The ATM Forum
Technical Committee

Physical Interface Specification
for
25.6 Mb/s over Twisted Pair Cable

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1. Physical Layer for 25.6 Mbit/s

This document specifies the physical layer for the 25.6 Mbit/s Private UNI. 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.

Transmission Convergence (TC) Sublayer	HEC Generation/Verification Cell Scrambling/Descrambling Line Coding/Decoding Cell Delineation
Physical Media Dependent (PMD) Sublayer	Bit Timing Physical Media Connectors

Figure 1.1. Functions of the TC and PMD

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).

2. Physical Media Dependent (PMD) Sub layer

2.1 Transmission Link Requirements

2.1.1 Line and Bit Rates

(R) 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 Mbit/sec ± 100 ppm.

2.1.2 Bit Rate Symmetry

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

2.1.3 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 transmitted through the channel reference model described in Section 2.4 in the presence of the worst-case crosstalk noise specified in Section 2.4.

2.1.4 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 local crystal oscillator or a distributed low jitter timing reference that supports a nominal transmission rate of 25.6 Mbit/s.

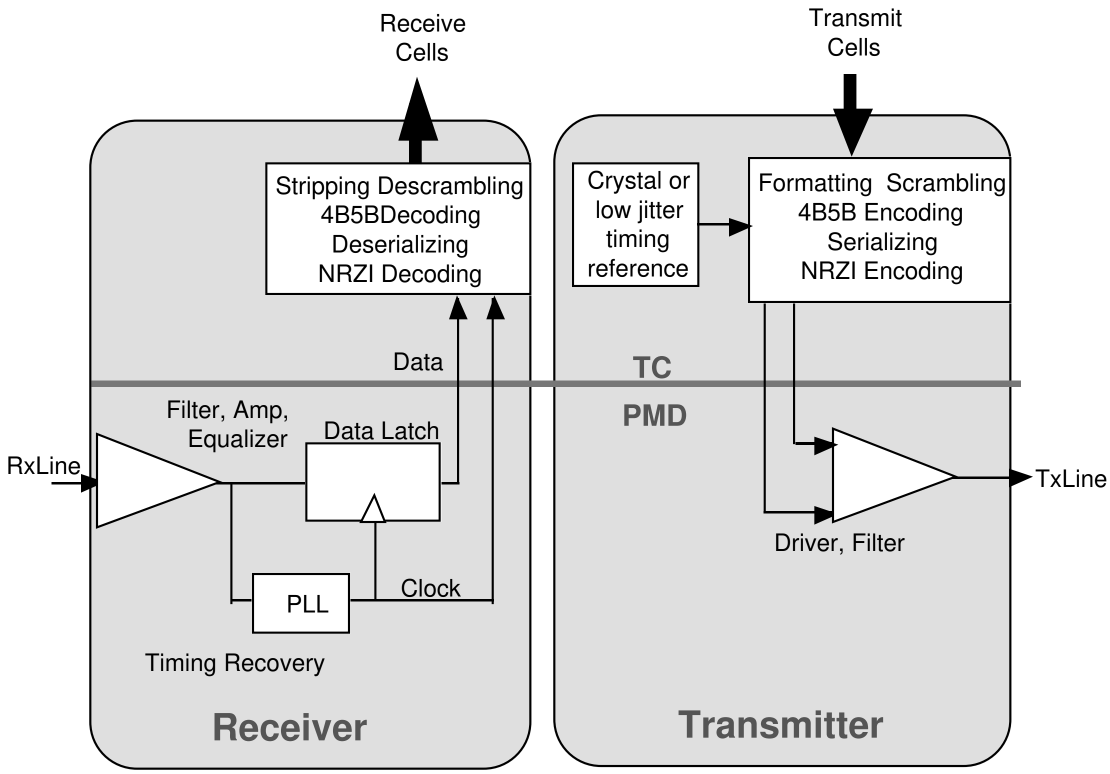

Figure 2.1. Illustration of Example TC/PMD Components and Transmitter Timing

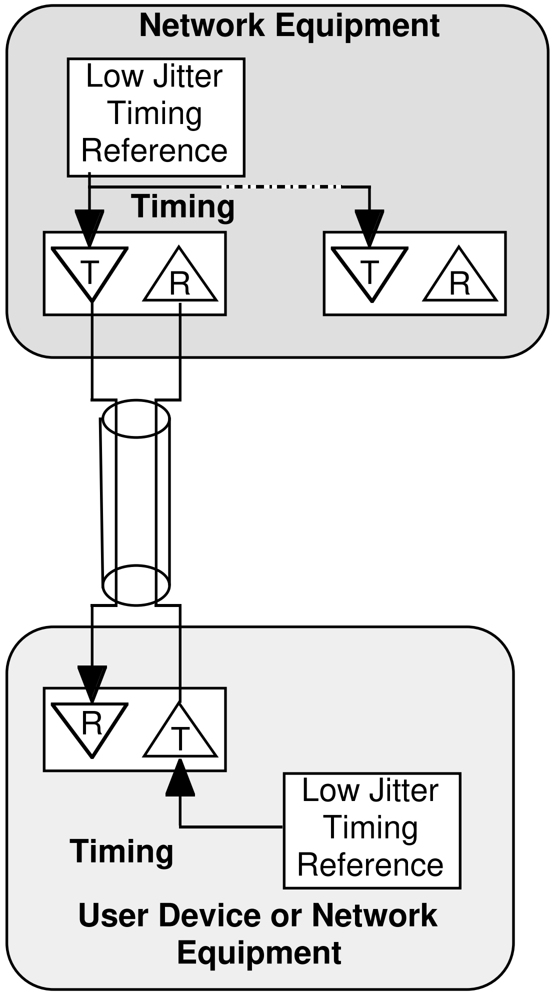

Figure 2.2. User Device—Network Equipment Timing Configurations.

2.1.5 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. Under these conditions, the pulse waveform templates of Section 2.2.2 bound the acceptable pulse shapes to be found an any link.

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) All transmitter measurements shall match the copper link segment(s) supported by the interface including one or more of the following impedances: 100 Ohms, 120 Ohms, or 150 Ohms.

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

(CR) The transmitter shall be terminated in a 150 Ohm resistive load for 150 Ohm STP specifications.

(CR) The transmitter shall be terminated in a 120 Ohm resistive load for 120 Ohm specifications.

Unless specified separately, the parameters specified below apply to all of the 100, 120, and 150 Ohm measurements.

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.

2.2.1.1 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 wave form.

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

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

Two test wave forms (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).

2.2.1.2 Edge Jitter

Edge jitter is specified for any wave form 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 (TEJ) shall be less than 4 ns peak-to-peak when the output is clocked by a local clock source.

2.2.2 Transmitter Waveshapes

(R) The transmitter wave shape shall conform to the waveform templates defined in Tables 2.0, 2.1, 2.2, 2.3, and 2.4 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.)

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	-	-

Table 2.0. Template for 5 Symbol Element Waveform

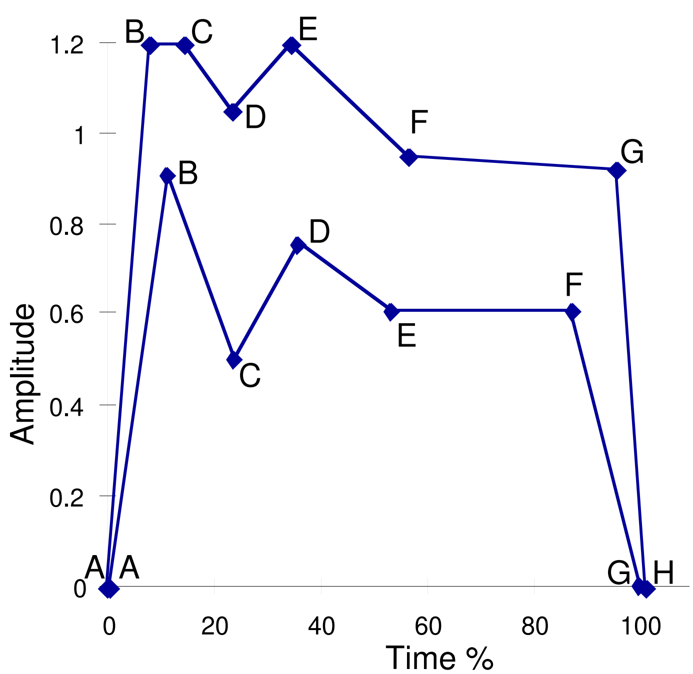

Figure 2.3a. Pulse Template for Table 2.0
Five Symbol Element Waveform

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	-	-

Table 2.1. Template for 4 Symbol Element Waveform

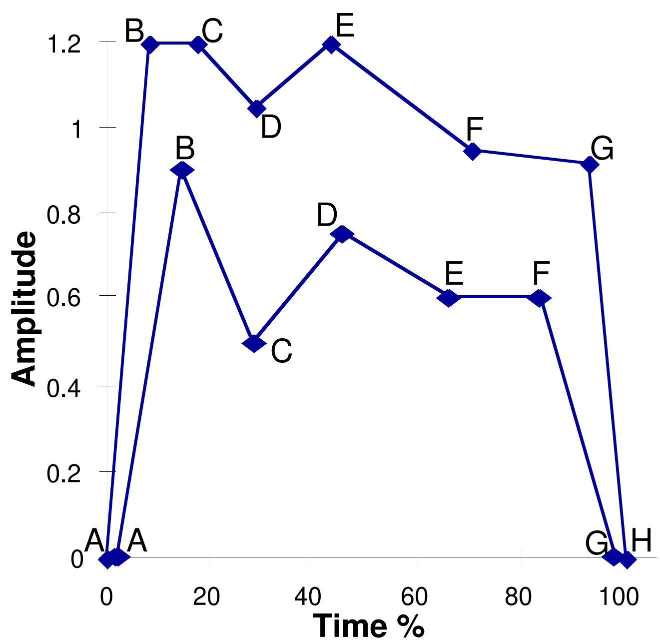

Figure 2.3b. Pulse Template for Table 2.1
Four Symbol Element Waveform

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	-	-

Table 2.2. Template for 3 Symbol Element Waveform

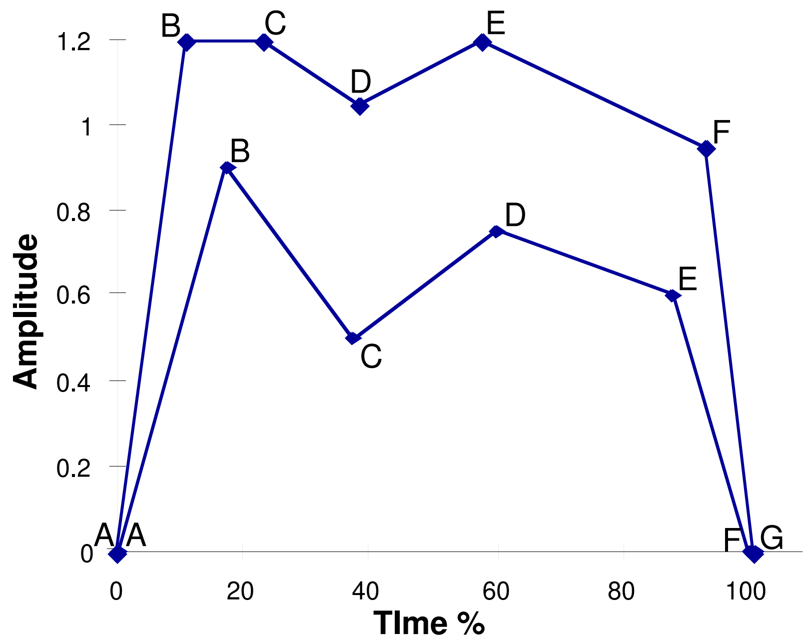

Figure 2.3c. Pulse Template for Table 2.2
Three Symbol Element Waveform

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	-	-

Table 2.3. Template for 2 Symbol Element Waveform

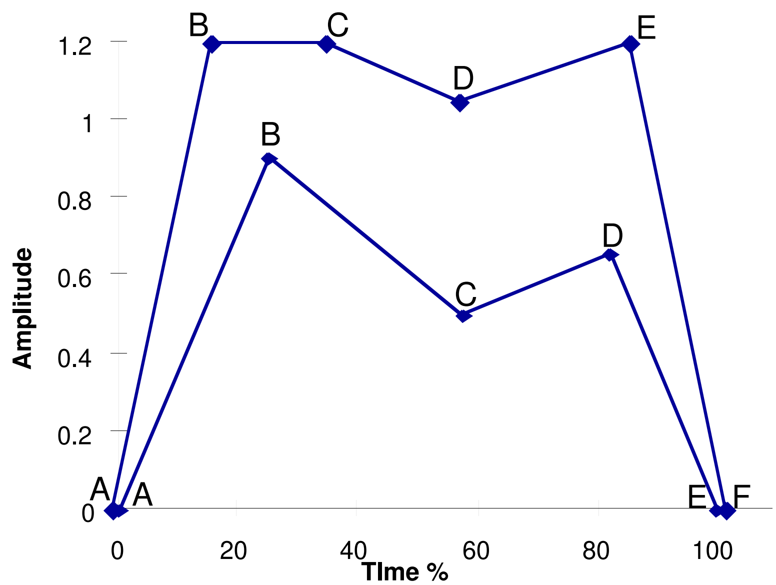

Figure 2.3d. Pulse Template for Table 2.3
Two Symbol Waveform

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

Table 2.4. Template for 1 Symbol Element Wave form

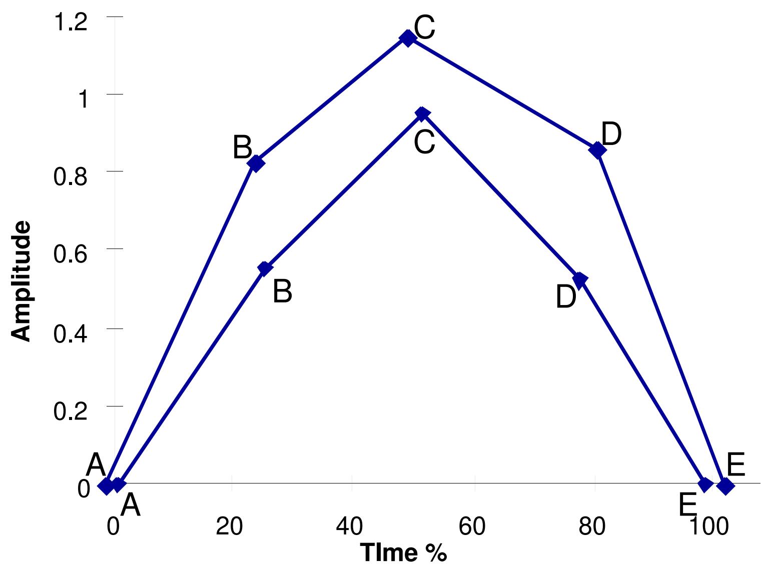

Figure 2.3e. Pulse Template for Table 2.4
One Symbol Element Waveform

2.2.3 Transmitter Launch Amplitude

Transmitter launch amplitude is specified for the transmitted data stream shown below and is defined as the peak-to-peak amplitude of the transmitted wave form.

(R) The transmitter launch amplitude (TLA) shall be between the values specified below. The test wave form (symbol elements at line symbol rate) is defined to be: 01010101....

- 100 Ohm (UTP): 2.7 < TLA < 3.4 volts peak-to-peak
- 150 Ohm (STP): 3.3 < TLA < 4.2 volts peak-to-peak
- 120 Ohm: 2.95 < TLA < 3.75 volts peak-to-peak

2.2.4 Transmitter Return Loss

Transmitter return loss is specified for a transmitter which is actively transmitting any wave form compliant with the scrambling and encoding specifications in Section 3.

(R) The transmitter return loss (TRL) shall be greater than the values specified in Table 2.5 across the full allowed range of characteristic impedance (according to the media type).

Frequency Range	Return Loss
1-6 MHz	14 dB
6-17 MHz	12 dB
17-25 MHz	8 dB

Table 2.5. Transmitter Return Loss

2.3 Receiver Requirements

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 (RAT) 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 and scrambled and encoded as defined in Section 3 which has been sent through a channel that complies with Section 2.4.

2.3.2 Receiver Return Loss

(R) The receiver return loss (RRL) shall be greater than the values specified in Table 2.6 across the full allowed range of characteristic impedance (according to the media type).

Frequency Range	Return Loss
1-17 MHz	15 dB
17-25 MHz	8 dB

Table 2.6. Receiver Return Loss

2.4 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 transmitter and receiver requirements are specified for the media defined below. The implementation specified is for the horizontal distribution of the cable plant and extends from the telecomunications closet to the work area. The copper link segment is defined for 100 Ohm UTP, 120 Ohm, and 150 Ohm STP cabling systems.

(R) The physical interface shall support at least one of the copper link segment definitions described in this section: 100 Ohms, 120 Ohms, or 150 Ohms. For the selected impedance(s), all of the associated conditional requirements shall be met.

2.4.1 100 Ohm Copper 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* requisites for a compliant and functional system. Note that as long as 100 Ohm components are used consistently, a specification of category 3 unshielded cable and connectors allows for the optional use of higher grade components (e.g., category 4, category 5) and the optional use of shielded cabling and components.

2.4.1.1 100 Ohm UTP Link Segment Specifications

The electrical parameters important to link performance are attenuation, near end crosstalk loss (NEXT loss), characteristics impedance, and structural return loss (SRL).

(CR) All components comprising a link segment shall meet or exceed all of the requirements for category 3 as specified by EIA/TIA-568-A and ISO/IEC 11801.

(CR) The composite channel attenuation shall meet or exceed the category 3 attenuation performance limits defined in Annex E of EIA/TIA-568-A.

(CR) The composite channel NEXT loss shall meet or exceed the category 3 NEXT loss performance limits defined in Annex E of EIA/TIA-568-A.

2.4.1.2 Channel Reference Model Configuration for 100 Ohm UTP Systems

The channel reference model for a category 3 UTP system is defined to be a link consisting of 90 meters of category 3 UTP cable, 10 meters of category 3 flexible cords, and four (4) category 3 connectors internal to the link.

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 90 meters of category 3 UTP cable, no more than 10 meters of category 3 flexible cords, and no more than 4 category 3 connectors internal to the link are examples of compliant links.

However, any installed link consisting of category 3 components and meeting the link attenuation and NEXT loss requirements of Section 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.

2.4.1.4 100 Ohm UTP Attenuation

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

(CR) The cable used in constructing a link shall meet or exceed the horizontal category 3 UTP cable attenuation requirements of Section 10 of EIA/TIA-568-A and Clause 8 of ISO/IEC 11801.

(CR) The cordage used in constructing flexible cords and patch cables shall meet or exceed the attenuation requirements for category 3 flexible cordage specified in Section 10 of EIA/TIA-568-A.

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

2.4.1.5 100 Ohm UTP NEXT Loss

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

(CR) The cable and cordage used in constructing a link shall meet or exceed the horizontal category 3 UTP cable NEXT requirements of Section 10 of EIA/TIA-568-A and Clause 8 of ISO/IEC 11801.

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.

(CR) All measurements for these quantities shall be done in accordance with ASTM D 4566 method 3.

(CR) 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 3 in Section 10 of EIA/TIA-568-A and Clause 8 of ISO/IEC 11801.

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.

(CR) All connecting hardware used within this PMD channel (outlets, transition connectors, patch panels, and cross-connect fields) shall meet or exceed the category 3 electrical requirements for attenuation, NEXT loss, and return loss specified in Section 10 of EIA/TIA-568-A and Clause 9 of ISO/IEC 11801.

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

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

2.4.1.8 UTP Media Interface Connector

(CR) Each end of the category 3 UTP 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, and the mated combination shall meet the requirements of Sections 2.4.1.7.

(CR) 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.

(CR) The UTP-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 2.4.

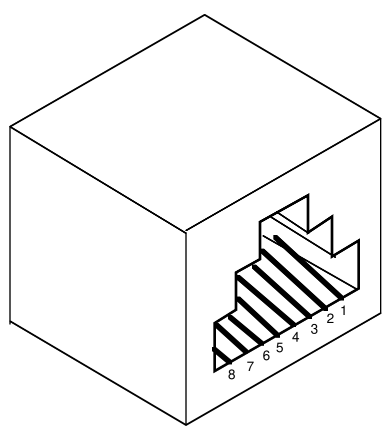

Figure 2.4 Example of UTP–MIC Jack

(CR) The contact assignments for the UTP-MIC receptacle (jack) shall be as listed in Table 2.7.

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 –

Table 2.7. Contact Assignments for UTP-MIC Jack

2.4.2 120 Ohm Link Segment Characteristics

This section defines the cabling and connector conditional requirements when a 120 Ohm cable/connector system is deployed. These requirements define the *minimum* requisites for a compliant and functional system. Note that as long as 120 Ohm components are used consistently, a specification of category 4 unshielded cable and connectors allows for the optional use of higher grade components (e.g., category 5) and the optional use of shielded cabling and components.[1]

The 120 Ohm cable system connects the transmitter on one end of the link segment to the receiver on the other end of the link segment. The cable system consists of one or more sections of 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 transmitters and receivers at the endpoints.

2.4.2.1 120 Ohm Link Segment Specifications

This section defines the link segment characteristics for 120 Ohm link using 120 Ohm category 4 cable specified in ISO/IEC 11801 which meets 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 4 cable. The maximum allowable length of the cable system will vary depending on the quality of the cable, and flexible cord(s).

(CR) The composite channel attenuation for a 120 Ohm link shall meet the attenuation performance limits defined in Annex E of EIA/TIA-568-A for category 4 cables.

(CR) The composite channel NEXT loss for a 120 Ohm link shall meet the NEXT loss performance limits defined in Annex E of EIA/TIA-568-A for category 4 cables.

---

[1] Note, therefore, that systems commonly called “FTP” (foiled twisted pair) which employ 120 Ohm shielded category 5 twisted pair are typically consistent with the requirements in this section.

(CR) 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 4 in Section 10 of EIA/TIA-568-A and Clause 8 of ISO/IEC 11801.

2.4.2.2 Channel Reference Model Configuration for 120 Ohm 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 11801, Clause 6 for more detailed information.

The channel reference model for a 120 Ohm system is defined to be a link consisting of 90 meters of 120 Ohm cable, 10 meters of 120 Ohm flexible cord, and 4 Category 4 connectors internal to the link.

2.4.2.3 Examples of 120 Ohm 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 of 120 Ohm cable, no more than 10 meters of 120 Ohm flexible cord, and no more than 4 Category 4 connectors internal to the link are examples of compliant links. However, any installed link consisting of Category 4 components and meeting the link attenuation and NEXT loss requirements of Section 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.

2.4.2.4 120 Ohm Connecting Hardware and Media InterfaceConnector

(CR) The connecting hardware and media interface connector defined for 100 Ohm link segments (Sections 2.4.1.7 and 2.4.1.8) shall also apply to 120 Ohm systems except that all references to Category 3 requirements shall be replaced by Category 4.

2.4.3 150 Ohm Link Segment Characteristics

The 150 Ohm cable system connects the transmitter on one end of the link segment to the receiver 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 transmitters and receivers at the endpoints.

2.4.3.1 150 Ohm STP Link Segment Specifications

The sytem can operate with a variety of STP cable types. EIA/TIA-568-A and ISO/IEC 11801 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 3 UTP cable. The maximum allowable length of the cable system will vary depending on the quality of the STP cable, and flexible cord(s).

(CR) 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 for category 3 UTP cables.

(CR) 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 for category 3 UTP cables.

(CR) 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 150 Ohm STP in Section 10 of EIA/TIA-568-A.

2.4.3.2 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 11801, Clause 6 for more detailed information.

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 flexible cord, and 4 STP-A connectors internal to the link.

2.4.3.3 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 STA-A cable, no more than 10 meters of STP-A flexible 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 loss requirements of Section 2.4.3.1 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.

2.4.3.4 STP Media Interface Connector

(CR) Each end of the fixed cable shall be terminated in the STP media interface connector as shown in Figure 2.5.

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

(CR) The STP media interface connector contact assignments shall be as listed in Table 2.8.

Contact	Signal at the ATM User Device	Signal at the ATM Network Equipment
B	Transmit +	Receive +
R	Receive +	Transmit +
G	Receive -	Transmit -
O	Transmit -	Receive -

Table 2.8. Contact assignments for STP–MIC connectors.

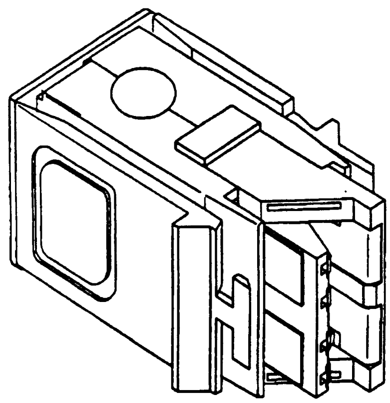

Figure 2.5 Example of STP–MIC Jack

3. Transmission Convergence (TC) Sublayer

This section describes the Transmission Convergence sublayer for the 25.6 Mbit/s ATM PHY. The functions of the TC sublayer are:

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

Figure 3.1 is a block diagram of the Transmission Convergence sublayer that identifies the above functions and their data flow relationships.

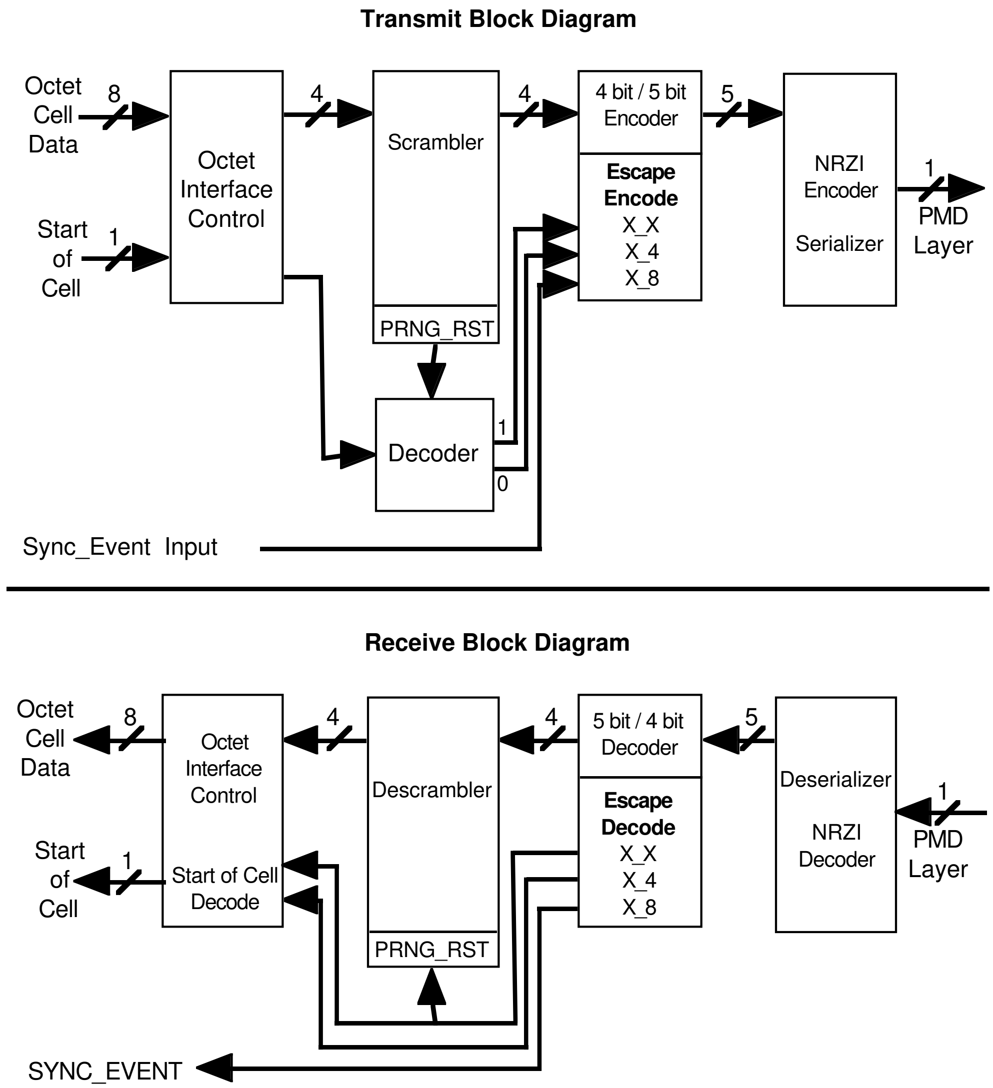

Figure 3.1. Block Diagrams of the Transmission Convergence Sub layer.
For information only—not intended as a required implementation.

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.

(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:

$$x^{10} + x^{7} + 1$$

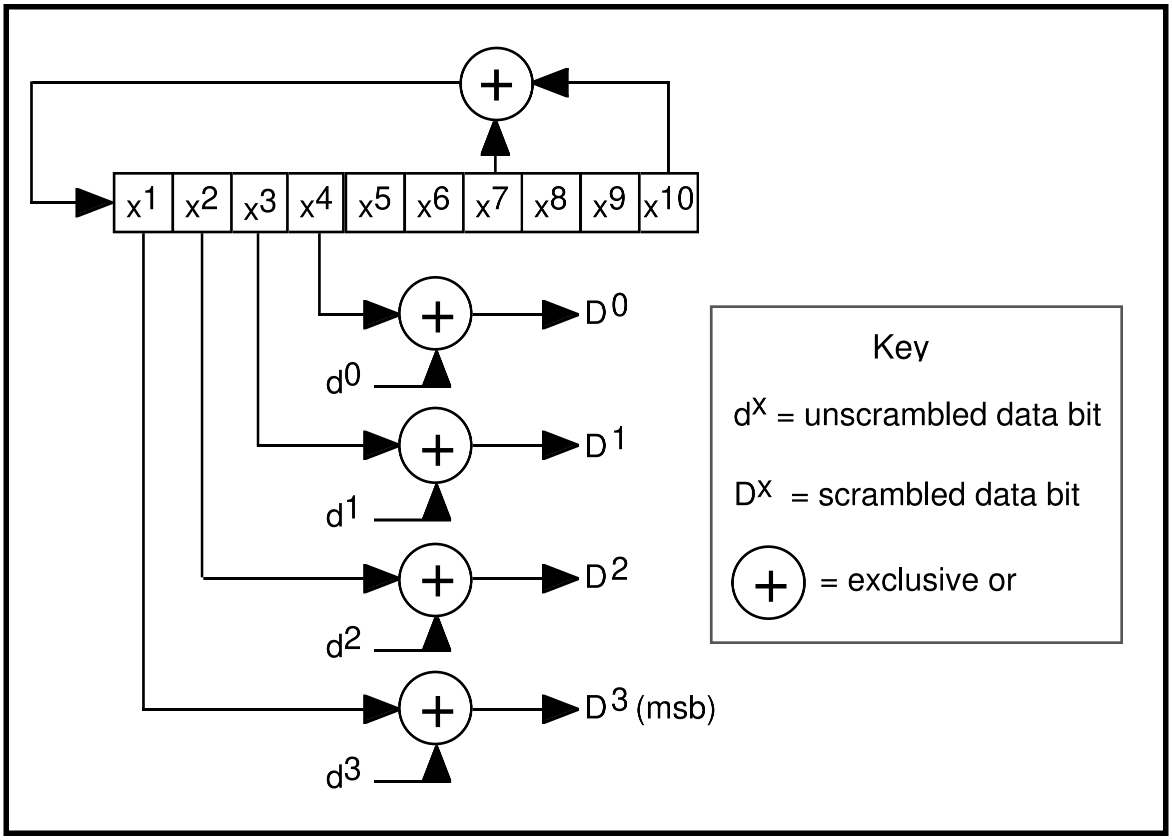

Figure 3.2. Pseudo Random Number Generator block diagram.
For information only—not intended to depict a required implementation.

(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'ed with the corresponding 4 bits of the PRNG (x^1 x^2 x^3 x^4 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[2], 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-ed 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.

[2] Figure 3.3 shows a case that will occur in normal operation whenver 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.

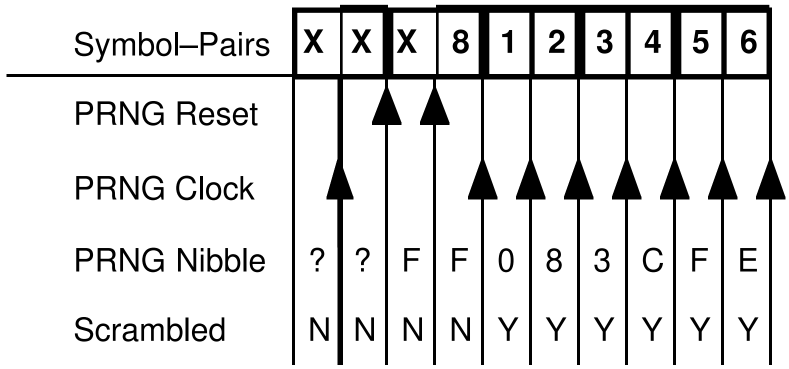

Figure 3.3. Start of Cell Symbol–pairs

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 misaligned in the scrambler sequence.

3.1.1 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...

3.2 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:

- Provides an average of over 3 transitions per 5 bit symbol
- Run length is limited to less than or equal to 5
- 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 3.1 below lists the valid 4-bit nibble to 5-bit symbol conversions.

(R) Table 3.1 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.

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						

Table 3.1. Conversion Table—4-bit command/data to 5-bit symbols

Note: The binary values for 4-bit data nibbles and 5-bit encoded symbols in Table 3.1 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 shall always be paired. Two types of symbol pair entities are defined which represent:

- Commands, and
- 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 three are defined and valid. The set of 3 valid (bold) and 14 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 = Invalid (reserved for future use)

- 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, and X_8) 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.

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

(O) Transport of a timing sync pulse to support isochronous communications may 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.

(CR) 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 showing Start–of–cell commands with and without Scrambler Reset, and a Sync_Event command interrupting the flow of Cell N+1.

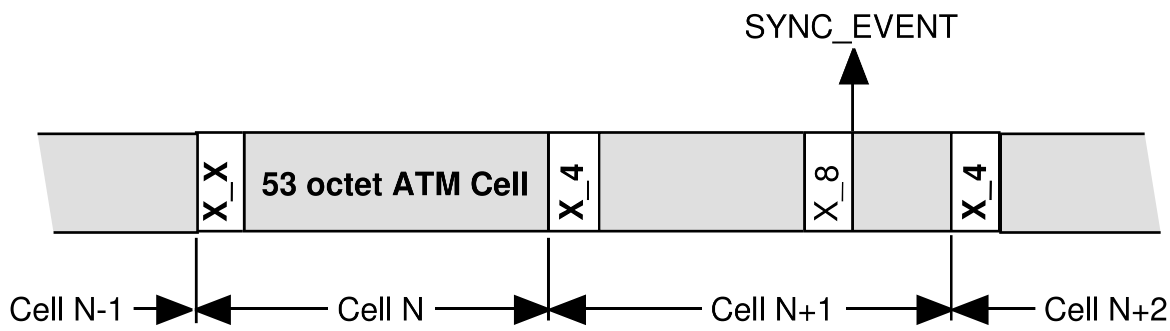

Figure 3.4. Example of Cell Delineation and Sync_Event using Commands

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.

(R) Reception of any command other than X_X, X_4 or X_8 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) 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 (where no command or data are being transmitted) will continually be sent out onto the line. This arbitrary 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) The TC sublayer shall transfer to and from the ATM layer complete 53-octet ATM cells.

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 XORed 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 3.5 depicts the HEC verification flow at the receiver. The TC shall not forward any cell to the ATM layer which has an incorrect HEC.

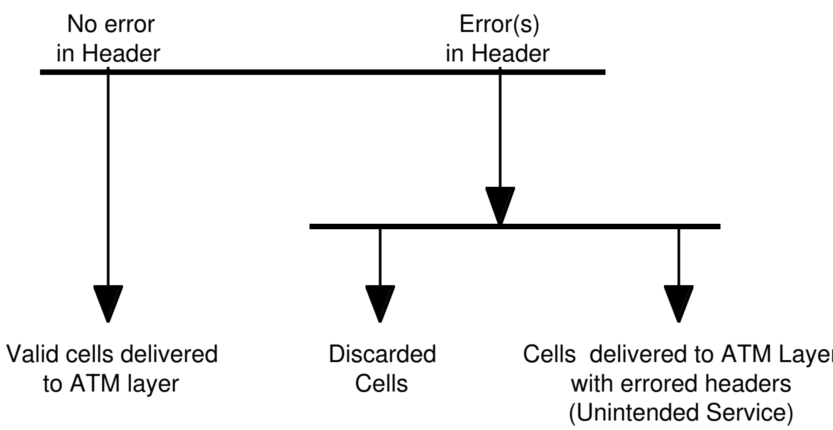

Figure 3.5—HEC Verification Flow

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.

4. References

[1] TIA/EIA-568-A, "Commercial Building Telecommunications Cabling Standard", 1995.

[2] ISO/IEC 11801:1995, "Generic Cabling for Customer Premises"

[3] The ATM Forum Technical Committee, ATM User Network Interface Specification, Version 3.1, Prentice Hall, Englewood Cliffs, NJ, 1994.

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

[5] IEC 603-7, "Connectors for frequencies below 3 MHz for use with printed boards, Part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features" 1990-04.