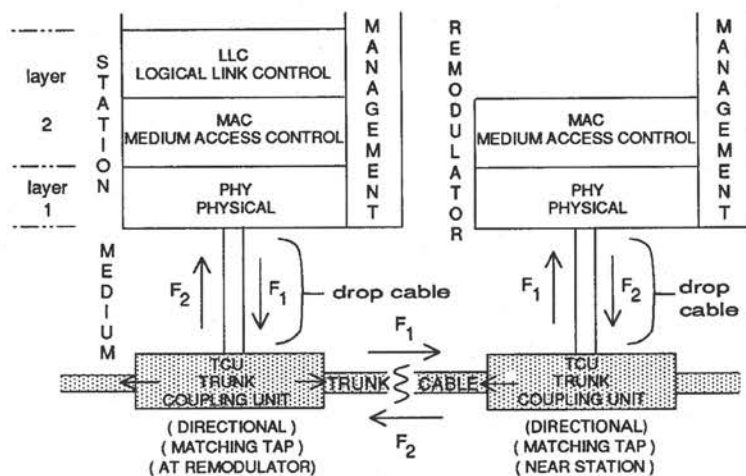


Fig 15-2  
Physical Hardware Partitioning

**15.1 Nomenclature.** Terms used in this section whose meanings within the section are more specific than indicated by glossaries referred to in 1.2 are as follows:

**bidirectional broadband amplifier.** An assemblage of amplifiers and filters that amplifies and re-equalizes in the *forward* direction all signals received in the higher-frequency portion of the broadband spectrum, and simultaneously amplifies and re-equalizes in the *reverse* direction all signals received in the lower-frequency portion of the broadband spectrum.

**broadband coaxial system.** A system whereby information is encoded, modulated onto a carrier, and band-pass filtered or otherwise constrained to occupy only a limited frequency spectrum on the coaxial transmission medium. Many information signals can be present on the medium at the same time without disruption provided that they all occupy nonoverlapping frequency regions within the cable system's range of frequency transport.

**dBmV.** A measure of rms signal level on a 75  $\Omega$  cable compared to 1 mV. In terms of SI units, dBmV is defined as dB (1 mV, 75  $\Omega$ ) rms.

**drop cable.** The smaller diameter flexible coaxial cable of the broadband bus medium that connects to a station.

**dual-cable.** A broadband coaxial cable system in which separate coaxial cables are used for the *forward* and *reverse* directions of signal transmission. Connection of a dual-cable system to a station requires dual F-connectors at the station—one for transmission and one for reception.

**F-connector.** A 75  $\Omega$  F-series coaxial cable connector.

**forward.** The direction of transmission originating at the remodulator of a broadband cable system and relayed “outbound” by the system’s bidirectional broadband amplifiers to the system’s “subscribers.” Transmission on the higher-frequency channels is supported in this direction.

remodulator. The unit located at the logical root of a broadband bus LAN which demodulates the  $F_1$  frequency signals transmitted by other network stations and rebroadcasts them as  $F_2$  frequency signals back to those stations. In this standard, it transmits continuously and in doing so specifies the precise data rate at which all stations shall transmit.

**high-split.** The broadband system configuration, as determined by the system’s bidirectional amplifiers, in which signaling in the spectrum from 5–174 MHz is relayed in the *reverse* direction and signaling in the spectrum from 234 MHz up is relayed in the *forward* direction. (The frequency range used is determined by convention. The values given here are commonly found in North American CATV systems.)

**mid-split.** The broadband system configuration, as determined by the system’s bidirectional amplifiers, in which signaling in the spectrum from 5–108 MHz is relayed in the *reverse* direction and signaling in the spectrum from 162 MHz up is relayed in the *forward* direction. This is the configuration preferred in the broadband portion of this standard. (The frequency range used is determined by convention. The values given here are commonly found in North American CATV systems.)

**(impedance-matching) power splitter.** A small module that electrically and mechanically couples one large diameter trunk cable to other large diameter trunk cables, providing a branching topology for the broadband trunk. A power splitter splits the signal energy received in the forward direction among the outgoing trunks, and combines any signal energy received in the reverse direction. It passes low-frequency (<1 kHz) ac power between the trunk cables. It contains only passive electrical components (R, L, C).

**reverse.** The direction of transmission originating at the “subscribers” of a broadband cable system, terminating at the remodulator and relayed “inbound” by the system’s bidirectional broadband amplifiers. Transmission on the lower-frequency channels is supported in this direction.

**(impedance-matching) splitter.** A smaller version of the power splitter used to couple drop cables together. It does not pass low-frequency ac power between the drop cables.

**sub-split.** The broadband system configuration, as determined by the system's bidirectional amplifiers, in which signaling in the spectrum from 5–30 MHz is relayed in the *reverse* direction and signaling in the spectrum from 54 MHz up is relayed in the *forward* direction. (The frequency range is determined by convention. The values given here are commonly found in North American community residential CATV systems.)

**(impedance-matching) tap.** A small module that electrically and mechanically couples the large diameter trunk cable to smaller diameter drop cables, passes low-frequency (<1 kHz) ac power between input and output trunk cable sections, and isolates that ac power from drop cable sections. It splits the signal energy received in the forward direction very asymmetrically, with the bulk of that signal energy passed to the outgoing trunk cable and only a small percentage going to the drop cables, and combines with similar asymmetry any signal energy received in the reverse direction. It contains only passive electrical components (R, L, C).

**trunk cable.** The main (larger-diameter) semirigid coaxial cable of a broadband coaxial cable system. Both ac power and RF signaling are carried on the cable.

**15.2 Object.** The object of this section is to

- (1) Provide a description of the physical medium necessary for communication between local network stations employing the token-passing bus access method defined in this standard and a broadband bus PLE.
- (2) Provide a medium that can be shared by multiple LANs and by totally unrelated applications (such as voice, data, and analog video).
- (3) Provide for high network availability.
- (4) Provide for ease of installation and service in a wide range of environments.
- (5) Permit use of existing components mass produced for the CATV industry, and of the corresponding set of installation practices, where feasible.

**15.3 Compatibility Considerations.** This standard applies to media that are designed to operate as conventional bidirectional (by frequency) CATV-like broadband coaxial cable systems. Such systems generally use standard CATV taps, connectors, amplifiers, power supplies, and coaxial cable. This specification primarily applies to a single trunk system in which two-way alternate communication usually is accomplished through the use of bidirectional amplifiers whose filters permit differing parts of the available cable spectrum to be transmitted in each direction. Dual-trunk systems in which each trunk is used unidirectionally are also permitted, but require both stations and the remodulator to have the necessary dual-cable connector fittings.

The use of a coaxial broadband system permits the assignment of different frequency bands to multiple simultaneous applications. For example, a portion of the cable spectrum can be used by LANs while other portions are used for point-to-point or multipoint data links, and others are used to convey television and audio signals. With the proper selection of signal levels and proper equipment design all of the applications can be propagated without deleterious interference.



Compatibility of medium conformant to this standard is determined at their station interfaces. Specific implementations based on this standard may be conceived in different ways provided compatibility at the actual station interfaces is maintained.

## 15.4 Overview

**15.4.1 General Description of Functions.** The functions performed by the broadband bus medium are described informally here. Jointly, these functions provide a means whereby signaling in the reverse-direction spectrum presented at the station interfaces of drop cables can be combined and conveyed as corresponding forward-channel spectrum signaling (with the assistance of remodulators functioning as relay entities) to all of the stations on all of the medium's drop cables. Thus, stations connected to these drop cables can communicate.

**15.4.1.1 Operational Overview.** The use of a coaxial cable operating as a broadband medium introduces special system considerations that are not encountered in single-channel transmission systems. A conventional CATV-like system uses bidirectional amplifiers to achieve two-way transmission on a single coaxial cable. The amplifier actually consists of two independent unidirectional amplifiers, together with the appropriate crossover filters, so that one amplifier transmits the upper portion of the cable spectrum in the *forward* direction, outbound from the remodulator, while the other amplifier transmits the lower portion in the *reverse* direction, toward the remodulator. (Therefore, each station requires an RF transmitter and receiver, each operating in a different portion of the cable spectrum.)

The remodulator is where forward direction signals originate and reverse direction signals converge. The remodulator receives the lower-frequency reverse channel signal and retransmits it as the higher-frequency forward channel signal to the "downstream" stations. One remodulator is needed for each separate channel pair used as a broadband bus LAN.

Stations are connected to the *trunk* coaxial cable in such systems by smaller-diameter *drop* cables and impedance-matching *taps*. These taps are passive devices that are highly directional with regard to signal propagation as shown in Fig 15-2. The directional characteristics of the taps improve the impedance matching at the *ports* of the tap and minimize the effects of reflections due to any impedance mismatches along the trunk or on other drop cables.

The directionality of the tap is such that the transmission loss between the station and the reverse direction trunk is considerably less than that between the station and the forward direction trunk. Hence, communication between devices connected to different taps along the coax occurs through the transmission of a frequency  $F_1$  in the low-band toward the remodulator, reception at the remodulator and retransmission in the forward direction at a remodulator frequency  $F_2$ , and reception by the "listening" stations.

NOTE: Remodulator taps are connected with forward and reverse directions interchanged to support the remodulator's role as a relay entity.

The topology of the broadband system is that of a highly branched tree, with the remodulator equipment located at the tree's roots, and the other equipment connected as leaves to the tree's branches. Branching is accomplished in the trunk itself by way of *power splitters*, which provide nondirectional coupling of the ac power carried on the trunk cables, and directional coupling of the RF power similar to that of the just-described *taps*. Like the taps, the power splitters also employ only passive electrical components (R, L, C only).

Branching in the drop cables is provided by (drop cable) splitters that block ac power flow among their ports. They also employ only passive electrical components.

The amplifiers of the broadband system are powered from the trunk cable itself. Low-voltage (30 V or 60 V) ac power usually is carried on the center conductor and grounded shield of the cable at a nominal frequency of 50 Hz or 60 Hz; the amplifiers use some of that power and pass the rest to the connected "downstream" trunk cable. Standard CATV-like power supplies and power-combining and power-blocking components permit the power to be supplied to the trunk cabling at one or more points in the system.

**15.4.1.2 Remodulator Functions.** In an actual broadband bus system, stations do not transmit and receive on the same frequency channel. For each broadband bus LAN, one central station, designated the *remodulator*, receives on a low-frequency channel and transmits on a high-frequency channel. All of the other stations of that particular network receive on the high-frequency channel and transmit on the low-frequency channel. Thus, any one network really uses a pair of directional channels, with the low-frequency (*reverse*) channel having many transmitters and one receiver, and the high-frequency (*forward*) channel having one transmitter and many receivers.

To support its functioning as a relay, the remodulator is located at the "root" of the tree-like structure of the medium, and is connected to the trunk by way of a tap so installed that the remodulator receives signaling originating "downstream" from it, and also transmits its signal "downstream."

**15.4.2 Basic Characteristics and Options.** All signal-conveyance characteristics and station-interface characteristics are mandatory. All other characteristics are optional.

**15.5 Functional, Electrical, and Mechanical Specifications.** The broadband bus medium is an entity whose sole function (relative to this standard) is signal transport between the stations and remodulator of a broadband bus LAN. Consequently, only those characteristics of the medium that impinge on station to remodulator and remodulator to station signal transport, or on human and equipment safety, are specified in this standard.

An implementation of the medium shall be deemed conformant to this standard if it provides the specified signal transport services and characteristics for the stations and remodulator of a broadband bus LAN, and if it meets the relevant safety and environmental codes.

NOTE: IEEE Std 802.7-1989 [11] provides some guidelines in this area.

All measurements specified in 15.5 are to be made at the point of station or remodulator connection to the medium. Unless otherwise indicated, these measurements shall be made across that central portion of the 1.5 MHz, 6 MHz, or 12 MHz channel actually used for signaling, that is, the central 1 MHz, 5 MHz, or 10 MHz, respectively. Unless otherwise stated, all voltage and power levels specified are in rms and dBmV, respectively, based on transmissions of random data patterns (dBmV is defined as dB [1 mV, 75  $\Omega$ ] rms in 15.1). (See 14.8 for more details.)

**15.5.1 Coupling to the Station/Remodulator.** The connection of the broadband bus medium to the station or remodulator shall be by way of a flexible 75  $\Omega$  drop cable terminated in a male F-series 75  $\Omega$  connector; this combination shall mate with a female F-series 75  $\Omega$  connector mounted on the station or remodulator.

In addition to this coupling, the shield(s) of the coaxial drop cable medium shall be connected to the shell of the terminating male F-connector and the impedance of that connection over the range from dc to 450 MHz shall be less than 0.1  $\Omega$ . Also, the impedance of a connection between the shell of that male F-series connector and the outer barrel of a mated female F-series connector over the range from dc to 450 MHz shall be less than 0.1  $\Omega$ . In addition to this coupling, the shield(s) of the coaxial drop cable medium shall be connected to the shell of the terminating male F-series connector and the dc impedance of that connection shall be less than 0.001  $\Omega$ . Also, the dc impedance of a connection between the shell of that male F-series connector and the outer barrel of a mated female F-series connector shall be less than 0.001  $\Omega$ .

NOTE: At the time this standard was written, there were no recognized standards for F-connectors. A standard for F-connector mating interface dimensions was being drafted by the IEC as Publication 169: (to be determined), Radio-frequency connectors (Type F). A comprehensive Type FD connector standard (intermateable with Type F) was being drafted by the Electronic Industries Association to be published as EIA 550. F-connectors vary greatly in quality. It is suggested that high quality F-connectors be used. Further, since the center conductor of the cable in some F-connectors becomes the male part of the connector, caution should be used in mixing different types of cables with F-connectors. Where possible, the use of connectors with captive center conductors is recommended.

**15.5.1.1 Station-to-Station Isolation.** The isolation from any point of station connection to any other point of station connection within the transmit and receive channel bandwidth shall be a minimum of 25 dB.

**15.5.2 Characteristic Impedance.** The nominal characteristic impedance of the broadband medium shall be 75  $\Omega$ . The maximum VSWR at each of the medium's F-connector shall be 1.5:1 or less when the F-connector is terminated with a 75  $\Omega$  resistive load, as measured over the entire broadband cable frequency spectrum supported by the medium.

NOTE: This spectrum shall include both the forward and reverse channels in use in the network.

**15.5.3 Path Loss.** The broadband bus medium shall exhibit a total path loss from any single station to the remodulator or from the remodulator to any single station of 44 dB with a permissible uncertainty due to all factors of  $\pm 5$  dB. The maximum short-term variance component of this path loss shall be no more than  $\pm 1$  dB/minute.

**15.5.4 Signal-to-Noise (S/N) Level.** It is recommended that the signal-to-noise level be at least 40 dB (V rms/[V rms]). In no case shall it be less than 30 dB (as measured at any station or remodulator). The noise floor, averaged across the channel bandwidth, shall not exceed -57 dBmV as measured in any 30 kHz band at the remodulator.

**15.5.5 Power Handling Capability.** The 50 Hz or 60 Hz ac power commonly carried on broadband trunk cables shall not be carried on the (drop-cable) medium that connects directly to the station or remodulator. The total power over the entire cable spectrum, as presented to the station or remodulator, shall be less than +55 dB dBmV.

**15.5.6 Compatibility with the Stations and Remodulator.** An embodiment of a broadband bus medium is deemed to support a specific broadband bus LAN if

- (1) It provides a *forward* channel of suitable bandwidth for the LAN and a *reverse* channel of equal bandwidth.
- (2) The stations of that LAN can receive on that forward channel and transmit on that reverse channel.
- (3) The network has a remodulator connected closer to the cable system's head-end than all (other) stations, and that remodulator can transmit on that forward channel and receive on that reverse channel.
- (4) The requirements of 15.5.1 through 15.5.5 (inclusive) are met on the reverse channel when measured from the point of remodulator connection to the medium, independent of which point of station connection to the medium is chosen for test signal origination.
- (5) The requirements of 15.5.1 through 15.5.5 (inclusive) are met on the forward channel when measured from each point of station connection to the medium, with test signals originated at the point of remodulator connection to the medium.

**15.5.7 Alternate Broadband Media (OPTIONAL).** Section 14 specifies the standard (preferred) broadband bus medium configuration as a single trunk cable and single drop cable, bidirectional by frequency, mid-split CATV-like configuration. Other configurations are possible which meet the intent of this standard, including sub-split, high-split, or dual-cable media, and redundant media.

**15.5.8 Redundancy Considerations.** As implied by 14.8.8 and 14.8.16, redundant broadband media are not precluded from this standard. Where redundant media are employed, the provisions of 15.5.1 to 15.5.6 shall apply separately and independently to each single nonredundant medium interface. Additionally, the forward channel frequency and bandwidth, and reverse channel frequency and bandwidth, for the LAN shall be the same on all of the redundant media.

**15.5.9 Reliability.** All active (powered) medium equipment should be designed so that the aggregate probability of that equipment causing a communication failure at more than one station connected to the medium is less than  $10^{-4}$  per hour of continuous (or discontinuous) operation. Connectors and other passive components comprising the means of connecting the station to the coax-

ial cable medium shall be designed to minimize the probability of total network failure.

### 15.6 Environmental Specifications

**15.6.1 Electromagnetic Emanation.** LAN cable systems shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**15.6.2 Safety Requirements.** All media meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [7].

**15.6.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The medium embodiment shall meet its specifications when operating in an ambient continuous wave plane wave field of

- (1) 80 mV/m within the operational channel bandwidth,
- (2) 2 V/m for other frequencies from 10 kHz through 30 MHz,
- (3) 5 V/m for other frequencies from 30 MHz through 1 GHz outside the operational channel bandwidth.

NOTE: IEEE Std 802.7-1989 [11] provides some guidelines in this area.

**15.7 Transmission\_path\_delay Considerations.** When specifying an embodiment of a medium that conforms to the specifications of this Section, a vendor shall state the transmission\_path\_delay as the maximum delay that the broadband bus medium could be expected to induce on a transmission from any connected station through the remodulator and back to that station. The delays induced by the transmitting and receiving stations themselves should not be included in the transmission\_path\_delay.

For each potentially worst-case path through the medium, a path delay is computed as the sum of the medium-induced delay and remodulator-induced delay in propagating a signal from one station to another. The transmission\_path\_delay used for determining the network's slot\_time (see 6.1.9) shall be the largest of these path delays for the cable system.

These path delay computations shall take into account all circuitry delays in the remodulator and the medium amplifiers, taps, splitters, etc., and all signal propagation delays within the cable segments themselves.

The transmission\_path\_delay shall be expressed in terms of the network's symbol signaling rate on the medium. When not an integral number of signaled symbols, it shall be rounded up to such an integral number. When uncertain of the exact value of the delay, vendors shall state an upper bound for the value.

**15.8 Documentation.** It is recommended that each vendor of an embodiment of a medium conformant to this standard provide to the user supporting documentation with at least these parameters:

- (1) Specific sections of the standards to which the embodiment conforms.
- (2) Configuration type—sub-split, mid-split, high-split, or dual-cable.
- (3) Upper limit of forward channel frequency spectrum (for example, 300 MHz, 400 MHz, 450 MHz).
- (4) The transmission\_path\_delay, as specified in 15.7 and 6.1.9.
- (5) For remodulators, the proper range of transmitter output levels so that the signal-level requirements of 14.8.5.4, 14.8.9, and 14.8.19 are all met.

### 15.9 Network Sizing

**15.9.1 Topology Considerations.** Very small systems can be constructed using only flexible coaxial cable and passive impedance-matching networks. Larger systems require amplifiers and power supplies, together with semirigid trunk cable and flexible drop cables. Highly-branched topologies are achieved easily in this medium using standard CATV-like components.

Each remodulator shall be “upstream” from all of the (other) stations on its LAN, but need not actually be at the head-end of the entire cable system. It is only necessary that the remodulator be closer to the “root” of the tree-shaped cable system than any of the other stations of its network. Thus, in large systems (for example, campus-wide or city-wide), a large cable tree could have many subtrees, with a remodulator at the root of each subtree controlling a LAN within that subtree, and with all the networks using the same pair of forward and reverse channels. Band-stop (notch) filters would be needed in the cable segments that connect those subtrees to isolate the forward and reverse channels of each subtree’s network to that subtree.

**15.9.2 Signal Loss Budget Considerations.** The placement of broadband amplifiers, and the placement of taps, choice of number of drops in each tap, and determination of the tap’s insertion and drop losses shall take into account the following:

- (1) Each station’s minimum transmit level and receive level specifications (see 14.8.5.4 and 14.8.9).
- (2) The desired current and anticipated future placement of station’s and remodulator.
- (3) Each station’s transmit level and receive level specifications (see 14.8.5.4 and 14.8.9).

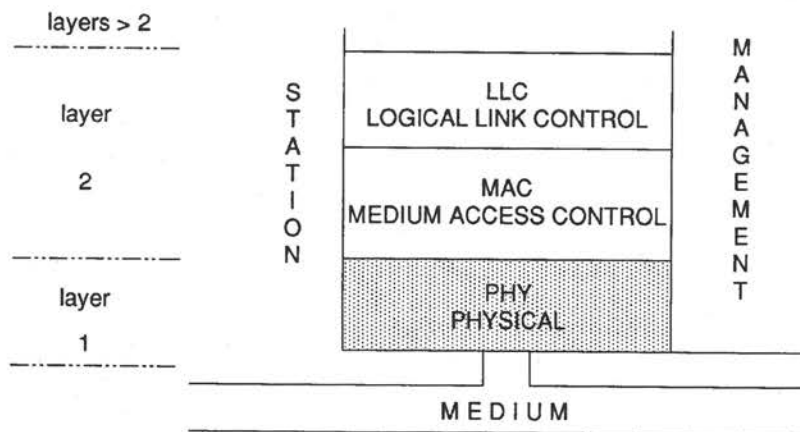
## 16. Fiber Optic Physical Layer Entity (PLE)

The functional, optical, electrical, and mechanical characteristics of one specific form of PLE (fiber optic) of this standard are specified in this section. This standard specifies these PLEs only in so far as necessary to ensure

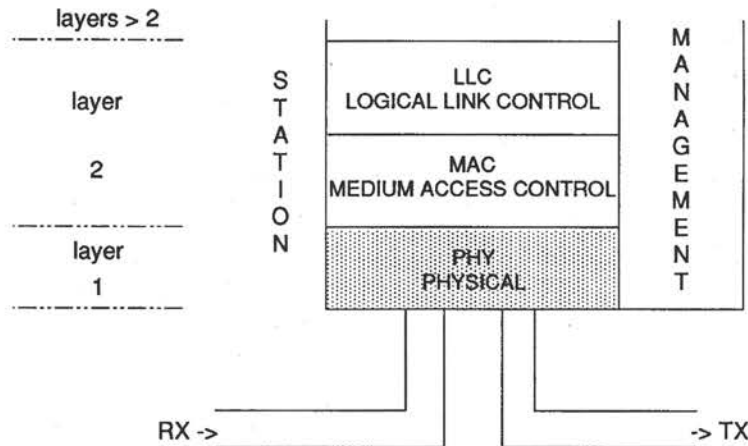
- (1) The interoperability of implementations conforming to this specification, and
- (2) The protection of the Local Area Network (LAN) itself and those who use it.

The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 16-1. The relationship of this section to the fiber optic PLE and medium is illustrated in Fig 16-2.

**Fig 16-1**  
**Relation to LAN Model**







**Fig 16-2**  
**Physical Hardware Partitioning**

**16.1 Nomenclature.** Terms used in this section whose meanings within the section are more specific than indicated by glossaries referred to in 1.2 are as follows:

**cable plant interface connector (CPIC).** The point at which test and conformance measurements are made; the interface between the station and the cable plant. The CPIC is keyed to correspond to the receiver operating range that is supported by the attached PLE. This connector is in the form of a duplex connector whose intermateability geometry is as defined in ISO/IEC 7498-4 : 1989 [14].

**center wavelength.** The wavelength that is the arithmetic mean of the half-maximum spectral intensity points of the transmitter. If the spectral intensity distribution is symmetric and singly peaked, the center wavelength is at maximum intensity.

**dBm.** A measure of optical power. In terms of SI units (International System of Units), dBm is defined as dB (1 mW).

**detected bit error.** An error which is reported as *bad\_signal*. *Bad\_signal* reported during the preamble or during the four symbols following the last end delimiter of a transmission is not included.

**effective launch power.** The effective power coupled into the core of a fiber optic waveguide by the transmitter. This power is measured with a standard test fiber connected to the CPIC (see 16.7.3.2).

**effective power.** The difference, expressed in dBm, between the absolute optical power measured in milliwatts at the midpoint in time of the  $\{H\}$  PHY-symbol to the absolute optical power measured in milliwatts at the midpoint of the  $\{L\}$  PHY-symbol.

NOTE: Effective power is believed to give a more accurate measurement of the conditions that affect receivers than traditional measurements, such as peak and average power. Methods for measuring effective power are for further study.

**extinction ratio.** The ratio of the absolute optical power measured in milliwatts at the midpoint in time of the  $\{H\}$  PHY-symbol to the absolute optical power measured in milliwatts at the midpoint of the  $\{L\}$  PHY-symbol.

NOTES: (1) In computing effective power and extinction ratio, the absolute power of an  $\{L\}$  cannot be assumed to be lower than the maximum power of an  $\{off\}$ .

(2) The following gives an example of the computation of effective power and extinction ratios:

If the midpoint of  $\{H\}$  is measured as 105  $\mu$ W,

and if the midpoint of  $\{L\}$  is measured as 5  $\mu$ W,

then the difference is 100  $\mu$ W.

Therefore, the effective power is  $10 \log_{10} (100 \mu\text{W}/1 \text{ mW})$ , which equals -10 dBm. The extinction ratio is 105/5, which equals 21:1.

**fiber optic cable.** A cable containing one or more fiber optic waveguides. Jacketing material is provided to facilitate handling and to protect the fiber.

**fiber optic receiver.** The optics and electronics in the station that accept the optical signal received by the station through the CPIC.

**fiber optic receiver operating range.** The range of effective power that must be present at the CPIC to ensure that the bit error rate specifications are met.

**fiber optic transmitter.** A device that emits optical signals for propagation onto a fiber optic waveguide through the CPIC.

**fiber optic waveguide.** A flexible optically transparent strand that is used to transport optical signals from one geographic point to another geographic point.

**full width half maximum (FWHM).** A measure of the width of a singly peaked function. After determining the maximum (peak) value of the function, one determines the two arguments of the function that yield half of this maximum (peak) value. The FWHM value is the magnitude of the arithmetic difference of these two arguments.

**inband optical power.** The optical spectral power density integrated over the range from 720–990 nm.

**jitter.** The offset of the 50% transition points of pulse edges from their ideal position as a result of all causes.

**Manchester encoding.** A means by which separate data and clock signals can be combined into a single, self-synchronizable data stream, suitable for transmission on a serial channel.

**optical fall time.** The time it takes for a pulse that is within the limits of Fig 16-3 to go from 90% effective power to 10% effective power. When expressed as a percentage, the fall time is specified as a percent of the PHY-symbol\_time.

**optical rise time.** The time it takes for a pulse that is within the limits of Fig 16-3 to go from 10% effective power to 90% effective power. When expressed as a percentage, the rise time is specified as a percent of the PHY-symbol\_time.

**optical silence power.** When the absolute power imposed on the CPIC from the cable plant is less than this power, the PLE will report *silence* to the MAC sub-layer entity. This power is measured with a standard test fiber connected to the CPIC.

**PHY-symbol\_time.** One half the MAC-symbol\_time.

**standard test fiber.** A silica fiber optic waveguide with the following nominal characteristics: core diameter of 62.5  $\mu\text{m}$ , outside diameter of 125  $\mu\text{m}$ , an effective numerical aperture of 0.275, and terminated in a CPIC compatible connector.

NOTE: Operation using a 50  $\mu\text{m}$  alternate test fiber is described in Appendixes 16.10 and 17.9.

**undetected bit error.** An error that is not reported as *bad\_signal* by the PLE.

**16.2 Object.** The object of this specification is to

- (1) Provide the physical means necessary for communication between local network stations employing the token-passing bus access method defined in this standard and a fiber optic PLE,
- (2) Provide for high network availability,
- (3) Provide for ease of installation and service in a wide range of environments,
- (4) Provide for different topologies and three signaling rates to accommodate a variety of user requirements,
- (5) Use components that are readily available in the commercial marketplace,
- (6) Provide a communication channel capable of high bandwidth and low bit error rate performance.

**16.3 Compatibility Considerations.** This standard applies to PLEs that are designed to operate on fiber optic cables. For compatibility, fiber optic PLEs are characterized by the keying of the CPIC (and the implied receiver operating range) and the signaling rate. Specific implementations based on this standard may be conceived in different ways provided compatibility at the CPIC is maintained.

This specification assumes the use of 62.5  $\mu\text{m}$  standard test fiber. Implementations using a 50  $\mu\text{m}$  alternate test fiber are specified in Appendix 16.10. For the purposes of compatibility, all measurements listed in this section are referenced to the use of the standard test fiber. Vendors may claim conformance using the standard test fiber, the alternate test fiber, or both test fibers.

A station is implemented using one type of fiber optic transmitter and either of two types of fiber optic receiver: a moderate sensitivity receiver or a high sensitivity receiver. This standard allows multiple compliant topologies to be implemented providing the user flexibility in network design without sacrificing interoperability. The transmitter and moderate sensitivity receiver may be used in active star or low station count passive star topologies. The transmitter and high sensitivity receiver may be used in high station count passive star topologies and in topologies with high media attenuation. The high sensitivity receiver also may be used in place of the moderate sensitivity receiver through the use of manual or automatic attenuation mechanisms.

**16.4 Operational Overview.** The medium specified in Section 17 consists of a pair of fiber optic waveguides providing bidirectionality by use of a separate fiber for each direction of signal propagation. These dual fibers connect to the CPIC of a station. The exposed point of attachment to the station shall use the CPIC specified in 16.7.12 and the signal characteristics at this interface are to be as specified in this section.

Subsection 17.11.1 provides examples of some of the topologies that are considered compatible within the scope of this standard. To be considered compatible, a topology shall function properly under the control of the MAC machine described in Sections 5, 6, and 7 and utilize PLEs and media detailed in Sections 16 and 17 of this document.

#### 16.5 Physical Layer Overview

**16.5.1 General Description of Functions.** The functions performed by the fiber optic PLE are described informally here. Jointly, these functions provide a means whereby symbols presented at the MAC interface of one PLE can be conveyed to all of the PLEs via the media for presentation to their respective MAC interfaces.

**16.5.1.1 Symbol Transmission and Reception Functions.** Successive symbols presented to the PLE at its MAC-PHY interface are applied to an encoder that produces as output a PHY-symbol pair from the set of PHY-symbols  $\{H\}$ ,  $\{L\}$ , and  $\{off\}$ . The output is then applied to an optical transmitter, and the resultant optical signal is coupled to the fiber optic broadcast medium and conveyed by the medium to all the receivers.

Each receiver is also coupled to the broadcast medium. It detects the received signal and infers the transmitted PHY-symbol from the presence or absence of optical power. It then decodes that inferred PHY-symbol by an approximate inverse of the encoding process and presents the resultant decoded MAC-symbols at its MAC-PHY interface. The receiver reports *silence* at the MAC-PHY interface when the optical power present at the CPIC is less than the optical silence power.

For all MAC-symbols except *pad\_idle*, this decoding process is an exact inverse of the encoding process in the absence of errors. The *pad\_idle* symbols, which are referred to collectively as *preamble*, are transmitted at the start of each MAC frame to provide a training signal for receivers and to provide a nonzero mini-

imum separation between consecutive frames. In fiber optic broadcast systems the MAC-symbol encoding for successive *pad\_idles* is identical with the encoding for an alternating series of *ones* and *zeros*, and receivers are permitted to decode the transmitted representation of successive *pad\_idles* as an alternating series of *ones* and *zeros* and report it as such to the MAC entity.

**16.5.1.2 Regenerative Repeater Functions.** Regenerative repeaters may be used to extend the network size beyond the maximum that would otherwise be dictated by signal attenuation and timing jitter considerations. Regenerative repeaters do so by connecting two or more medium segments and repeating any thing “heard” on one segment, excepting its own transmissions, to the other segments. For the purposes of this standard, regenerative repeaters are considered stations, whether or not they have functionality beyond that of a repeater.

**16.5.1.3 Jabber-Inhibit Function.** To protect the LAN from most faults in a station, each station contains a jabber-inhibit function. This function serves as a “watchdog” on the transmitter; if the station does not turn off its transmitter after a prolonged time (roughly one-half second), then the transmitter output shall be automatically disabled for at least the remainder of the transmission.

**16.5.1.4 Local Administrative Functions (OPTIONAL).** These functions are activated either manually, or by way of the PLE’s management interface, or both. They can include

- (1) Enabling or disabling each of the station’s outputs to the CPICs, and
- (2) Selecting the received signal source: either medium or loopback point.

NOTE: If a loopback point is selected, all transmitter outputs to the media shall be inhibited. (See 16.7.9.)

**16.5.2 Basic Functions and Options.** Symbol transmission and reception functions and jabber-inhibit functions are required in all implementations. All other functions are optional.

**16.6 Application of Management.** The following constraints are imposed on the parameters and actions specified in Section 9:

- (1) In the capabilities group, the dataRates parameter sequence shall specify one or more of the values 5, 10, and 20.
- (2) In the local management information, the value of minPostSilencePreambleLength shall be 3 for 5 and 10 Mb/s, and 6 for 20 Mb/s.

**16.7 Functional, Optical, Electrical, and Mechanical Specifications.** Unless otherwise stated, optical power levels are specified as effective, inband optical power in dBm (dBm is defined as dB [1 mW] in 16.1).

NOTE: Standard test procedures, test fiber, and fixture for measuring launch power, optical silence power, and fiber optic receiver operating range are under study by EIA and IEEE 802.8, the Fiber Optic Technical Advisory Group.

**16.7.1 Data Signaling Rates.** The standard data signaling rates for single channel fiber optic systems are 5 Mb/s, 10 Mb/s, and 20 Mb/s. The permitted tolerance for each signaling rate is  $\pm 0.01\%$  for an originating station, and  $\pm 0.015\%$  for repeating stations while performing repeating or regenerating functions.

**16.7.2 Symbol Encoding.** The PLE transmits symbols presented to it by the MAC sublayer entity at the MAC-PHY interface. The possible MAC-symbols are Manchester-encoded into the PHY-symbols  $\{H\}$  and  $\{L\}$ . The encoding action to be taken for each of the input MAC-symbols is as follows:

- (1) *Silence*. Each *silence* symbol shall be encoded as  $\{off\ off\}$ .
- (2) *Pad\_idle*. *Pad\_idle* symbols are always originated in octets. Each pair of consecutive *pad\_idle* symbols shall be encoded as the sequence  $\{L\ H\} \{H\ L\}$ .
- (3) *Zero*. Each *zero* symbol shall be encoded as  $\{H\ L\}$ .
- (4) *One*. Each *one* symbol shall be encoded as  $\{L\ H\}$ .
- (5) *Non\_data*. *Non\_data* symbols are transmitted by the MAC sublayer entity in pairs. Each such pair of consecutive *non\_data* symbols shall be encoded as the sequence  $\{L\ L\} \{H\ H\}$  when the immediately preceding PHY-symbol is an  $\{L\}$ , and shall be encoded as the sequence  $\{H\ H\} \{L\ L\}$  when the immediately preceding PHY-symbol is an  $\{H\}$ . Thus, the (start delimiter) subsequence

*non\_data non\_data zero non\_data non\_data zero*

shall be encoded as the subsequence

$\{L\ L\} \{H\ H\} \{H\ L\} \{L\ L\} \{H\ H\} \{H\ L\}$

and the (end delimiter) subsequence

*non\_data non\_data one non\_data non\_data one*

shall be encoded as the subsequence

$\{L\ L\} \{H\ H\} \{L\ H\} \{H\ H\} \{L\ L\} \{L\ H\}$

after an immediately preceding  $\{L\}$ , and as the subsequence

$\{H\ H\} \{L\ L\} \{L\ H\} \{H\ H\} \{L\ L\} \{L\ H\}$

after an immediately preceding  $\{H\}$ .

**16.7.3 Line Signal (at the output of the station).** The PHY-symbols resulting from the encoding of 16.7.2 shall be converted to its line representation, as described in 16.7.3.1, and the resultant signaling shall be imposed on the single channel fiber optic broadcast medium. The rate at which these symbols are imposed on the medium is a function of the data rate in operation at the time. Table 16-1 summarizes the relationship between data rate, media transmission rate, and PHY-symbol\_time.

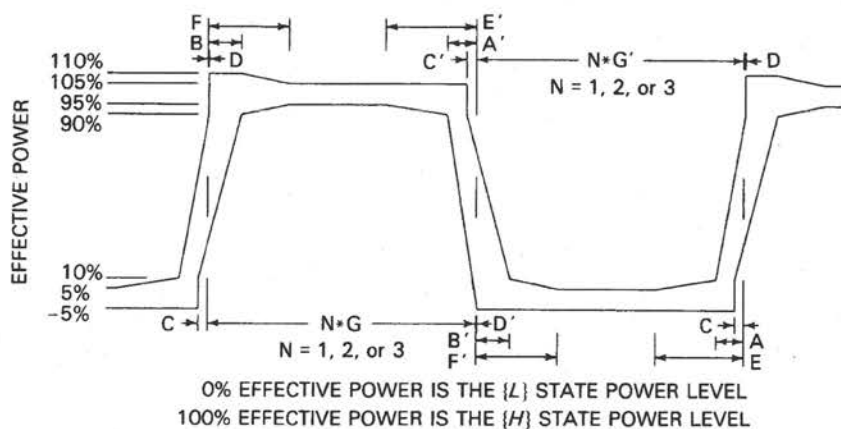
**Table 16-1**  
**Data Rate Versus Media Transmission Rate**

Media Data Rate (in Mb/s)	PHY-Symbol Transmission Rate (in Mbaud)	Time (in ns)
5	10	100
10	20	50
20	40	25

**16.7.3.1 Line Representations.** The line signal representations of the  $\{H\}$ ,  $\{L\}$ , and  $\{off\}$  PHY-symbols shall be as follows:

- (1) An  $\{H\}$  shall be represented nominally as the absolute power level corresponding to 100% effective power for the full period of a PHY-symbol time as shown in Fig 16-3.
- (2) An  $\{L\}$  shall be represented nominally as 0% effective power for the full period of a PHY-symbol time as shown in Fig 16-3. The absolute power levels corresponding to transmitted  $\{H\}$  and  $\{L\}$  PHY-symbols may be any values which, taken together, meet the output power (16.7.3.2) and extinction ration (16.7.3.3) specifications.
- (3) An  $\{off\}$  shall be represented nominally as less than  $-45$  dBm for the full period of a PHY-symbol time and shall be transmitted as specified in 16.7.3.3.

**Fig 16-3**  
**Optical Wave Shape Template**



Transmit (in ns)			Parameter	Receive (in ns)		
5 Mb/s	10 Mb/s	20 Mb/s		5 Mb/s	10 Mb/s	20 Mb/s
10.46	5.23	2.62	A=A'	17.44	8.72	4.36
13.54	6.77	3.88	B=B'	22.56	11.28	5.64
3.5	1.75	0.88	C=C'	3.5	1.75	0.88
0.5	0.25	0.125	D=D'	0.5	0.25	0.125
33.24	16.62	8.3	E=E'	55.46	28.03	14.02
30.16	15.08	7.54	F=F'	50.86	25.43	12.22
N*100	N*50	N*25	G	N*100	N*50	N*25

NOTE: Where N can be 1, 2, or 3.



**16.7.3.2 Output Power.** The effective launch power shall be between  $-7$  dBm and  $-11$  dBm (except when transmitting *silence*). This is a measure of the effective power launched into the core of a standard test fiber from the station CPIC at a distance of 1 meter down the fiber on the cable plant side.

**16.7.3.3 Transmitter Characteristics.** The transmitter shall have its center wavelength between 800 and 910 nm. The power distribution shall exhibit a FWHM power not to exceed 60 nm. The transmitter extinction ratio shall be a minimum of 20:1. Average optical power measured over one PHY-symbol time shall be less than  $-45$  dBm four MAC-symbol\_times and longer after the last {H} or {L} PHY-symbol of a transmission. Average in-band optical power measured over one PHY-symbol time shall be less than  $-60$  dBm 1  $\mu$ s and longer after the last {H} or {L} PHY-symbol of a transmission.

The rise times and fall times of the transmit eye pattern shall be each less than 24% of the PHY-symbol\_time, and the difference between rise and fall times shall be less than 8% of the PHY-symbol\_time. Overshoot of transitions shall be less than 10% of the effective power. The transmit jitter shall not exceed  $\pm 4\%$  of the PHY-symbol\_time. Figure 16-3 illustrates the template of these parameters (transmit only) as they would appear while transmitting continuous *pad\_idle* symbols.

NOTE: 1300 nm operation may be desirable in certain applications and is a subject of future study.

**16.7.4 Jabber-Inhibit.** Each PLE shall have self-interrupt capability to inhibit optical energy from reaching the LAN medium. Hardware within the PLE (with no external indication other than the prolonged detection of a non-*silence* condition within the transmitter) shall provide a nominal window of one-half second  $\pm 25\%$  during which time a normal data link transmission may occur. If a transmission is in excess of this duration, the jabber-inhibit function shall operate to inhibit any further output from reaching the medium. Reset of this jabber-inhibit function is implementation-dependent.

**16.7.5 Coupling to the Medium.** The PLE functions are intended to operate satisfactorily over a medium consisting of fiber optic waveguides and splitter combiners in any configuration consistent with Section 17 of this document. The mechanical coupling of the station to the medium shall be by a connector as specified in 16.7.13.

**16.7.6 Receiver Characteristics.** The physical entity shall provide an undetected bit error rate of  $10^{-9}$  or lower and a detected bit error rate of  $10^{-8}$  or lower, when receiving signals from the standard test fiber whose effective, in-band power is within the specified receiver operating range. This bit error rate applies when receiving a properly transmitted frame or valid silence and conveyed by a medium conforming to the requirements of Section 17. The receiver shall operate within the above specification when receiving signals of any shape falling within the template of Fig 16.3 (receive only) and with received jitter which is less than  $\pm 10\%$  of the PHY-symbol\_time and with any extinction ratio of at least 10 to 1. The signal reported to the MAC sublayer shall be *silence* four MAC-symbol\_times and longer after the last {H} or {L} PHY-symbol of a transmission whenever the absolute optical power is less than the specified silence power. Receivers



shall be designed so that non-*silence* is reported to the MAC-PHY interface whenever there is optical energy present at the CPIC above the minimum required receiver operating power defined in the following subsections.

**16.7.6.1 Receiver Operating Range—Moderate Sensitivity Receiver.** The specified receiver sensitivity range is -11 dBm to -31 dBm effective power with an optical silence power of -40 dBm.

**16.7.6.2 Receiver Operating Range—High Sensitivity Receiver.** The specified receiver sensitivity range is -21 dBm to -41 dBm effective power with an optical silence power of -50 dBm.

NOTE: It is permissible to extend the receiver operating range so long as the receiver still operates within the specified range and conforms to the silence power specifications. The receiver should be labeled to indicate the guaranteed operating range.

**16.7.7 Symbol Timing.** During the recovery of *pad\_idle* and *silence* symbols, it is permissible to vary the MAC-symbol reporting time by up to one nominal MAC-symbol\_time. The time of each reported MAC-symbol shall nonetheless be within 90–210% of the nominal MAC-symbol time at all times. Further, the time of each reported MAC-symbol after *pad\_idle* symbol recovery and until either *silence* or *bad\_signal* is reported shall be within 90–110% of the nominal MAC-symbol\_time.

**16.7.8 Symbol Decoding.** After determination of each received PHY-symbol pair, that PHY-symbol pair shall be decoded by a process inverse to that described in 16.7.2 and the decoded MAC-symbols shall be reported at the MAC-PHY interface. Whenever a signaled sequence is received for which the encoding process has no inverse, those PHY-symbol pairs shall be decoded as an appropriate number of *bad\_signal* MAC-symbols and reported as such at the MAC-PHY interface.

NOTES: (1) Receivers are permitted to decode each transmitted *pad\_idle* MAC-symbol as a *zero* or a *one* MAC-symbol.

(2) When measuring bit error rate, multiple errors in a frame may be counted as a single error.

**16.7.9 Transmitter Enable/Disable and Received Signal Source Selection (OPTIONAL).** The ability to enable and disable transmission onto the medium as directed by the management entity is recommended but optional.

The ability to select the source of received signaling, either a loopback point within the PLE or (one of) the (possibly redundant) media, as directed by the management entity, is recommended but optional. When such an option is invoked and the selected source is other than (one of) the media, transmission to all connected media shall be disabled automatically while such selection is in force.

**16.7.10 Redundant Media Considerations.** Embodiments of this standard that can function with redundant media are not precluded, provided that the embodiment, as delivered, functions correctly in a non-redundant environment. Where redundant media are employed, the provisions of 16.7.4 and 16.7.9 shall apply separately and independently to each single medium interface, and much of 16.7.9 shall be mandatory. Specifically, separate jabber-inhibit monitoring shall exist for each medium (although common inhibition is permissible),

receiver signal source selection shall be provided capable of selecting any one of the redundant media, and it shall be possible to enable or disable each single transmitter independently of all other redundant transmitters when the source of received signaling is one of the redundant media.

**16.7.11 Reliability.** The PLE shall be designed so that its probability of causing a communication failure among other stations connected to the medium is less than  $10^{-6}$  per hour of operation. Connectors and other components whose failure may cause interruption of the fiber optic media shall be designed to minimize the probability of total network failure.

**16.7.12 Regenerative Repeater Considerations.** The PLE of a regenerative repeater can be considered to be a composite entity, with separate electrical and mechanical transmit and receive functions for each connected trunk segment (that is, each port), that all work under a common encoding, decoding, timing-recovery and control function.

In performing its repeating functions, the regenerative repeater serves as a relay station. When a PHY-symbol other than *off* is received, the composite PLE determines which trunk carried the PHY-symbol, and it then selects that trunk as the source of reported PHY-symbols. Concurrently, the MAC entity begins to retransmit onto the other trunks all MAC-symbols reported. When a collision or noise is detected (for example, *bad\_signal* is reported), the repeater's MAC entity sends an abort sequence (see 4.1.8) in lieu of the received MAC-symbols.

The basic mode of operation, originating or repeating, shall be determined by the superior MAC entity and conveyed by the PHY-MODE invoke primitive (see 8.2.3).

When originating, the repeater PLE shall originate the symbol timing provided to the MAC entity and transmit the encoded MAC-symbols onto all connected trunk segments. The repeater PLE shall use either loopback or any one of the attached trunks as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When repeating and when switching to repeating, the repeater PLE shall delay for an implementation-dependent amount of time (typically a few symbol-durations) to prevent repeating the reflection of the just-prior transmission, and shall then scan the connected ports for one on which signaling is being received. During the delay period, and while this scan for signal is unsuccessful, the repeater PLE shall indicate silence symbols to its MAC-entity using its locally originated symbol timing. Upon detecting signaling at one or more ports, the repeater entity shall select one of those active ports as the source of its received signaling. It shall then temporarily disable that selected port's transmitter function, decode the received signaling, retime that signaling before or after decoding, and indicate the decoded MAC-symbols to its associated MAC entity. It should then vary the frequency of the MAC-symbol timing, within the bounds of this subsection (16.7), as necessary to maintain the proper relationship with the frequency of the received PHY-symbol timing.

In summary, when the MAC entity is originating

- (1) The PLE alone shall determine the MAC-symbol timing.
- (2) Transmission occurs on all attached trunks (unless disabled by the provisions of 16.7.9).

- (3) Loopback or any one of the attached trunks can be used as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When the MAC entity is repeating

- (a) The PLE first delays long enough to ensure that the prior transmission is not repeated, then scans all attached trunks for signaling and selects one of those trunks with signaling as the source of received signaling.
- (b) Transmission to the selected trunk is temporarily inhibited.
- (c) The received signaling from the selected trunk is decoded and indicated to the MAC entity.
- (d) The frequency of MAC-symbol timing is varied as necessary (at most  $\pm 0.015\%$ ) to track the frequency of the peer transmitter's MAC-symbol timing until the MAC entity requests transmission of *silence*, and then repeats the whole procedure.

**16.7.13 Connectors.** The CPIC is specified in accordance with the intermateability geometry given in ISO/IEC JTC1 DIS 9314-3 [17]. No specifications are given for non-CPIC connectors. The receptacle portion of the CPIC is considered part of the station. This receptacle uses key B for high sensitivity receivers and key A for moderate sensitivity receivers. A station that functions in either operating range uses the universal key. This CPIC can either be integral to the station or can be mounted at the end of a pigtail that is a part of the station.

NOTE: Steps have been undertaken by the IEC to standardize the CPIC. At the time this standard was written, a draft document IEC SC 86B (USA) 7 existed.

## 16.8 Environmental Specifications

**16.8.1 Electromagnetic Emanation.** Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**16.8.2 Safety Requirements.** All stations meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [7]. The recommendations of IEC Publication 825 (1984) [6] shall be followed in determining the optical source safety and user warning requirements.

**16.8.3 Electromagnetic and Electric Environment.** The PLE embodiment shall meet its specifications when operating in an ambient continuous wave plane wave field of

- (1) 2 V/m for other frequencies from 10 kHz through 30 MHz, and
- (2) 5 V/m for other frequencies from 30 MHz through 1 GHz.

**16.9 Labeling.** It is recommended that each embodiment (and supporting documentation) of a PLE conformant to this standard be labeled in a manner visible to the user with at least these parameters:

- (1) Data rate capabilities in Mb/s.

- (2) Worst-case round trip delay this equipment introduces on a one-way transmission exchange between stations as specified in 6.1.9.
- (3) Any delays that add to transmission\_path\_delay.
- (4) Operating modes and selection capabilities as defined in 16.7.9 and 16.7.10.
- (5) Whether the CPIC is keyed as high sensitivity using key B, moderate sensitivity using key A, or universal with no key.
- (6) Fiber size or sizes that this equipment is capable of operating.

Additionally, when the station has multiple CPICs, the role of each such CPIC shall be clearly designated on the station in the vicinity of that CPIC.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.<sup>16</sup>)

**16.10 Appendix—Alternative Fiber Optic Medium.** This appendix defines parameters values for claiming conformance to the alternative test fiber. These values are specified in Table 16-2.

**Table 16-2**  
**Alternate Test Fiber Parameter Values**

Parameter	As Specified in Subsection	As Specified for Alternate Test Fiber
<b>Fiber</b>		
Core diameter	16.7.1	50 $\mu\text{m}$
Cladding diameter	16.7.1	125 $\mu\text{m}$
Numerical aperture	16.7.1	0.21
<b>Transmitter</b>		
Silence transmit and <i>{off}</i> sent as	16.7.3.1 (3)	-48 dBm
Output power	16.7.3.2	-10 to -14 dBm
Silence power after 4 MAC-symbol times	16.7.3.3	-48 dBm
Silence power after 1 $\mu\text{s}$	16.7.3.3	-63 dBm
<b>Moderate sensitivity receiver</b>		
Operating range	16.7.6.1	-14 to -34 dBm
Silence level	16.7.6.1	-43 dBm
<b>High sensitivity receiver</b>		
Operating range	16.7.6.2	-24 to -44 dBm
Silence level	16.7.6.2	-53 dBm

<sup>16</sup>Although a strong attempt was made to align IEEE and ISO/IEC versions of this Standard, the version approved by the IEEE Standards Board included this Appendix as a normative Appendix. Therefore, this Appendix is now under consideration by IEEE as an informative Appendix.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

**16.11 Appendix—Comparison of Parameter Values of Standard and Alternative Fiber Optic Medium.** This appendix tabulates the parameters values for the standard test fiber and the alternative test fiber.

The parameter values are reproduced in Table 16-3 for clarity only; the values that appear in 16.7 or Table 16-2 take precedence.

**Table 16-3**  
**Parameter Values for Standard and Alternate Test Fiber**

Parameter	As Specified in Subsection	As Specified for Standard Test Fiber	As Specified for Alternate Test Fiber
<b>Fiber</b>			
Core diameter	16.7.1	62.5 $\mu\text{m}$	50 $\mu\text{m}$
Cladding diameter	16.7.1	125 $\mu\text{m}$	125 $\mu\text{m}$
Numerical aperture	16.7.1	0.275	0.21
<b>Transmitter</b>			
Silence transmit and (off) sent as	16.7.3.1 (3)	−45 dBm	−48 dBm
Output power	16.7.3.2	−7 to −11 dBm	−10 to −14 dBm
Silence power after 4 MAC-symbol times	16.7.3.3	−45 dBm	−48 dBm
Silence power after 1 $\mu\text{s}$	16.7.3.3	−60 dBm	−63 dBm
<b>Moderate sensitivity receiver</b>			
Operating range	16.7.6.1	−11 to −31 dBm	−14 to −34 dBm
Silence level	16.7.6.1	−40 dBm	−43 dBm
<b>High sensitivity receiver</b>			
Operating range	16.7.6.2	−21 to −41 dBm	−24 to −44 dBm
Silence level	16.7.6.2	−50 dBm	−53 dBm

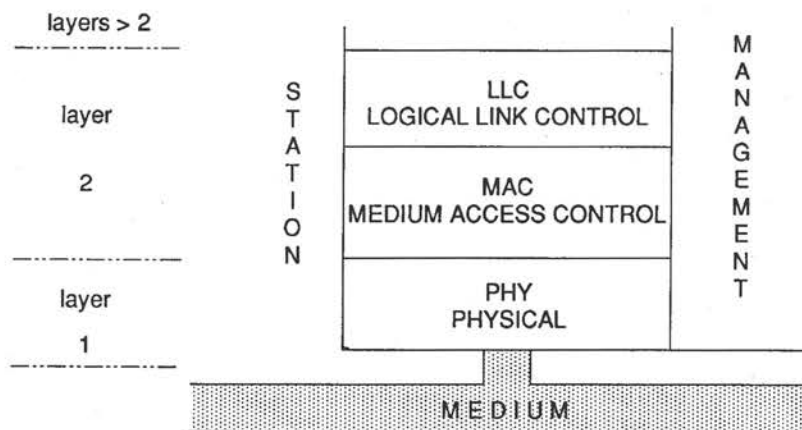
## 17. Fiber Optic Medium

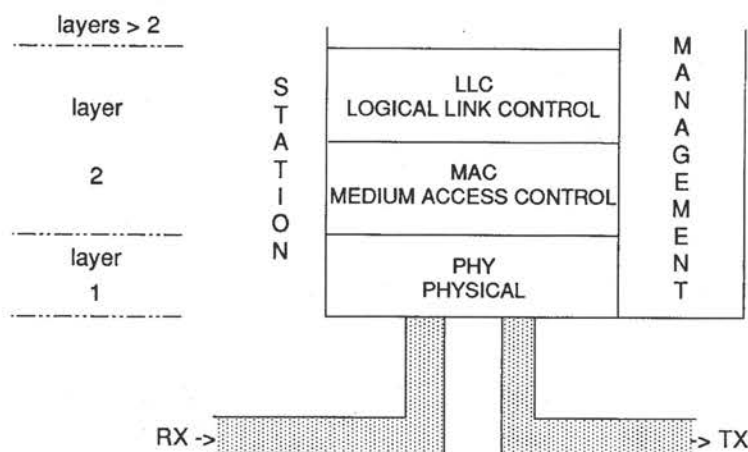
The functional, electrical, optical, and mechanical characteristics of one form of medium of this standard are specified in this section. This specification includes medium embodiments of a fiber optic media Local Area Network (LAN). The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 17-1. The relationship of this section to the fiber optic bus PLE and medium is illustrated in Fig 17-2.

This standard specifies the medium only insofar as necessary to ensure

- (1) The interoperability of PLEs conforming to Section 16 when connected to a medium conformant to this section, and
- (2) The protection of the LAN itself and those using it.

**Fig 17-1**  
**Relation to LAN Model**





**Fig 17-2**  
**Physical Hardware Partitioning**

**17.1 Nomenclature.** Terms used in this section whose meanings within the section are more specific than indicated by glossaries referred to in 1.2 are as follows:

**cable plant interface connector (CPIC).** The point at which test and conformance measurements are made; the interface between the station and the cable plant. The CPIC is keyed to correspond to the receiver operating range which is supported by the attached PLE. This connector is in the form of a duplex connector whose intermateability geometry is as defined in ISO/IEC JTC1 DIS 9314-3 [17].

**center wavelength.** The wavelength that is the arithmetic mean of the half-maximum spectral intensity points of the transmitter. If the spectral intensity distribution is symmetric and singly peaked, the center wavelength is at maximum intensity.

**dBm.** A measure of optical power. In terms of SI units (International System of Units), dBm is defined as dB (1 mW).

**detected bit error.** An error that is reported as *bad\_signal*. *Bad\_signal* reported during the preamble or during the four symbols following the last end delimiter of a transmission is not included as a bit error.

**effective launch power.** The effective power coupled into the core of a fiber optic waveguide by the transmitter. This power is measured with a standard test fiber connected to the CPIC (see 16.7.3.2).

**extinction ratio.** The ratio of the absolute optical power measured in milliwatts at the midpoint of the {H} PHY-symbol to the absolute optical power measured in milliwatts at the midpoint of the {L} PHY-symbol.

**fiber optic cable.** A cable containing one or more fiber optic waveguides. Jacketing material is provided to facilitate handling and to protect the fiber.

**fiber optic receiver.** The optics and electronics in the station that interpret the optical signal received by the station through the CPIC.

**fiber optic receiver operating range.** The range of effective power that must be present at the CPIC to ensure that the bit error rate specifications are met.

**fiber optic transmitter.** A device that emits optical energy signals for propagation onto a fiber optic waveguide through the CPIC.

**fiber optic waveguide.** A flexible transparent strand that is used to transport optical signals from one geographic point to another geographic point.

**full width half maximum (FWHM).** A measure of the width of a singly peaked function. After determining the maximum (peak) value of the function, one determines the two arguments of the function which yield half of this maximum (peak) value. The FWHM value is the magnitude of the arithmetic difference of these two arguments.

**inband optical power.** The optical spectral power density integrated over the range from 720–990 nm.

**jitter.** The offset of the 50% transition points of pulse edges from their ideal position as a result of all causes.

**optical fall time.** The time it takes for a pulse that is within the limits of Fig 16-3 to go from 90% effective power to 10% effective power. When expressed as a percentage, the fall time is specified as a percent of the PHY-symbol\_time.

**optical rise time.** The time it takes for a pulse that is within the limits of Fig 16-3 to go from 10% effective power to 90% effective power. When expressed as a percentage, the rise time is specified as a percent of the PHY-symbol\_time.

**optical silence power.** When the absolute power imposed on the CPIC is less than this power, the PLE will report *silence* to the MAC sublayer entity. This power is measured with a standard test fiber connected to the CPIC.

**path loss.** The difference between the launch power at the transmitting CPIC and the effective power at the receiving CPIC.

**PHY-symbol\_time.** One half the MAC-symbol\_time.

**reflections.** Optical energy that is inadvertently deflected from following the intended path and, hence, arrives at a later time as a spurious signal.



**splitter/combiner primitive.** A device that couples power received on any input port to all of its output ports. Examples of splitter/combiner primitives are active and passive star couplers.

**star coupler, active.** A device that couples optical power received on its input ports to all of its output ports. These devices are active and, hence, may regenerate the signals to their original power level. These devices require electrical power to operate.

**star coupler, passive.** A device that couples optical power received on its input ports to all of its output ports with an associated power loss that is a function of the number of ports and the excess loss parameter. These devices require no electrical power to operate.

**standard test fiber.** A silica fiber optic waveguide with the following nominal characteristics: core diameter of 62.5  $\mu\text{m}$ , outside diameter of 125  $\mu\text{m}$ , an effective numerical aperture of 0.275, and terminated in a CPIC compatible connector.

NOTE: Operation using silica fiber waveguide with the following nominal characteristics: a core diameter of 50  $\mu\text{m}$ , outside diameter of 125  $\mu\text{m}$ , and an effective numerical aperture of 0.21 is described in Appendix 16.10.

**17.2 Object.** The object of this specification is to

- (1) Provide the physical medium necessary for communications between local network stations employing the token-passing bus access method defined in this standard and a fiber optic PLE,
- (2) Provide for high network availability,
- (3) Provide for ease of installation and service in a wide range of environments,
- (4) Permit the use of commercially available components,
- (5) Allow for incorporation of future advances in fiber optic technology where possible,
- (6) Allow the use of low-cost solutions wherever possible, and
- (7) Take advantage of the capabilities of fiber as a transmission medium and to exploit its desirable features wherever possible.

**17.3 Compatibility Considerations.** This standard applies to medium entities that are designed to operate with fiber optic broadcast systems. This specification applies to systems in which two-way alternate communication is accomplished through the use of fiber optic waveguides and active or passive splitter/combiner primitives in the media. This specification assumes the use of 62.5  $\mu\text{m}$  fiber. Implementations using other fiber sizes are possible. For the purposes of compatibility, all measurements reference the use of the standard test fiber.

This specification assumes the use of 62.5  $\mu\text{m}$  standard test fiber. Implementations which are tested using a 50  $\mu\text{m}$  alternate test fiber are specified in Appendix 17.9. For the purposes of compatibility, all measurements listed in this section are referenced to the use of the standard test fiber.

All implementations of medium entities that have the same signaling rate and are conformant to this standard shall be compatible at their CPIC interface. Specific implementations based on this standard may be conceived in different ways provided compatibility at the CPIC interface is maintained.

#### 17.4 Overview

**17.4.1 General Description of Functions.** The functions performed by the fiber optic medium are described informally here. Jointly, these functions provide a means whereby signaling presented at the station interfaces to the fiber optic waveguides can be conveyed to all of the stations attached to the medium.

**17.4.1.1 Operational Overview.** Media topologies are generated by with fiber optic waveguides and  $n$  by  $m$  splitter/combiner (see Fig 17-3). The splitter/combiner has  $n$  optical inputs and  $m$  optical outputs; the signals arriving at the inputs are distributed to the outputs. The splitter/combiner can be either active or passive. A topology is acceptable if

- (1) Optical energy associated with transmission is presented only once at each CPIC receive port,

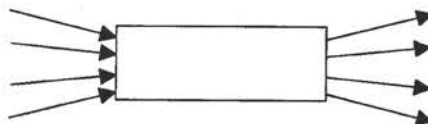
NOTE: This implies that there is effectively only one transmission path between each input and output pair of CPICs.

- (2) The exiting of energy from the network occurs independent of the intelligent activity of any media element, and
- (3) The line representation of PHY-symbols presented to the media is not modified by an intelligent activity of any media element.

**17.4.1.2 Basic Topologies.** A number of basic topologies can be built. These range in scope from a single passive star to a tree topology. The basic observations about the nature of a medium that appear in Section 5 serve as a guideline in the design of primitive elements.

**17.5 Functional, Optical, and Mechanical Specifications.** The fiber optic broadcast medium is an entity whose sole function is signal transport between stations of a fiber optic LAN. Consequently, only those characteristics of the medium entities that impinge on station-to-station transport, or on human and equipment safety, are specified in this standard.

**Fig 17-3**  
 **$n$  by  $m$  Splitter/Combiner Primitive**



An implementation of the medium entity shall be deemed conformant to this standard if it provides the specified signal transport services and characteristics for the stations of a fiber optic LAN, and if it meets the relevant safety and environmental codes.

All measurements specified in 17.5 are to be made at the CPIC interface of station attachment to the cable plant on the receiving side of the connector (so that connector losses are attributed to the cable plant). Unless otherwise stated, all optical power levels are specified as effective, in-band optical power in dBm (dBm is defined as dB [1 mW] in 16.1).

NOTE: Standard test procedures for measuring launch power, optical silence power, and fiber optic receiver operating range are under study by EIA and IEEE 802.8, the Fiber Optic Technical Advisory Group.

**17.5.1 Coupling to the Station.** The PLE functions are intended to operate satisfactorily over a medium consisting of fiber optic waveguides and splitter/combiners in any configuration consistent with this section. The mechanical coupling of the medium to the station shall be by a connector as specified in 16.7.12.

**17.5.2 Power Levels.** When a signal that complies with the specifications of 16.7.3.2 and 16.7.3.3 is impressed on any of the medium's CPIC *transmit* ports, the signals delivered to all of the medium's CPIC *receive* ports, shall comply with the specifications of 16.7.6 and 16.7.6.1 for ports designated as *moderate sensitivity* or with 16.7.6 and 16.7.6.2 for ports designated as *high sensitivity*.

**17.5.3 Data Signaling Rate.** The media must present the data signaling rate with a tolerance of  $\pm 0.015\%$  at all of the medium's CPIC *receive* ports when presented with a data signaling rate with a tolerance of  $\pm 0.015\%$  on any of the medium's CPIC *transmit* ports.

**17.5.4 Noise and Reflections.** The power of extraneous optical energy in the receiver sensitivity band present at the interface to the medium shall not exceed -60 dBm averaged over one PHY-symbol time, when the fiber connectors are fully seated.

The reflections present at the receive port of any moderate sensitivity CPIC shall be less than -42 dBm power averaged over one PHY-symbol time. The reflections present at the receive port of any high sensitivity CPIC shall be less than -52 dBm power averaged over one PHY-symbol time.

**17.5.5 Compatibility with the Stations.** An embodiment of a single channel fiber optic broadcast medium entity is deemed to support a specific LAN if the requirements of 17.5.1 through 17.5.4 are met when measured from each CPIC, independent of which CPIC is chosen for test signal origination.

**17.5.6 Path Loss.** A path loss between 4 dB and 20 dB is required from the transmit port of any CPIC to the receive port of any moderate sensitivity CPIC. A path loss between 14 dB and 30 dB is required from the transmit port of any CPIC to the receive port of any high sensitivity CPIC. In accordance with the definition of launch power, losses due to the connector at the receive port of the CPIC shall be included in the path loss and losses at the transmit port shall be excluded.

**17.5.7 Signal Distortion.** When a signal complying with 16.7.3.3 is imposed on any of the medium's CPIC transmit ports, signals complying with 16.7.6 shall be received on all of the medium's CPIC receive ports. The transmit ports of active media elements shall comply with 16.7.3.3.

**17.5.8 Jitter.** The medium itself, consisting of fiber optic waveguides, connectors, and splitter/combiners, when it is presented with signals transmitted in accordance with Section 16, shall deliver signals at all receiving CPICs with total jitter less than  $\pm 10\%$  of the PHY-symbol\_time.

**17.5.9 Signal Conveyance.** The medium shall convey each transmitted PHY-symbol, including the first PHY-symbol of each transmission, to all receive ports when it is presented with signals transmitted in accordance with Section 16. Where active elements exist in the medium, detected errors should be flagged by octet-aligned abort sequences, as described in Section 4.

**17.5.10 Redundancy Considerations.** Where redundant media are employed, the provisions of 17.5.1 to 17.5.7 shall apply separately to each single nonredundant medium interface.

**17.5.11 Reliability.** All medium equipment shall be designed so that the aggregate probability of that equipment causing a communication failure at any station connected to the medium is less than  $10^{-6}$  per hour of operation.

**17.6 Safety Requirements.** All media meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [8]. The recommendations of IEC Publication 825 (1984) [6] shall be adhered to in determining the optical source safety and user warning requirements.

**17.7 Transmission\_path\_delay Considerations.** When specifying an embodiment of a medium that conforms to the specification of this section, a vendor shall state the transmission\_path\_delay as the maximum one-way delay that the fiber optic broadcast medium could be expected to induce on a transmission from the CPIC of any connected station through the medium and any intervening fiber optic regenerative repeaters to the CPIC of any other station. The delays induced by the transmitting and receiving stations themselves should not be included in the transmission\_path\_delay.

For each potentially worst-case path through the medium, a path delay is computed as the sum of the medium-induced delay and repeater-induced delay, if any, in propagating a signal from one station to another. The transmission\_path\_delay used for determining the network's slot time (see 6.1.9) shall be the largest of these path delays for the cable system.

These path delays shall take into account all optical and electronic circuitry delays in all relevant fiber optic regenerative repeaters, combiner/splitters, etc., and all signal propagation delays within the cable segments up to the CPICs.

The transmission\_path\_delay shall be expressed in terms of the network's symbol signaling rate on the medium. When not an integral number of signaled symbols, it shall be rounded up to such an integral number. When uncertain of the exact value of the delay, vendors shall state an upper bound for the value.

**17.8 Documentation.** It is recommended that each vendor of an embodiment of a medium conformant to this standard provide to the user supporting documentation with at least these parameters:

- (1) Specific sections of the standard to which the embodiment conforms,
- (2) Transmission\_path\_delay introduced on a one way transmission exchange between CPIC's as specified in 6.1.9 and 17.7, and
- (3) CPIC keyed as *high sensitivity* using key B or *moderate sensitivity* using key A.

Additionally, when the cable plant has multiple connectors, the role of each such connector shall be designated clearly by marking the station and cable plant in the vicinity of these connectors.

## Appendix

(This Appendix is a binding part of IEEE Std 802.4-1990; it is not a part of this International Standard.<sup>17</sup>)

**17.9 Appendix—Alternative Fiber Optic Medium.** This appendix defines parameters values for claiming conformance to the alternative test fiber. These values are specified in Table 17-1.

**Table 17-1**  
**Alternate Test Fiber Parameter Values**

Parameter	As Specified in Subsection	As Specified for Alternate Test Fiber
Fiber		
Core diameter	16.7.1	50 $\mu\text{m}$
Cladding diameter	16.7.1	125 $\mu\text{m}$
Numerical aperture	16.7.1	0.21
Moderate sensitivity CPIC Allowable reflection level	17.5.4	-45 dBm
High sensitivity receiver Allowable reflection level	17.5.4	-55 dBm

<sup>17</sup>Although a strong attempt was made to align IEEE and ISO/IEC versions of this Standard, the version approved by the IEEE Standards Board included this Appendix as a normative Appendix. Therefore, this Appendix is now under consideration by IEEE as an informative Appendix.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

**17.10 Appendix—Comparison of Parameter Values of Standard and Alternative Fiber Optic Medium.** This appendix tabulates the parameters values for the standard test fiber and the alternative test fiber.

The parameter values are reproduced in Table 17-2 for clarity only; the values that appear in 16.7 and 17.5 or Table 17-1 take precedence.

**Table 17-2**  
**Parameter Values for Standard and Alternate Test Fiber**

Parameter	As Specified in Subsection	As Specified for Standard Test Fiber	As Specified for Alternate Test Fiber
Fiber			
Core diameter	16.7.1	62.5 $\mu\text{m}$	50 $\mu\text{m}$
Cladding diameter	16.7.1	125 $\mu\text{m}$	125 $\mu\text{m}$
Numerical aperture	16.7.1	0.275	0.21
Moderate sensitivity CPIC Allowable reflection level	17.5.4	−42 dBm	−45 dBm
High sensitivity CPIC Allowable reflection level	17.5.4	−52 dBm	−55 dBm

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

**17.11 Appendix—Network Size and Configuration.** This appendix illustrates some of the network topologies that can be constructed compliant to this section. This appendix does not imply that these are the only topologies possible.

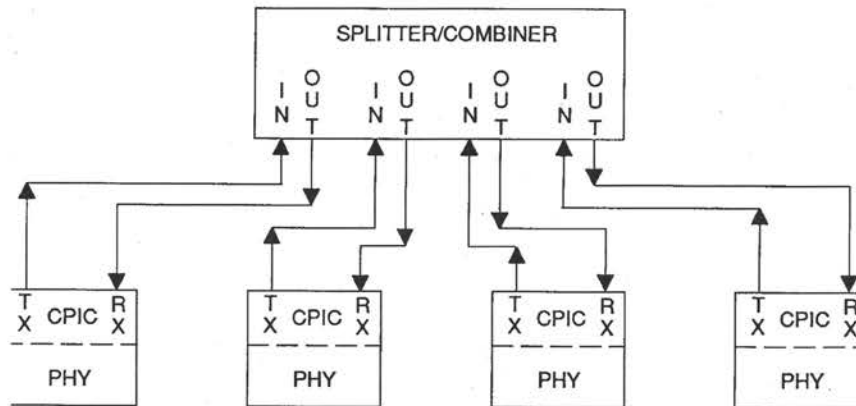
**17.11.1 Network Topology.** The physical size of a network, both in geographic length and the number of desired stations, will have a significant impact on the choice of network topology. When a limited number of stations (five to ten, for instance) are required, almost any topology can be utilized. Figure 17-4 illustrates a possible topology that meets the requirement of 17.4.1.1. For situations that require a large number of stations located in widely separated geographic locations, a multi-tiered topology may be required. Topologies of this type may grow to very large numbers of stations.

In applying any of these topologies, it is the responsibility of the network designer to assure that the overall system rise time, jitter, and signal power levels are maintained and that the requirements given in 17.4.1.1 are met. Practical networks are possible using fibers that range in size from 100/140 to 50/125  $\mu\text{m}$  (for example, see 17.9).

**17.11.2 Loss Budgets for Passive Star Topologies.** The following are two examples of loss budgets for passive star topologies. A maximum radius of 500 meters is used.

In either configuration, if the radius is increased to 1 km, an extra 3.5 dB for attenuation and 0.5 dB for dispersion should be added.

**Fig 17-4**  
**Star Topology**



**Table 17-3**  
**Passive Star Power Loss Budget**

	8-Port Passive Star	32-Port Passive Star
Receiver sensitivity	moderate	high
Fiber attenuation	3.5 dB	3.5 dB
Fiber dispersion	0.5 dB	0.5 dB
Connectors	2.0 dB	2.0 dB
Star coupler	11.0 dB	19.0 dB
System margin	3.0 dB	3.0 dB
<b>Total</b>	<b>20.0 dB</b>	<b>28.0 dB</b>

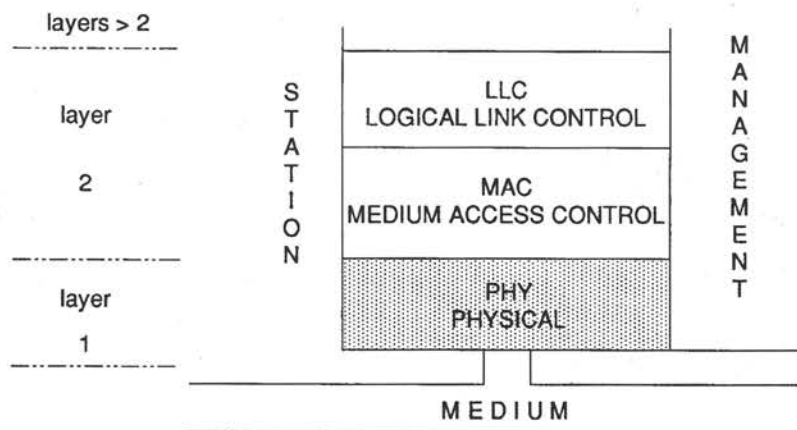
### 18. Single-Channel Phase-Continuous-FSK Bus Physical Layer Entity (PLE)

The functional, electrical, and mechanical characteristics of one specific form of PLE (single-channel phase-continuous-FSK bus) of this standard are specified in this section. This specification includes the PLE embodiments found in stations that could attach to the single-channel phase-continuous-FSK bus Local Area Network (LAN). The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 18-1. The relationship of this section to the single-channel phase-continuous-FSK bus PLE and medium is illustrated in Fig 18-2.

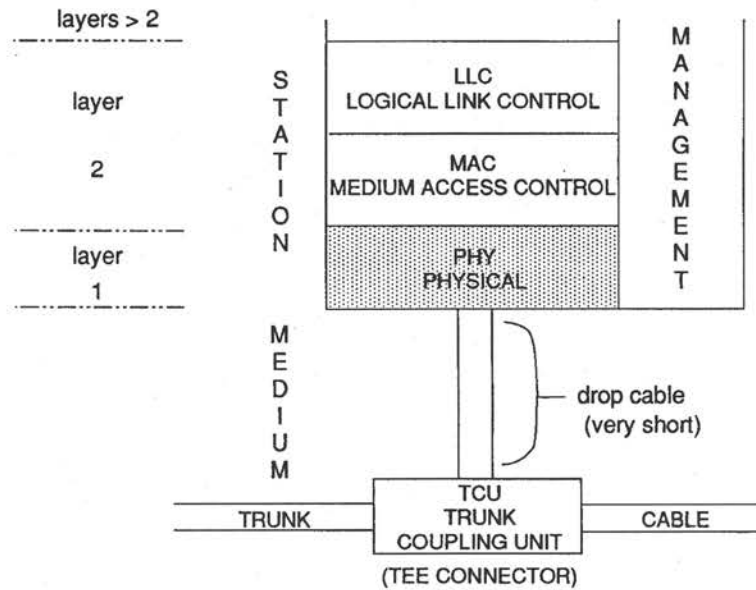
This standard specifies these PLEs only insofar as necessary to ensure

- (1) The interoperability of implementations conforming to this specification, and
- (2) The protection of the LAN and those using it.

**Fig 18-1**  
**Relation to LAN Model**







**Fig 18-2**  
**Physical Hardware Partitioning**

**18.1 Nomenclature.** Some terms used in this section whose meanings within the section are more specific than indicated by glossaries referred to in 1.2 are as follows:

**detected bit error.** An error that is reported as *bad\_signal*. *Bad\_signal* reported during the preamble or during the four symbols following the last end delimiter of a transmission is not included.

**drop cable.** The very short 34–53  $\Omega$  stub cable that connects the station to a tee connector on the trunk cable.

**frequency shift keying (FSK).** A modulation technique whereby information is impressed upon a carrier by shifting the frequency of the transmitted signal to one of a small set of frequencies.

**Manchester encoding.** A means by which separate data and clock signals can be combined into a single, self-synchronizable data stream, suitable for transmission on a serial channel.

**phase-continuous FSK.** A particular form of FSK where the translations between signaling frequencies are accomplished by a continuous change of fre-

quency (as opposed to the discontinuous replacement of one frequency by another, such as might be accomplished by a switch). Thus, it is also a form of frequency modulation.

**regenerative repeater.** A device used to extend the length, topology, or interconnectivity of a LAN beyond that imposed by the minimum transmit and receive level specifications of the station and the connectivity restrictions of the medium. Regenerative repeaters perform the basic actions of restoring signal amplitude, waveform, and timing. They also prefix enough *pad\_idle* symbols to a transmission to compensate for any symbols lost in transmission from the prior station or repeater.

**single-channel FSK coaxial system.** A system whereby information is encoded, frequency modulated onto a carrier, and impressed on the coaxial transmission medium. At any point on the medium, only one information signal at a time can be present within the channel without disruption.

**trunk cable.** The main 75  $\Omega$  coaxial cable of a single-channel phase-continuous FSK coaxial cable system.

**undetected bit error.** An error that is not reported as *bad\_signal* by the PLE.

**18.2 Object.** The object of this specification is to

- (1) Provide the physical means necessary for communication between local network stations employing the LAN token-passing bus access method described in this standard and a single-channel phase-continuous-FSK bus medium.
- (2) Define a physical interface that can be implemented independently among different manufacturers of hardware and achieve the intended level of compatibility when interconnected to a common single-channel phase-continuous-FSK bus LAN medium.
- (3) Provide a communication channel capable of high bandwidth and low bit error rate performance. The resultant mean bit error rate at the MAC service interface (see Section 8) shall be less than  $10^{-8}$ , with a mean undetected bit error rate of less than  $10^{-9}$  at that interface.
- (4) Provide for ease of installation and service in a wide range of environments.
- (5) Provide for high network availability.
- (6) Facilitate low-cost and low-data-rate implementations.

**18.3 Compatibility Considerations.** This standard applies to PLEs that are designed to operate on a 75  $\Omega$  coaxial trunk cable with the approximate configuration of an unbranched trunk, as specified in Section 19. All single-channel phase-continuous-FSK bus coaxial cable systems shall be compatible at the (drop cable) medium interface. Specific implementations based on this standard may be conceived in different ways provided compatibility at the medium is maintained.

**18.4 Medium Overview.** The communications medium specified in Section 19 consists of a long unbranched trunk cable that connects to stations by way of tee connectors and very short stubbed drop cables. Extension of the topology to a branched trunk usually is accomplished by way of active regenerative repeaters that are connected to span the branches.

### 18.5 Physical Layer Overview

**18.5.1 General Description of Functions.** The functions performed by the single-channel phase-continuous-FSK bus PLE are described informally here. Jointly, these functions provide a means whereby symbols presented at the MAC interface of one PLE can be conveyed to all of the PLEs on the bus for presentation to their respective MAC interfaces.

**18.5.1.1 Symbol Transmission and Reception Functions.** Successive symbols presented to the PLE at its MAC service interface are applied to an encoder that produces as output a pair of PHY-symbol code from the set  $\{H\}$ ,  $\{L\}$ ,  $\{off\}$ . The output is then applied to a two-tone FSK modulator which represents each  $\{H\}$  as the higher frequency tone, each  $\{L\}$  as the lower frequency tone, and each  $\{off\}$  as no tone. This modulated signal is then ac-coupled to the single-channel bus medium and conveyed by the medium to one or more receivers.

Each receiver is also ac-coupled to the single-channel bus medium. It bandpass filters the received signal to reduce received noise, demodulates the filtered signal, and then infers the transmitted PHY-symbol from the presence of carrier and the frequency of the received signal. It then decodes that inferred PHY-symbol by an approximate inverse of the encoding process and presents the resultant decoded MAC-symbols at its MAC service interface.

For all MAC-symbols except *pad\_idle*, this decoding process is an exact inverse of the encoding process in the absence of errors. The *pad\_idle* symbols, which are referred to collectively as *preamble*, are transmitted at the start of each MAC frame, to provide a training signal for receivers and to provide a nonzero minimum separation between consecutive frames. Since each transmission begins with *pad\_idle* symbols, it is expected that some of these initial symbols may be "lost in transit" between the transmitter and receivers. Additionally, in phase-continuous-FSK systems, the MAC-symbol encodings for successive *pad\_idles* are identical with the encoding for an alternating series of *ones* and *zeros*, and receivers are permitted to decode the transmitted representation of successive *pad\_idles* as an alternating series of *ones* and *zeros* and report it as such to the MAC entity.

**18.5.1.2 Regenerative Repeater Functions.** Regenerative repeaters may be used to extend the network size beyond the maximum signal loss budget of an unassisted station, or the topology to that of a branched trunk. They do so by connecting two or more medium segments and repeating anything "heard" on one segment to the other segments. For the purposes of this standard, regenerative repeaters are considered stations, whether or not they have functionality beyond that of a repeater.

**18.5.1.3 Jabber-Inhibit Function.** To protect the LAN from most faults in a station, each station contains a jabber-inhibit function. This function serves as

a "watchdog" on the transmitter; if the station does not turn off its transmitter after a prolonged time (roughly one-half second), then the transmitter output shall be automatically disabled for at least the remainder of the transmission.

**18.5.1.4 Local Administrative Functions (OPTIONAL).** These functions are activated either manually, or by way of the PLE's management interface, or both. They can include

- (1) Enabling or disabling each transmitter output. (A redundant medium configuration has two or more transmitter outputs.)
- (2) Selecting the received signal source: any single medium (if redundant media are present) or any available loopback point.

NOTE: If a loopback point is selected, then all transmitter outputs shall be inhibited.

**18.5.2 Basic Functions and Options.** Symbol transmission and reception functions and jabber-inhibit functions are required in all implementations. All other functions are optional.

**18.6 Application of Management.** The following constraints are imposed on the parameters and actions specified in Section 9:

- (1) In the capabilities group, the dataRates parameter sequence shall specify the value 1.
- (2) In the local management information the value of minPostSilencePreamble Length shall be 1.

**18.7 Functional, Electrical, and Mechanical Specifications.** Unless otherwise stated, all voltage and power levels specified are in rms and dB (1 mV, 37.5  $\Omega$ ) rms, respectively, based on transmissions of arbitrary data patterns.

**18.7.1 Data Signaling Rates.** The standard data signaling rate for phase-continuous-FSK systems is 1 Mb/s. The permitted tolerance for this signaling rate is  $\pm 0.01\%$  for an originating station, and is  $\pm 0.015\%$  for a repeater station while repeating. When a composite PLE is embodied in a regenerative repeater, it shall originate signaling on all trunks at the exact same data rate.

**18.7.2 Symbol Encoding.** The PLE transmits MAC-symbols presented to it at its MAC interface by the MAC sublayer entity. The possible MAC-symbols are (see 8.2.1.2) *zero*, *one*, *non\_data*, *pad\_idle*, and *silence*. Each of these MAC-symbols is Manchester encoded into a pair of PHY-symbols from a different three-symbol {*H*}, {*L*}, {*off*} code and then transmitted. The encoding action to be taken for each of the input MAC-symbols is:

- (1) *Silence*—Each *silence* symbol shall be encoded as the sequence {*off off*}.
- (2) *Pad\_idle*—*Pad\_idle* symbols are always originated in octets. Each pair of consecutive *pad\_idle* symbols shall be encoded as the sequence {*L H*} {*H L*}.
- (3) *Zero*—Each *zero* symbol shall be encoded as the sequence {*H L*}.
- (4) *One*—Each *one* symbol shall be encoded as the sequence {*L H*}.
- (5) *Non\_data*—*Non\_data* symbols are transmitted by the MAC sublayer entity in pairs. Each such pair of consecutive *non\_data* symbols shall be encoded as the sequence {*L L*} {*H H*} when the immediately preceding

PHY-symbol is an  $\{L\}$  and shall be encoded as the sequence  $\{H H\} \{L L\}$  when the immediately preceding PHY-symbol is an  $\{H\}$ . Thus, the (start delimiter) subsequence

*non\_data non\_data zero non\_data non\_data zero*

shall be encoded as the subsequence

$\{L L\} \{H H\} \{H L\} \{L L\} \{H H\} \{H L\}$

and the (end delimiter) subsequence

*non\_data non\_data one non\_data non\_data one*

shall be encoded as the subsequence

$\{L L\} \{H H\} \{L H\} \{H H\} \{L L\} \{L H\}$

after an immediately preceding  $\{L\}$ , and as the subsequence

$\{H H\} \{L L\} \{L H\} \{H H\} \{L L\} \{L H\}$

after an immediately preceding  $\{H\}$ .

**18.7.3 Modulated Line Signal (at the line output of the station).** The PHY-symbols resulting from the encoding of 18.7.2 shall be applied to an FSK modulator with the result that each  $\{H\}$  shall be represented by the higher of the modulator's two signaling frequencies, each  $\{L\}$  shall be represented by the lower of the modulator's two signaling frequencies, and each  $\{off\}$  shall be represented by the absence of both carrier and modulation. The resultant modulated carrier shall be coupled to the single-channel bus medium as specified in 18.7.5.

**18.7.3.1** The line signal shall correspond to an FSK signal with its carrier frequency at 5.00 MHz, varying smoothly between the two signaling frequencies of  $3.75 \text{ MHz} \pm 80 \text{ kHz}$  and  $6.25 \text{ MHz} \pm 80 \text{ kHz}$ .

**18.7.3.2** Each of the PHY-symbols resulting from the encoding of 18.7.2 shall be transmitted for a period equal to one-half of the inter-arrival time of the MAC-symbols which the MAC entity presents at the MAC interface. The maximum jitter in this periodicity shall be less than 1% of that MAC-symbol inter-arrival time.

**18.7.3.3** When transitioning between the two signaling frequencies, the FSK modulator shall change its frequency in a continuous and monotonic manner within 100 ns, with amplitude distortion of at most 10%.

**18.7.3.4** The output level of the transmitted signal at the modulated carrier frequency into a  $37.5 \Omega$  resistive load shall be between +54 dB and +60 dB (1 mV,  $37.5 \Omega$ ).

NOTE: The signal level on the cable due to a single transmitter is propagated along the very short (stub) drop cable to a tee connector and thence along the trunk cable in two directions. Thus, the two half sections of the  $75 \Omega$  trunk cable appear as a  $37.5 \Omega$  load to the transmitting entity.

**18.7.3.5** When in the transmitter-off state (that is, while "transmitting" the PHY-code  $\{off\}$ ), the station shall present a dc shunt impedance of  $50 \text{ k}\Omega$  or more at its medium interface. When in the transmitter-on state (that is, while trans-

mitting the PHY-codes {*H*} and {*L*}), the station shall function as a voltage source with an impedance of 38  $\Omega$  or less at its medium interface. In either state, the station shall present a maximum shunt capacitance of 25 pF at that medium interface.

**18.7.3.6** The residual or leakage transmitter-off output signal (that is, while “transmitting” the PHY-code {*off*}) shall be no more than -26 dB (1 mV, 37.5  $\Omega$ ).

**18.7.4 Jabber-Inhibit.** Each PLE shall have a self-interrupt capability to inhibit modulation from reaching the LAN medium. Hardware within the PLE (with no external message other than the prolonged detection of an output-on condition within the transmitter) shall provide a nominal window of one-half second  $\pm 25\%$  during which time a normal data link transmission may occur. If a transmission is in excess of this duration, the jabber-inhibit function shall operate to inhibit any further output from reaching the medium. Reset of this jabber-inhibit function is implementation-dependent.

**18.7.5 Coupling to the Medium.** The Physical Layer functions are intended to operate satisfactorily with a medium consisting of a 75  $\Omega$  bidirectional coaxial trunk cable, tee connectors, and short stubbed 34–53  $\Omega$  drop cables. The mechanical coupling of the station to the medium shall be to the 34–53  $\Omega$  drop cable by way of a 50  $\Omega$  male BNC-series connector, as specified in Section 19 and defined in IEC Publication 169-8 (1978) [4].

Both the transmitter and the receiver shall be ac-coupled to the center conductor of one of the medium’s drop cables, and the breakdown voltage of that ac coupling means shall be at least 500 V ac rms at 50/60 Hz. In addition to this coupling, the shield of the coaxial cable medium shall be connected to chassis ground, and the impedance of that connection shall be less than 0.1  $\Omega$ .

**18.7.6 Receiver Sensitivity and Selectivity.** The PLE shall be capable of providing an undetected bit error rate of  $10^{-9}$  or lower, and a detected bit error rate of  $10^{-8}$  or lower, when receiving signals with a level of +24 to +60 dB (1 mV, 37.5  $\Omega$ ), in a system with an in-band noise floor of +4 dB (1 mV, 37.5  $\Omega$ ) or less, as measured at the point of connection to the station.

**18.7.7 Symbol Timing.** During the recovery of *pad\_idle* and *silence* symbols, it is permissible to vary the MAC-symbol reporting period by up to one nominal MAC-symbol\_time. The time of each reported MAC-symbol shall nonetheless be within 90–210% of the nominal MAC-symbol\_time under all conditions. Further, the time of each reported MAC-symbol after *pad\_idle* symbol recovery and until either *silence* or *bad\_signal* is reported, shall be within 90–110% of the nominal MAC-symbol time.

**18.7.8 Symbol Decoding.** After demodulation and determination of each received signaled PHY-symbol, that PHY-symbol shall be decoded by the process inverse to that described in 18.7.2, and the decoded MAC-symbols shall be reported at the MAC interface. (As noted in 18.5.1.1, receivers are permitted to decode the transmitted representation of *pad\_idle* as *zero* or *one*.) Whenever a signaled PHY-symbol sequence is received for which the encoding process has no inverse, those PHY-symbols shall be decoded as an appropriate number of *bad\_signal* MAC-symbols and reported as such at the MAC interface. In such cases,

the receiving entity should resynchronize the decoding process as rapidly as possible.

**18.7.9 Transmitter Enable/Disable and Received Signal Source Selection (OPTIONAL).** The ability to enable and disable the transmission of modulation onto the single-channel bus medium as directed by the management entity is recommended but optional.

The ability to select the source of received signaling, either a loopback point within the PLE or (one of) the (possibly redundant) media, as directed by the management entity, is recommended but optional. When such an option is invoked and the selected source is other than one of the media, transmission to all connected bus media shall be disabled automatically while such selection is in force.

**18.7.10 Redundant Media Considerations.** Embodiments of this standard that can function with redundant media are not precluded, provided that the embodiment, as delivered, functions correctly in a nonredundant single-cable environment. Where redundant media are employed, the provisions of 18.7.4 and 18.7.9 shall apply separately and independently to each single medium interface, and much of 18.7.9 shall be mandatory. Specifically, separate jabber-inhibit monitoring shall exist for each medium (although common inhibition is permissible), receiver signal source selection shall be provided capable of selecting any one of the redundant media, and it shall be possible to enable or disable each single transmitter independently of all other redundant transmitters when the source of received signaling is one of the redundant media.

**18.7.11 Reliability.** The PLE shall be designed so that its probability of causing a communication failure among other stations connected to the medium is less than  $10^{-6}$  per hour of continuous (or discontinuous) operation. For regenerative repeaters this requirement is relaxed to a probability of  $10^{-5}$  per hour of operation. Connectors and other passive components comprising the means of connecting the station to the coaxial cable medium shall be designed to minimize the probability of total network failure.

**18.7.12 Regenerative Repeater Considerations.** The PLE of a regenerative repeater can be considered to be a composite entity, with separate electrical and mechanical low-level transmit and receive functions for each connected trunk segment (that is, each port), all under a common encoding, decoding, timing-recovery and control function.

The basic mode of operation, originating or repeating, shall be determined by the superior MAC entity and conveyed by the PHY-MODE invoke primitive (see 8.2.3). When originating, the repeater PLE shall originate the symbol timing provided to the MAC entity and transmit the encoded MAC-symbols onto all connected trunk segments. It shall use either internal loopback or any one of the attached trunks as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When switching to repeating, the repeater PLE shall delay for an implementation-dependent amount of time (typically, a few symbol-durations) to prevent repeating the end of the just-prior transmission, and shall then scan the connected ports for one on which signaling is being received. During the delay



period, and while this scan for signal is unsuccessful, the repeater PLE shall indicate *silence* symbols to its MAC entity using its locally originated symbol timing. Upon detecting signaling at one or more ports, the repeater entity shall select one of those active ports as the source of its received signaling. It shall then temporarily disable that selected port's low-level transmitter function, decode the received signaling, and indicate the decoded MAC-symbols to its associated MAC entity. It should then vary the frequency of the MAC-symbol timing, within the bounds of this subsection (18.7), as necessary to maintain the proper relationship with the frequency of the received PHY-symbol timing.

When repeating, after decoding the MAC-symbol *silence* received from the active port, the repeater PLE shall await the MAC-entity's transmission of *silence* by way of a PHY-DATA request, shall then re-enable the temporarily disabled low-level transmitter function, and shall then again follow the procedure outlined in the prior paragraph just as if the MAC entity had just switched to repeating.

In summary, when the MAC entity is originating

- (1) The PLE alone shall determine the MAC-symbol timing,
- (2) Transmission occurs on all attached trunks (unless disabled by the provisions of 18.7.9),
- (3) Loopback or any one of the attached trunks shall be used as the source of PHY-symbols that are decoded and reported by way of the PHY-DATA indicate primitive.

When the MAC entity is repeating

- (a) The PLE first delays long enough to ensure that the prior transmission is not repeated, then scans all attached trunks for signaling and selects one of those trunks with signaling as the source of received signaling,
- (b) Transmission to the selected trunk is temporarily inhibited,
- (c) The received signaling from the selected trunk is decoded and indicated to the MAC entity,
- (d) The frequency of MAC-symbol timing is varied as necessary (at most  $\pm 0.015\%$ ) to track the frequency of the peer transmitter's MAC-symbol timing,
- (e) Upon detecting a loss of signaling (that is, receiving *silence*) from the selected trunk, the PLE first waits until the MAC entity requests transmission of *silence*, and then repeats the whole procedure.

## 18.8 Environmental Specifications

**18.8.1 Electromagnetic Emanation.** Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**18.8.2 Safety Requirements.** All stations meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [7].



**18.8.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The PLE embodiment 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.

**18.9 Labeling.** It is recommended that each embodiment (and supporting documentation) of a PLE conformant to this standard be labeled in a manner visible to the user with at least these parameters:

- (1) Data rate capability in Mb/s (that is, 1 Mb/s).
- (2) Worst-case round-trip delay (for nonrepeaters) or one-way delay (for repeaters) that this equipment induces on a two-way transmission exchange between stations, as specified in 6.1.9.
- (3) Operating modes and selection capabilities as defined in 18.7.9 and 18.7.10.

Additionally, when the station has multiple BNC-series connectors (for example, for redundant media), the role of each such connector shall be designated clearly by markings on the station in the vicinity of that connector.

### 19. Single-Channel Phase-Continuous-FSK Bus Medium

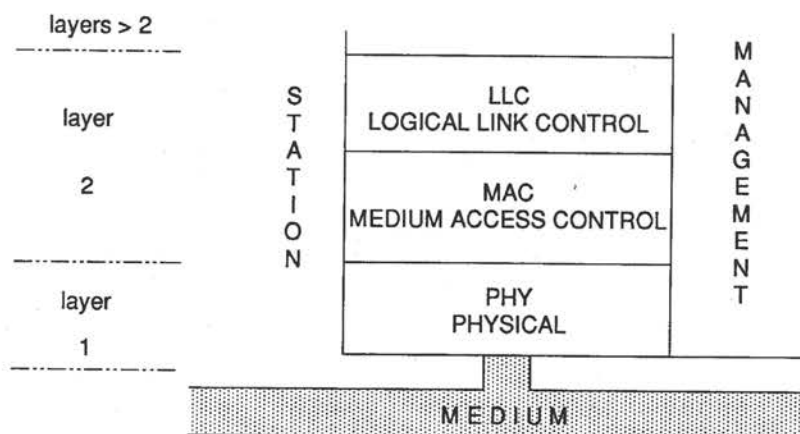
The functional, electrical, and mechanical characteristics of one specific form of medium (single-channel phase-continuous-FSK bus) of this standard are specified in this section. This specification includes the medium embodiments of a single-channel phase-continuous-FSK bus Local Area Network (LAN).

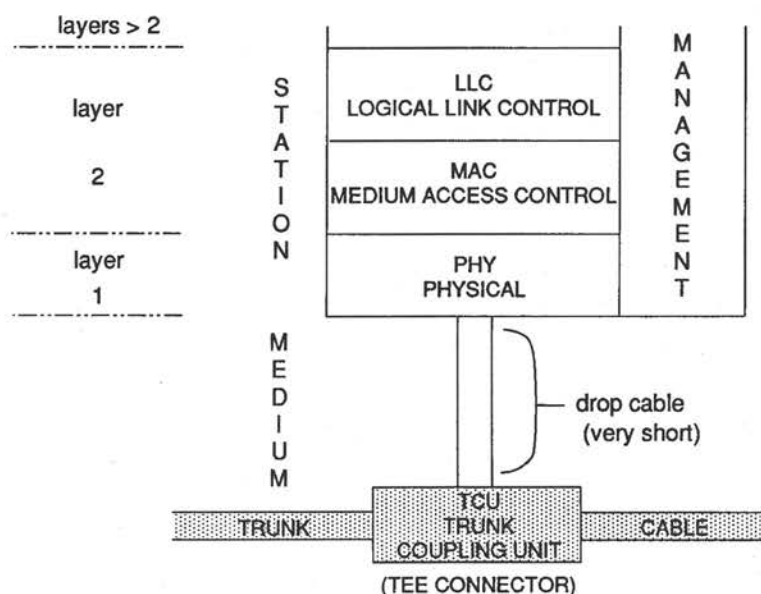
The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 19-1. The relationship of this section to the single-channel phase-continuous-FSK bus PLE and medium is illustrated in Fig 19-2.

This standard specifies the medium only in so far as necessary to ensure

- (1) The interoperability of PLEs conforming to Section 18 when connected to a medium conformant to this section, and
- (2) The protection of the LAN and those using it.

**Fig 19-1**  
**Relation to LAN Model**





**Fig 19-2**  
**Physical Hardware Partitioning**

**19.1 Nomenclature.** Terms used in this section whose meanings within the section are more specific than indicated glossaries referred to in 1.2 are as follows:

**BNC-connector.** A 50  $\Omega$  BNC-series coaxial cable connector (of the kind commonly found on RF equipment), as defined by IEC Publication 169-8 (1978) [4].

**detected bit error.** An error that is reported as *bad\_signal*. *Bad\_signal* reported during the preamble or during the four symbols following the last end delimiter of a transmission is not included.

**drop cable.** The very short 34–53  $\Omega$  stub coaxial cable that connects the station to a tee connector on the trunk cable.

**frequency shift keying (FSK).** A modulation technique whereby information is impressed upon a carrier by shifting the frequency of the transmitted signal to one of a small set of frequencies.

**phase-continuous FSK.** A particular form of FSK where the translations between signaling frequencies are accomplished by a continuous change of frequency (as opposed to the discontinuous replacement of one frequency by another, such as might be accomplished by a switch).

**regenerative repeater.** A device used to extend the length, topology, or interconnectivity of a single-channel bus LAN beyond the limits imposed by the minimum transmit and receive level specifications of the station. Regenerative repeaters perform the basic actions of restoring signal amplitude, waveform, and timing. They also prefix enough *pad\_idle* symbols to a transmission to compensate for any symbols lost in transmission from the prior station or repeater.

**(impedance-matching) splitter.** A small module that electrically and mechanically couples one trunk cable to other trunk cables, providing a branching topology for the single-channel FSK trunk. An impedance-matching splitter combines signal energy received at its ports, splitting any signal energy received from a trunk symmetrically among the other trunks. It contains only passive electrical components (R, L, C).

**single-channel FSK coaxial system.** A system whereby information is encoded, frequency modulated onto a carrier, and impressed on the coaxial transmission medium. At any point on the medium, only one information signal at a time can be present within the channel without disruption.

**tee connector.** A small module, usually a T-shaped connector, that electrically and mechanically couples the trunk cable to a very short drop cable.

**trunk cable.** The main cable of a single-channel phase-continuous-FSK bus coaxial cable system.

**undetected bit error.** An error that is not reported as such by the PLE.

**19.2 Object.** The object of this specification is to

- (1) Provide the physical medium necessary for communication between local network stations employing the LAN token-passing bus access method defined in this standard and a single-channel phase-continuous-FSK bus PLE,
- (2) Provide for ease of installation and service in a wide range of environments,
- (3) Provide for high network availability,
- (4) Facilitate low-cost implementations.

**19.3 Compatibility Considerations.** This standard applies to medium entities that are designed to operate as nondirectional single-channel coaxial cable bus systems. Such systems generally use a long flexible trunk cable connected by way of tee connectors to very short (stubbed) drop cables to stations. This specification applies to a single trunk system in which two-way alternate communication is accomplished through the use of nondirectional tee connectors and splitters and, in large systems, multidirectional regenerative repeaters.

All implementations of medium entities conformant to this standard shall be compatible at their station interfaces. Specific implementations based on this standard may be conceived in different ways provided compatibility at the actual station interfaces is maintained.

## 19.4 General Overview

**19.4.1 General Description of Functions.** The functions performed by the single-channel phase-continuous-FSK bus medium are described informally here. Jointly, these functions provide a means whereby signaling presented at the station interfaces of very short 34–53  $\Omega$  drop cables can be combined and conveyed to all of the stations on all of the medium's drop cables. Thus stations connected to these drop cables can communicate.

**19.4.1.1 Operational Overview of the Single-Channel Phase-Continuous-FSK Bus Medium.** Stations are connected to the long *trunk* coaxial cable(s) of single-channel phase-continuous-FSK bus systems by very short *drop* cables and *tee connectors* (which do not impedance-match the drop cable to the trunk). These tee connectors are passive devices, usually simple connectors, which are nondirectional (that is, omnidirectional) with regard to signal propagation. The nondirectional characteristics of the tee connectors permit the station's signal to propagate in both directions along the trunk cable. The very short length of the drop cables minimizes the effect of the reflections on the drop cable due to the impedance mismatch between the 34–53  $\Omega$  drop cable and the 37.5  $\Omega$  apparent impedance of the bidirectional trunk cable.

The topology of the single-channel phase-continuous-FSK bus system is that of a very long unbranched tree trunk, with the stations connected as leaves to the very short stubs (drop cables) extending from the trunk. Branching is accomplished in the trunk itself by way of *regenerative repeaters* (described below) and *splitters*, which provide nondirectional coupling of the signaling carried on the trunk cables. The splitters employ only passive electrical components (R, L, C, only).

Regenerative repeaters provide both branching and the ability to extend a system topology beyond that permitted by the minimum transmit and receive level specifications of an unassisted station. The regenerative repeaters of the single-channel phase-continuous-FSK bus system are connected to trunk cables by tee connectors and drop cables and function as specialized stations that normally repeat signaling received on any branch to all other branches of the trunk cable system.

**19.4.1.2 Regenerative Repeater Functions.** In an actual single-channel phase-continuous-FSK bus system, regenerative repeaters may be used to connect trunk segments into a highly branched topology, or to extend the length of, or number of tee connectors and drops on, a trunk beyond that which the unassisted station's minimum transmit and receive level specifications would allow. Regenerative repeaters are discussed in detail in 18.7.12.

**19.4.2 Basic Characteristics and Options.** All signal-conveyance characteristics and station-interface characteristics are mandatory. All other characteristics are optional.

**19.5 Functional, Electrical, and Mechanical Specifications.** The single-channel phase-continuous-FSK bus medium entity is an entity whose sole function (relative to this standard) is signal transport between the stations of a single-channel phase-continuous-FSK bus LAN. Consequently, only those char-

acteristics of the medium that impinge on station-to-station signal transport, or on human and equipment safety, are specified in this standard.

An implementation of the medium shall be deemed conformant to this standard if it provides the specified signal transport services and characteristics for the stations of a single-channel phase-continuous-FSK bus LAN, and if it meets the relevant safety and environmental codes.

All measurements specified in the following paragraphs are to be made at the point of station or regenerative repeater connection to the medium. Unless otherwise stated, all voltage and power levels specified are in rms and dB (1 mV, 37.5  $\Omega$ ) rms, respectively, based on transmissions of arbitrary data patterns.

**19.5.1 Coupling to the Station.** The connection of the single-channel phase-continuous-FSK bus medium to the station shall be by way of a flexible 34–53  $\Omega$  drop cable terminated in a female BNC-series 50  $\Omega$  connector, see IEC Publication 169-8 (1978) [4]. This combination shall mate with a male BNC-series 50  $\Omega$  connector mounted on the station.

In addition to this coupling, the shield(s) of the coaxial drop cable medium shall be connected to the outer barrel of the terminating female connector and the impedance of that connection shall be less than 0.1  $\Omega$ . Also, the impedance of a connection between the outer barrel of that female connector and the shell of a mated male connector shall be less than 0.1  $\Omega$ .

NOTE: For tee-connectors that do not impedance match the drop cable to the trunk cabling, the length of the stub cable should be 350 mm or less.

**19.5.2 Characteristic Impedance.** The characteristic impedance of the single-channel phase-continuous-FSK bus drop cable medium shall be 34–53  $\Omega$ . The maximum VSWR at each of that medium's BNC-connectors shall be 1.5:1 or less when the BNC-connector is terminated with a 37.5  $\Omega$  resistive load.

The trunk cable shall be properly terminated at its ends. The maximum VSWR at each of those terminators shall be 1.5:1 or less when the trunk cable is terminated with a 75  $\Omega$  resistive load.

Characteristic impedance measurements shall be made over the entire single-channel phase-continuous-FSK bus cable spectrum of 3–7 MHz.

**19.5.3 Signal Level.** When receiving the signal of a single station or regenerative repeater whose transmit level is as specified in 18.7.3.4, the single-channel phase-continuous-FSK bus medium shall present that signaling to the connected station or regenerative repeater at an amplitude of between +24 and +60 dB (1 mV, 37.5  $\Omega$ ).

**19.5.4 Distortion.** The maximum group delay distortion shall be 25 ns or less over the frequency range of 3–7 MHz.

**19.5.5 Signal-to-Noise (S/N) Level.** It is recommended that the in-band (3–7 MHz) noise floor be 0 dB (1 mV, 37.5  $\Omega$ ) or less. In no case shall it be worse than +4 dB (1 mV, 37.5  $\Omega$ ) as measured at the point of connection to any station or regenerative repeater.

**19.5.6 Power Handling Capability.** The total power over the entire cable spectrum, as presented to the station or regenerative repeater, shall be less than 0.25 W.

**19.5.7 Compatibility with the Stations and Regenerative Repeaters.** An embodiment of a single-channel phase-continuous-FSK bus medium is deemed to support a specific single-channel phase-continuous-FSK bus LAN if the requirements of 19.5.1 through 19.5.6 (inclusive) are met when measured from each point of station connection to the medium, independent of which one of the points of station connection is chosen for test signal origination.

**19.5.8 Redundancy Considerations.** As stated in 18.7.10, redundant single-channel phase-continuous-FSK bus media are not precluded from this standard. Where redundant media are employed, the provisions of 19.5.1 to 19.5.7 shall apply separately and independently to each single nonredundant medium interface.

**19.5.9 Reliability.** All active (powered) medium equipment shall be designed so that the aggregate probability of that equipment causing a communication failure at more than one station connected to the medium is less than  $10^{-4}$  per hour of continuous (or discontinuous) operation. Connectors and other passive components comprising the means of connecting the station to the coaxial cable medium shall be designed to minimize the probability of total network failure.

## 19.6 Environmental Specifications

**19.6.1 Electromagnetic Emanation.** LAN cable systems shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [3].

**19.6.2 Safety Requirements.** All medium meeting this standard shall comply with relevant local, national, and international safety codes and standards such as IEC Publication 950 (1986) [7].

**19.6.3 Electromagnetic Environment.** Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc. Several sources of interference contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the station.

The medium embodiment shall meet its specifications when operating in an ambient cw plane wave field of

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

**19.7 Transmission\_path\_delay Considerations.** When specifying an embodiment of a medium that conforms to the specifications of this section, a vendor shall state the transmission\_path\_delay as the maximum one-way delay that the single-channel phase-continuous-FSK bus medium could be expected to induce on a transmission from any connected station through any intervening regenerative repeaters to any other station. The delays induced by the transmitting and receiving stations themselves should not be included in the transmission\_path\_delay.

For each potentially worst-case path through the medium, a path delay is computed as the sum of the medium-induced delay and repeater-induced delay, if

any, in propagating a signal from one station to another. The `transmission_path_delay` used for determining the network's `slot_time` (see 6.1.9) shall be the largest of these path delays for the cable system.

These path delay computations shall take into account all circuitry delays in all relevant regenerative repeaters and medium splitters, etc., and all signal propagation delays within the cable segments.

The `transmission_path_delay` shall be expressed in terms of the network's symbol signaling rate on the medium. When not an integral number of signaled symbols, it shall be rounded up to such an integral number. When uncertain of the exact value of the delay, vendors shall state an upper bound for the value.

**19.8 Documentation.** It is recommended that each vendor of an embodiment of a medium conformant to this standard provide to the user supporting documentation with at least these parameters:

- (1) The `transmission_path_delay`, as specified in 19.7 and 6.1.9.
- (2) Data-rate capabilities in Mb/s, where regenerative repeaters are part of the medium and so constrain the supported data rates.

### 19.9 Network Sizing

**19.9.1 Topology Considerations.** Small to medium-sized systems can be constructed using only flexible coaxial cable and tee connectors. Larger systems require both semirigid and flexible trunk cable segments, or splitters, or regenerative repeaters, or any combination of the three. Branched topologies are achieved in this medium using CATV-like splitters and regenerative repeaters.

**19.9.2 Signal Loss Budget Considerations.** The placement of phase-continuous-FSK regenerative repeaters and splitters shall take into account

- (1) Each station's minimum transmit level and receive level specifications (see 18.7.3.4 and 18.7.6).
- (2) The desired current and anticipated future placement of stations and regenerative repeaters.
- (3) The presented signal level and noise floor specifications of 19.5.

## Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

**19.10 Appendix—Guidelines for Configuring the Medium.** The following recommendations for designing and installing LANs using phase-continuous-FSK transmission are the result of practical experience, and correspond to typical field conditions that are encountered.

**19.10.1 Application.** One of the first tasks in network design is the definition of both the current application and the possible future expanded or upgraded services. In typical situations where phase-continuous-FSK at 1 Mb/s is chosen,



it is probable that planned (and unplanned) future changes will be limited to adding more drops on the existing trunk cable, and adding extensions at the ends of the cable. If the present network is small, and the possible future network is much larger, it probably will be more cost-effective, temporarily, to install a minimum network of low-cost flexible cable. Future requirements can then be based on current experience, but without any particular commitment to the current cable.

**19.10.2 Network Size.** Two important aspects of network size are overall length of the cable and total number of drops. Since phase-continuous-FSK PLEs (modems) simply bridge the cable by a relatively loss-free tee connection, the loss per drop is small. Thus, in typical practical networks the cable length is usually limited by cable attenuation rather than tap loss. The network's signal loss budget is then essentially equal to the dynamic range (difference between transmit and receive levels) specified in 18.7 (30 dB). Since cable loss increases with frequency, cable loss should be measured at 6.25 MHz, the highest frequency of interest.

Sections 18 and 19 recommend use of RG-6, RG-11, and semirigid (typical CATV trunk) types of 75  $\Omega$  cable. Many networks predating these specifications, but essentially conforming to them, are now installed and operating with cables of these types (and of various other 75  $\Omega$  cable types). Typical maximum network lengths achieved with several commercially available cables are the following:

Cable	Distance
RG-59	1280 m
RG-6	1600 m
RG-11 (foam)	2900 m
JT4412J	4600 m
JT4750J	7600 m

Although this specification includes the use of repeaters to extend the trunk cable beyond the length permitted by the loss budget, this has rarely been needed in practice, and such use may compromise the simplicity otherwise offered by the phase-continuous-FSK type of service.

The number of drops in the above networks has typically ranged from 2 to approximately 30. These numbers simply represent users' needs, not physical limitations. This specification does not constrain explicitly the maximum number of drops, nor is that number explicitly defined by cable parameters. The largest number of drops can be facilitated by minimizing the drop cable length.

**19.10.3 Network Topology.** The preferred network topology is a long unbranched trunk requiring a single trunk cable to be routed to every station site in turn. In principle, branches could be added by lossy nondirectional impedance-matching couplers, but this would usually lead to building a smaller network or requiring more expensive cable; such an approach is not recommended.

This specification does cover the use of active, regenerative repeaters for branching. Even so, the branch should be relatively long to justify its existence, and the evaluation of alternate unbranched routes is recommended first. The range of low-loss cables available makes it possible to meet most LAN needs with a completely passive medium.

**19.10.4 Drop Cables.** The maximum length of drop cables permitted for phase-continuous-FSK bus networks is 350 mm. Since it is not matched or terminated, the drop cable is an open stub much shorter than  $1/4$  wavelength, and effectively presents a shunt capacitance to the trunk cable. (The purpose of the length limitation is to limit the shunt capacitance, which causes reflections, not to limit the length per se.)

Each drop causes a small reflection on the trunk. Since the size of the reflection is proportional to the stub length, it is beneficial to keep the stub length short. Only the maximum length is specified, and the length may be zero if convenient or desirable. This minimizes reflections, and maximizes the number of drops possible in a given network.

**19.10.5 Trunk Connection.** The drop cable is usually coupled to the trunk cable through a simple tee connection. This is typically a matched  $75\ \Omega$  connector for the trunk cable used, with a suitable adapter for the drop cable.

If use of a particular tap is permanently discontinued, the tee connector should be replaced with a corresponding straight-through (barrel) type, or the stub cable should be removed from the tee connector and replaced with a standard shielding cap.

NOTE: Since each tap introduces an impedance mismatch, spacing of taps can cause signal distortion due to accumulated reflections degrading signal-to-noise of the cable system. Network designers should consider the effects of tap placement.

**19.10.6 Earthing.** The trunk cable shield may be floating, single-point, or multiple-point earthed as far as signal transmission is concerned. Earths thus may be installed to eliminate electromagnetic interference (EMI) and comply with safety codes and other regulations applicable to the particular installation. This usually means grounding where the cable enters or leaves a building, and at intervals not exceeding approximately 100 m within the building. Earths should be applied carefully by a clamp that does not crush or damage the cable, because such cable damage causes serious reflections. Suitable clamps are available from suppliers of CATV system hardware.

**19.10.7 Surge Protection.** It is good practice to protect the cable against surges due to lightning. Suitable surge protectors that meet the requirements of IEEE C37.90.1-1989 [8] should be used at each end of the cable. The capacitive loading of surge protectors should be small to avoid affecting PLE (modem) performance, and should not exceed values permitted for a standard tap. For maximum surge protection, a low impedance, heavy-duty earth connection is required.

**19.10.8 Termination.** The trunk cable should be properly terminated at both ends. Shielded  $75\ \Omega$  coaxial terminations with good broadband characteristics

are commercially available for most coaxial cables. Since transmit levels do not exceed 60 dB (1 mV, 37.5  $\Omega$ ), power ratings of 0.25 W are sufficient.

*Do not terminate any drop cable.* Drop cables are short unmatched stubs on the trunk cable; they must present a high dc shunt impedance to the tee connector.

**19.10.9 Joining Cable Sections.** In general, a trunk cable will consist of a number of separate sections of coaxial cable, each with a matched connector at each end. Some sections will be joined by the tee connectors used for taps, and others will be joined by straight-through (barrel) connectors. A good engineering practice is to maintain constant impedance between cable sections by using one cable type (such as RG-6 or RG-11) from one manufacturer for the entire trunk. This practice avoids significant reflections where cables are joined. When dissimilar types have to be joined, it is suggested that a lossy (attenuating) impedance-matched connector, such as a tap, be employed to reduce repeated reflections. In order to minimize discontinuities, cable should be obtained from the same lot (same extruder at about the same time of manufacture). It is the extruder-to-extruder differences that contribute to the mismatch. A minimal-loss splice should only be used between two pieces of cable from the same roll, or at worst from the same lot.

**19.10.10 Pretested Cable.** It is a good practice to pretest all trunk cable before installation. The objectives are to ensure that the attenuation does not exceed the expected values at frequencies of interest, and to ensure that concealed (that is, internal) discontinuities that can cause reflections do not exist. For a nominal charge, most cable suppliers will pretest or certify all cable before shipment. On-site testing after installation is also recommended, since any damage may degrade operating margins or cause outright failure. A recommended method for testing the installed cable for damage, improper termination, shorts, or discontinuities is to use a time domain reflectometer, which is available from various instrument manufacturers.

## Appendix A

### A Model Used for the Service Specification

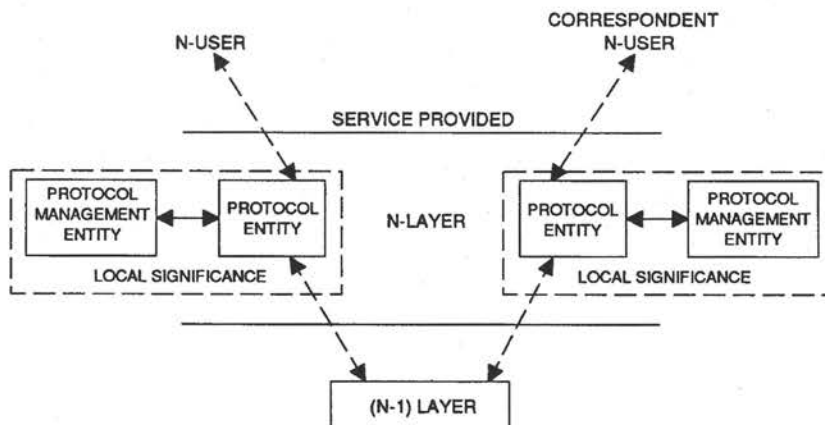
(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

**A1. Service Hierarchy.** The services of a layer are the capabilities that it offers to a user in the next higher layer. In order to provide its service, a layer builds its functions on the services that it requires from the next lower layer. Figure A1 illustrates this notion of service hierarchy and shows the relationship of the two correspondent N-users and their associated N-layer peer protocol entities.

**A2. N-Layer Interface.** Services are specified by describing the information flow at the interface between the N-user and the N-layer. This information flow is modeled by discrete, instantaneous interface events, which characterize the provision of a service. Each event consists of passing a service primitive from one layer to the other through an N-layer service access point associated with an N-user. Service primitives convey the information required in providing a particular service. These service primitives are an abstraction in that they specify only the service provided rather than the means by which the service is provided. This definition of service is independent of any particular interface implementation.

Specific implementations may also include provisions for interface interactions that have no direct end-to-end effects. Examples of such local interactions include interface flow control, status requests and indications, error notifications, and layer management.

**Fig A1**  
**Service Hierarchy Relationships**



**A3. Specification of Services.** Services are specified here by describing the service primitives and parameters that characterize each service. A service may have one or more related primitives that constitute the interface activity that is related to the particular service. Each service primitive may have zero or more parameters which convey the information required to provide the service.

**A4. Classification of N-Layer Service Primitives.** Primitives are of two generic types.

**A4.1 Request.** The request primitive is passed from the N-layer to the (N-1) layer to request that a service be initiated.

**A4.2 Indication.** The indication primitive is passed from the (N-1) layer to the N-layer to indicate an internal (N-1) layer event that is significant to the N-layer. This event may be logically related to a remote service request, or may be caused by an event internal to the (N-1) layer.

**A5. Interaction Behavior.** Possible relationships among primitive types are illustrated by the time sequence diagrams shown in Fig A2. The figure also indicates the logical relationship of the primitive types. Primitive types that occur earlier in time and are connected by dotted lines in the diagrams are the logical antecedents of subsequent primitive types. Note that the logical and time relationship of the indication and the response primitive types are specified by the semantics of a particular service.

**Fig A2**  
**Service Primitive Interactions**

