The ATM Forum

Technical Committee

Residential Broadband Physical Interfaces Specification

AF-RBB-PHY-0101.000

January, 1999

The ATM Forum
Worldwide Headquarters
2570 West El Camino Real, Suite 304
Mountain View, CA 94040-1313
Tel: +1-650-949-6700
Fax: +1-650-949-6705

Table of Contents

1. Introduction

This specification defines physical layer (PHY) interfaces for residential broadband (RBB) deployment. It references, where appropriate, other standards and specifications.

This specification defines physical layers for the 25.6/51.2 Mb/s Private UNI. Devices meeting this specification shall be able to operate at the 25.6 Mb/s rate and may also operate at the 51.2 Mb/s rate. Automatic speed detection of the ATM End System shall be implemented where the local device has 25.6/51.2 Mb/s capability.

The physical layer is divided into a Physical Media Dependent sublayer (PMD) and a Transmission Convergence (TC) sublayer. The PMD sublayer provides the specifications for the transmitter, the receiver, timing recovery, media interface connector and the channel transmission media. The TC sublayer defines the line coding, scrambling, data framing and synchronization. This specification defines both a metallic twisted pair and plastic optical fiber PMD, using a common TC. The TC is based on the one specified in the ATM Forum specification "Physical Interface Specification for Twisted Pair Cable" (af-phy-0040.000) but with some modifications to improve RF egress. The PMD for metallic twisted pair is such that components meeting the above specifications will interoperate at 25.6 Mb/s over Category 5 metallic channels of up to 50m length as described in this specification. Although such interoperability is supported, it is recommended that use of devices conforming to af-phy-0040.000 is minimized in the home environment, and the devices used shall normally conform to this specification. Devices conforming to this specification have improved RF egress characteristics intended to allow coexistence of home networks with residential activities sensitive to RF egress, such as amateur band and shortwave radio listening.

The bit rate used throughout this document refers to the logical information rate, before line coding. The term line symbol rate will be used when referring to the rate after line coding (25.6 Mb/s bit rate results in a 32 Mbaud line symbol rate after 4B5B encoding, 51.2 Mb/s bit rate results in a 64 Mbaud line symbol rate after 4B5B encoding).

Within the context of this document, specifications are presented as *requirements*, denoted by (R), *conditional requirements*, denoted by (CR), *recommendations,* denoted by (REC) or *optional requirements*, denoted by (O). In this document *requirements* are functions that are necessary for operational compatibility. *Conditional requirements* are functions that are necessary for operational compatibility if the stated conditional clause is satisfied *Recommendations* are provided as guidelines and usually refer to measurement criteria. *Optional requirements* indicate functions, which if implemented, should be according to the stated methodology for compatibility.

2. Physical Media Dependent (PMD) Sub layers

2.1 Line and Bit Rates

(R) At 25.6 Mb/s: the line symbol rate shall be 32 Mbaud +/- 100 ppm. Due to the use of the 4B5B block code, the bit rate is 25.6 Mb/s +/- 100 ppm.

(CR) If the 51.2 Mb/s mode is implemented: the line symbol rate shall be 64 Mbaud +/- 100 ppm. Due to the use of the 4B5B block code, the bit rate is 51.2 Mb/sec +/- 100 ppm.

2.1.1 Bit Rate Symmetry

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

2.1.2 Transmission Link Timing

Figure 2-1 illustrates the conceptual components of the TC/PMD and the timing source.

(R) The TC/PMD shall use a low jitter timing reference that supports a nominal transmission rate of 25.6 Mb/s.

(CR) If the 51.2 Mb/s mode is implemented the TC/PMD shall use a low jitter timing reference that supports a nominal transmission rate of 51.2 Mb/s .

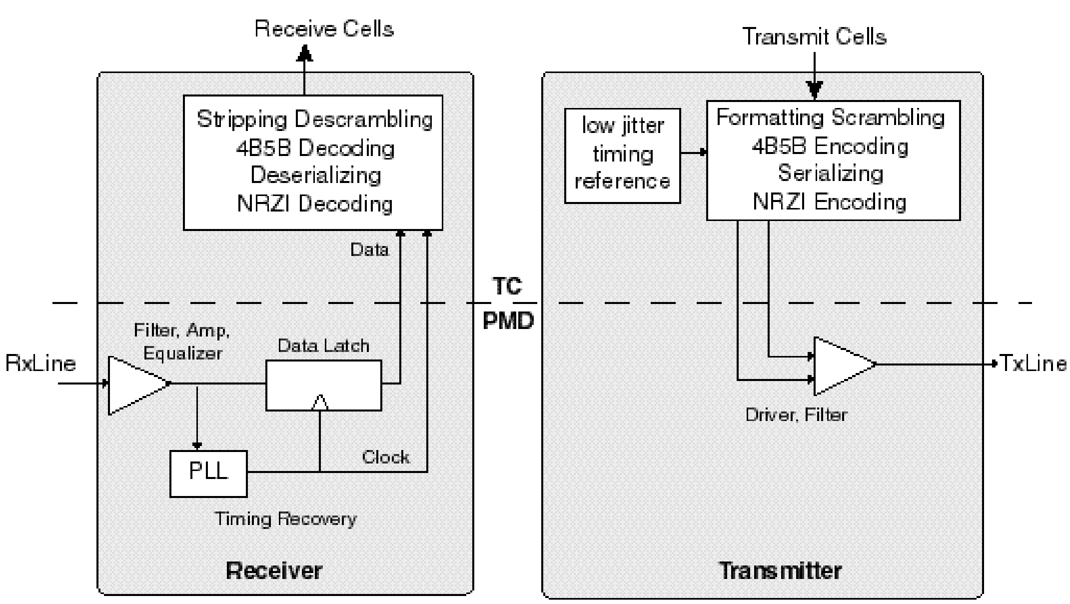


Figure 2-1 Illustration of Example TC/PMD Components and Transmitter Timing

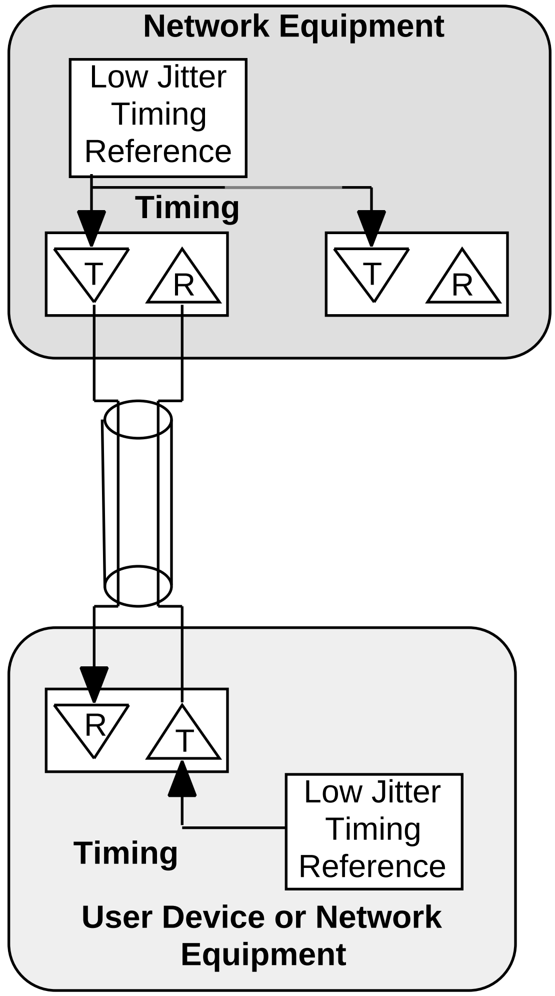


Figure 2-2 User Device - Network Equipment Timing Configurations

2.1.3 Free Running Timing Configurations

The recommended approach is to use point to point timing where the transmit clock on each end of a link is independent.

2.2 Transmission Link Requirements for Metallic Twisted Pair Cabling Systems

2.2.1 Bit Error Rate (BER)

(R) The active Input Interface shall operate at a BER not to exceed 1E-10 when presented with a transmitter specified in Section 2.2.2 transmitted through the channel reference model described in Section 2.2.4.1.2 in the presence of the worst-case cross talk noise specified in Section 2.2.4.1.1. For the 120 Ohm channel model and crosstalk noise refer to Sections 2.2.4.2.2 and 2.2.4.2.1 .

2.2.2 Transmitter Requirements

These specifications place requirements on the transmitted signal. Measurement to these specifications will require that a means exists to send unscrambled, unencoded data streams at the line symbol rate through the transmitter circuitry.

(R) The transmitter shall be terminated in a 100 Ohm resistive load for 100 Ohm TP specifications.

(CR) If the 120 Ohm metallic link is implemented the transmitter shall be terminated in a 120 Ohm resistive load for 120 Ohm UTP specifications.

2.2.2.1 Transmitter Zero-crossing Distortion

These specifications limit the distortion of the transmitted data edge zero-crossings relative to the transmit clock. Duty cycle distortion is intended to measure the static, non-data-dependent distortion in the data edge zero-crossings typically caused by asymmetrical propagation or rise/fall times of transmitter logic or in the conversion from a single-ended to a differential data stream. Edge jitter is intended to measure the dynamic and data dependent distortion in the data edge zero-crossings typically caused by transmit filtering and noises internal and external to the transmitter circuitry.

2.2.2.1.1 Duty Cycle Distortion

Duty cycle distortion is specified for the transmitted data stream shown below and is defined as one half the difference in the positive and negative pulse widths of the AC coupled transmitter waveform.

Note: The waveform specified below is only a test waveform for the purpose of measuring the launch amplitude and should not be construed as a waveform seen during normal operation of the PHY.

(R) The transmitter duty cycle distortion shall be less than 1.5 ns peak when the output is clocked by a local clock source:

Two test waveforms (symbol elements at line symbol rate) are defined to be: 00110011...., and 01010101... These waveforms are described as would be found on the wire (i.e., following all scrambling, and 4B5B and NRZI encoding).

2.2.2.1.2 Edge Jitter

Edge jitter is specified for any waveform compliant with the scrambling and encoding specifications in Section 3. It is defined as the maximum of the peak variation of the rising edges of data relative to the transmit clock and the falling edges of data relative to the transmit clock.

(R) The transmitter edge jitter shall be less than 4 ns peak-to-peak when the output is clocked by a local clock source.

2.2.2.2 Transmitter Waveshapes

(R) The transmitter wave shape shall conform to the waveform templates defined in Tables 2.1, 2.2, 2.3, 2.4, and 2.5 below. An additional constraint shall be that the worst case 3dB corner frequency of the transmitter output shall be less than or equal 12 KHz.

The table and graph pairs below list and then plot the data points that define the pulse templates.

> Note: Amplitude is expressed as the measured pulse amplitude normalized such that the value 1 on each graph represents the amplitude of the fundamental frequency for the single symbol element. Time is expressed in percent of the measured pulse width. With a line symbol rate of 32 Mbaud, the nominal line symbol width is 31.25 nanoseconds. (Therefore, for example, the nominal duration -- corresponding to the 100% mark -- for the five-symbol element is 156.25 nanoseconds.) Likewise with a line symbol rate of 64 Mbaud, the nominal line symbol width is 15.625 nanoseconds. (Therefore, for example, the nominal duration -- corresponding to the 100% mark -- for the five-symbol element is 78.125 nanoseconds.)

Table 2-1 Template for 5 Symbol Element Waveform

Point	Upper Time (%)	Upper Amplitude	Lower Time (%)	Lower Amplitude
A	-0.3	0	0.3	0
B	6.3	1.20	10.5	0.90
C	14	1.20	23.0	0.50
D	23	1.05	36.0	0.75
E	34	1.20	53.0	0.60
F	56	0.95	87.0	0.60
G	95	0.92	99.7	0
H	100.3	0	-	-

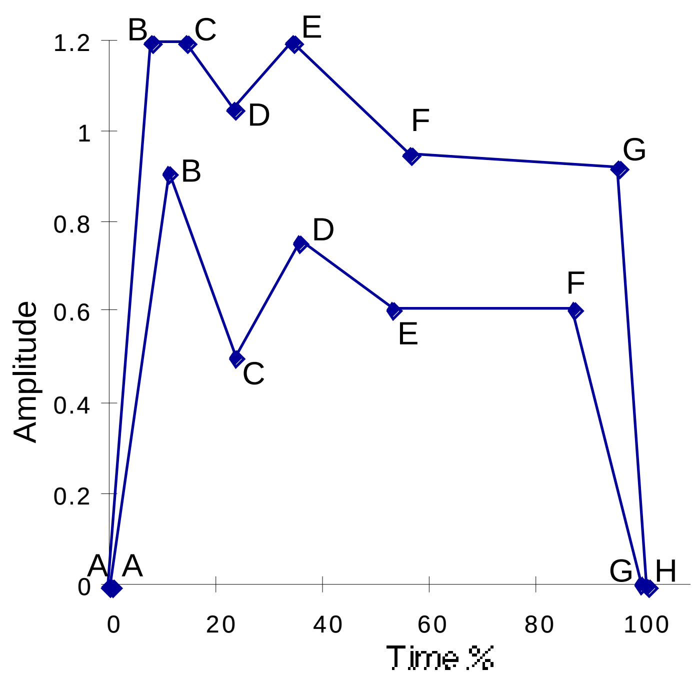


Figure 2-3 Pulse Template for Table 2-1 Five Symbol Element Waveform

Table 2-2 Template for 4 Symbol Element Waveform

Point	Upper Time (%)	Upper Amplitude	Lower Time (%)	Lower Amplitude
A	-0.4	0	0.4	0
B	7.9	1.20	13.1	0.90
C	17	1.20	28.0	0.50
D	29	1.05	45.0	0.75
E	43	1.20	66.0	0.60
F	70	0.95	84.0	0.60
G	93.5	0.92	99.6	0
H	100.4	0	-	-

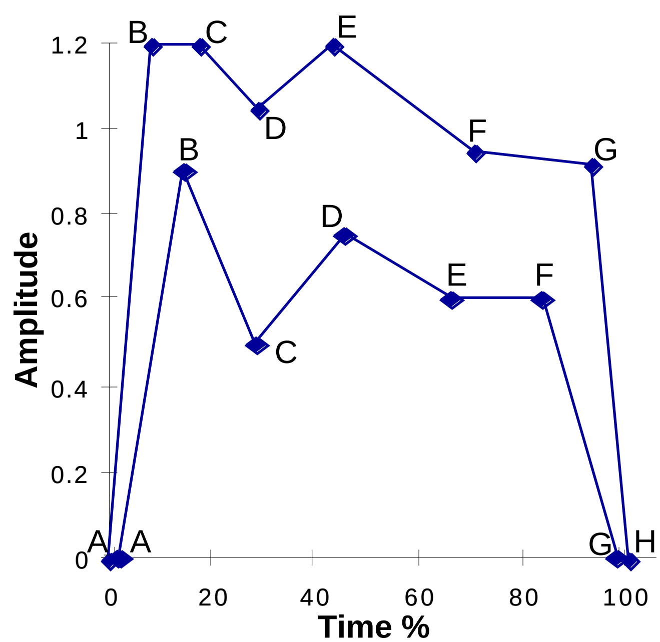


Figure 2-4 Pulse Template for Table 2-2 Four Symbol Element Waveform

Table 2-3 Template for 3 Symbol Element Waveform

Point	Upper Time (%)	Upper Amplitude	Lower Time (%)	Lower Amplitude
A	-0.5	0	0.5	0
B	10.5	1.20	17.5	0.90
C	23.0	1.20	37.5	0.50
D	38.0	1.05	59.5	0.75
E	57.0	1.20	87.5	0.6
F	93.0	0.95	99.5	0
G	100.5	0	-	-

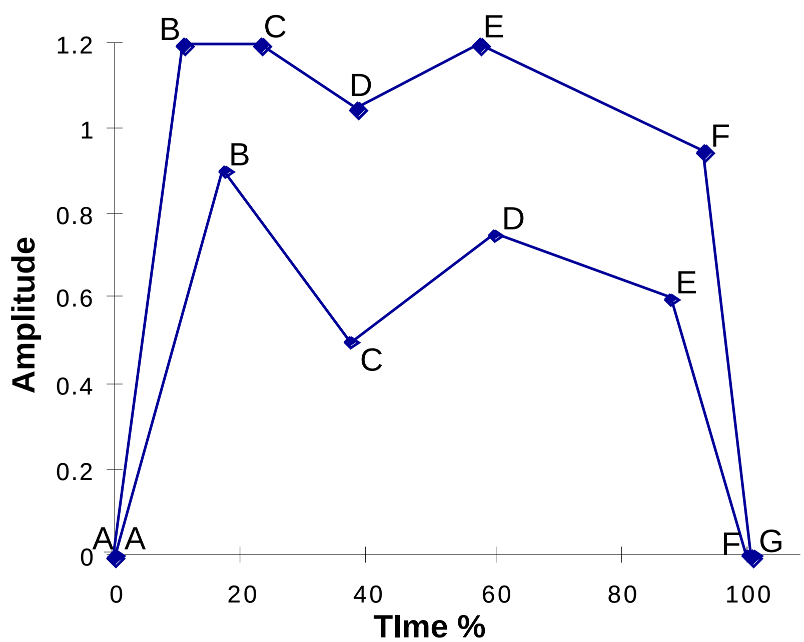


Figure 2-5 Pulse Template for Table 2-3 Three Symbol Waveform

Table 2-4 Template for 2 Symbol Element Waveform

Point	Upper Time (%)	Upper Amplitude	Lower Time (%)	Lower Amplitude
A	-1.0	0	1.0	0
B	15.5	1.20	26.0	0.90
C	34.5	1.20	57.0	0.50
D	56.5	1.05	81.5	0.65
E	85.0	1.20	99.0	0
F	101.0	0	-	-

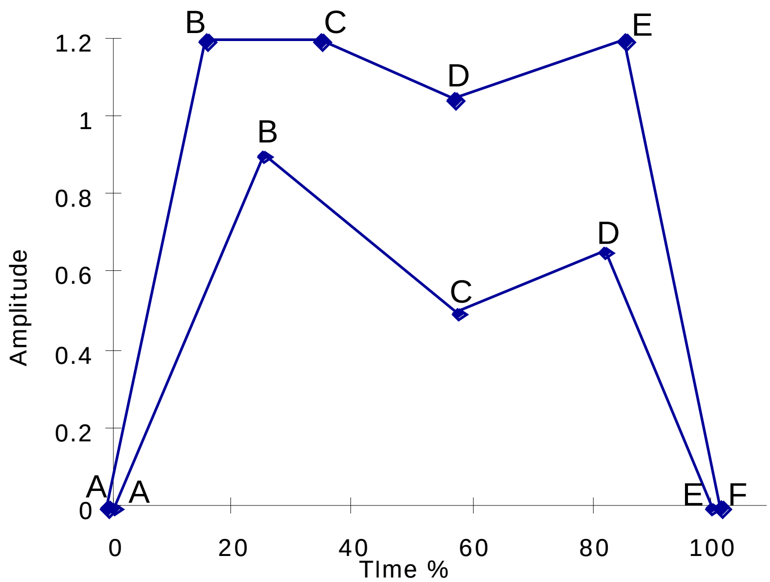


Figure 2-6 Pulse Template for Table 2-4 Two Symbol Waveform

Table 2-5 Template for 1 Symbol Element Waveform

Point	Upper Time (%)	Upper Amplitude	Lower Time (%)	Lower Amplitude
A	-1.5	0	1.5	0
B	23.5	.83	26.0	0.55
C	48.5	1.15	51.5	0.95
D	80.0	.86	77.5	0.52
E	101.5	0	98.5	0

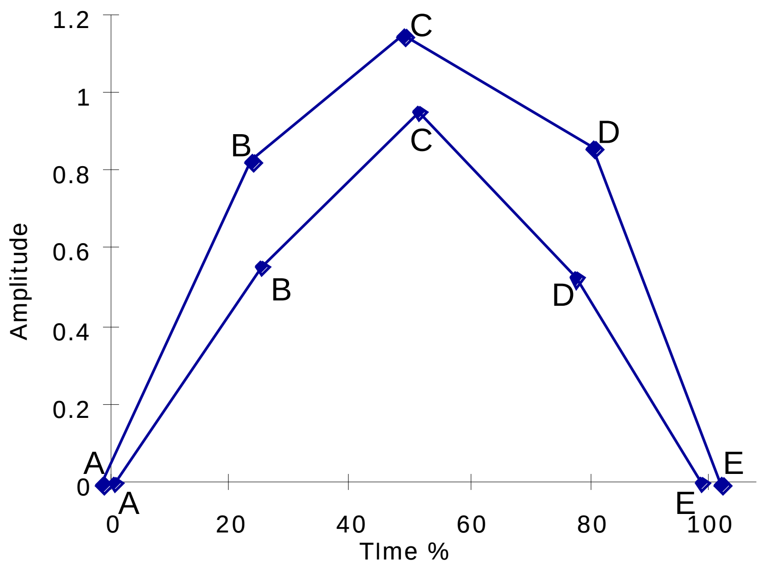


Figure 2-7 Pulse Template for Table 2-5 One Symbol Element Waveform

2.2.2.3 Transmitter Launch Amplitude

Transmitter launch amplitude (TLA) is specified for the transmitted data stream shown below and is defined as the peak-to-peak amplitude of the transmitted waveform.

(R) The test waveform (symbol elements at line symbol rate) is defined to be: 01010101....

(R) The TLA for 100 Ohm UTP for 25.6 Mb/s and 51.2 Mb/s shall be between 1.0 and 1.2 volts peak-to-peak (1.1 volts p-to-p nominal). These levels will provide the minimum signal required by the af-phy-0040 receiver at the end of 50 meters of Category 5 UTP cable.

(CR) The TLA for 120 Ohm TP for 25.6 Mb/s and 51.2 Mb/s shall be between 1.1 and 1.3 volts peak-to-peak (1.2 volts p-to-p nominal). These levels will provide the minimum signal required by the af-phy-0040 receiver at the end of 50 meters of 120 Ohm Category–5 TP cable.

2.2.2.4 Transmitter Return Loss

Transmitter return loss is specified for a transmitter which is actively transmitting any waveform compliant with the scrambling and encoding specifications in Section 3.1.

(R) The transmitter return loss shall be greater than the values specified in Table 2-6 across the full allowed range of characteristic impedance (according to the media type).

Table 2-6 Transmitter Return Loss

Frequency Range	Return Loss
1-30 MHz	>14 dB
30-60 MHz	>14dB - 20log(f/30)

2.2.2.5 Transmitter common mode output/RF egress

The EMC regulations which apply to the home are more stringent than those of the business environment, but in addition, there is a catch-all requirement not to interfere with any existing licensed service. This is a particular concern in the home due to the close proximity to services which may be highly sensitive to RF egress such as broadcast, amateur and short wave radio listening.

Meeting the formal Class B requirements of FCC part 15, EN 55022 and CISPR 22 (which now includes a requirement for the measurement of conducted signal line emissions in the frequency band 150 kHz to 30 MHz) will help to minimize the threat of interference to the radio frequency spectrum from unwanted Common Mode signal components propagated on signal lines. However, meeting the limits specified is unlikely to be sufficient to prevent interference to nearby radio receivers, especially those in use within the internationally standardized amateur radio bands, where efficient external antennas are employed.

Techniques for minimizing common mode signal emissions discussed in Annex A of [1], including common mode termination, may prove necessary for some implementations to meet the above requirements not to interfere with other services. It should be noted that the systems described in this specification have higher power spectral density than the 155 Mb/s system in [1], due to their lower bandwidth, and that the requirement not to interfere with existing licensed services implies a limit on radiated emissions below 30 MHz which is not explicitly stated in the formal EMC requirements.

(R) The transmitter output balance shall be greater than the values specified in Table 2-7 when the differential and common mode signals are terminated in 100 Ohms and 50 Ohms respectively. Output balance is defined as the ratio of differential voltage to common mode voltage expressed in dB.

(CR) The transmitter output balance shall be greater than the values specified in Table 2-7 when the differential and common mode signals are terminated in 120 Ohms and 50 Ohms respectively. Output balance is defined as the ratio of differential voltage to common mode voltage expressed in dB.

Table 2-7 Transmitter Balance

Frequency Range	Balance
0.1-30 MHz	>50 dB
30-60 MHz	>45dB

A practical measurement technique may consist of terminating the transmit pair into a well-balanced center-tapped auto-transformer in parallel with an appropriate resistor (or equivalent reflected impedance from another winding on the transformer), and measuring the common mode signal across a 50 ohm resistor between the center tap and the local ground (see Appendix 1 for further details.)

2.2.3 Receiver Requirements

2.2.3.1 Receiver Acquisition Timing

(R) The receiver shall acquire phase lock in the presence of a BER of less than 1E-10 with a Receiver Acquisition Time of less than 50 ms when provided with a valid signal. A valid signal is defined as a signal from a transmitter compliant with Section 2.2.2 and scrambled and encoded as defined in Section 3 which has been sent through a channel that complies with Section 2.2.4.

2.2.3.2 Receiver Return Loss

(R) The receiver return loss shall be greater than the values specified in Table 2-8 across the full allowed range of characteristic impedance (according to the media type).

Table 2-8 Receiver Return Loss

Frequency Range	Return Loss
1-30 MHz	>15 dB
30-60 MHz	>15 dB-20log(f/30MHz)

2.2.3.3 Receiver Dynamic Range

(R) The receiver dynamic range for 100 Ohm links shall accommodate an af-phy-0040 transmitter at 3.4 volts p-to-p.

(CR) The receiver dynamic range for 120 Ohm links shall accommodate an af-phy-0040 transmitter at 3.75 volts p-to-p.

2.2.4 Metallic Link Segment Characteristics

The metallic link segment consists of one or more sections of metallic twisted pair 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 transmitter and receiver requirements are specified for the media defined below. The metallic link segment is defined for 100 Ohm UTP or as an alternative a 120 Ohm Category 5 TP system may be used.

(R) The physical interface shall support at least one of the impedance values for copper link segments described in this section. For the selected impedance(s), all of the associated requirements shall be met.

2.2.4.1 100 Ohm Metallic Link Segment

This section defines the cabling and connector conditional requirements when a 100 Ohm cable/connector system is deployed. These requirements define the minimum for a compliant and functional system. Note that as long as 100 Ohm components are used consistently, a specification of Category 5 unshielded cable and connectors allows for the optional use of shielded cabling and components.

2.2.4.1.1 100 Ohm UTP Link Segment Specifications

The electrical parameters important to link performance are attenuation, near end cross talk 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 ANSI/TIA/EIA-568-A and ISO/IEC 11801:1995.

(R) The composite channel attenuation shall meet or exceed the Category 5 attenuation performance limits defined in Annex E of ANSI/TIA/EIA-568-A adjusted for a maximum channel length of 50m by subtracting the worst case attenuation of 50m of horizontal Category 5 cable. For information, this implies a maximum channel attenuation of 5.1 dB and 6.95 dB at 16 and 32 MHz respectively.

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

2.2.4.1.2 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 40 meters of Category 5 UTP cable, 10 meters of Category 5 flexible cords, and four (4) Category 5 connectors internal to the link.

2.2.4.1.3 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 40 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 loss requirements of Section 2.2.4.1.1 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.

2.2.4.1.4 100 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 cable used in constructing a link shall meet or exceed the Category 5 UTP cable attenuation requirements of Section 10 of ANSI/TIA/EIA-568-A and Clause 8 of ISO/IEC 11801:1995.

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

2.2.4.1.5 100 Ohm UTP NEXT Loss

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

(R) The cable and cordage used in constructing a link shall meet or exceed the Category 5 UTP cable NEXT requirements of Section 10 of ANSI/TIA/EIA-568-A and Clause 8 of ISO/IEC 11801:1995.

2.2.4.1.6 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.

(R) Under these conditions both the characteristic impedance and SRL of cables and cords used in construction of a link shall meet the requirements specified for 100 Ohm Category 5 in Section 10 of ANSI/TIA/EIA-568-A and Clause 8 of ISO/IEC 11801:1995.

2.2.4.1.7 100 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.

(R) All connecting hardware used within this PMD channel shall meet or exceed the Category 5 electrical requirements for attenuation, NEXT loss, and return loss specified in Section 10 of ANSI/TIA/EIA-568-A and Clause 9 of ISO/IEC 11801:1995.

(R) All measurements on connecting hardware shall be conducted in accordance with the procedures described in Annex B of ANSI/TIA/EIA-568-A and Annex A.2 of ISO/IEC 11801:1995.

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

2.2.4.2 120 Ohm Metallic Link Segment

This section defines the cabling and connector conditional requirements when a 120 Ohm cable/connector system is deployed. These requirements define the minimum for a compliant and functional system

2.2.4.2.1 120 Ohm Link Segment Specifications

The electrical parameters important to link performance are attenuation, near end cross talk loss (NEXT loss), characteristics 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 ANSI/TIA/EIA-568-A and ISO/IEC 11801:1995.

(R) The composite channel attenuation shall meet or exceed the category 5 attenuation performance limits defined in Annex E of ANSI/TIA/EIA-568-A adjusted for a maximum channel length of 50m by subtracting the worst case attenuation of 50m of horizontal category 5 cable. For information, this implies maximum channel attenuation of 5.1 dB and 6.95 dB at 16 and 32 MHz respectively.

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

2.2.4.2.2 Channel Reference Model Configuration for 120 Ohm Systems

The channel reference model for a 120 Ohm category 5 cabling system is defined to be a link consisting of 40 meters of 120 Ohm category 5 cable, 10 meters of category 5 flexible cords, and four (4) category 5 connectors internal to the link.

2.2.4.2.3 Examples of 120 Ohm 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 40 meters of 120 Ohm category 5 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 loss requirements of Section 2.2.4.2.1 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.

2.2.4.2.4 120 Ohm Attenuation

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

(R) The cable used in constructing a link shall meet or exceed the horizontal 120 Ohm category 5 cable attenuation requirements of Clause 8 of ISO/IEC 11801:1995.

(R) The cordage used in constructing flexible cords and patch cables shall meet or exceed the attenuation requirements for category 5 flexible cordage specified in Clause 8 of ISO/IEC 11801:1995.

2.2.4.2.5 120 Ohm NEXT Loss

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

(R) The cable and cordage used in constructing a link shall meet or exceed the horizontal 120 Ohm category 5 cable NEXT requirements of Section 10 of Clause 8 of ISO/IEC 11801:1995.

2.2.4.2.6 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.

(R) Under these conditions both the characteristic impedance and SRL of cables and cords used in construction of a link shall meet the requirements specified for 120 Ohm category 5 in Clause 8 of ISO/IEC 11801:1995.

2.2.4.2.7 120 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.

(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 Clause 9 of ISO/IEC 11801:1995.

(R) All measurements on connecting hardware shall be conducted in accordance with the procedures described in Annex A.2 of ISO/IEC 11801:1995. These requirements apply to all individual connectors, including patch panels, transition connectors, cross-connect fields, and telecommunication outlets.

(R) The connector Termination practices and cable practices described in Clause 9 of ISO/IEC 11801:1995 shall be followed.

2.2.5 TP Media Interface Connector

(R) Each end of the Category 5 TP link segment shall be terminated with Media Interface Connectors specified in IEC 603-7 (commonly referred to as RJ-45). This connector is an 8-contact modular jack/plug.

(R) The cable assembly shall connect the corresponding contacts 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 TP-MIC shall be an 8-contact receptacle (jack) as specified in ISO/IEC 603-7, that is attached to the ATM user device and ATM network equipment as illustrated in Figure 2-8.

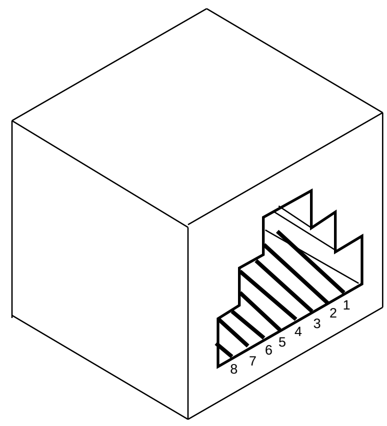


Figure 2-8 Example of TP-MIC Jack

(R) The contact assignments for the TP-MIC receptacle (jack) shall be as listed in Table 2-9.

Table 2-9 Contact Assignments for TP-MIC Jack

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

2.3 Transmission Link Requirements for Plastic Optical Fiber

This section specifies a Physical Media Dependent (PMD) sublayer over plastic optical fiber (POF) using light emitting diodes (LED) operating at 25.6/51.2 Mb/s. The POF interface is intended for link lengths of up to 50 meters.

2.3.1 Bit Error Ratio

(R) A POF interface receiver shall operate with a bit error ratio not to exceed 1E-10 (one bit error in 10^{10} bits) when presented with a transmitter signal as specified in Section 2.3.2.2 transmitted through a POF link subject to the system budget constraints specified in Section 2.3.2.1.

2.3.2 Transceiver Interface

2.3.2.1 System Budget

Proper system performance is ensured by considering the attenuation and modal bandwidth of the optical path and including them as part of the link budget. In addition to these cable plant characteristics, a system power penalty is normally included in the link budget. The power penalty includes the effects of eye closure due to transmitter characteristics (finite rise and fall times, random and systematic jitter). This system power penalty is accounted for in the receiver sensitivity specification; therefore, the system budget is composed entirely of losses due to the cable plant and connectors.

The attenuation range specification for POF link is defined based on the use of components meeting the requirements specified in Sections 2.3.3, 2.3.4 and operating up to 50 meters. The static attenuation in the optical path includes worst case loss values for the fiber media and connectors. The attenuation range is 0 to 17 dB of which 4 dB is allocated for connectors and 13 dB for worst case attenuation of 50 m POF.

(R) A POF link shall have an end-to-end attenuation of 17 dB or less under the worst case conditions shown in Table 2-11.

2.3.2.2 Transmitter Characteristics

The values prescribed are for worst case operating conditions and end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The following parameters are specified for the transmitter.

(R) The center wavelength range shall be from 640 to 660 nm.

(R) The maximum full width half-maximum (FWHM) spectral width shall be 40 nm.

(R) The mean launched power into POF shall be from -9 to -2 dBm.

(R) The source NA shall be from 0.2 to 0.3.

(R) The minimum extinction ratio shall be 10 dB.

(R) The transmitter exit rise (fall) time shall be less than 5.5 ns.

(R) The maximum transmitter overshoot shall be 25%.

(R) The systematic interface jitter at the transmitter output shall be less than 4.8 ns.

(R) The random interface jitter at the transmitter output shall be less than 1.8 ns.

2.3.2.3 Receiver Characteristics

The values prescribed are for worst case end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The following characteristics are specified for the receiver.

(R) The minimum receiver sensitivity shall be -26 dBm.

(R) The minimum receiver overload shall be -2 dBm.

(R) The receiver optical input rise (fall) time shall be less than 6.0 ns.

(R) The systematic interface jitter at the receiver input shall be less than 6.0 ns.

(R) The random interface jitter at the receiver input shall be less than 1.8 ns.

(R) The minimum receiver eye opening at a 1E-10 BER shall be 3.69 ns.

The POF interface parameters are summarized in Table 2-10.

Table 2-10 Optical Parameters for POF Interface

	POF	Unit
Transmitter Interface Characteristics		
Center Wavelength	640 to 660	nm
Maximum Spectral Width (FWHM)	40	nm
Mean Launched Power (Note 1)	-9 to -2	dBm
Source NA	0.2 to 0.3	
Minimum Extinction Ratio	10	dB
Maximum Rise (Fall) Time, (10-90%)	5.5	ns
Maximum Overshoot	25	%
Maximum Systematic Interface Jitter	4.80	ns
Maximum Random Interface Jitter	1.80	ns
Receiver Interface Characteristics		
Minimum Receiver Input Power (Note 2)	-26	dBm
Minimum Overload	-2	dBm
Maximum Rise (Fall) Time, (10-90%)	6.0	ns
Maximum Systematic Interface Jitter	6.0	ns
Maximum Random Interface Jitter	1.80	ns
Minimum Receiver Eye Opening (Note 3)	3.69	ns

NOTE 1: A 17 dB system budget is specified for POF link. The entire system budget is allocated for cable plant losses and connector losses as described in Section 2.3.2.1. The interface point for the mean launched power specification is a short length of fiber (e.g. 50 cm) located immediately after the plug of the connector attached to the transmitter receptacle. The connector at this interface point is therefore considered to be part of the equipment and not part of the cable plant.

NOTE 2: The interface point for the minimum receiver input power specification is located between the plug of the connector and the receptacle.

NOTE 3: The receiver eye opening represents the time interval allocated for the clock recovery function after the optical to electrical conversion at the receiver.

2.3.2.4 Receiver Acquisition Timing

(R) The receiver shall acquire phase lock in the presence of a BER of less than 1E-10 with a Receiver Acquisition Time of less than 50 ms when provided with a valid signal. A valid signal is defined as a signal from a transmitter compliant with Section 2.3.2.2 and scrambled and encoded as defined in Section 3 which has been sent through a channel that complies with Section 2.3.2.1.

2.3.3 Optical Fiber

(R) The optical fiber shall be 1000 µm multimode, step index plastic optical fiber as specified in IEC 793-2 section 4 Category A4d [2] including test conditions (as proposed by the IEC).

(R) The minimum modal bandwidth of POF shall be 10 MHz*km at 650 nm in accordance with IEC 793-1-C2A or C2B [3]. The specifications for fiber modal bandwidth include a variation in source numerical aperture and account for the effect of bandwidth degradation to ensure correct system operation.

(R) The maximum attenuation of 50 m POF, under the condition of -20 to 70 degrees C and 95% relative humidity, shall be 9.1 dB. The attenuation shall be measured in accordance with IEC 793-1-C1A or C1B [4] using a nominal 650 nm narrow (< 5 nm FWHM) spectral width light source.

The fiber loss due to environmental conditions and launch NA is included in the 9.1 dB maximum attenuation for 50 m POF. The source spectral loss increment of 3.4 dB in Table 2-11 accounts for both a source center wavelength shift to 660 nm or 640 nm and the difference between the < 5 nm spectral width of the test source and the 40 nm worst case spectral width. A 0.5 dB loss increment due to cable bends is also accounted for as shown in Table 2-11 .

(R) For the conditions shown in Table 2-10 the worst case fiber attenuation for 50m POF shall be 13 dB. It is the sum of the loss increments shown in Table 2-11 and the 9.1 dB maximum attenuation of 50 m POF.

Table 2-11 Worst case loss increments for 50m POF cable

Parameters		Unit	Min.	Max.	Loss Increment	Test Method Reference
Source center wavelength		nm	640	660		
Source spectral width (FWHM)		nm		40	3.4 dB	IEC 793-1-C1A
Cable bends	Radius	mm	25.4			
	Number of 90 degree bends			15	0.5 dB	(FFS)

2.3.4 Physical media interface

(R) The optical fiber interface should be either the PN receptacle and the Duplex F07 plug or PN plug which should meet the interface standard, IEC 1754-AA [5] or the Fiber Jack receptacle, jack and plug (and should meet the intermateability standard, TIA/EIA PN-3871 [6]). The physical media interfaces shall meet the performance standard, IEC 1753-BB [7]. It is presumed that the PN receptacle accepts the PN plug and the duplex F07 plug. An example is shown in Figure 2-9. An example of the Fiber Jack connector is shown in Figure 2-10 and Figure 2-11. The performance of the connector shall be tested by a standard test method (as being determined by the IEC). It is recommended that the network polarity (transmit and receive) be managed in accordance with ANSI/TIA/EIA-568-A [8].

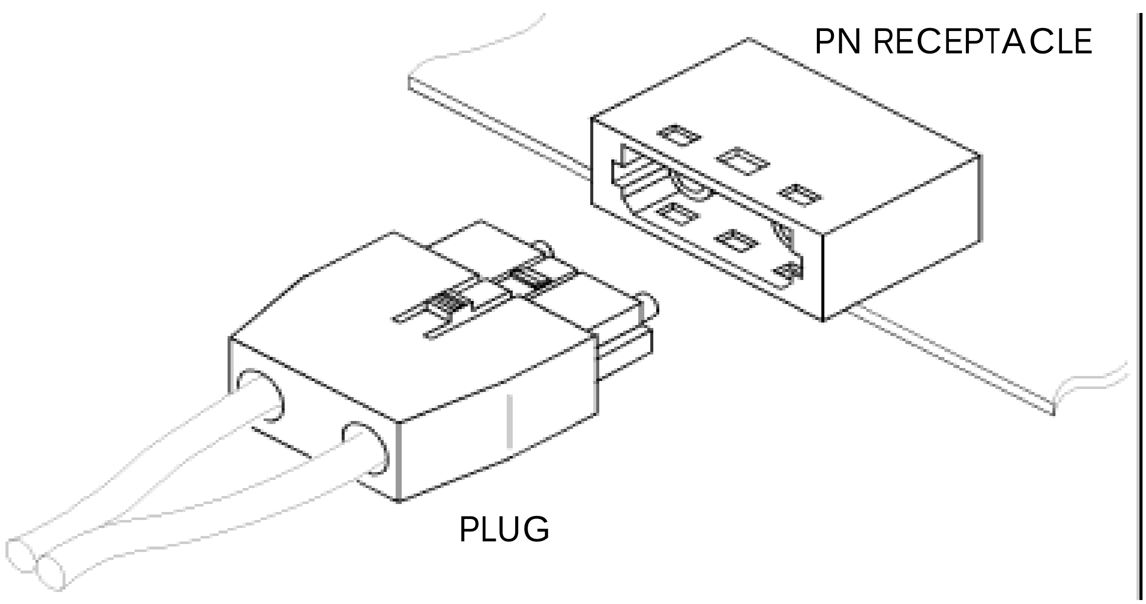


Figure 2-9 Physical Media Plug and Receptacle Example (F07 Plug shown)

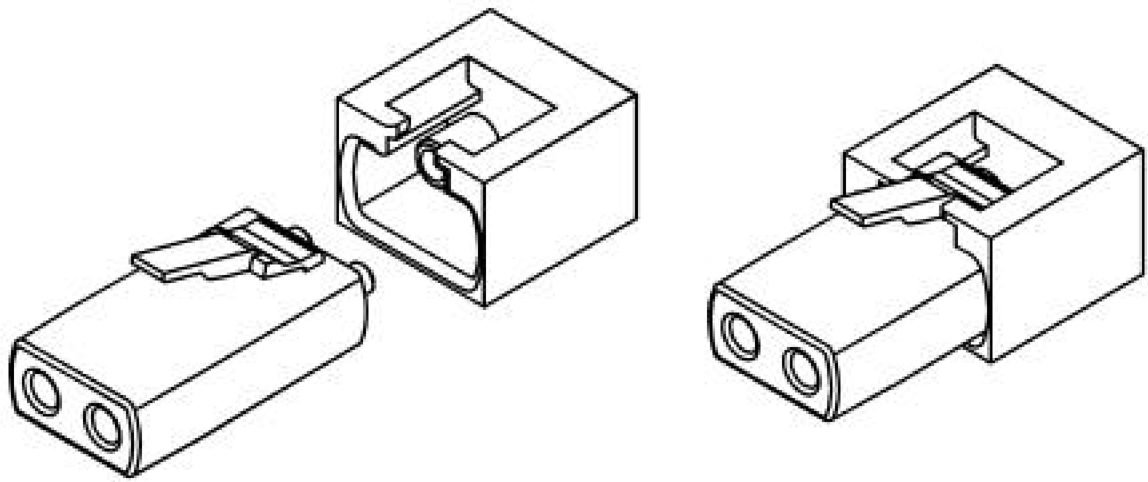


Figure 2-10 Physical Media Plug and Receptacle Example (Fiber Jack, TIA PN3871)

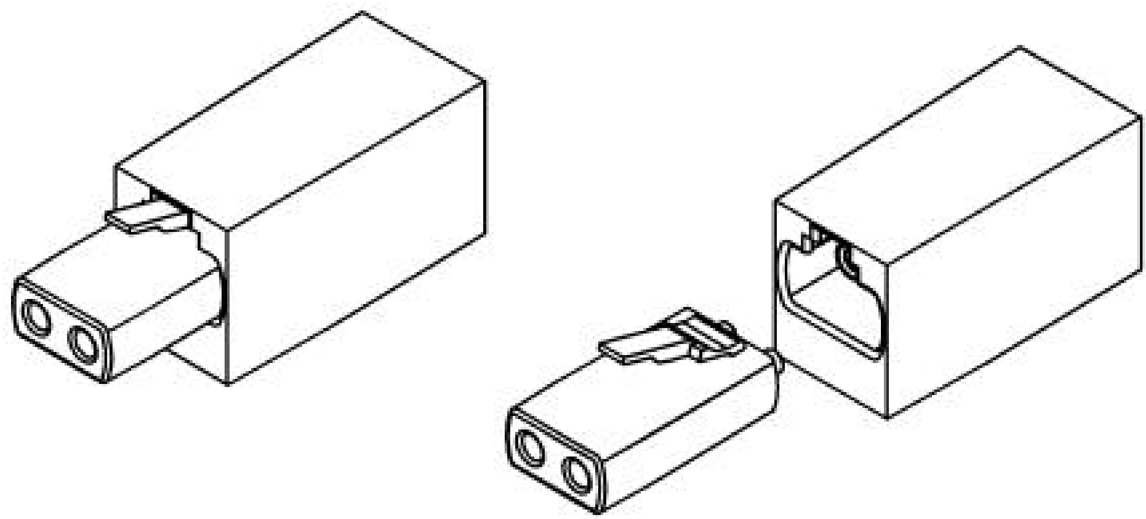


Figure 2-11 Physical Media Plug and Jack Example (Fiber Jack, TIA PN3871)

Alternative connector styles are for future study and shall be defined by the IEC.

(R) The worst case connector insertion loss, including the effect of environmental conditions, shall be less than 1.3 dB.

3. Transmission Convergence (TC) Sublayer

This section describes the Transmission Convergence sublayer for the 25.6/51.2 Mb/s ATM PHY. This TC is to be used with both the copper and plastic optical fiber PMDs.

The functions of the TC sublayer are:

1. Scrambling and descrambling
2. 4B5B Block encoding and decoding (including command codes) which provides the means for:
   a) Cell delineation and scrambler/descrambler reset
   b) Support of a periodic timing signal for isochronous services
3. NRZI Encoding and Decoding
4. HEC generation and verification

The informative Figure 3-1, below, shows a block diagram of the Transmission Convergence sublayer components and identifies their functions and the data flow relationships. Note: This figure is for information only and is not intended as a required implementation.

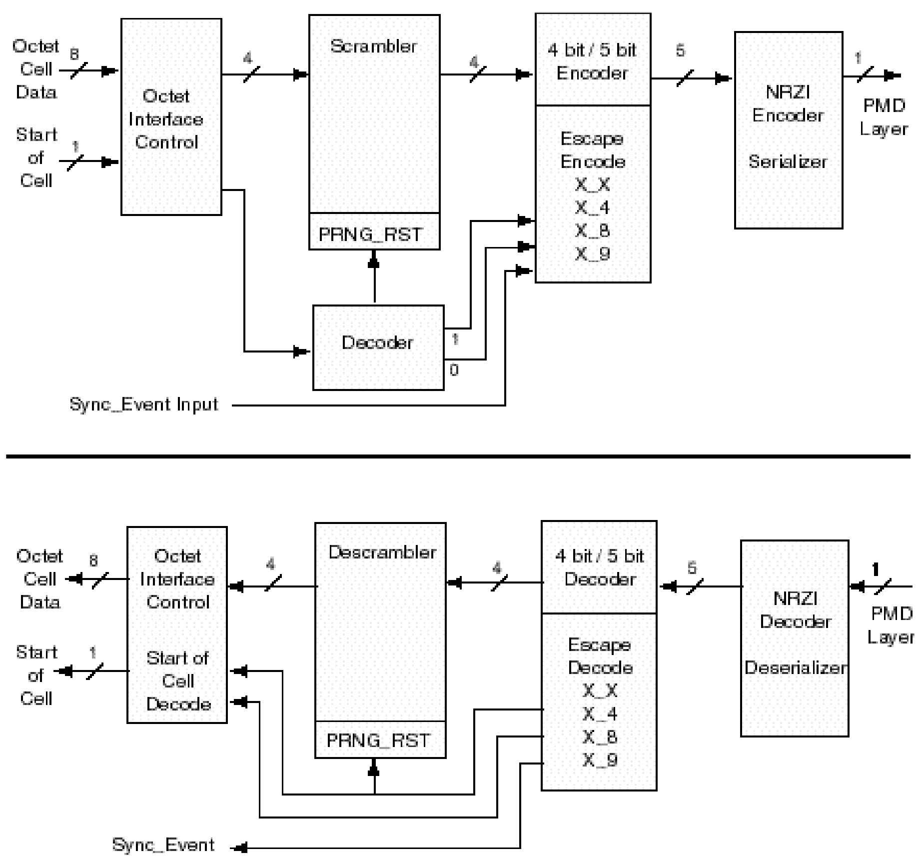


Figure 3-1 Block Diagrams of the Transmission Convergence Sub Layer

3.1 Cell Scrambling and Descrambling

(R) To provide the appropriate frequency distribution of the electrical signal across the line, the data octets shall be scrambled before transmission.

(R) All 53 octets of the ATM cell shall be scrambled and encoded prior to transmission.

3.1.1 Scrambler for 25.6 Mb/s

(R) The scrambler and the de-scrambler are each comprised of a 10-bit PRNG (pseudo-random number generator). The PRNG is based on the following polynomial:

x**10+x**7+1

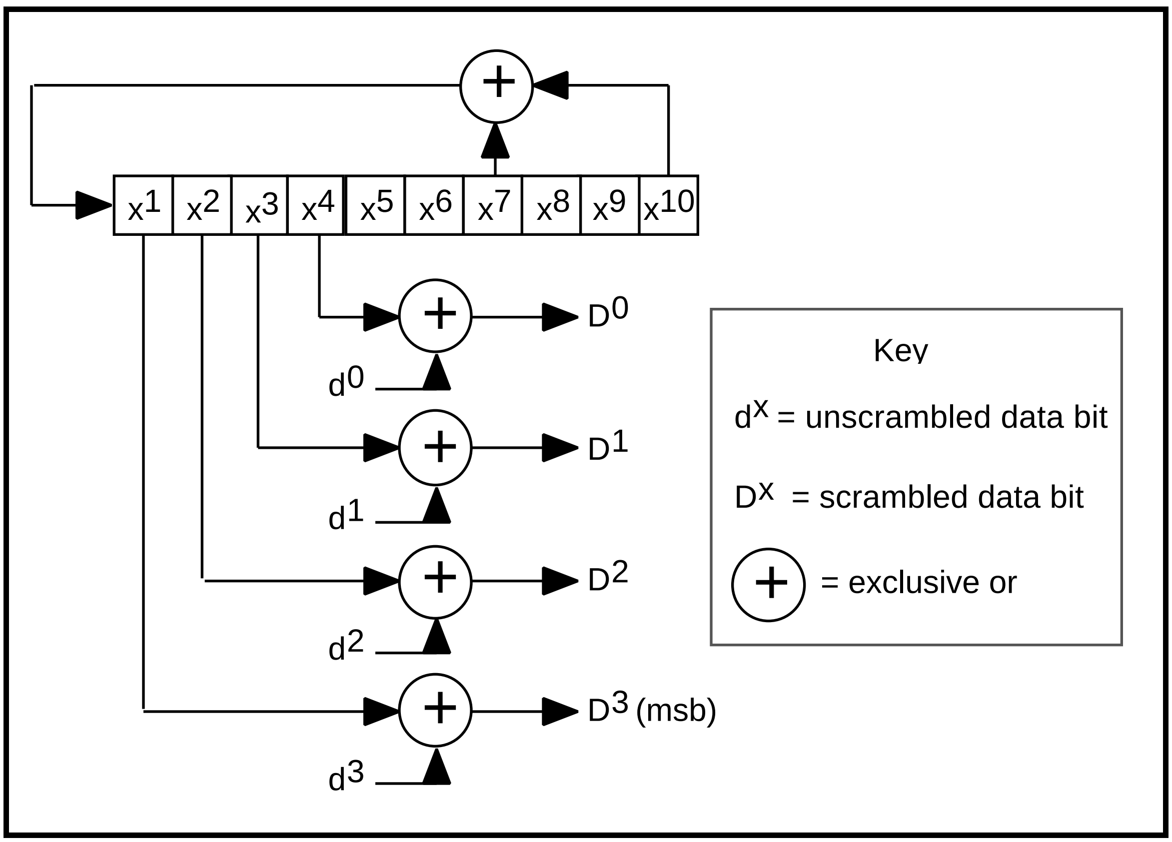


Figure 3-2 Pseudo Random Number Generator Block Diagram

Note: For information only-not intended to depict a required implementation.

(R) The PRNG shall be clocked 4 times after each nibble regardless of whether the command octet, valid data or idle data is being transmitted. Command octets shall not be scrambled.

(R) The scrambler/de-scrambler shall be implemented such that each successive data nibble (starting with the high order nibble and high order bit within each nibble) is XOR'd with the corresponding 4 bits of the PRNG (x1 x2 x3 x4 as illustrated in the above diagram) each nibble cycle (4 x bit cycle time).

(R) The PRNG shall be reset to its initial state ('3FF'x) upon every detection of two consecutive escape ('X') nibbles, whether or not these escape nibbles are octet-aligned (i.e. form a start-of-cell X_X sequence). The first nibble after the two consecutive escape nibbles shall then be XOR'd with the initial 'F' of the scrambler sequence, unless it is part of a command byte, as these are never scrambled. The PRNG shall always be either reset or clocked (four new PRNG bits generated) after every nibble (including idles and commands), regardless of whether or not the nibble was scrambled.

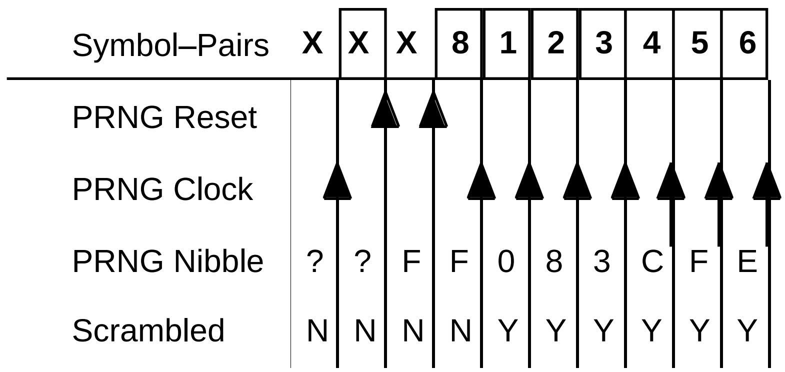


Figure 3-3 Start of Cell Symbol-pairs

Note: Figure 3-3 shows a case that will occur in normal operation whenever X_X is immediately followed by another command octet such as X_8. In this case, a second PRNG reset occurs as a result of the detection of a second pair of X symbols.

Because the scrambler is designed to spread the signal across the spectrum, the reset of the scrambler/de-scrambler by the X_X symbol pair command (the reset state is "3FF"x) should not occur too often.

(REC) For this PRNG to approximate a random source, it is recommended that the time between PRNG resets be no less than 100 microseconds. A maximum of 500 milliseconds between resets is recommended to limit the time two end stations can be mis-aligned in the scrambler sequence.

3.1.1.1 PRNG Sequence

For clarification purposes, the PRNG sequence for each nibble (starting from its reset state) is as follows:

F, 0, 8, 3, C, F, E, 8, C, 7 ,C, C, 7, D, 4, 3, 9, 4, 0, 0, 1,
8, 4, 4, 0, 3, 9, 5, 8, 4, 5, 8, 7, D, 5, B, D, 0, 0, 3, 8, D...

3.1.2 Scrambler for 51.2 Mb/s

(R) A 25 bit self synchronized scrambler and de-scrambler shall be used based on the following polynomial:

x**25+x**22+1

(R) The scrambler and de-scrambler shall provide the functionality illustrated in Figures 3-4 and 3-5 (not intended to depict a required implementation).

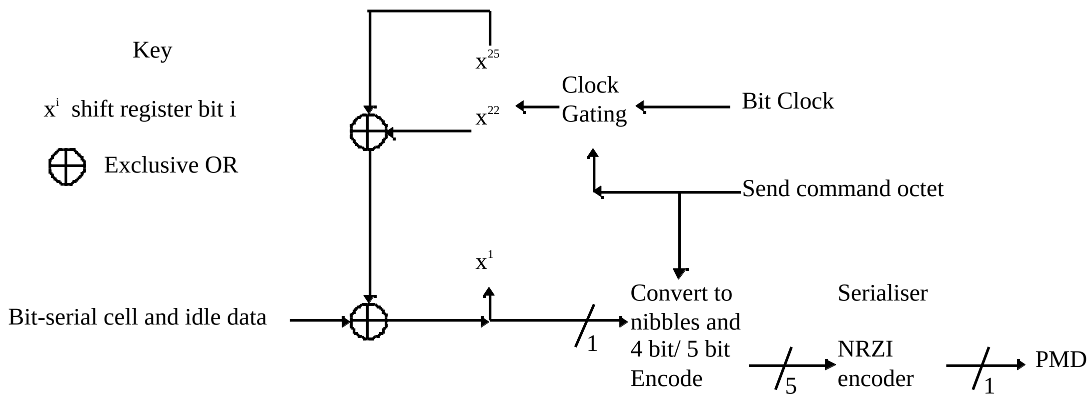


Figure 3-4 Scrambler Functionality for 51.2 Mb/s

Note: For information only-not intended to depict a required implementation.

(R) The scrambler/de-scrambler shall be clocked once per bit time except during command octets when the scrambler/de-scrambler shall not be clocked. A command octet is a pair of nibbles where the first is an X and the second is either an X or a valid symbol 0-F. The receiver can determine the octet alignment and hence the start of a command octet by reception of an X nibble following any non-X nibble, thus ensuring that the descrambler will be clocked during the nibble following X_X, unless it is the start of another command. In the special case of X_X followed by another command, the scrambler/de-scrambler will not be clocked during this sequence of four consecutive nibbles.

(R) Both X_4 and X_X shall be interpreted as start of cell commands. Since the self-synchronizing scrambler does not require resets, X_X does not have any significance other than start of cell at 51.2Mb/s. It is however recommended to use X_4 to denote start of cell although X_X is allowed.

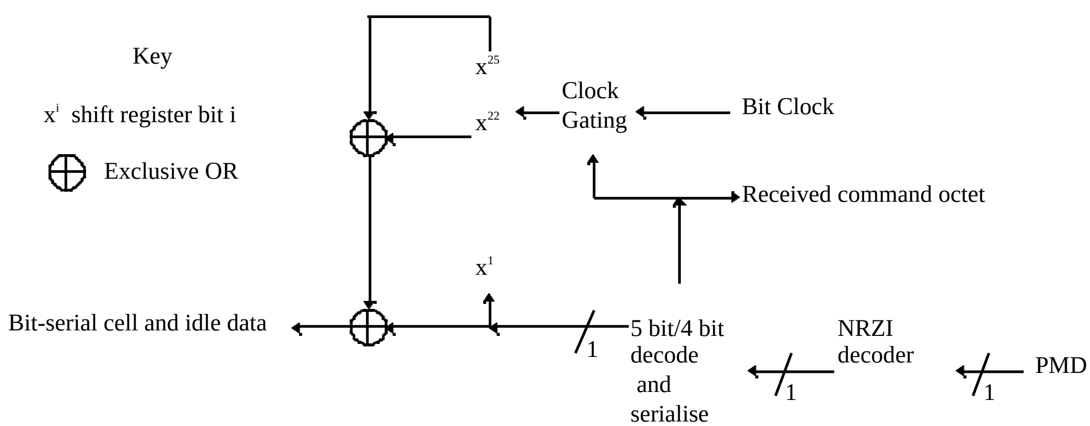


Figure 3-5 Descrambler Functionality for 51.2 Mb/s

3.2 4B5B Block Coding and Decoding

A 4B5B encode/decode scheme is utilized to ensure that an adequate number of transitions occur on the line. The code provides the following features:

1. An average of over 3 transitions per 5 bit symbol.
2. Run length is limited to less than or equal to 5.
3. Free of DC frequencies on average.

Each symbol of the code is composed of 5 bits. Of the 32 possible symbols, 17 are valid in this implementation. The remaining 15 symbols are invalid. The 17 valid symbols represent 16 4-bit data nibbles (hex 0 through F) and the one Escape (X) code. This Escape symbol has the "Comma" property of being unique among all possible valid symbol pairs. Table 3.6 lists the valid 4-bit nibble to 5-bit symbol conversions.

(R) Table 3.6 shall be used to encode data nibbles for transmission and to decode 5-bit symbols upon reception. All symbols not listed in this table shall be invalid.

Table 3-6 Conversion Table 4-bit command/data to 5-bit symbols

Data	Symbol	Data	Symbol	Data	Symbol	Data	Symbol
0000	10101	0001	01001	0010	01010	0011	01011
0100	00111	0101	01101	0110	01110	0111	01111
1000	10010	1001	11001	1010	11010	1011	11011
1100	10111	1101	11101	1110	11110	1111	11111
ESC (X)	00010						

Note: The binary values for 4-bit data nibbles and 5-bit encoded symbols in Table 3.6 are shown most-significant bit first (i.e., at left).

(R) For each ATM cell processed, the data within shall be scrambled, encoded and NRZI-coded before it is transmitted. Likewise on the receiver, once a start of cell command is detected, the serial data is NRZI decoded, and the resulting 5-bit symbols decoded to form a data nibble. The nibbles are then descrambled and re-combined to form the ATM cell.

3.2.1 Symbol-pair Level Code Structure

(R) 5-bit encoded symbols shall always be paired. Two types of symbol pair entities are defined which represent:

1. Commands
2. Data octets

(R) Commands are composed of the Escape symbol followed by any of the 16 data symbols or by the Escape symbol. This provides 17 possible Commands of which four are defined and valid. The set of 4 valid (bold) and 13 invalid (reserved for future use) commands are:

X_X = Start-of-cell (with scrambler reset)
X_0 = Invalid (reserved for future use)

X_1 = Invalid (reserved for future use)
X_2 = Invalid (reserved for future use)
X_3 = Invalid (reserved for future use)
X_4 = Start-of-cell (with no scrambler reset)
X_5 = Invalid (reserved for future use)
X_6 = Invalid (reserved for future use)
X_7 = Invalid (reserved for future use)
X_8 = Sync_Event
X_9 = FERF Reporting
X_A = Invalid (reserved for future use)
X_B = Invalid (reserved for future use)
X_C = Invalid (reserved for future use)
X_D = Invalid (reserved for future use)
X_E = Invalid (reserved for future use)
X_F = Invalid (reserved for future use)

(R) All the above described Command symbol pairs (X_X, X_4, X_8 and X_9) shall be transmitted in symbol-pair alignment. The symbol-pair alignment boundary shall be defined by the first occurrence of a Command symbol-pair. Subsequent Command symbol-pairs shall be transmitted in symbol-pair alignment with the first Command symbol-pair.

(R) All five-bit encoded symbols shall be transmitted serially with the most significant bit transmitted first.

(R) Reception of any command other than X_X, X_4, X_8 or X_9 within the 53 octet ATM cell shall be considered an error and the cell may be discarded. Reception of the X_X or X_4 command within the 53 octet ATM cell shall cause the octets of the cell that have been received to be discarded and the reception of a new cell to be initiated.

(R) On the receiver, the decoder shall determine from the received symbols whether a timing marker command (X_8), FERF reporting (X_9) or a start-of-cell command was sent (X_X or X_4). Anytime a start-of-cell command is detected, the next 53 octets received shall be decoded and forwarded to the descrambler.

(R) Transmissions during idle states at 25.6 Mb/s (where no command or data are being transmitted) will continually be sent out onto the line. The data will continue to be encoded and scrambled to maintain synchronization of the received PLL. Upon the beginning of a valid cell transmission, the command symbol-pair would be immediately initiated. (Note that the 4B5B code guarantees a maximum run length of five bits. This, in addition to the fact that all non control octets are scrambled, will provide more than sufficient transitions to maintain bit sync during idle states.)

(R) At 51.2 Mb/s, an idle pattern of empty cells with GFC=0, VPI=0, VCI=0, PT=0, CLP=1 and valid header HEC shall be sent when there are no other cells to send. This enables unambiguous signal presence detection.

(REC). In order to minimize the effect of spectral lines arising from the short scrambler at 25.6 Mb/s, it is recommended that long period pseudo-random idle data is used.

(R) The TC sublayer shall transfer to and from the ATM layer complete 53-octet ATM cells.

3.2.2 Cell Delineation

(R) Cell delineation shall be accomplished by prepending either of two valid commands to the each ATM cell before transmission. As defined above, the two valid start of cell commands are

X_X = Start-of-cell (with scrambler reset), and

X_4 = Start-of-cell (with no scrambler reset)

3.2.3 Support for a Timing Signal

(R) Transport of a timing sync pulse to support isochronous communications shall be accommodated. A special Sync_Event command symbol-pair, X_8, may be inserted into the transmitted stream at any symbol-pair boundary. It is expected that this means will be used to carry an 8 kHz timing signal although this feature could be used to carry other timing references.

(R) The Sync_Event timing marker command shall be generated at the next octet boundary after the incoming synchronization event is detected. The Sync_Event command symbol-pair shall have priority over all line activity (data or command symbol pairs) and shall be transmitted at the next symbol-pair boundary after the incoming synchronization event is detected. When this occurs during a cell transfer, the data transfer shall be temporarily interrupted on a symbol-pair boundary and the X_8 command symbol-pair shall be inserted. This condition is the only allowable interrupt in an otherwise contiguous transfer of the 54 symbol-pair stream (1 command symbol-pair plus 53 data symbol pairs).

(O) As an option, when a Sync_Event command is detected by the receiver (ATM user equipment), the Sync_Event command can be "wrapped around" and transmitted onto the upstream path (to the ATM network equipment).

Below is an illustration of cell structure (at 25 Mb/s) showing Start-of-cell commands with and without Scrambler Reset, and a Sync_Event command interrupting the flow of Cell N+1.

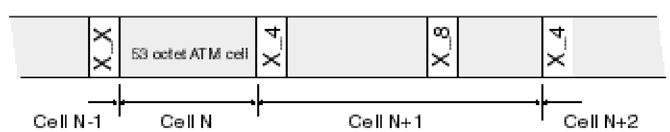


Figure 3-6 Example of Cell Delineation and Sync_Event using Commands

In the example above, the Nth ATM cell is preceded by a X_X start-of-cell command. This causes both the scrambler and the descrambler to reset its pseudo-random nibble generators to its initial state. For cell N+1, the ATM cell is simply preceded by an X_4 start-of-cell command without scrambler/descrambler reset. Also in cell N+1, a timing sync pulse results in an X_8 timing marker command.

3.3 NRZI Encoding and Decoding

(R) In order to bound the run length of either logic 1s or 0s during transmission, data symbols from the encoder shall be serialized and NRZI encoded before transfer to the PMD layer.

(R) Each symbol shall be serialized most significant bit first, and then NRZI encoded.

(R) Serial data received from the PMD shall be NRZI decoded before symbol boundaries are detected.

3.4 HEC Generation and Verification

The Header Error Control (HEC) covers the entire cell header. For the private environment, only detection of bit errors is described. Support of bit error detection based on HEC field is mandatory. The transmitter calculates the HEC value for the first four octets of the cell header, and inserts the result into the HEC field (the last octet of the ATM cell header). The HEC field shall be an 8-bit sequence. It shall be the remainder of the division (Modulo 2) by the generator polynomial x^8+x^2+x+1 of the polynomial x^8 multiplied by the content of the header excluding the HEC field. The pattern 01010101 is XOR'd with the 8-bit remainder before being inserted into the HEC field.

(R) Equipment supporting this private UNI shall implement HEC error detection as defined in ITU Recommendation I.432.

(R) Equipment supporting this private UNI shall generate the HEC octet as defined in ITU Recommendation I.432.

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

Figure 3-7 depicts the HEC verification flow at the receiver. The TC shall not forward any cell to the ATM layer which has an incorrect HEC.

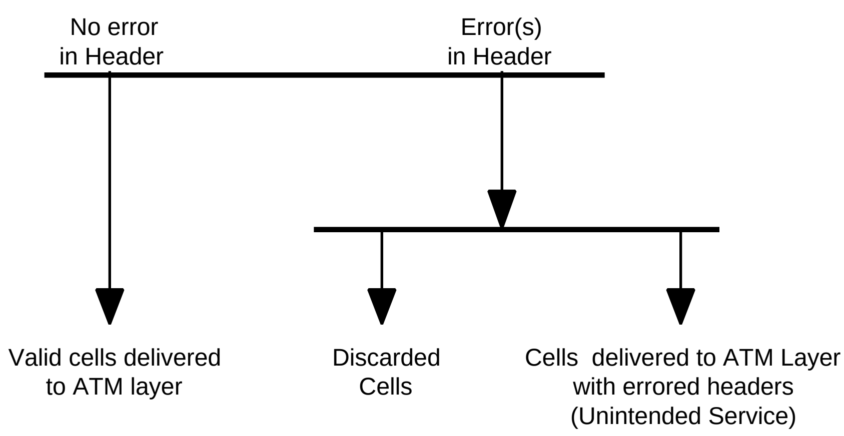


Figure 3-7 HEC Verification Flow

As defined in I.432, the HEC method is capable of single bit error correction and multiple bit error detection. Because the 4B5B block code used in this private UNI causes multiple bit errors per corrupted bit, the HEC error correction mode shall not be used.

(R) HEC error detection is mandatory.

(R) Upon detection of a header error, that cell shall be discarded.

3.5 Automatic speed detection

(R) Automatic speed detection of the remote terminal shall be implemented where the local device has 25.6/51.2 Mb/s capability.

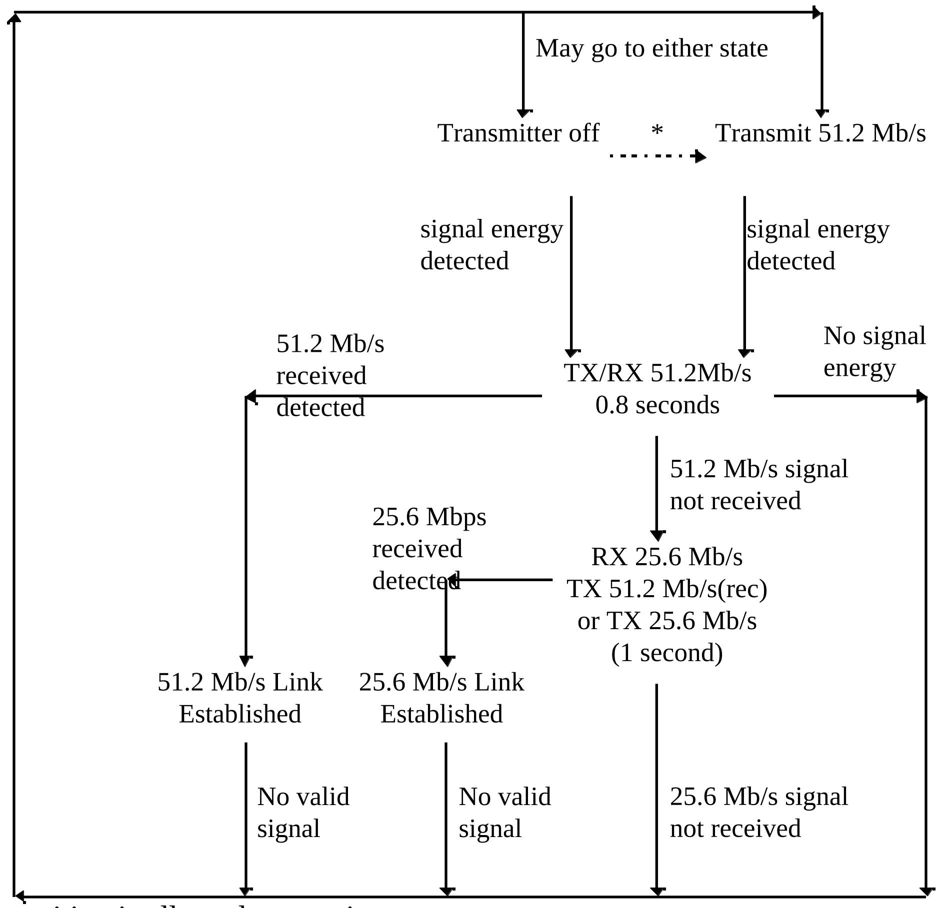
(R) Devices having 25.6/51.2 Mb/s capability shall transmit by default at 51.2 Mb/s. When incoming signal energy is detected, the local device shall continue to transmit at 51.2 Mb/s for a period of 0.8 seconds. During this period the local device shall determine if a valid 51.2 Mb/s signal is being received and if so shall establish the link at 51.2 Mb/s.

(R) If a valid 51.2 Mb/s signal is not received within 0.8 seconds of the detection of incoming signal energy, the local device shall attempt to transmit and receive at 25.6 Mb/s for a period of 1 second. It is recommended that the local device continues to transmit at 51.2 Mb/s unless it receives a valid 25.6 Mb/s signal, although it is permitted to both transmit and receive at 25.6 Mb/s. During this period the local device shall determine if a valid 25.6 Mb/s signal is being received and if so shall establish the link at 25.6 Mb/s. If a valid 25.6 Mb/s signal is not received during this period, the local device shall return to the initial state of attempting to establish the link at 51.2 Mb/s.

(R) The local device shall not interrupt its transmissions or change its bit rate within a period of 0.8 seconds or 1 second when transmitting at 51.2 Mb/s or 25.6 Mb/s respectively. The timing periods shall start from the commencement of transmission at a particular bit rate or the detection of incoming signal energy, whichever is the later. Short breaks in transmission should be avoided when a remote device may be trying to sense the bit rate. Otherwise it is permissible for the local device to cease transmitting at any time.

The method used to determine if valid signals are being received is implementation dependent but for example could be based on continuous detection of valid 4B5B symbols with a minimal rate of invalid symbols. It should be noted that some valid symbols may be generated by a remote transmitter operating at the wrong data rate, or by noise if there is no remote transmitter, so the detection thresholds must be chosen to exclude such cases. Since energy detection is used to start the automatic speed detection process at the higher bit rate, it is also essential that devices can reliably distinguish between noise and the presence of signal energy.

Figure 3-8 depicts the automatic speed detection process.



* this transition is allowed at any time.

Figure 3-8 Automatic Speed Detection Flowchart

3.6 Physical layer OAM

The residential broadband environment is likely to be very dynamic in terms of network configuration, in the sense that equipment will be powered down, moved and disconnected on a regular basis. These reconfigurations all give rise to the possibility of subsequent mis-operation, and the situation is exacerbated by the fact that the typical user may not have the network skills or tools to diagnose even the simplest of faults. A basic level of physical layer OAM functionality is therefore defined so as to enable physical layer operation to be established prior to attempting any service connection. The mechanism for this is to determine the ratio of valid to invalid 4B5B symbols seen by the 4B5B decoder, and assert a fault signal (LOQ) when a predetermined threshold is exceeded. This signal may be used to:

1. illuminate a local LED fault indicator
2. contribute to performance monitoring control or statistics
3. provide information to a MIB
4. generate a control character which is transmitted to the far end of the link and can be used there for remote fault indication

(R) The 4B5B decoder shall monitor the total number of symbols and the number of invalid symbols received. The received symbol stream shall be logically divided into blocks of 2^{16} contiguous symbols in time such that each received symbol belongs to one and only one logical block. If more than one invalid symbol is received in a logical block, then a fault indication control signal (LOQ) shall be generated.

(R) The state of LOQ shall be continuously monitored, and then inspected at intervals of approximately 100 msec. If LOQ has been asserted during the interval, a FERF control character, defined as:

X_9 = FERF

shall be generated, inserted into the character stream and sent to the far end of the link. On receipt of FERF, the far end shall assert an rLOQ control signal. rLOQ shall be deasserted not less than 200 ms after the last FERF was received.

4. References

[1] ATM Forum Technical Committee “ATM Physical Media Dependent Interface Specification for 155 Mb/s over Twisted Pair Cable” af-phy-0015.000, September, 1994.

[2] IEC 793-2 (1992) Optical Fibres Product Specifications, Section 4: Product Specifications for Class A Optical Fibres (multi-mode fibres) New Work Item Proposal.

[3] IEC 793-1 (1992) Optical Fibres Generic Specifications, Section 4: Measuring Method for Transmission and Optical Characteristics, C2A Impulse Response, C2B Frequency Response, New Work Item Proposal.

[4] IEC 793-1 (1992) Optical Fibres Generic Specifications, Section 4: Measuring Method for Transmission and Optical Characteristics, C1A Cut-back Technique, C1B Insertion Loss Technique.

[5] IEC 1754-AA Interface Standard, New Work Item Proposal.

[6] TIA/EIA PN-3871 Intermateability Standard, Work in Progress.

[7] IEC 1753-BB New Work Item Proposal.

[8] ANSI/TIA/EIA 568-A-1995 : Commercial Building Telecommunications Cabling Standard.

[9] IEC 603-7 “Connectors for Frequencies Below 3 MHz for use with Printed Boards”, Part 7; 1996. Electrical specifications may be found in ISO/IEC 11801:1995, “Information Technology - Generic cabling for customer premises”.

5. Glossary

ATM	Asynchronous Transfer Mode
BER	Bit Error Ratio
EMC	Electro-Magnetic Compatibility
FWHM	Full Width Half Maximum
HEC	Header Error Control
LED	Light Emitting Diode
LOQ	Loss of Quality
NA	Numerical Aperture
PHY	Physical (layer)
POF	Plastic Optical Fiber
RBB	Residential Broadband
rLOQ	Remote Loss of Quality
TLA	Transmitter Launch Amplitude
TP	Twisted Pair
UNI	User Network Interface
UTP	Unshielded Twisted Pair

Appendix A Balance Measurement Methods

One method of measuring the balance is to drive the transmitter into a well balanced center tapped auto-transformer (balun) with a 100 ohm differential load resistance reflected via another winding on the transformer, across which the differential signal level is measured. The common mode signal is measured across a 50 ohm resistance between the center tap of the balun and the local ground (rear panel in the case of PC mounted cards). The balance at any given frequency is the difference between the common mode and the differential signal levels at that frequency. A schematic of the measurement method is shown in Figure A-1.

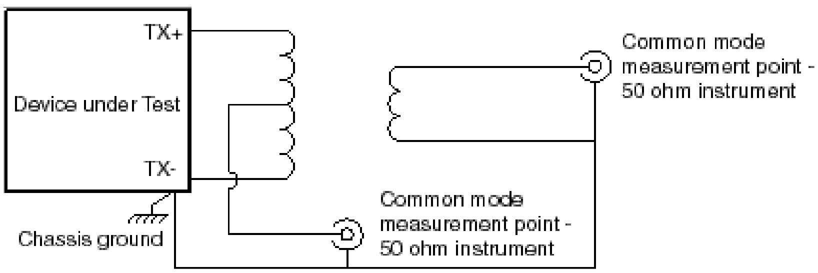


Figure A-1 Balun Measurement method for Differential and Common Mode Output

The connection between the balun and the transmitter should be of minimum length and needs care to ensure that it does not degrade the balance. The ground connection should also be of minimum length. Also, the balun transformer must have an inherent balance significantly better than the balance specification being measured. Unbalance of the balun can be detected by reversing the TX+ and TX- inputs to the balun: if there is a significant change in the measured common mode signal level this indicates that the balun is degrading the measurement accuracy.

An alternative to a balun is the use of a resistive network as shown in Figure A-2. A closely matched pair of resistors, R1 and R2, form a voltage divider whose output relative to ground should be exactly zero for a perfectly balanced system. This is a well-known method referenced in a number of documents (for example, EIA/TIA Tele-communications Systems Bulletin, TSB67, section A.2.2 output Signal Balance.) Resistor R3 ensures that the network presents the common mode termination impedance of 50 ohms required by the RBB PHY specification. Careful construction of the resistive network is necessary using high frequency techniques to ensure valid measurements across the specified frequency range.

While the differential signal level could in principle be measured simultaneously with the common mode, this is not recommended because the addition of test points and probes is likely to add stray impedances which will degrade the balance. To avoid upsetting the balance of the common mode measurement, it is best to make a separate measurement of the differential mode signal across a 100 Ohm resistive termination.

The balance at any given frequency is the difference between the common mode and the differential signal levels at that frequency. With the resistive network method, 6dB must be added to the measured common mode signal to correct for the attenuation of the network. As with the balun method, unbalance of the measurement setup can be detected by reversing the TX+ and TX- inputs: if there is a significant change in the measured common mode signal level this indicates that the test setup is degrading the measurement accuracy. The TIA/EIA reference, op. Cit., suggests that reversing the input connections should not change the measurement by more than 3dB, and if this is the case the average of the two values obtained in the reversal, expressed in dB, can be used to determine the balance.

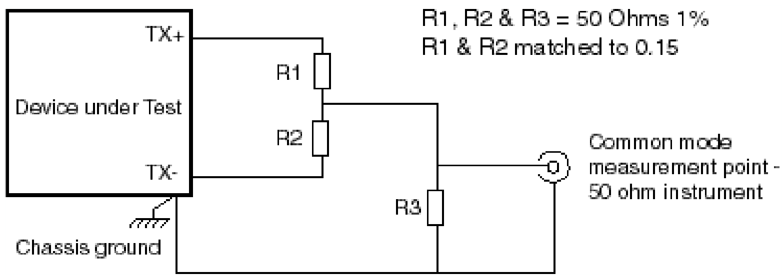


Figure A-2 Resistive Measurement method for Common Mode Output