The ATM Forum ATM User-Network Interface, Version 3.1 (UNI 3.10 Specification
Part II

Introduction to Part II

The three physical layer interface specifications contained in this part of UNI 3.1 represent additional implementation agreements to those contained in UNI 3.0. These additional interfaces are:

Section	Physical Layer Specification
II.1	ATM Physical Medium Dependent Interface Specification for 155 Mb/s over Twisted Pair Cable
II.2	Mid-range Physical Layer Specification for Category 3 Unshielded Twisted Pair
II.3	DS1 Physical Layer Specification

Part II.1
ATM Physical Medium Dependent Interface Specification for 155 Mb/s over Twisted Pair Cable

Ballot Version 0.99

II.1.1. Introduction

This specification describes the Physical Medium Dependent (PMD) sublayer for a 155.52 Mb/s private User Network Interface (UNI) over twisted pair cabling. The remaining Physical layer functions as required by a Transmission Convergence (TC) sublayer are referenced in this specification to existing or in-progress documents from ANSI, ITU-T, or the ATM Forum.

II.1.1.1. Scope

The PMD provides the digital baseband point-to-point communication between ATM user devices and ATM network equipment. The PMD shall provide all the services required to transport a suitably coded digital bit stream across the link segment. This PMD sublayer specification assumes an accompanying 155.52 Mb/s SONET/SDH based ATM TC sublayer. Operation of other TCs with this PMD is beyond the scope of this specification.

The PMD sublayer specified in this document has the following general characteristics:

- Provides a means of coupling the SONET/SDH TC physical sublayer to the twisted pair line segment by way of the Active Interface.
- Provides for driving twisted pair cable between two active electrical interfaces.
- Supports the topology and distance requirements of the building and wiring standards, specifically as described in EIA/TIA-568-A[1] and ISO/IEC DIS 11801[2] .

II.1.1.2. Transmission Convergence Sublayer Specification

The Transmission Convergence (TC) sublayer deals with Physical Layer aspects which are independent of the transmission medium characteristics. Most of the functions comprising the TC sublayer are involved with the generating and processing of overhead bytes contained in the SONET/SDH frame. Unless otherwise described in this specification, the requirements for the TC functions are as defined for the private UNI in the ATM Forum ATM UNI Specification, Version 3.0, Section 2.1[3].

Transmission Convergence Sublayer	HEC Generation/Verification Cell Scrambling/Descrambling Cell Delineation (HEC) Path Signal Identification (C2) Frequency Justification/Pointer Processing SONET Scrambling/Descrambling Transmission Frame Generation/Recovery
Physical Media Dependent Sublayer	Bit Timing, Line Coding Physical Medium

Figure II.1-1 Physical Layer Functions (U-plane)

II.1.1.3. Acronym Glossary

AII	Active Input Interface
AOI	Active Output Interface
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
EMC	Electromagnetic Compatibility
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
MIC	Media Interface Connector
NEXT	Near End Crosstalk
NRZ	Non-Return to Zero
PC	Printed Circuit
PMD	Physical Medium Dependent
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical NETwork
SRL	Structural Return Loss
STS	Synchronous Transfer Signal
STM	Synchronous Transfer Mode
STP	Shielded Twisted Pair
TC	Transmission Convergence
UNI	User Network Interface
UTP	Unshielded Twisted Pair

II.1.2. Transmission Requirements

II.1.2.1. Line Rates and Bit Timing

(R) The bit stream of this PMD interface has an external frame based upon the SONET STS-3c frame as defined in ATM Forum UNI Specification 3.0, Section 2.1[3].

(R) The encoded line rate shall be 155.52 Mbaud +/- 20 ppm for ATM network equipment.

(R) The transmitter at the ATM user device uses a transmit clock which is derived from its received line signal.

(R) In the absence of a valid clock derived from the received line signal, the transmitter at the ATM user device shall use a free-running transmit clock that operates at 155.52 MHz +/- 100 ppm.

II.1.2.2. Line Code

(R) The line coding shall be binary Non-Return to Zero (NRZ).

II.1.2.3. Bit Error Rate

(R) The Active Input Interface shall operate with a bit error rate not to exceed 10^{-10} when provided with a signal transmitted through the channel reference model described in Section II.1.5 with the worst-case crosstalk noise characteristics as specified in Section II.1.5.

II.1.3. Active Output Interface (AOI)

(R) The PMD sublayer shall provide transmit functions in accordance with the electrical specifications of this Section.

The transmitter transforms the bit stream that is presented from the TC sublayer to the equivalent differential voltage signal to be placed onto the media. The active output interface is defined to operate with two cable types as defined in Section II.1.5; 100 ohm category 5 Unshielded Twisted Pair (UTP), and 150 ohm Shielded Twisted Pair (STP).

(R) A logical ONE from the TC shall be represented by a positive voltage on the TX+ pin with respect to the TX- pin. A logical ZERO shall be represented by a positive voltage on the TX- pin with respect to the TX+ pin.

II.1.3.1. Test Load

(R) Unless otherwise specified, all measurements in this Section shall utilize the reference test load.

II.1.3.1.1. UTP Test Load

(R) The test load shall consist of a single 100 ohm +/- 0.2% resistor connected across the transmit pins of the AOI. For frequencies < 100 MHz, the series inductance of the resistor shall be less than 20 nH and the parallel capacitance shall be less than 2 pF.

II.1.3.1.2. STP Test Load

(R) The test load shall consist of a single 150 ohm +/- 0.2% resistor connected across the transmit pins of the AOI. For frequencies < 100 MHz, the series inductance of the resistor shall be less than 30 nH and the parallel capacitance shall be less than 1.5 pF.

II.1.3.2. Differential Output Voltage

(R) When TX+ and TX- are terminated in the test loads of Section II.1.3.1, the peak-to-peak differential output voltage between TX+ and TX- shall be:

940 mV < Vout < 1060 mV	'for UTP test load'
1150 mV < Vout < 1300 mV	'for STP test load'.

II.1.3.3. Waveform Overshoot

Overshoot is defined as the percentage excursion of the differential signal transition beyond its final adjusted value (Vout) during the symbol interval following the preceding 50% voltage crossing.

(R) The overshoot shall be less than 10%.

(R) Any overshoot shall settle to its final adjusted value within 3.2 ns from the beginning of the preceding 50% voltage crossing.

II.1.3.4. Return Loss

(R) The UTP and STP Active Output Interfaces (AOI) shall be implemented such that the following return loss characteristics are satisfied for the specified reference impedance (UTP - 100 ohms +/- 15%, STP - 150 ohms +/- 10%).

Table II.1.2-1 Return Loss Characteristics

Return Loss	Frequency Range
> 16 dB	2 MHz - 30 MHz
> 16 dB - 20*log(f/30 MHz)	30 MHz - 60 MHz
> 10 dB	60 MHz - 100 MHz

II.1.3.5. Rise/Fall Times

The AOI signal rise is defined as a transition from logical ZERO to logical ONE. Signal fall is conversely defined as a transition from logical ONE to logical ZERO. The rise and fall times of the waveform is the time difference between the 10% and the 90% voltage levels of the signal transition excuding overshoot and undershoot of the waveform.

(R) Measured rise and fall times shall be between the limits:

1.5 ns < Trise/fall < 3.5 ns.

(R) The difference between the maximum and minimum of all measured rise and fall times shall be < 0.5 ns.

II.1.3.6. Duty Cycle Distortion

Duty cycle distortion is measured at the 50% voltage crossing points on rise and fall transitions of the differential output waveform.

(R) The 50% voltage crossing times at three successive NRZ transitions for a 0101 bit sequence shall be used.

(R) The deviations of the 50% voltage crossing times from a best fit to a time grid of 6.43 ns spacing shall not exceed +/-0.25 ns.

(R) This measurement shall be made under the conditions that the baseline wander at the output of the AOI shall be less than 5% of the nominal value (Vout).

II.1.3.7. Jitter

The transmit jitter is determined by measuring the variation of the NRZ signal transitions at the 50% voltage crossings. For this measurement, the output of the transmitter is properly terminated in the reference load (Section II.1.3.1). For all measurements in normal loop time applications, the network equipment transmit clock is used as the reference trigger.

(R) Total transmit jitter at the network equipment shall not exceed 1.5 ns peak to peak.

(R) Total transmit jitter at the user device shall not exceed 2.0 ns peak to peak.

II.1.3.8. Baseline Wander

Active output waveform droop is the decay of output voltage following a signal transition. Baseline wander tracking by a receiver is dependent on the worst case droop that can be produced by a transmitter. Worst case baseline wander bit sequences vary the transformer bias which causes the droop to change with data content. This variation must be accounted for by the receiver to track the baseline wander over long bit sequences.

(R) Output waveform droop shall be defined as the decrease in output voltage at the end of the sequence with respect to the differential transition voltage (neglecting overshoot) measured at the beginning of the transition.

(R) For the measurement of output waveform droop, the AOI shall be configured such that 100 bits of logical ONE are transmitted. The preceding bit pattern shall consist of an alternating sequence resulting in negligible (<1%) baseline wander.

(R) The output voltage droop shall not exceed 10% of the differential transition voltage amplitude.

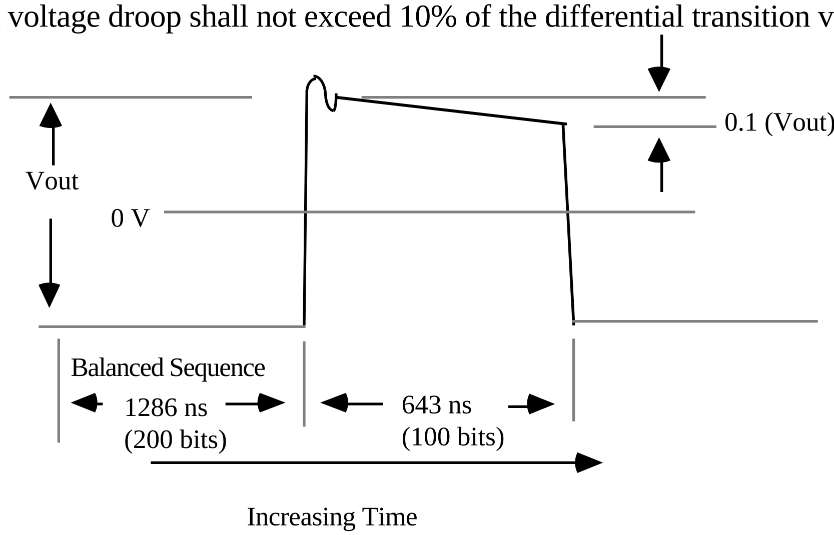


Figure II.1.3-1 AOI Signal Droop

II.1.4. Active Input Interface (AII)

(R) The PMD sublayer shall provide a Receiver with functions in accordance with the electrical specifications of this Section.

(R) The Receiver shall transform the incoming differential voltage signal to an equivalent bit stream that is presented to the TC sublayer.

II.1.4.1. Differential Input Signals

The differential input signals RX+/RX- are defined at the output of the channel reference model with worst case electrical characteristics (described in Section II.1.5) when the differential signals TX+/TX- at the input to the channel reference model are as specified in Section II.1.3 (AOI).

(R) A positive voltage on the RX+ pin with respect to the RX- pin shall be decoded as a logical ONE. A positive voltage on the RX- pin with respect to the RX+ pin shall be decoded as a logical ZERO.

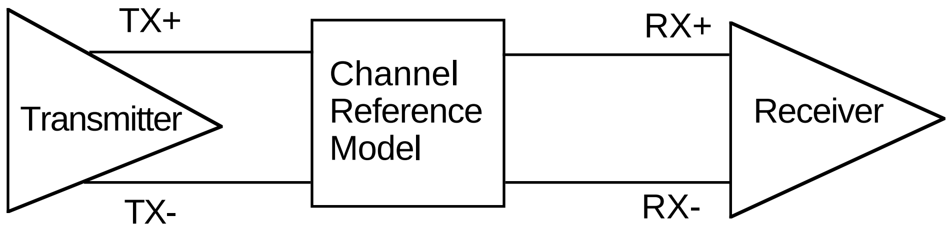


Figure II.1.4-1 Differential Input Signals

II.1.4.2. Differential Return Loss

(R) The differential return loss from the differential receiver input signals RX+ and RX- shall be as listed in Table II.1.4-1.

The requirement is specified for any reflection, due to differential signals incident upon RX+ and RX- from the media having any impedance within the range specified in Section II.1.5.

(R) The return loss shall be measured when the receiver circuit is powered.

Table II.1.4-1 Return Loss Characteristics

Return Loss	Frequency Range
> 16 dB	2 MHz - 30 MHz
> (16- 20*log (f/(30 MHz)) dB	30 - 60 MHz
> 10 dB	60 - 100 MHz

II.1.4.3. Common-Mode Rejection

(R) The Receiver PMD shall deliver the correct data signal to the TC interface with a less than 10^{-10} Bit Error Rate when Ecm is applied as shown in Figure II.1.4-2. Ecm shall be a 1.0 V peak-to-peak sinusoid from 0 to 155 MHz.

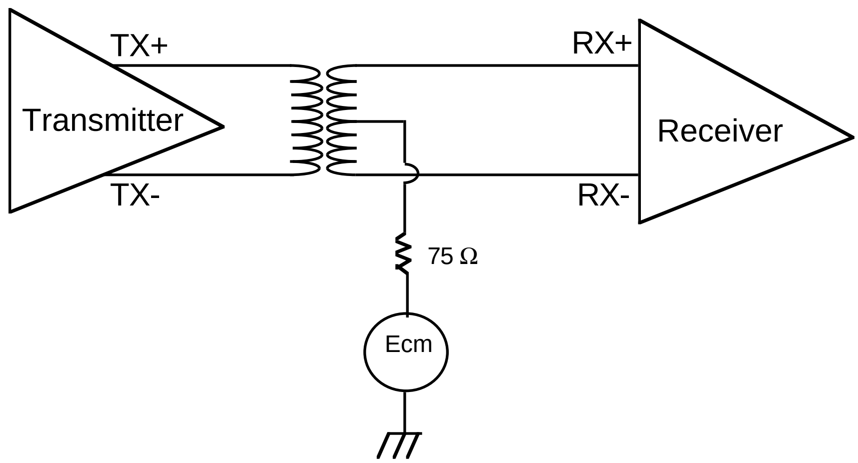


Figure II.1.4-2 Common Mode Rejection

II.1.4.4. Input Jitter Tolerance

Specification of receiver jitter tolerance is not commonly done. This section is for informational purposes. Differential attenuation over the transmission band introduced by the cable severely distorts the signal. The amount of distortion differs with the length of cabling between the transmitter and receiver. Measuring jitter before the signal is equalized is meaningless. Furthermore, specifying a measurement point embedded within an implementation (i.e., at some point after the receive equalizer) is inappropriate since determination of compliance can not achieved. Investigations have shown that the amount of jitter remaining in the recovered NRZ signal that can be attributed to the channel is approximately 1.5 ns, although the sophistication of the equalizer can affect this number. Given the worst case AOI jitter as specified in Section II.1.3, a receiver should be able to tolerate up to 3.5 ns of jitter in the NRZ data transitions. This leaves nearly 3.0 ns of worst-case eye-opening in the NRZ signal.

II.1.5. Copper Link Segment Characteristics

The copper link segment consists of one or more sections of twisted pair copper cable media containing two or four pairs along with intermediate connectors required to connect sections together and terminated at each end in the specified electrical data connector. The cable is interconnected to provide two continuous electrical paths which are connected to the interface port at each end. The AOI and AII requirements are specified for the media defined below. The implementation specified is for the horizontal distribution of the cable plant and extends from the telecommunications closet to the work area.

II.1.5.1. 100 Ohm Copper Link Segment

This section describes the link segment specifications, a channel reference model, and the Media Interface Connector (MIC) specifications for a 100 ohm link segment.

II.1.5.1.1. 100 Ohm UTP Link Segment Specifications

Since the signals provided by the PMD contain significant high frequency energy, it is imperative to specify a high bandwidth channel which introduces negligible distortion in terms of both noise and dispersion. The electrical parameters important to link performance are attenuation, near end crosstalk loss (NEXT loss), characteristic impedance, and structural return loss (SRL).

(R) All components comprising a link segment shall meet or exceed all of the requirements for category 5 as specified by EIA/TIA-568-A[1 and ISO/IEC DIS 11801[2].

(R) The composite channel attenuation shall meet or exceed the category 5 attenuation performance limits defined in Annex E of EIA/TIA-568-A[1].

(R) The composite channel NEXT loss shall meet or exceed the category 5 NEXT loss performance limits defined in Annex E of EIA/TIA-568-A[1].

II.1.5.1.2. Channel Reference Model Configuration for 100 Ohm UTP Systems

The channel reference model for a category 5 UTP system is defined to be a link consisting of 90 meters of category 5 UTP cable, 10 meters of category 5 flexible cords, and four (4) category 5 connectors internal to the link.

II.1.5.1.3. Examples of 100 Ohm UTP Compliant Channels

Since the link segment requirements for attenuation and NEXT loss are derived from the electrical performance of the channel reference model, the channel reference model (properly installed) defines a compliant link. Additionally, properly installed link segments consisting of no more than 90 meters of category 5 UTP cable, no more than 10 meters of category 5 flexible cords, and no more than 4 category 5 connectors internal to the link are examples of compliant links. However, any installed link consisting of category 5 components and meeting the link attenuation and NEXT requirements of Section II.1.5.1.1. is compliant.

In many situations it is also possible to trade off attenuation for NEXT loss and derive links which may differ from the topology of the channel reference model but still have acceptable performance. The number of potential tradeoffs is quite large and this subject is beyond the scope of this document.

II.1.5.1.4. 100 Ohm UTP Attenuation

Attenuation describes the loss in signal level as a signal propagates along a homogeneous medium such as a cable or cord.

(R) The category 5 cable used in constructing a link shall meet or exceed the horizontal UTP cable attenuation requirements of Chapter 10 of EIA/TIA-568-A[1] and Chapter 7 of ISO/IEC DIS 11801[2].

(R) The category 5 cordage used in constructing flexible cords and patch cables shall meet or exceed the attenuation requirements for flexible cordage specified in Chapter 10 of EIA/TIA-568-A[1].

In general, the per unit length attenuation limits for cordage are 20% higher than those allowed for horizontal cables.

II.1.5.1.5. 100 Ohm UTP NEXT Loss

NEXT loss defines the amount of unwanted signal coupling between distinct pairs of a multipair cable. It is the result of parasitic capacitive and inductive coupling between the various conductors comprising a cable.

(R) The category 5 cable and cordage used in constructing a link shall meet or exceed the horizontal UTP cable NEXT requirements of Chapter 10 of EIA/TIA-568-A[1] and Chapter 7 of ISO/IEC DIS 11801[2].

II.1.5.1.6. Characteristic Impedance and Structural Return Loss

Characteristic impedance is the ratio of voltage to current of a wave propagating along one direction in a uniform transmission line. When a transmission line is not completely uniform in construction, the characteristic impedance may exhibit slight variations as a function of length. This variation is measured by a quantity defined as structural return loss (SRL). It is a measure of the deviation of characteristic impedance from a nominal value in a transmission line which is not perfectly homogeneous.

(R) All measurements for these quantities shall be done in accordance with ASTM D 4566 method 3[4].

(R) Under these conditions both the characteristic impedance and SRL of category 5 cables and cords used in construction of a link shall meet the requirements specified in Chapter 10 of EIA/TIA-568-A[1] and chapter 7 of ISO/IEC DIS 11801[2].

II.1.5.1.7. 100 Ohm Connecting Hardware

The electrical performance of connecting hardware can be critical to the overall performance of a transmission channel. In general, the electrical parameters specified for connecting hardware are attenuation, NEXT loss, and return loss. Inadvertent use of the wrong category of connecting hardware can seriously degrade performance including the emission characteristics for a category 5 link.

(R) All connecting hardware used within this PMD channel (outlets, transition connectors, patch panels, and cross-connect fields) shall meet or exceed the category 5 electrical requirements for attenuation, NEXT loss, and return loss specified in Chapter 10 of EIA/TIA-568-A[1] and Chapter 8 of ISO/IEC DIS 11801[2].

(R) All measurements on connecting hardware shall be conducted in accordance with the procedures described in Annex B of EIA/TIA-568-A[1] and Annex A.2 of ISO/IEC DIS 11801[2]. These requirements apply to all individual UTP connectors, including patch panels, transition connectors, cross-connect fields, and telecommunications outlets.

The intent of this specification is to minimize the effects of UTP connecting hardware on end-to-end system performance. However, it should be noted that the requirements for connectors for category 5 UTP cable are not sufficient in themselves to insure system performance. Channel performance also depends upon cable characteristics, the care in which connectors are installed and maintained, and the total number of connections. Extreme care should be given to minimize the amount of untwisting involved with the installation of connectors as this is one of the prime sources of NEXT degradation.

(R) The connector termination practices and UTP cable practices described in Chapter 10 of EIA/TIA-568-A[1] shall be followed.

II.1.5.1.8. UTP Media Interface Connector (UTP-MIC)

(R) Each end of the category 5 UTP link segment shall be terminated with Media Interface Connectors specified in ISO/IEC 8877[5]. (Commonly referred to as RJ-45.) This connector is an 8-pole modular jack/plug and mated combination shall meet the requirements of Section II.1.5.1.7.

(R) The cable assembly shall connect the corresponding connects of the plugs at either end of the link. (i.e. Pin 1 to Pin 1, Pin 2 to Pin 2, etc.)

This ensures that the cable assembly is a straight through (no crossover) cable and that the polarity of the assembly is maintained.

(R) The UTP-MIC Receptacle (Jack) shall be an 8-pole connector that is attached to the ATM user device and ATM network equipment.

(R) The connect assignment for the UTP-MIC Receptacle (Jack) shall be as listed in Figure II.1.5-1.

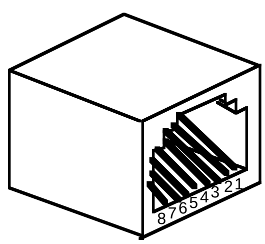
	Contact #	ATM User Device	ATM Network Equipment
	1	Transmit +	Receive +
	2	Transmit -	Receive -
	3	Note 1	Note 1
	4	Note 1	Note 1
	5	Note 1	Note 1
	6	Note 1	Note 1
(JACK)	7	Receive +	Transmit +
	8	Receive -	Transmit -

Figure II.1.5-1 UTP-MIC Receptacle (Jack) Contact Assignment Detail

Note 1: Refer to Part II Annex A for optional termination of these contacts.

II.1.5.2. 150 Ohm Link Segment Characteristics

The 150 ohm cable system connects the Active Interface on one end of the link segment to the Active Interface on the other end of the link segment. The cable system consists of one or more sections of shielded twisted pair cable containing two wire pairs, along with intermediate connectors required to connect sections together. The media interface connector is used to terminate the ends of the fixed wiring. The cable is interconnected to provide two continuous electrical paths between the Active Interfaces.

II.1.5.2.1. 150 Ohm STP Link Segment Specifications

The system can operate with a variety of STP cable types. EIA/TIA-568-A[1] and ISO/IEC DIS 11801[2] define STP cables which will meet the performance requirements of this system. The channel link requirements are independent of the cable type but have been defined using the attenuation and NEXT loss requirements for Category 5 UTP cable. The maximum allowable length of the cable system will vary depending on the quality of the STP cable, and patch cord.

(R) The composite channel attenuation for a 150 Ohm STP link shall meet the attenuation performance limits defined in Annex E of EIA/TIA-568-A[1] for category 5 UTP cables.

(R) The composite channel NEXT loss for a 150 Ohm STP link shall meet the NEXT loss performance limits defined in Annex E of EIA/TIA-568-A[1] for category 5 UTP cables.

(R) The characteristic impedance of the STP cable shall be 150 Ohm +/- 10%, from 3 - 100 MHz.

II.1.5.2.2. Channel Reference Model Configuration for 150 Ohm STP Systems

A typical cable system includes fixed cable terminated in the media interface connector, and attachment cables for both ends. The per unit length attenuation of an attachment cable is typically allowed to be up to 150% that of the fixed cable. Refer to ISO/IEC DIS 11801, Section 5 for more detailed information[2].

The channel reference model for an STP system is defined to be a link consisting of 90 meters of STP-A cable, 10 meters of STP-A patch cord, and 4 STP-A connectors internal to the link.

II.1.5.2.3. Examples of 150 Ohm STP Compliant Channels

Since the link requirements for attenuation and NEXT loss are derived from the electrical performance of the channel reference model, the channel reference model (properly installed) defines a compliant link. A properly installed channel reference model defines a compliant link. Additionally, properly installed links consisting of no more than 90 meters STP-A cable, no more than 10 meters of STP-A patch cord, and no more than 4 STP-A connectors internal to the link are examples of compliant links. However, any installed link consisting of STP components and meeting the link attenuation and NEXT requirements of Section II.1.5.2.1 is compliant.

In many situations it is also possible to trade off attenuation for NEXT loss and derive links which may differ from the topology of the channel reference model but still have acceptable performance. The number of potential tradeoffs is quite large and this subject is beyond the scope of this document.

II.1.5.2.4. STP Media Interface Connector

(R) Each end of the fixed cable shall be terminated in the STP media interface connector.

(R) The STP media interface connector shall meet all the requirements of the Telecommunications Connector as defined in EIA/TIA-568-A, Section 11[1].

(R) The STP media interface connector contact assignments shall be as listed in Table II.1.5-1.

Table II.1.5-1 STP MIC Contact Assignments

MIC Contact	ATM User Device	ATM Network Equipment
B	Transmit +	Receive +
R	Receive +	Transmit +
G	Receive -	Transmit -
O	Transmit -	Receive -

The STP MIC drawing is included for reference in Figure II.1.5-2.

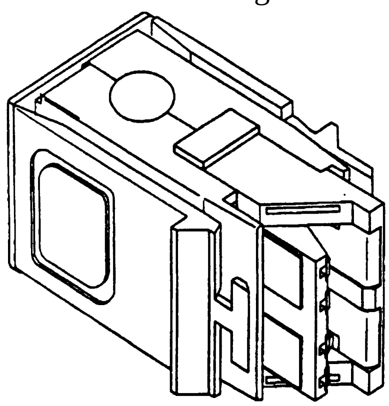


Figure II.1.5-2 STP Media Interface Connector

II.1.5.2.5. STP Active Interface Connector

To allow maximum flexibility in system design, and allow for future connector enhancements, an optional Active Interface Connector is specified.

The patch cord between the wall connector and the terminal device provides interconnection capability between any connector and the STP Media Interface Connector. The use of an alternative STP connector is optional. It allows STP system designers to use a common connector where appropriate.

II.1.5.2.5.1. Optional STP Active Interface Connector

The optional connector may be used at one end or both ends of a link segment.

(CR) The optional STP Active Interface Connector shall be a 9-pole D-Shell connector that meets the requirements in EIA/TIA 574:1990 Section 2 as it relates to intermateability[7].

(CR) When the optional 9-pole D-Shell connector is used, the Receptacle (Jack) shall be mounted on the equipment (ATM Network Equipment and ATM User Equipment) and the Plug connector shall be used on the STP cable.

(CR) The 9-pole D-Shell Receptacle shall be used with contact assignments as listed in Figure II.1.5-3.

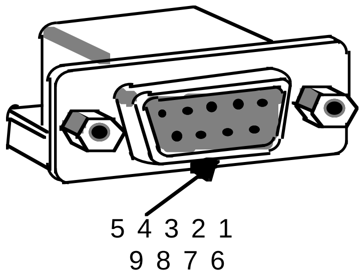
9-Pole D Connector (Jack)	Contact #	ATM Network Equipment Signal	ATM User Equipment Signal
	1	Transmit +	Receive +
	2	Not used	Not used
	3	Not used	Not used
	4	Not used	Not used
	5	Receive +	Transmit +
	6	Transmit -	Receive -
	7	Not used	Not used
	8	Not used	Not used
	9	Receive -	Transmit -
	Shell	Chassis	Chassis

Figure II.1.5-3 STP 9-Pole D Connector Contact Assignment

II.1.5.3. Noise Environment

II.1.5.3.1. Self NEXT Channel Noise

In order for a channel to support data traffic at the desired BER performance level, the crosstalk noise from all sources must be limited to an acceptable level.

(R) The time domain crosstalk noise from all data signals in the channel shall be no more than 20 mV peak-to-peak.

The noise environment consists of primarily two contributors; NEXT noise from all data signals in the cable (including self NEXT noise) and externally induced impulse noise from other office and building equipment. Impulse noise is generally the result of mechanical switching transients and common mode coupling phenomena.

II.1.5.3.2. Electromagnetic Susceptibility and Impulse (Fast Transient) Noise

Refer to Part II Annex B for guidelines on electromagnetic susceptibility and impulse noise guidelines.

II.1.6. References

[1] EIA/TIA Standards Proposal No. 2840-A, EIA/TIA-568-A, "Commercial Building & Wiring Telecommunications Wiring Standard", Draft Ballot, March 29, 1994.

[2] ISO/IEC DIS 11801, JTC1/SC25 N106, "Generic Cabling for Customer Premises", Draft Ballot, October 12, 1992.

[3] The ATM Forum, ATM User Network Interface Specification, Version 3.0, Prentice Hall, Englewood Cliffs, NJ, 1993.

[4] ASTM Designation: D 4566-90, "Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable," 1990.

[5] ISO 8877, "Informational processing systems, Interface connector and contact assignments for ISDN basic access interface located at reference points S and T.", August 15, 1987.

[6] 88025 / ISO Rev. 2, "Token Ring Access Method and Physical Layer Specifications", Letter Ballot 1994.

[7] ANSI EIA/TIA 574, "9 Position Non-Synchronous Interface between DTE and DCTE employing Serial Binary Data Interchange", 1990.

[8] Solid State Radio Engineering, H. Kraus, C. Bostran, F. Raab, ISBN 0-471-03018-X, John Wiley & Sons, Inc., 1980.

[9] Antenna Impedance Matching, W. Caron, ISBN 0-87259-220-0, The ARRL, 1989.

[10] IEC 801-3, International Electrotechnical Commission, IEC Standard, "Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment, Part 3: Radiated Electromagnetic Field Requirements", 1992.

[11] IEC 801-4, International Electrotechnical Commission, IEC Standard, "Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment, Part 4: Electrical Fast Transient/Burst Requirements", 1991.

Part II.1 Annex A (Informative) System Balance (Common Mode Rejection) Considerations

The system or link interface balance (e.g., transmitter and cable plant) does not directly constrain the interoperability of SONET/SDH UTP conforming UNIs, but poor balance will cause the differential line signal to be partially converted to common mode (also called longitudinal mode) on the cable plant. The resulting common mode currents will likely result in electromagnetic emissions which may potentially violate statutory emission or susceptibility requirements. While a detailed treatment of this subject is beyond the scope of this specification, a more thorough understanding of the system considerations may be found in EIA/TIA-568-A[1] and ISO/IEC DIS 11801[2].

As this behavior is a system effect, it is desirable that equipment implementations not be the dominant contributor to conversion. As a guideline to implementors, data have shown that a typical category 5 cable plant exhibits common mode rejection of approximately 40 dB. The Annex sections below details recommendations which may be useful during system design and test to aid the implementor in meeting the particular EMC requirements.

II.1.A.1. Common Mode Signal Rejection Guidelines at the UTP MIC

Common Mode Signals present on the UTP medium connected to the MIC due to an imbalance in the transmitted differential data signal or electrically noisy ground references may cause radiated radio frequency emissions in excess of regulatory agency requirements. Unlike lower speed protocols with clocks and baud rates below the 30 MHz radiated emission frequency limit, the SONET NRZ data signal consists of spectral components in excess of 75 MHz with a clock frequency of 155 MHz.

It has been demonstrated that operation with emissions below the FCC and CISPR Class B limits are practical due to the superior balance of the category 5 cable when driven by balanced signals with each line referenced to an electrically quiet ground reference. This may be achieved if RF techniques are used in the design of the interface.

It should be understood that the cable connected to the MIC forms a random length monopole antenna. The efficiency of this antenna is a function of the physical configuration of the cable, and more importantly, the efficiency of the coupling of any common mode signals to the common mode impedance of the cable. The common mode signal may be generated by an imbalance in the differential data driver or by inadvertent coupling of clocks or other signals on the PC board to the MIC. The common mode impedance of the cable, and generally the MIC are complex and the typical method of common mode characterization in a 50 Ohm measurement system is inadequate to predict radiated emission performance of either in an open field test environment. The metric which would ensure emission compliance is a measurement of the true amount of common mode power available at the MIC into any common mode impedance presented to the port by a connected cable.

If one makes a reasonable estimate of the realizable gain of the cable when driven as a monopole due to directional effects, one can determine the maximum common mode power level allowed at the MIC. The requirement at test is that the common mode impedance of the port be matched to the measurement device at the frequency of the measurement. This will be the complex conjugate of the common mode output impedance of the port under test with real impedance matched to the input impedance of the measurement device.

A practical implementation of this measurement technique may consist of simultaneously terminating each of the 4 pair connections at the MIC into a combination center tapped auto-transformer and 100 Ohm termination resistor, with the center taps of the transformers joined and measurements made of this point with respect to a front panel ground reference of the device under test. At frequencies where signal levels seem suspect, the common mode impedance of the point should be measured, and a conjugate match designed to couple the power to the measurement device. Output impedance may be measured using an S-parameter test set, and methods to effect the matching network are available in literature referring to radio frequency engineering design techniques.[8,9] RF design techniques must be employed when designing this test fixture.

A more straightforward measurement technique is the measurement of current maxima which occur on the cable when driven by a port using an inductively coupled current clamp. Though not as exact as the above method of measurement, correlation to the open field test site should be adequate.

To employ this technique, the current level at a suspect frequency should be isolated using the current clamp. At this frequency, the physical location of the current clamp should be moved over a distance of at least an electrical half-wavelength to determine a current maximum. This test should be performed as close to the port as possible. The level of current observed should be compared to the current required at the center of an equivalent half-wave dipole that will radiate a field in excess of that allowed. In effect, the cable itself becomes the conjugate match of the port. A requirement is that the linear dimension of the cable should be longer than a halfwave length at the frequency of measurement. Calibrated current clamps are common in the industry.

Derivations of typical limits of port measurements as discussed are presented in the following sections..

II.1.A.1.1. Common Mode Power

If one assumes a maximum "Antenna Gain" of 6 dB over an isotropic radiator for the cable[1] and an emission limit of 30 dBμV , the maximum common mode power allowed at the port is:

$$P_{port} = \{r * E_o\}^2 /(30 * G_t)$$

Where:

P_{port} = Power at port
r = Radius from transmitter to receiving antenna in meters
E_o = Field strength in V/m
G_t = Antenna gain above an isotropic radiator

$$P_{port} = \{10 \text{ m} * 31.62*10^{-6} \text{ V/m}\}^2 / (30 * 4)$$
$$= 833 * 10^{-12} \text{ Watts}$$
$$= -61 \text{ dBm}$$

The frequency versus radiated field limits are dependent upon local agency requirements and this analysis should be modified accordingly.

[1] This value is a conservative estimate since antenna gain is difficult to calculate using simple wire configurations.

II.1.A.1.2. Common Mode Current

In order to determine the maximum common mode current allowed on the cable, one calculates the current at the center of a half wave dipole which is radiating a field strength of 30 dBµV at 10 meters.

The power gain of a half wave dipole is 1.64 times that of an isotropic source. The power applied to this dipole is :

$$P = \{10\ m * 31.62*10^{-6}\ V/m\}^2 / (30 * 1.64) = 2*10^{-9}\ Watts$$

The radiation resistance of a half wave dipole is 73 Ohms,

$$I = SQRT\ (P/R) = SQRT\ (2*10^{-9}\ Watts/\ 73\ Ohms)$$

$$= 5.2\ \mu A$$

when observed in a 100 kHz Bandwidth. The 6 dB "antenna gain" is not included in this calculation since it is a direct result of multiple current maxima occurring at half wave intervals on a long cable, and we are measuring the current at only one point on the cable at a time.

II.1.A.1.3. Common Mode Rejection

In order to determine the "Common Mode Rejection" required of the transmitter, one must first determine what portion of the transmitted data signal power is present in the 100 kHz measurement bandwidth specified by the Class B limits. The ratio of this power to the -61 dBm of common mode power we are allowed at the port is the common mode rejection required.

The power spectrum of the data signal takes the form of $(\sin X / X)^2$ with nulls occurring at multiples of the bit-rate. Since radiated measurements are performed only above 30 MHz, the maximum density of common mode power available to radiate will occur in a passband from 30 to 30.III.1. MHz. Evaluating the integral of the power available at this point relative to the total power transmitted in an infinite passband gives us a ratio of 29.2 dB. If we assume rectangular pulse shaping at the transmitter, and a 1V peak to peak drive level, the transmitted power is $(0.5)^2/100 = 2.5$ mW or +4 dBm.

Common Mode Rejection (dB) = $P_{trans} - P_{port} - D_{gain}$

Where: P_{trans} = Transmitted Power (dBm)
P_{port} = Common Mode Power at port (dBm)
D_{gain} = Dispersion Gain due to scrambling

4 dBm - (-61 dBm) - 29.2 dB = 35.8 dB

Actual common mode rejection required at other frequencies may be determined by evaluating the $(\sin X / X)^2$ power spectrum in a 100 kHz bandwidth at that frequency. The common mode rejection specification alone will not ensure compliance if other sources of common mode energy are coupled to the port.

II.1.A.1.4. Common Mode Measurement Conclusions

These measurement techniques are suggested as a guide to those interested the quantitative measurement of the emission performance at the MIC in a laboratory environment prior to open field test site measurements of the product. It will also aid the designer in specifying components used in the MIC cable driver when specifying their common mode characteristics. The accuracy of the results is totally dependent upon the care with which these measurements are performed.

II.1.A.2. Common Mode Termination Guidelines

This section outlines methods of terminating the twisted pair cable for improved EMC performance. Such improvements include reduction of radiated emissions and increased immunity to electromagnetic noise. Techniques as outlined below may prove beneficial in some implementations.

Work shown has indicated that such techniques have no impact on interoperability between PMD implementations. That is to say, the presence or absence of such a technique on a ATM system on one side of a UNI does not affect the ability of the alternate UNI station to interoperate across the link segment.

As an example, three techniques of terminating the unused pairs of the cable are outlined below. The first consists of a scheme in which the common mode impedance of the cable pairs is resistively terminated at the UNI. Such a scheme could be implemented as shown in Figure II.1.A-1 The second technique involves the termination of one or more of the unused cable pairs to the chassis reference of the equipment. Such a scheme could be implemented as shown in Figure II.1.A-2. The third technique is a derivation of the second and includes longitudinal chokes in the active pairs. Such a scheme could be implemented as shown in Figure II.1.A-3. It should be noted that these techniques as described here may have patent or patent pending implications. The ATM Forum patent policy has been followed with respect to any known patent related issues at the time of specification approval.

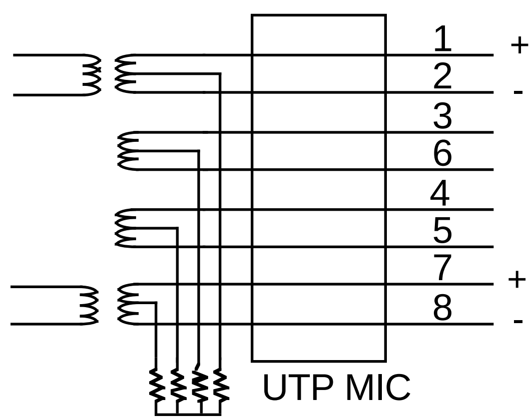


Figure II.1.A-1 Example of Common Mode Resistive Termination of Pairs

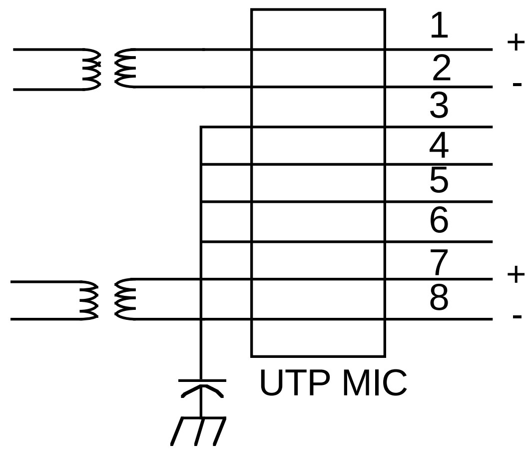


Figure II.1.A-2 Example of Common Mode Termination to Chassis Reference

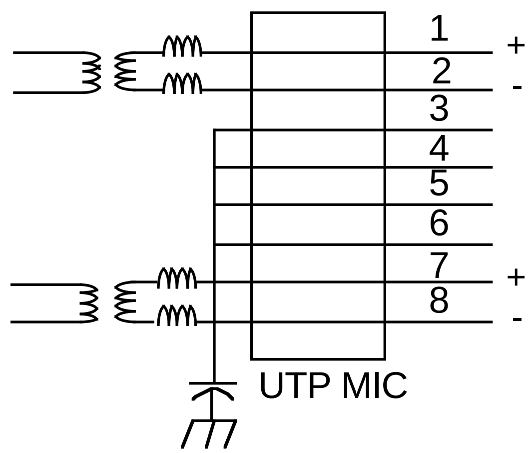


Figure II.1.A-3 Example of Common Mode Termination to Chassis Reference with Chokes

Part II.1 Annex B. (Informative) Electromagnetic Susceptibility and Impulse Noise Guidelines

II.1.B.1. Electromagnetic Susceptibility

With no degradation in BER, the PMD/PHY implementation should pass a 3 V/m field electromagnetic susceptibility test (IEC 801-3, Level 2). The PMD/PHY should be tested using the test methods described in IEC 801-3[10].

II.1.B.2. Impulse (Fast Transient) Noise

Since the majority of impulse noise is generated by mechanical switching, the requirements for impulse noise should be generated by standard tests designed to simulate this phenomena.

The PMD/PHY implementation operating on media cables, should recover without operator intervention, from 0.5 kV impulse noises (fast transients) (IEC 801-4, Level 2). The PMD/PHY should be tested using the test methods described in IEC 801-4[11].

Part II.2
ATM Forum
Mid-range Physical Layer Specification for Category 3 Unshielded Twisted-Pair

II.2.1. Introduction

This specification describes a physical layer for a mid-range private UNI over Category 3 unshielded twisted-pair cabling. This specification does not preclude extensions to support lower data rates over cables with worse characteristics than Category 3 Unshielded Twisted Pair or extensions to support higher data rates over cables with better characteristics than Category 3 Unshielded Twisted Pair.

II.2.1.1 Overview

This section specifies the physical layer electrical interface for a 51.84 Mb/s (and sub-rates) private UNI. The functions of the Physical Layer are grouped into the Physical Media Dependent (PMD) sublayer and the Transmission Convergence (TC) sublayer as shown in Figure II.2.2-1. The PMD Sublayer addresses bit rates and symmetry, bit error rate, bit timing, line coding and modulation characteristics, medium characteristics, and connectors. Also included in an Annex are discussions on impulse noise and electromagnetic susceptibility. The TC Sublayer addresses frame format, transfer capability, Header Error Control (HEC), etc.

Transmission Convergence Sublayer	*HEC generation/verification* *Cell scrambling/descrambling* *Cell delineation (HEC)* *Path signal identification (C2)* *Frequency justification/Pointer processing (optional for transmit)* *Scrambling/descrambling (SONET)* *Transmission frame generation/recovery*
Physical Media Dependent Sublayer	*Bit timing* *Line coding* *Physical medium* *Scrambling/descrambling*

FIGURE II.2.2-1 PHYSICAL LAYER FUNCTIONS (U-PLANE)

II.2.1.2 Acronyms

AIS	Alarm Indication Signal
AII	Active Input Interface
AOI	Active Output Interface
ATE	ATM Terminating Equipment
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
BIP	Bit Interleaved Parity
k-CAP	Carrierless Amplitude/Phase Modulation with k constellation points
DSn	Digital Signal, Level n
EMC	Electromagnetic Compatibility
FEBE	Far End Block Error
HEC	Header Error Check
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LOC	Loss of Cell Delineation
LOF	Loss of Frame
LOP	Loss of Pointer
LOS	Loss of Signal
LTE	SONET Line Terminating Equipment
NEXT	Near End Crosstalk
OAM	Operation, Administration and Maintenance
OCD	Out-of-Cell Delineation
OOF	Out Of Frame
POH	Path Overhead
PMD	Physical Media Dependent
PTE	SONET Path Terminating Equipment
RDI	Remote Defect Indicator
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
SPE	SONET Synchronous Payload Envelope
STE	SONET Section Terminating Equipment
STS-1	Synchronous Transfer Signal, level 1, the fundamental level of the SONET hierarchy.
TC	Transmission Convergence
TP-MIC	Twisted-Pair Media Interface Connector
UNI	User-Network Interface
UTP	Unshielded Twisted Pair

II.2.1.3 Reference Configurations

The private UNI is described in the ATM User-Network Specification, Version 3.0[1], Section 1.6, User-Network Interface Configuration. This document specifies the link between a user device and the network equipment.

II.2.2. Physical Medium Dependent (PMD) Sublayer Specification

The PMD sublayer provides bit transmission capability for point-to-point communication between a user device and network equipment. The implementation of the PMD shall provide all the services required to transport a suitably coded digital bit stream across the link segment.

This PMD specification gives the requirements for a 51.84 Mb/s interface using Category 3 Unshielded Twisted Pair (UTP) cabling. Optional sub-rate interfaces of 25.92 and 12.96 Mb/s are included for supporting a longer link or links that consist of cabling components that do not meet the specifications of Category 3 UTP. Greater range can be achieved by the use of higher quality (e.g. Category 5) cabling or by adopting one of the lower, optional bit rates.

The design goal of this specification is a total link length of 100m using Category 3 cables and interconnect components. The connection is duplex using a pair of wires for each direction of transmission.

II.2.2.1 Bit Rates and Bit Rate Symmetry

II.2.2.1.1 Bit Rates

Bit rate (data rate) refers to the logical bit rate for data (expressed in Mb/s). Encoded line rate (symbol rate) refers to the modulation rate of the electrical signal on the media (expressed in Mbaud).

(R) The bit rate shall be 51.84 Mb/s (the SONET STS-1 rate as described in ANSI T1.105[2]). Extensions to support lower data rates are optional. This PMD specification may also be used as the physical interface for link lengths that are longer than those specified for Category 3 UTP in EIA/TIA-568-A[3].

(O) Operation at 25.92 Mb/s and/or 12.96 Mb/s shall be optional (See Sections II.2.2.5.2 Encoding and II.2.2.8, Link Length Using a Reference Channel Model).

II.2.2.1.2 Bit Rate Symmetry

(R) Interfaces shall be symmetric, i.e., the bit rates are the same in both transmit and receive directions.

II.2.2.2 Bit Error Rate (BER)

(R) The Active Input Interface (AII) shall operate with a BER not to exceed 10^{-10} when presented with an Active Output Interface (AOI) signal (i.e., a valid signal as specified in Section II.2.2.5) transmitted through the cable plant specified in Section II.2.2.7 Copper Link Characteristics with the worst-case attenuation and Near End Crosstalk (NEXT) loss as specified in EIA/TIA-568-A[3]. The cable plant encompasses all components between any two communicating stations which include cords, wall outlets, horizontal cables, cross-connect fields, and associated patch cords.

II.2.2.3 Timing

On a link connecting an ATM user device and an ATM network equipment, the transmitter at the ATM user device uses a transmit clock which is derived from its received data clock, i.e., the ATM user device is loop timed.

(R) The bit rate shall be the nominal rate of 51.84 Mb/s, or one of the optional nominal rates of 25.92 or 12.96 Mb/s, all with a tolerance of ±20 ppm for network equipment.

(R) The transmitter at the user device shall use a transmit clock which is derived from its received data clock.

(R) In the absence of a valid clock derived from the received signal, the transmitter at the user device shall use a free-running transmit clock that operates at the nominal bit rate with a tolerance of ±100 ppm.

II.2.2.4 Jitter

(R) Jitter of the transmitter, τ, shall be obtained by transmitting an all ones pattern at the input of the encoder, shown in the Block Diagram in Figure II.2.2-3, into the test load specified in Section II.2.2.5.3.2. and measure the variation of the zero-crossings of the resulting waveform as shown in Figure II.2.2-2. For all measurements, the network equipment transmitter clock is used as the reference clock. for network equipment shall not exceed 2.0 ns peak-to-peak and for user devices shall not exceed 4.0 ns peak-to-peak with an input from the network of the maximum specified jitter.

(R) Transmitters shall be capable of transmitting an all ones signal as observed at the input of the encoder functional block in the Block Diagram of Figure II.2.2-3.

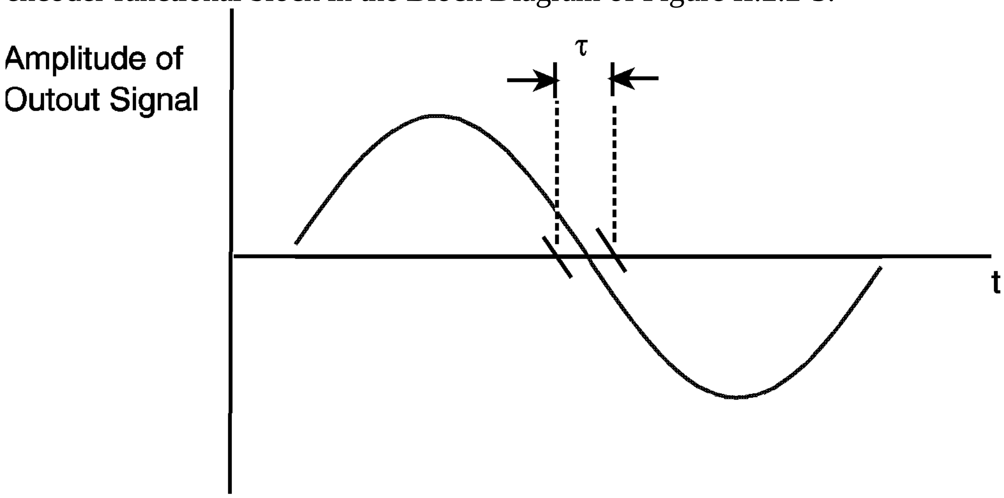


FIGURE II.2.2-2 ILLUSTRATION OF TRANSMITTER JITTER

II.2.2.5 Carrierless Amplitude Modulation/Phase Modulation

This PMD specification uses the Carrierless Amplitude Modulation/Phase Modulation (CAP) technique to provide bit transmission capability and bit timing. The sublayer includes functions to generate and receive waveforms suitable for the medium, and the insertion and extraction of symbol timing information. The implementation of the PMD receives a bit stream from the TC sublayer, scrambles, encodes , and transmits the signal to the adjacent PMD sublayer over a Category 3 UTP link. The receiving implementation of the PMD decodes and descramblers the signal and delivers it as a bit stream to the TC sublayer. These operations are described below. Design principles for a CAP system are referenced in Annex A.

II.2.2.5.1 Transmit Functionality

The PMD sublayer is comprised of transmit functionality obtained from the blocks shown in Figure II.2.2-3. Any implementation that produces the same functional behaviour at the Active Output Interface is equally valid. The transmit function scrambles and encodes the bit stream received from the TC into an equivalent CAP encoded symbol stream and then into a modulated signal for presentation to the medium at the Active Output Interface.

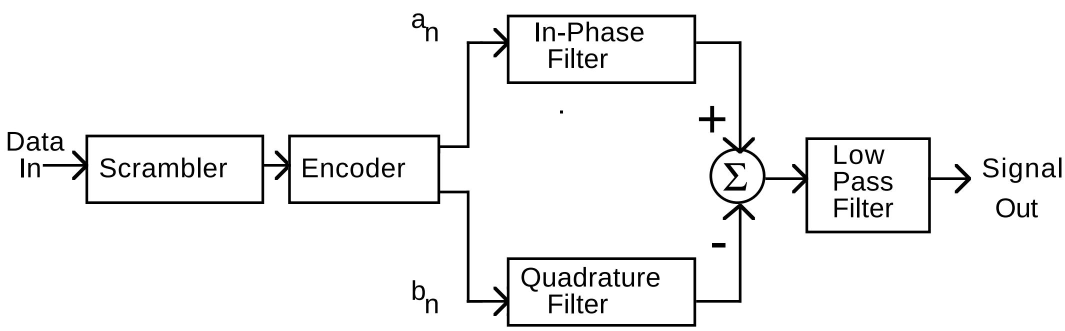


FIGURE II.2.2-3 BLOCK DIAGRAM OF DIGITAL 16-CAP TRANSMITTER FUNCTIONALITY

The symbol stream from the encoder is divided into two paths, a_n and b_n, where n designates the n^{th} symbol period. The two symbol streams are sent to passband in-phase and quadrature shaping filters, respectively. The output of the in-phase filter and the negative of the output of the quadrature filter are summed into a single signal, the result passed through a low-pass filter, and then transmitted onto the twisted pairs.

II.2.2.5.2 Encoding

The amplitudes of the a_n and b_n components in the k-CAP constellations shall maintain the relative values 1 and 3, with a tolerance of ±0.06, as depicted in the respective constellation diagrams of Figures II.2.2-5, II.2.2-7, and II.2.2-8.

II.2.2.5.2.1 Operation at 51.84 Mb/s

(R) For 51.84 Mb/s, the encoding used shall be the 16-CAP code. The symbol rate is 12.96 Mbaud.

(R) For 16-CAP, the encoder shall map data four data bits into a symbol as shown in Figure II.2.2-5. Bits shall be mapped from the PMD scrambler (see Section II.2.2.6) into the four bit symbol. The first bit out of the PMD scrambler into a given symbol shall be b_1.

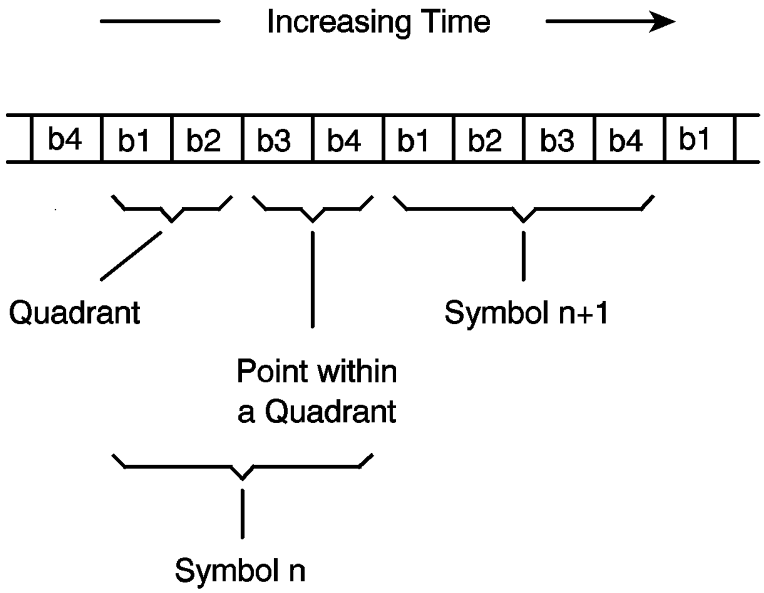


FIGURE II.2.2-4 BIT-TO-SYMBOL MAPPING FOR 16-CAP

(R) For 16-CAP, the signal constellation shall be as shown in Figure II.2.2-6.

Each incoming group of 4 bits is Gray encoded into a 16-CAP symbol. The relative levels of the amplitude of the symbols in each dimension are proportional to the four different levels, ±1 and ±3. Bits b_1b_2 (circled in Figure II.2.2-4) designates the quadrant. Bits b_3b_4 designates the point being used within the quadrant.

For example, an incoming bit stream 10010110 would translate into two symbols:
(a_n= +1, b_n= -3) and (a_{n+1}= -3, b_{n+1}= +1).

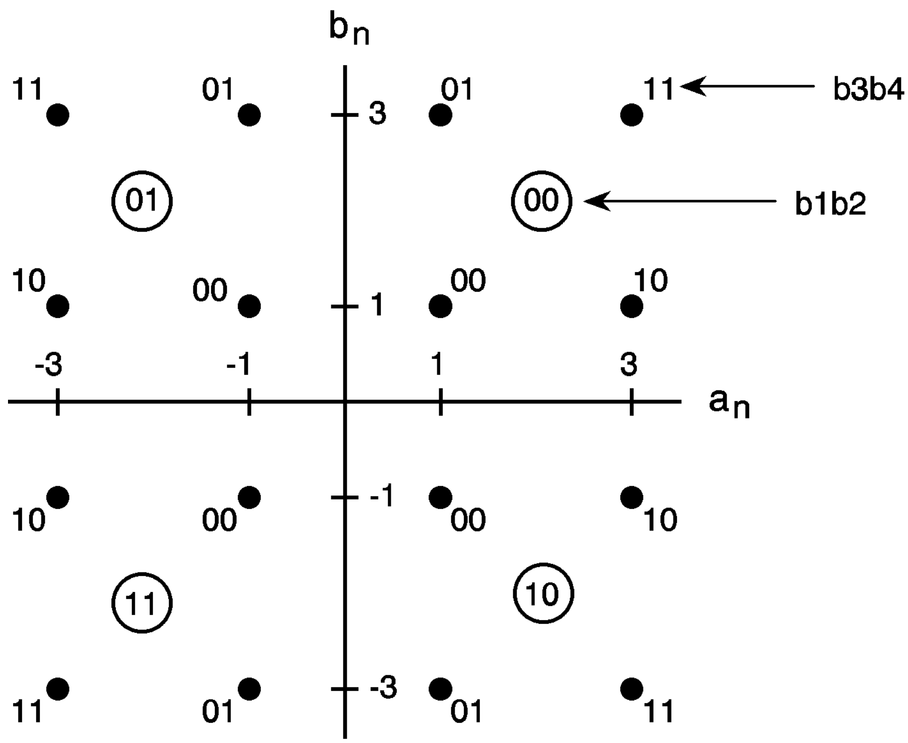


FIGURE II.2.2-5 16-CAP SIGNAL CONSTELLATION

II.2.2.5.2.2 Operation at 25.92 Mb/s

Operation at 25.92 Mb/s is optional. However, if operation at 25.92 Mb/s is implemented, the following statements marked **CR** are required.

(CR) For 25.92 Mb/s, the encoding used shall be the 4-CAP code. The symbol rate shall be 12.96 Mbaud.

(CR) For 4-CAP, the encoder shall map two data bits into a symbol as shown in Figure II.2.2-6. Bits shall be mapped from the PMD scrambler (see Section II.2.2.6) into the two bit symbol. The first bit out of the PMD scrambler into a given symbol shall be b_1.

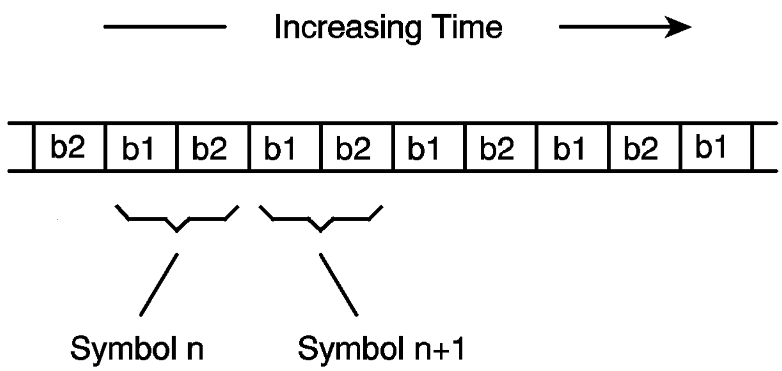


FIGURE II.2.2-6 BIT-TO-SYMBOL MAPPING FOR 4-CAP

(CR) For 4-CAP, the signal constellation shall be as shown in Figure II.2.2-7.

Each incoming group of 2 bits is Gray encoded into a 4-CAP symbol. The relative levels of the amplitude of the symbols in each dimension are proportional to the four different levels, ±1 and ±3.

For example, the first two symbols in an incoming bit stream 10010110 would translate into (a_n= +1, b_n= -3) and (a_{n+1}= -1, b_{n+1}= +3).

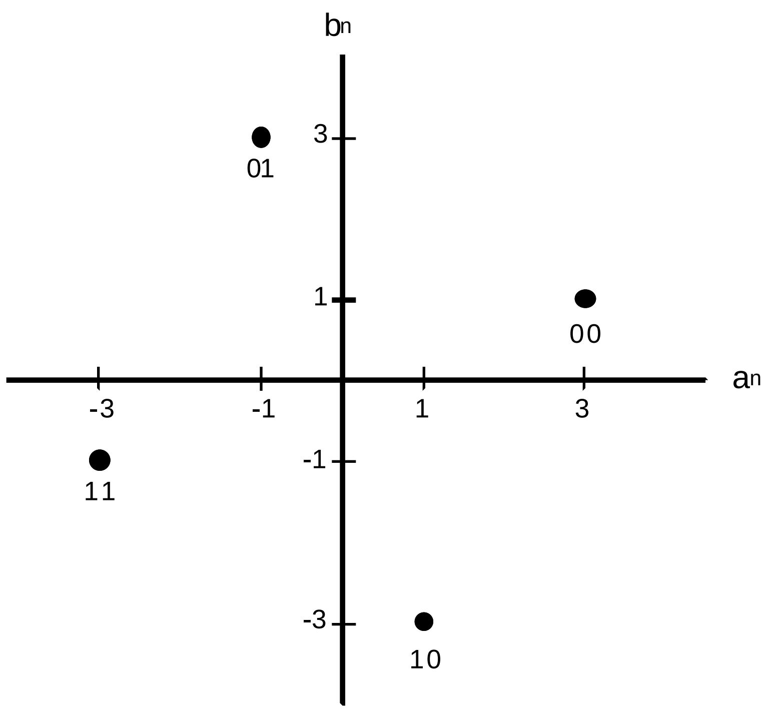


FIGURE II.2.2-7 4-CAP SIGNAL CONSTELLATION

II.2.2.5.2.3 Operation at 12.96 Mb/s

Operation at 12.96 Mb/s is optional. However, if operation at 12.96 Mb/s is implemented, the following statements marked (CR) are required.

(CR) For 12.96 Mb/s, the encoding used shall be the 2-CAP code. The symbol rate shall be 12.96 Mbaud.

(CR) For 2-CAP, the encoder shall map each data bit into a symbol. Bits shall be mapped from the PMD scrambler (see Section 2.6) from left to right, each bit to be mapped into a symbol.

(CR) For 2-CAP, the signal constellation shall be as shown in Figure II.2.2-7.

The relative levels of the amplitude of the symbols in each dimension are proportional to the two different levels, ±3 for a_n and ±1 for b_n.

For example, the first two symbols in an incoming bit stream 10010110 would translate into (a_n= -3, b_n= -1) and (a_{n+1}= +3, b_{n+1}= +1).

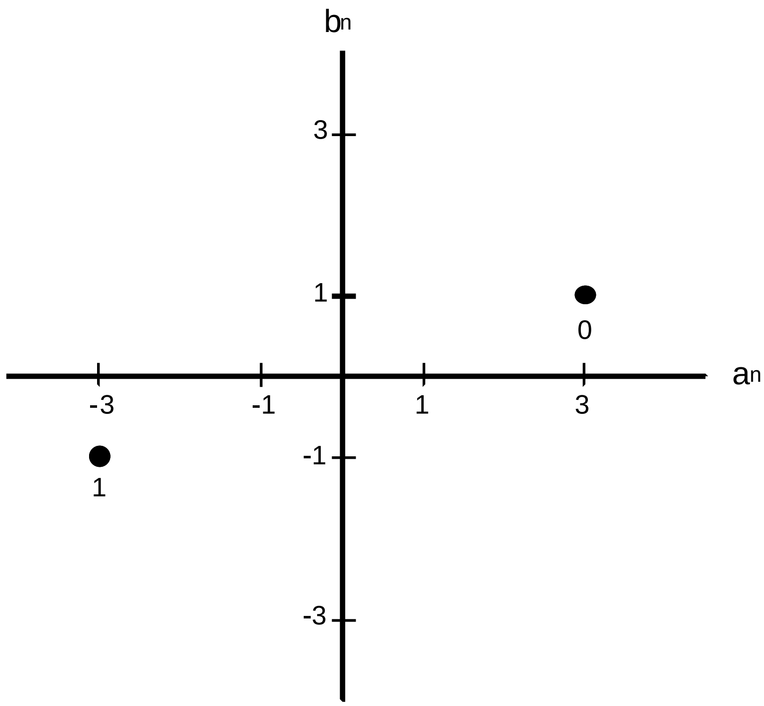


FIGURE II.2.2-8 2-CAP SIGNAL CONSTELLATION

II.2.2.5.3 Active Output Interface

This section specifies the impulse response for the transmit filters, transmit level, and the transmit signal power spectrum of the AOI.

II.2.2.5.3.1 Impulse Response for the Transmit Filters

The impulse response of the in-phase and quadrature filters shown in Figure II.2.2-3 is described as follows.

Let

$$g(t) = \begin{cases} \dfrac{4}{\pi} \dfrac{\cos[2\pi\, t/T]}{[1-(4\,t/T)^2]}, t \neq \pm \dfrac{T}{4} \\ 1, t = \pm \dfrac{T}{4} \end{cases}$$

be a square-root raised-cosine pulse with 100% excess bandwidth. The in-phase filter impulse response is defined as

$$f(t) = g(t) \bullet \cos(2\pi\, t/T)$$

and the quadrature filter impulse response,

$$\tilde{f}(t) = g(t) \bullet \sin(2\pi\, t/T)$$

where T is the symbol period.

The actual impulse responses of the transmitter will be truncated approximations of the above equations over a fixed interval such as $-T \le t \le T$. (See Part II.2 Annex A for technical references.)

Since the symbol rates for the required bit rate and the two optional bit rates are the same, the line interface components, including low-pass filter and transformer, can be identical for all three rates.

II.2.2.5.3.2 Active Output Signal Spectrum

(R) The Active Output signal shall have a power spectrum equivalent to the square root of a raised-cosine shaping with 100% excess bandwidth.

(R) The normalized power spectrum of the Active Output signal of the k-CAP transmitter shall fit within the template of the spectral envelope shown in Figure II.2.2-9.

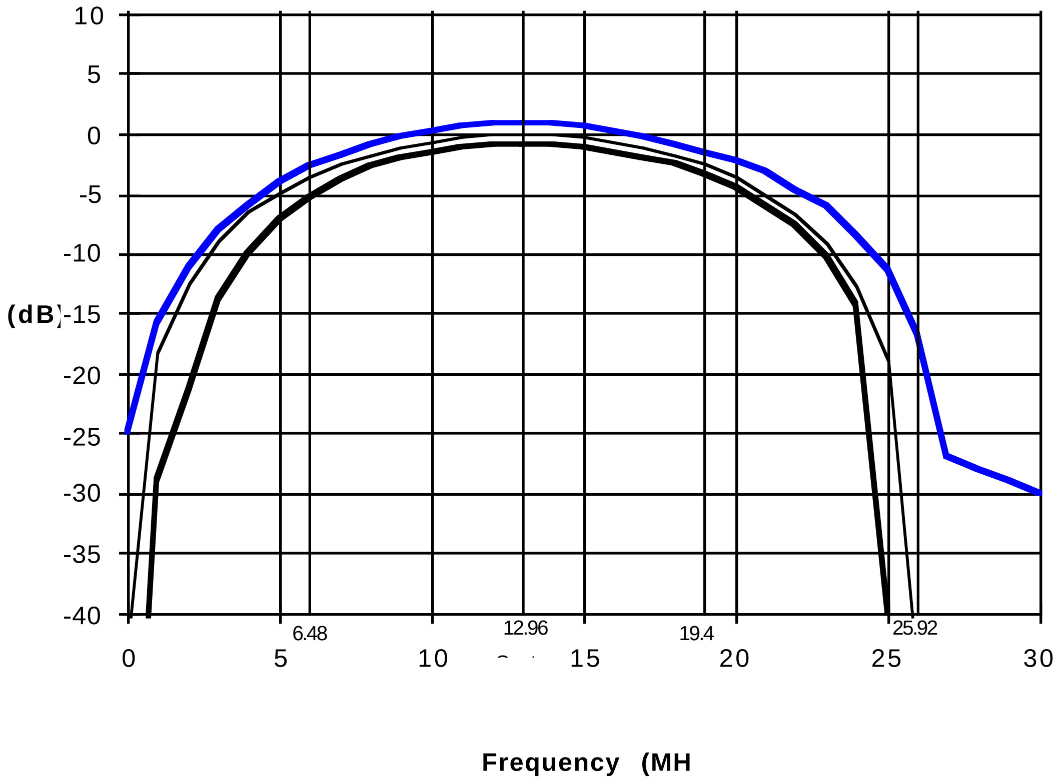


FIGURE II.2.2-9 TEMPLATE FOR THE POWER SPECTRUM OF THE SIGNAL AT THE OUTPUT OF THE TRANSMITTER

[Editor's Note: The figure and table on power spectrum will be modified so they are consistent with each other; the shape of the curve will not change.]

Values are normalized to the mean value at the Center Frequency. Table II.2.2-1 gives quantitative values for breakpoints of the curves in Figure II.2.2-9.

Table II.2.2-1 Breakpoints for the Power Spectrum Curves in Figure II.2.2-9

Frequency (MHz)	0	3	6	9	13	17	20	23	27	30
Upper (dB)	-25	-8.1	-3.3	-0.23	0.8	-0.27	-2.3	-6.2	-22	-25
Lower (dB)	NA	-13.8	-5.3	-1.9	-0.9	-2.0	-4.5	-10.2	NA	NA

Note: NA indicates that no lower boundary is specified for the frequencies.

II.2.2.5.3.3 Voltage Output

(R) The test load shall consist of a single 100 ohm ±0.2% resistor connected across the transmit pins of the AOI. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20 nH and the parallel capacitance shall be less than 2 pF.

(R) The peak-to-peak differential voltage measured across the transmit pins at the AOI shall be 4.0 ±0.2V when terminated with the specified test load.

II.2.2.5.3.4 AOI Return Loss

The Return Loss of the AOI (RL_O) specifies the amount of the differential signal incident upon the AOI that is reflected.

(R) RL_O, specified at the AOI, shall be greater than 15 dB for the frequency range 1-30 MHz. The Return Loss shall be measured for a resistive test load range of 85-115 ohms. The return loss shall be measured while the implementation of the PMD is powered.

RL_O is defined in terms of the receiver impedance or as a differential reflected voltage:

$$RL_0 = 20\log\frac{|Z_r + R_{ref}|}{|Z_r - Z_{ref}|} = 20\log\frac{|V_i|}{|V_r|}$$

where

Z_r is the impedance of the AOI,
Z_{ref} is the reference impedance (85-115 ohms),
V_i is the differential voltage incident upon the AOI, and
V_r is the differential voltage reflected from the AOI.

II.2.2.5.4 Receive Functionality

A CAP receiver decodes the incoming k-CAP signal stream received from the Active Input Interface and converts it into an equivalent bit stream for presentation to the TC sublayer. Design principles for a CAP system are referenced in Part II.2 Annex A. An example of receiver equalizer start-up is described in Part II.2 Annex B.

(R) The receiver shall require no more than 500 ms to reach a state that achieves the BER specified in Section II.2.2.2 from the time presented with a valid signal transmitted through the cable plant specified in Section II.2.2.7 Copper Link Characteristics.

II.2.2.5.4.1 Receiver Return Loss

The Return Loss of the AII (Rl_i) specified the amount of the differential signal incident upon the AII that is reflected.

(R) RL_i, specified at the AII, shall be greater than 16 dB for the frequency range 1-30MHz. The Return Loss shall be measured for a resistive test load range of 85-115 ohms. The return loss shall be measured while the implementation of the PMD is powered.

RL_i is defined in terms of the receiver impedance or as a differential reflected voltage:

$$RL_i = 20\log\frac{|Z_r + R_{ref}|}{|Z_r - Z_{ref}|} = 20\log\frac{|V_i|}{|V_r|}$$

where

Z_r is the impedance of the receiver,
Z_{ref} is the reference impedance (85-115 ohms),
V_i is the differential voltage incident upon the receiver, and
V_r is the differential voltage reflected from the receiver.

II.2.2.6 PMD Scrambler/Descrambler

(R) A self-synchronizing PMD scrambler/descrambler shall be provided in the implementation of the PMD.

For performance reasons, two different scrambler polynomials are used to ensure that the signal in one direction is uncorrelated to the signal in the other direction.

(R) The generating polynomial for network equipment scramblers and user device descramblers shall be:

$GPN(x) = x^{23} + x^{18} + 1$.

(R) The generating polynomial for user device scramblers and network equipment descramblers shall be:

$GPU(x) = x^{23} + x^{5} + 1$.

II.2.2.7 Copper Link Characteristics

The copper medium consists of one or more sections of Category 3 UTP along with intermediate connectors required to connect sections together, and terminated at each end using the connectors specified in Section II.2.2.10. The cable is interconnected to provide two continuous electrical paths, one for each direction.

(R) The cable and patch cords shall meet or exceed the requirements of EIA/TIA-568-A[3] for Category 3 horizontal cabling and flexible cordage respectively. This includes requirements on NEXT loss, attenuation and characteristic impedance.

(R) All connecting hardware (outlets, transition connectors, patch panels and cross-connect fields) shall meet or exceed the Category 3 electrical requirements for NEXT loss and attenuation specified in EIA/TIA-568-A[3].

The intent of these requirements is to minimize the effect of degradation of UTP connecting hardware on end to end system performance. However, it should be noted that the requirements are not sufficient by themselves to ensure adequate system performance. System performance also depends on the care with which the cabling plant, especially the connectors, is installed, and the total number of connections.

(R) The connector termination practices and UTP cable installation practices described in Chapter 10 of EIA/TIA-568-A[3] shall be followed.

II.2.2.8 Link Length Using a Reference Channel Model

II.2.2.8.1 Operation at 51.84 Mb/s

The reference channel model as described in Annex E of EIA/TIA-568-A[3] is defined to be a link consisting of 90 meters of Category 3 cable, 10 meters of Category 3 flexible cords, and four Category 3 connector pairs internal to the link.

(R) The composite channel attenuation shall meet the Category 3 attenuation performance limits defined in Annex E of EIA/TIA-568-A[3].

(R) The composite channel NEXT loss shall meet the Category 3 NEXT loss performance limits defined in Annex E of EIA/TIA-568-A[3].

Since the above two requirements are derived from the electrical performance of the reference channel model, the reference channel model (properly installed) is by definition a compliant link. Additionally, properly installed links consisting of no more than 90m of Category 3 UTP cable, no more than 10m of Category 3 flexible cords, and no more than 4, Category 3 connectors internal to the link are also examples of compliant links. Any installed link meeting the link attenuation and NEXT loss requirements of this section is compliant.

Part II.2 Annex C contains guidance on the use of cable types other than Category 3 UTP.

II.2.2.8.2 Operation at 25.92 Mb/s

Operation at 25.92 Mb/s is achieved by changing the encoding to 4-CAP. The spectral properties of the signal are the same as Figure II.2.2-9 and Table II.2.2-1. However, it is still possible to achieve greater reach as the smaller number of constellation points are more widely separated, and, therefore, greater attenuation can be tolerated while still maintaining the required bit error rate. There is very little decrease in NEXT loss for cable lengths greater than 100m, and so the link NEXT loss requirement remains the same. The attenuation requirement is simply scaled by a factor equal to the increased separation of the constellation points.

(R) Systems operating at 25.92 Mb/s are required to work over a channel having as attentuation 6.9 dB greater than the attenuation at 16 MHz in Part II.2 Annex E of EIA/TIA-568-A[3].

This requirement implies that any implementation of a 25.92 Mb/s system will operate over a link distance up to Xm. More sophisticated implementations will operate over longer distances. *[Editors note: X will be determined at the ATM Forum meeting in July.]*

II.2.2.8.3 Operation at 12.96 Mb/s

Operation at 12.96 Mb/s is achieved by changing the encoding to 2-CAP. The spectral properties of the signal are the same as Figure II.2.2-8 and Table II.2.2-1. However, it is still possible to achieve greater reach as the smaller number of constellation points are more widely separated, and, therefore, greater attenuation can be tolerated while still maintaining the required bit error rate. There is very little decrease in NEXT loss for cable lengths greater than 100m, and so the link NEXT loss requirement remains the same. The attenuation requirement is simply scaled by a factor equal to the increased separation of the constellation points.

(R) Systems operating at 12.96 Mb/s are required to work over a channel having as attentuation 9.9 dB greater than the attenuation at 16 MHz in Part II.2 Annex E of EIA/TIA-568-A[3].

This requirement implies that any implementation of a 12.96 Mb/s system will operate over a link distance up to Ym. More sophisticated implementations will operate over longer distances. *[Editors note: Y will be determined at the ATM Forum meeting in July.]*

II.2.2.9 Noise Environment

The noise environment is discussed in Part II.2 Annex D.

II.2.2.10 Media Interface Connectors

ATM user device and ATM network equipment implementing the mid-range PMD specification shall be attached to the twisted-pair medium by Twisted-Pair Media Interface Connectors (TP-MIC). The media connection between a user device and a network equipment consists of a duplex cable assembly with TP-MIC modular jacks. To ensure interoperability between conforming user devices and network equipment, TP-MIC connectors are specified at the interfaces for user devices and network equipment.

II.2.2.10.1 Connectors for Category 3 UTP Cabling

(R) The cable assembly shall connect the corresponding pins of plugs at either each end of the link (i.e., pin 1 to pin 1, pin 2 to pin 2, etc.).

This method of connection assures that the cable assembly is straight through (no cross-overs) and that the correct polarity is maintained.

II.2.2.10.1.1 UTP-MIC Modular Plug

(R) Each end of the Category 3 UTP link shall be terminated with Media Interface Connectors specified in Section 4 and Figure 1of ISO 8877[4]. This connector is an 8-pin modular plug and shall meet or exceed the requirements for EIA/TIA-568-A[3] Category 3 100 ohm UTP connecting hardware. An illustration of the plug is shown in Figure II.2.2-10.

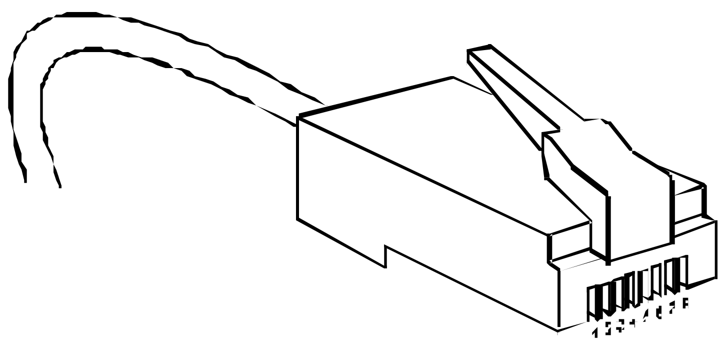


FIGURE II.2.2-10 EXAMPLE OF A UTP-MIC MODULAR PLUG

II.2.2.10.1.2 UTP-MIC Jack

(R) The jack/socket of the Category 3 UTP link shall be a connector specified in Section 4 and Figure 2 of ISO 8877[4]. The connector hardware used within this implementation of the PMD shall be an 8-contact jack and meet or exceed the electrical requirements of EIA/TIA Category 3 100 ohm UTP. These include specifications on NEXT loss. An illustration of the jack is shown in Figure II.2.2-11.

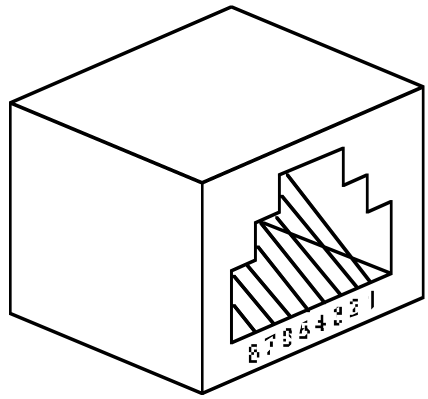


FIGURE II.2.2-11 EXAMPLE OF A UTP-MIC JACK

(R) The assignment of contacts for EIA/TIA cable shall be as shown Table II.2.2-2.

Table II.2.2-2 Contact Assignments for UTP-MIC Connectors

Contact	Signal at the User Device MIC	Signal at the Network Equipment MIC
1	Transmit+	Receive+
2	Transmit-	Receive-
3	Unused	Unused
4	Unused	Unused
5	Unused	Unused
6	Unused	Unused
7	Receive+	Transmit+
8	Receive-	Transmit-

These unused pairs may transport non-interfering signals providing the bit error rate of the pair in use meets the BER specified in Section II.2.2.2.

II.2.3. Transmission Convergence (TC) PHY Sublayer Specification

The Transmission Convergence (TC) sublayer deals with physical aspects which are independent of the transmission medium characteristics. Most of the functions comprising the TC sublayer are involved with generating and processing a subset of the overhead bytes contained in the SONET based STS-1 frame. The description of the SONET based STS-1 frame format and overhead bytes will be covered in Section II.2.3.3

II.2.3.1 SONET based TC Sublayer Functions

The B-ISDN independent TC sublayer functions and procedures involved at the UNI are defined in the relevant sections of ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].
(R) Equipment supporting the mid-range PHY shall perform the SONET procedures related to STS-1 frame scrambling, timing and framing as defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.2 Cell Specific TC Sublayer Functions

The B-ISDN specific TC sublayer contains functions necessary to adapt the service offered by the SONET based physical layer to the service required by the ATM layer. Some of these functions are not specified within SONET, but are required in the mid-range PHY. The B-ISDN specific physical layer functions are described in the following sections.

II.2.3.2.1 HEC Generation/Verification

The entire header (including the HEC byte) is protected by the Header Error Control (HEC) sequence. The HEC code is contained in the last octet of the ATM cell header.
The HEC sequence code is capable of:

- Single bit error correction.
- Multiple-bit error detection.

(R) Equipment supporting the mid-range PHY shall implement error detection as defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

Error correction as described in ITU-T Recommendation I.432[5], if implemented, is not effective. It is recommended that error correction not be implemented.

(R) Equipment supporting the mid-range PHY shall generate the HEC byte as described in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6] including the recommended modulo 2 addition (XOR) of the pattern 01010101 to the HEC bits.

(R) The generator polynomial coefficient set used and the HEC sequence generation procedure shall be in accordance with ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.2.2 Cell Scrambling and Descrambling

Cell Scrambling/Descrambling permits the randomization of the cell payload to avoid continuous non-variable bit patterns and improve the efficiency of the cell delineation algorithm.

(R) Equipment supporting the mid-range PHY shall implement the self synchronizing scrambler polynomial and procedures as defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.2.3 Cell Mapping

The mapping of ATM cells is performed by aligning by row, the byte structure of every cell with the byte structure of the SONET based STS-1 payload capacity, e.g. Synchronous Payload Envelope, (SPE). The entire STS-1 payload capacity, *except for columns 30 and 59* (see below), is filled with cells, yielding a transfer capacity for ATM cells of 48.384 Mb/s. Because the STS-1 payload capacity is not an integer multiple of cell length, a cell may cross an SPE boundary* .

---

*The two columns, number 30 and 59, listed above, are fixed stuff columns. These columns are used to compensate for the difference between the bandwidth available in the STS-1 and Virtual Tributary Synchronous Payload Envelopes and the bandwidth required for the actual payload mapping, (i.e. DS1, DS2, DS3 and so on). The bytes in these columns have no defined value, see Section II.2.3.3.1 for the actual transmitted value.

II.2.3.2.4 Cell Delineation

The cell delineation function permits the identification of cell boundaries in the payload. It uses the Header Error Control (HEC) field in the cell header.

(R) Equipment supporting the mid-range PHY shall perform cell delineation using the HEC based algorithm described in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(O) Equipment supporting the mid-range PHY may implement the cell delineation times in conformance with the state transition timing requirements as described in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6]:

- The time to declare "Hunt state" once cell delineation is lost shall be 7 cell times.
- The time to declare "Sync state" once "Pre-Sync state" is obtained (e.g. one valid HEC) shall be 6 cell times.

II.2.3.2.5 ATM Payload Construction Indication

The construction of STS-1 SPE loaded with ATM cell is indicated through the STS path signal label (C2) byte in the STS Path Overhead (STS POH).

II.2.3.3 SONET based STS-1 Frame

This section defines the STS-1 frame structure and describes its overhead bytes. First, in Section II.2.3.3.1, the frame structure is given and then, in Section II.2.3.3.2, the description of the overhead bytes is provided.

II.2.3.3.1 Frame description

The format of the STS-1 frame used at the 51.84 Mb/s B-ISDN User-Network Interface is given in Figure II.2.2-12.

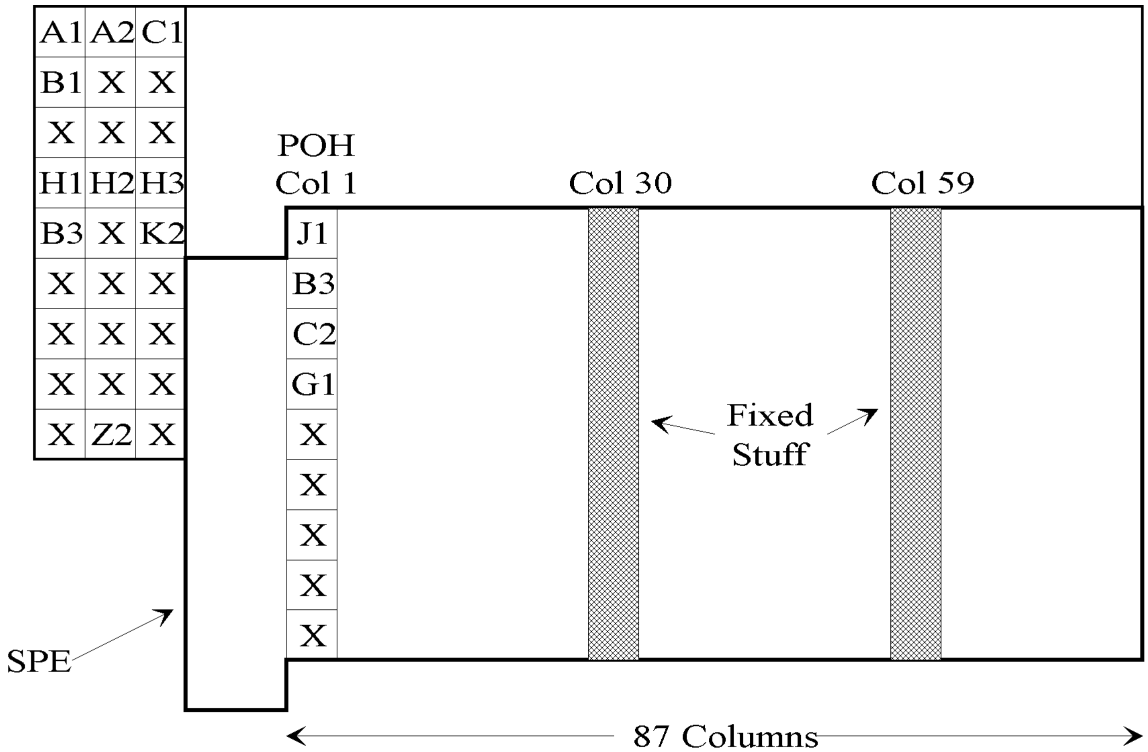


FIGURE II.2.2-12 SONET BASED STS-1 FRAME

Active overhead bytes/bits: **A1**, **A2**, **C1**, **J1**, **B1**, **B3**, **C2**, **H1**(1-4,7,8), **H2**, **H3**, **G1**(1-5), **K2**(6-8), **Z2**(5-8)

All other bytes (shown by X) and partial bytes are reserved.
Shaded areas: Fixed Stuff bytes
Bits are numbered from left to right, 1 to 8 with bit 1 being the first to be transmitted.

(R) Transmitting equipment supporting the mid-range PHY shall encode all undefined overhead bytes/bits to zero patterns before scrambling and transmission.

(R) Receiving equipment supporting the mid-range PHY shall ignore all overhead bytes/bits undefined at the mid-range PHY.

(R) Transmitting equipment supporting the mid-range PHY shall encode all Fixed Stuff bytes, (e.g. shaded bytes in Figure II.2.2-13), the contents of which may be any value with the constraint that the two bytes in each row be identical.

(R) The contents of the Fixed Stuff bytes are not placed in ATM cells. The BIP operations are applied to all bytes in the SONET[2] based payload.

II.2.3.3.2 Active Overhead Bytes Description

The following describes each of the overhead active bytes in the STS-1 frame.

II.2.3.3.2.1 Framing Bytes: A1, A2

(R) Transmitting equipment supporting the mid-range PHY shall transmit in these bytes the values:

- A1: 11110110
- A2: 00101000

(R) Receiving equipment supporting the mid-range PHY shall check that A1 and A2 bytes have the value specified above and implement the states, (e.g. Out Of Frame, (OOF), Loss Of Frame, (LOF), and Loss Of Signal, (LOS)), and related procedures, defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6] when detecting error patterns.

II.2.3.3.2.2 STS-1 ID: C1

(R) Transmitting equipment supporting the mid-range PHY shall transmit in this byte the value: 00000001.

II.2.3.3.2.3 Section Error Monitoring: B1

(R) Transmitting equipment supporting the mid-range PHY shall generate and transmit in the B1 byte, the bit interleaved parity 8 code using even parity over the bits in the previous STS-1 frame as specified in T1.105-1991[2].

(O) Receiving equipment supporting the mid-range PHY may check the B1 byte value in the received STS-1 frame and process it according to the algorithm, states and procedures defined in ITU-T Recommendation I.432[5]and T1E1 B-ISDN Draft[6].

II.2.3.3.2.4 New Data Flag, Pointer Value and Pointer Action Bytes: H1, H2, H3

(R) Transmitting equipment supporting the mid-range PHY can either support only fixed SPE or support floating SPE.

(CR) Transmitting equipment supporting the mid-range PHY which supports transmission of floating SPE shall transmit valid values in these bytes according to the algorithm specified in T1.105-1991[2].

(CR) Transmitting equipment supporting the mid-range PHY which only supports transmission of fixed SPE shall transmit the following values in these bytes:

(1) H1: 0110xx10

(2) H2: 00001010
(3) H3: 00000000
(4) OR, set all bits in these three bytes to 1 if Path AIS, (Alarm Indication Signal), is issued, (see below).

NOTE: The pointer value is fixed to 1000001010, (20A HEX), which is 522 decimal. This fixes the J1 byte to immediately follow the C1 byte.

(R) Transmitting equipment supporting the mid-range PHY shall generate Path AIS by setting all bits in H1, H2 and H3 bytes to 1, (as well as all bits in the payload), in the cases defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6], (e.g. LOF, LOS, LOP and Line AIS).

(R) Receiving equipment supporting the mid-range PHY shall process the H1, H2 and H3 bytes according to the algorithm, states, (including Loss Of Pointer, (LOP)), and procedures specified in ITU-T Recommendation I.432[5], and T1E1 B-ISDN Draft[6] and T1.105-1991[2].

II.2.3.3.2.5 Line Error Monitoring: B2

(R) Transmitting equipment supporting the mid-range PHY shall generate and transmit in the B2 byte, the bit interleaved parity 8 code using even parity over the bits in the previous STS-1 Line overhead and Envelope Capacity as specified in T1.105-1991[2].

(O) Receiving equipment supporting the mid-range PHY may check the B2 byte value in the received STS-1 frame and process it according to the algorithm, states and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.3.2.6 Line Status: K2 bits 6-8

(O) Transmitting equipment supporting the mid-range PHY may generate and transmit in the K2 byte bits 6-8, the Line AIS, Line RDI, and removal of Line RDI, according to the states, (e.g. LOS, LOF and incoming Line AIS), and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft.[6]

(O) Receiving equipment supporting the mid-range PHY may check the K2 byte bits 6-8, and act upon detecting Line AIS, Line RDI and removal of Line RDI, according to the states and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(CR) If this field is not used, it must be set to a zero pattern before scrambling and transmission.

II.2.3.3.2.7 Line Far End Block Error, (FEBE): Z2 bits 5-8

(O) Transmitting equipment supporting the mid-range PHY may transmit in these bits the count of B2 errors according to the definition in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(O) Receiving equipment supporting the mid-range PHY may process the count of B2 errors transmitted in these bits according to the states and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(CR) If this field is not used, it must be set to a zero pattern before scrambling and transmission.

II.2.3.3.2.8 Path Trace: J1

(O) Equipment supporting the mid-range PHY can perform facility testing by repetitively sending the appropriate 64 byte code in the J1 POH byte as defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(CR) If this field is not used, it must be set to a zero pattern before scrambling and transmission.

II.2.3.3.2.9 Path Error Monitoring: B3

(R) Transmitting equipment supporting the mid-range PHY shall generate and transmit in the B3 byte, the bit interleaved parity 8 code using even parity over the bits in the previous STS-1 SPE as specified in T1.105-1991[2].

(R) Receiving equipment supporting the mid-range PHY shall check the B3 byte value in the received STS-1 frame and process it according to the algorithm, states and procedures in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.3.2.10 Path Signal Label: C2

(R) Transmitting equipment supporting the mid-range PHY shall transmit in the C2 byte the value 00010011.

(O) Receiving equipment supporting the mid-range PHY may check the C2 byte value and if detecting a value other than the one specified above act according to the states and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.3.2.11 Path Status: G1 bits 1-5

(R) Equipment supporting the mid-range PHY shall detect the Out-of-Cell Delineation (OCD) anomaly when the HEC coding rule is determined to be incorrect 7 consecutive times for the incoming signal. A Loss-Of-Cell (LCD) Delineation state shall be declared after persistence of the OCD anomaly for a time period of 4 ms, at which time the "Path RDI" shall be generated and transmitted.

(R) Transmitting equipment supporting the mid-range PHY shall generate and transmit in the G1 bit 5 the Path RDI, (Remote Defect Indicator), and the in bits 1-4 the count of B3 errors, (Far End Block Error, FEBE), according to the states, (B3 errors for bits 1-4 and LOS, LOF, Line AIS, Path AIS and LOC for RDI), and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

(R) Receiving equipment supporting the mid-range PHY may check the G1 byte value and if detecting Path RDI or Path FEBE, act according to the states and procedures defined in ITU-T Recommendation I.432[5] and T1E1 B-ISDN Draft[6].

II.2.3.4 Frame Duration

The TC includes the transmission and reception of the 810 bytes STS-1 frame as described in Section II.2.3.3.1. The different rates are achieved as follows:

(R) 51.84 Mb/s: frames repeat at 125 microsecond intervals.

(CR) 25.92 Mb/s: frames repeat at 250 microsecond intervals.

(CR) 12.96 Mb/s: frames repeat at 500 microsecond intervals.

II.2.3.5 References

[1] ATM User-Network Specification, Version 3.1, 1994.

[2] ANSI T1.105, Digital Hierarchy - Optical Interface Rates and Formats Specifications, 1991.

[3] Commercial Building &Wiring Telecommunications Wiring Standard, EIA/TIA-568-A Standard, Letter Ballot, 1994.

[4] ISO 8877, Information processing systems – Interface connector and contact assignments fro ISDN basic access interface located at reference points S and T, 1991.

[5] ITU-T Recommendation I.432, B-ISDN User-Netwrok Interface - Physical Layer Specification, 1993.

[6] ANSI T1E1/LB93-05, Broadband ISDN and DS1/ATM User-Network Interfaces: Physical Layer Specification.

Part II.2 Annex A: Informational References on CAP Technology

J. J. Werner, "Tutorial on Carrierless AM/PM - Part I - Fundamentals and Digital CAP Transmitter," Contribution to ANSI X3T9.5 TP/PMD Working Group, Minneapolis, June 23, 1992.

J. J. Werner, "Tutorial on Carrierless AM/PM - Part II - Performance of Bandwidth-Efficient Line Codes," Contribution to ANSI X3T9.5 TP/PMD Working Group, Austin, February 16, 1993.

W. Y. Chen, G. H. Im, and J. J. Werner, "Design of Digital Carrierless AM/PM transceivers," AT&T/Bellcore Contribution T1E1.4/92-149, August 19, 1992.

Copies of these contributions may be obtained from:

ATIS
Mary Cloyd
Suite 500
1200 G Street, NW
Washington, D.C. 20005.

Part II.2 Annex B: An Example of Receiver Equalizer Start-Up

Start-up for a CAP receiver is an implementation issue. If the receiver's equalizer consists of two parallel fractionally spaced adaptive filters, the following simple procedure is adequate.

(1) A set of initial coefficients is loaded into the two filters.

(2) Let the equalizer converge with the slicer set to two levels on each dimension (i.e. 4-CAP).

(3) After initial convergence, the slicer is set to four levels on each dimension and continues to converge. Correct convergence may be verified by correct delineation of ATM cells.

(4) If correct convergence is not observed for a period of time, go to 1.

Part II.2 Annex C: The Use of Alternative Cable Types

Category 5 Cable at 51.84 Mb/s

It is possible to achieve greater than 100m reach by the use of higher performance, Category 5 cable. This is superior in both its NEXT loss and attenuation performance, and so the attenuation to crosstalk ratio (ACR) is very much higher, which offers the prospect of much greater reach. However, some care has to be exercised when trading attenuation for crosstalk, and this is outside the scope of this document.

It is still possible to gain from the superior attenuation performance of Category 5 cable while retaining the channel specification requirements of section II.2.2.7.1. This should permit a maximum reach of about 160m using a link made of Category 5 components and a receiver having a dynamic range which does not exceed what is required for a 100m category 3 cable. Links with lengths substantially in excess of 160m can be achieved with receivers having a dynamic range which is larger than the dynamic range required for a 100m Category 3 UTP cable.

The following table summarizes supportable link lengths for Category 3 and Category 5 UTP cabling.

Table II.2.A-1 Supportable Link Lengths for Allowable Bit Rates

	Bit Rates		
Cable Type	51.84 Mb/s	25.92 Mb/s	12.96 Mb/s
Category 3	100m	Xm	Y
Category 5	160m	320m	400m

Other Cable Types

There are a variety of cable types which have attenuation and crosstalk characteristics that are different than those of Category 3 which may be used to provide the copper link function. ISO 11801 describes cabling which may meet the requirements of the copper link specification, and possibly provide the copper link function at lengths other than 100m. Link lengths using these cables is not specified in this document and must be determined, in terms relative to the length of Category 3 UTP, by the user/provider.

Estimates for the achievable link lengths for these cables can be determined using the following method. Let Lx(f) and La(f) be the worst case NEXT loss and attenuation/insertion loss (in dB) at frequency for a given cabling system. At frequency f, the NEXT loss-to-insertion loss ratio NIR(f) is defined as

NIR(f) = Lx(f) - La(f).

The link length that can be supported using the alternate cable system is estimated by determining the cable length for which NIR(f) > NIFref(f) at all frequencies between 1 and 16 MHz. The reference, NIRref(f), is determined from the link performance data for Category 3 in Annex E of EIA/TIA-569-A as follows:

at 51.84 Mb/s determine NIRref(f) for a 100m Category 3 cable
at 25.92 Mb/s determine NIRref(f) for a Xm Category 3 cable
at 12.96 Mb/s determine NIRref(f) for a Ym Category 3 cable.

For example, at the sub-rate of 25.92 Mb/s, NIRref(f) at frequencies of 1 and 16 MHz is 30.7 and -10.5 dB, respectively.

Part II.2 Annex D: Noise Environment

The noise environment consists of two primary, external contributors: induced impulse noise from other office and building equipment and other, non-impulse background radiation.

Impulse Noise

The implementation of the PMD, operating over the specified cable plant, should recover without operator intervention when subjected to 0.5 kV impulse noise (fast transient) as described in IEC 801-4, Level 2. The implementation of the PMD should be tested using the methods described in IEC 801-4.

Electromagnetic Susceptibility

The implementation of the PMD should operate within the specified BER during the 3 V/m field EMC test described in IEC 801-3, Level 2. The implementation of the PMD should be tested using methods described in IEC 801-3.

Part II.3
DS1 Physical Layer Specification

April 20, 1994

II.3 DS1 Physical Layer Interface

This DS1 ATM UNI specification for a 1.544 Mbps interface rate is based on ANSI T1 (T1E1 LB 93-05) and ITU (G.804) documents to maintain consistency with existing standards for ATM over DS1.

This specification applies to the public UNI only. It is intended to operate over clear channel (transparent T 1) facilities.

II.3.1 Physical Media Dependent (PMD)Characteristics

(R) The DS1 ATM UNI shall meet the PMD characteristics of Ia at the U reference point as specified in ANSI T1.408 Sections 5.2, 5.3.3, 5.4 -5.4.2.3, 5.5 and 5.6.1.

Specific implementation requirements, especially regarding the ESF DataLink, are related to selection of the interface at Ia of the U reference point in ANSI T1.408.

II.3.1.1 Interface Bit Rate

(R) The physical layer bit rate at the DS1 ATM UNI shall be nominally 1.544 Mbps.

II.3.1.2 ATM Transfer Rate

(R) The nominal bit rate available for transport of ATM cells (user information cells, signaling cells and ATM higher layer OAM information cells) shall be 1.536 Mbps.

II.3.1.3 Interface Symmetry

(R) The DS1 ATM UNI is symmetric (i.e. it provides the same1.544 Mbps nominal bit rate in both transmission directions).

II.3.1.4 Synchronization

(R) The DS 1 ATM UNI shall meet the synchronization characteristics of Ia at the U reference point as described in ANSI T1.408 Sections 5.3.1.1 - 5.3.1.2.1 for public network access applications and Section 5.3.1.2.3 for leased line applications.

II.3.1.5 Line Code

(R) The line code used on the DS1 ATM UNI shall be Bipolar 8 Zero Substitution (B8ZS) as specified in ANSI T1.408 Section 5.3.2 (excludingZBTSI or interim solutions).

II.3.2 Transport Signal Format

II.3.2.1 FrameFormat

(R) The physical layer interface format shall be the 24 frame multiframe Extended Superframe Format (ESF) for DS1 as defined in ANSI T1.408 Sections 6.1 - 6.3 and 7 (excluding ZBTSI).

II.3.2.2 ESF Maintenance Functions

This section is consistent with the required message-oriented and bit-oriented messages of ANSI T1.408 Section 8.

(R) The DS1 ATM UNI shall provide bit-oriented alarm messages of theESF Data Link as specified in ANSI T1.408 Sections 8.1 and 8.2.

(R) The DS1 ATM UNI shall provide bit-oriented loopback messages of the ESF Data Link as specified in ANSI T1.408 Sections 8.3 (including Annex EPT FS and Ia FS required functions) and 8.3.1, 8.3.3 and 8.3.4.

(R) The DS1 ATM UNI shall provide the above bit-oriented messages in accordance with the conditions of the ESF Data Link as described in ANSI T1.408 Sections 8.4.1 - 8.4.2.2.

(R) The DS1 ATM UNI shall provide the message-oriented performance report messages of the ESF Data Link as specified in ANSI T1.408 Sections 8.4.3.1 - 8.4.3.1.2. These performance report messages shall have the format and meet the conditions described in ANSI T1.408 Sections 8.4.3.2 - 8.4.5.

II.3.3 Transmission Convergence (TC)Characteristics

II.3.3.1 ATM CellMapping

(R) ATM cells shall be carried in the DS1 payload (bits 2 -193), in accordance with ITU G.804 Section 2.1, by utilizing the direct mapping as shown by Figure II.3.2-1. ATM cells are byte-aligned to the DS1 frame.

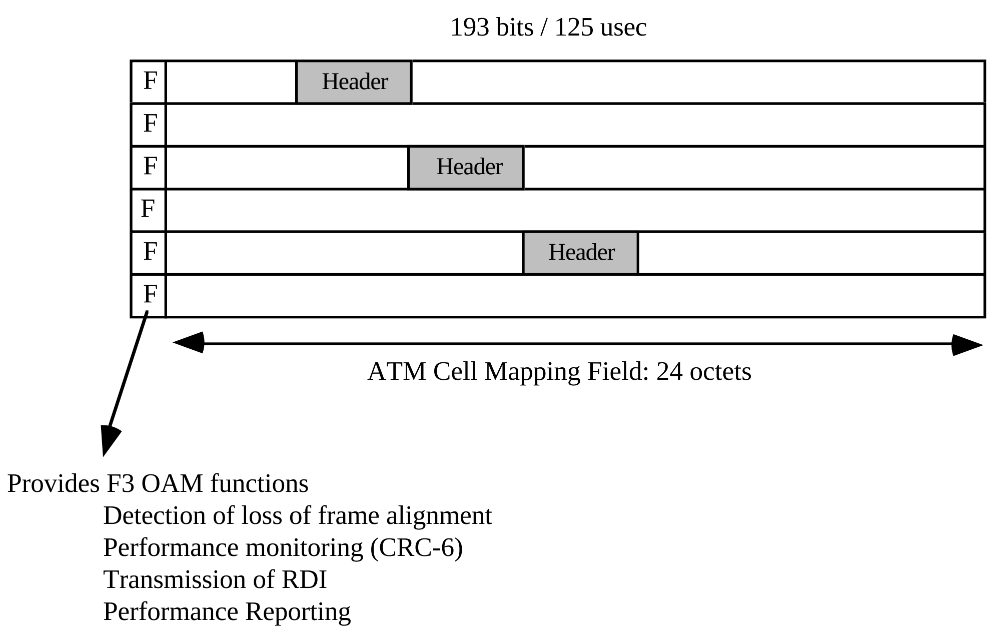


Figure II.3.2-1 ATM Cell Mapping

II.3.3.2 Cell Rate Decoupling[1]

(R) On the transmit side, the DS1 ATM UNI physical layer interface shall adapt the cell rate arriving from the ATM layer to the DS1 frame payload capacity by inserting unassigned or idle cells when assigned cells are not available from the ATM layer.

(R) The receive side of the interface shall be able to receive and filter unassigned cells and idle cells.

In the case that Generic Flow Control (GFC) is supported, the transmit side shall use unassigned cells when assigned cells are not available from theATM layer.

The use of idle cells is described in ITU I.432 Section 4.4. The use of unassigned cells is described in ANSI T1.627 Sections 7.5.3 and 10.12 - 10.13 as well as ITU I.361.

II.3.3.3 Cell Delineation

(R) The cell delineation function shall be performed using the HEC mechanism as defined in ITU I.432 Section 4.5. Payload scrambling shall not be used.

II.3.3.4 HEC Generation/Verification

The Header Error Control (HEC) covers the entire cell header.

(R) The HEC shall be generated as described in ITU I.432 Section 4.3.2.

(R) The generator polynomial and coset used shall be in accordance with ITU I.432 Section 4.3.2.

(R) HEC error detection as defined in ITU I.432 Sections 4.3.1 - 4.3.2 shall be implemented.

(O) Single bit error correction may be implemented in addition to error detection. In this case, the two modes of operation shall interact in accordance with procedures defined in ITU I.432 Section 4.3.1.

[1] See Section 3.4.2 on Cell Rate Decoupling in the ATM Forum UNI version 3.0 for further information regarding unassigned and assigned cells.