American National Standard

for Information Technology –

Fibre Distributed Data Interface (FDDI) – Token Ring Twisted Pair Physical Layer Medium Dependent (TP-PMD)

ANSI X3.263-1995

American National Standards Institute
11 West 42nd Street
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Secretariat

Information Technology Industry Council

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Abstract

The described Twisted Pair Physical Layer Medium Dependent Standard is intended for use in a high-performance multistation network. This protocol is designed to be effective at 100 megabits per second using a token ring architecture and twisted pair cabling as the transmission medium over link distances of up to one hundred meters.

American National Standard

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Foreword (This foreword is not part of American National Standard X3.263-1995.)

The Fibre Distributed Data Interface (FDDI) is intended for use in a high-performance general purpose multi-station network and is designed for efficient operation with a peak data rate of 100 Mbit/s. It uses a Token Ring architecture with optical fibre as the primary transmission medium. FDDI provides for hundreds of stations operating over an extent of tens of kilometers.

The FDDI Token ring twisted pair physical layer medium dependent (TP-PMD) standard specifies the lower sublayer of the Physical Layer for FDDI for operation on twisted pair cables. As such it specifies the power levels and characteristics of the transmitter and receiver, and the interface signal requirements including jitter. TP-PMD also specifies the connector details, the requirements of conforming FDDI cable plants, and the permissible bit error rates. TP-PMD is designed to operate with one twisted pair in each direction.

TP-PMD is one of a set of American National Standard alternative PMDs being developed, or already developed, for FDDI. This set includes the original PMD for multimode fibre, the Single Mode Fibre PMD (SMF-PMD), and the Low Cost Fibre PMD (LCF-PMD).

The set of FDDI standards, when completed, will include the following standards:

a) A FDDI PART: Token ring physical layer protocol (PHY), which specifies the upper sublayer of the physical layer for the FDDI, including the data encode/decode, framing and clocking, as well as the elasticity buffer, smoothing, and repeat filter functions;

b) A FDDI PART: Token ring media access control (MAC),which specifies the lower sublayer of the data link layer for FDDI, including the access to the medium, addressing, data checking, and data framing;

c) A FDDI PART: Token ring station management (SMT), which specifies the local portion of the system management application process for FDDI, including the control required for proper operation of a station in an FDDI ring.

American National Standards for FDDI MAC (ANSI X3.139-1987), FDDI PHY (ANSI X3.148-1988), and FDDI PMD (ANSI X3.166-1990) have been approved and published. In addition, FDDI standards are being processed as International Standards by standards committee ISO/IEC JTC 1/SC 25. International standards for FDDI PHY, FDDI MAC, and FDDI PMD (ISO 9314-1:1989, 9314-2:1989 and ISO/IEC 9314-3:1990, respectively) have also been published.

An extension to the basic FDDI is now in the X3 approval process. The standard FDDI HRC, commonly known as FDDI-II, will extend the capability of FDDI to handle isochronous data streams at a multiplicity of data rates.

A standard for an enhancement to MAC is in process. This standard will be referred to as FDDI MAC-2 when it is necessary to distinguish it from the approved FDDI MAC standard ANSI X3.139-1988. Changes to be considered for this update of the FDDI MAC standard include those identified in footnotes in the published standard on MAC as areas that the standards committee intended to change as well as changes that may be required for any proposed extensions to FDDI, such as FDDI-II or MAC Bridging. A similar enhancement project is in process for the FDDI PHY standard. This standard will be referred to as FDDI PHY-2.

The text and format of this FDDI TP-PMD standard is based upon the International FDDI PMD standard ISO/IEC 9314-3. As a consequence, certain conventions, references, spelling, and units commonly used in International Standards have been used in this standard. These are different from those normally used in American National Standards, but are not expected to cause difficulty in understanding or use.

This standard contains 11 annexes. Annex A is normative and is considered part of this standard. Annexes B–K are for information only.

Requests for interpretation, suggestions for improvement or addenda, or defect reports are welcome. They should be sent to the ITI, 1250 Eye Street, NW, Washington, DC 20005.

This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee on Information Technology, X3. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the X3 Committee had the following members:

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American National Standard
for Information Technology –

Fibre Distributed Data Interface (FDDI) – Token Ring Twisted Pair Physical Layer Medium Dependent (TP-PMD)

1 Scope

This standard specifies Twisted Pair Physical Layer Medium Dependent (TP-PMD) requirements for the Fibre Distributed Data Interface (FDDI).

FDDI provides a high-bandwidth (100 Mbit/s), general-purpose interconnection among computers and peripheral equipment using fibre optics and twisted pair as the transmission media. FDDI can be configured to support a sustained data transfer rate of at least 80 Mbit/s (10 Mbyte/s). FDDI provides connectivity for many nodes distributed over distances of several kilometers in extent. Default values for FDDI are calculated on the basis of 1 000 physical links and a total fibre path length of 200 km (typically corresponding to 500 nodes and 100 km of dual fibre cable).

FDDI consists of:

a) a Physical Layer (PL), which is divided into two sublayers:

1) A Physical Layer, Medium Dependent (PMD) sublayer (ISO/IEC 9314-3), with several alternative medium choices, which provides the digital baseband point-to-point communication between nodes in the FDDI network. The PMD provides all services necessary to transport a suitably coded digital bit stream from node to node. The PMD defines and characterizes the medium drivers and receivers, medium-dependent code requirements, cables, connectors, power budgets, optical bypass provisions, and physical-hardware-related characteristics. It specifies the point of interconnectability for conforming FDDI attachments.

The original PMD standard (ISO/IEC 9314-3), called PMD, defines attachment to multi-mode fibre up to 2 km, while this TP-PMD defines low-cost attachments to twisted pair up to 100 m. Additional PMD sublayer standards are being developed for attachment to single mode fibre (SMF-PMD), and multi-mode fibre up to 500 m (LCF-PMD);

2) A Physical Layer Protocol (PHY) sublayer (ISO/IEC 9314-1), and its enhancement, (PHY-2), which provides connection between the PMD and the Data Link Layer. PHY establishes clock synchronization with the upstream code-bit data stream and decodes this incoming code-bit stream into an equivalent symbol stream for use by the higher layers. PHY provides encoding and decoding between data and control indicator symbols and code bits, medium conditioning and initializing, the synchronization of incoming and outgoing code-bit clocks, and the delineation of octet boundaries as required for the transmission of information to or from higher layers. Information to be transmitted on the medium is encoded by the PHY using a group transmission code;

b) a Data Link Layer (DLL), which is divided into two or more sublayers:

1) An optional Hybrid Ring Control (HRC) (ISO/IEC 9314-5), which provides multiplexing of packet and circuit switched data on the shared FDDI medium. HRC comprises two internal components, a Hybrid Multiplexer (H-MUX) and an Isochronous MAC (I-MAC). H-MUX maintains a synchronous 125 µs cycle structure and multiplexes the packet and circuit switched data streams, and I-MAC provides access to circuit switched channels;

2) A Media Access Control (MAC) (ISO 9314-2), and its enhancement (MAC-2), which provides fair and deterministic access to the medium, address recognition, and generation and verification of frame check sequences. Its primary function is the delivery of packet data, including frame generation, repetition, and removal;

3) An optional Logical Link Control (LLC), which provides a common protocol for any required packet data adaptation services between MAC and the Network Layer. LLC is not specified by FDDI;

4) An optional Circuit Switching Multiplexer (CS-MUX), which provides a common protocol for any required circuit data adaptation services between I-MAC and the Network Layer. CS-MUX is not specified by FDDI;

c) a Station Management (SMT), which provides the control necessary at the node level to manage the processes under way in the various FDDI layers such that a node may work cooperatively on a ring. SMT provides services such as control of configuration management, fault isolation and recovery, and scheduling policies.

FDDI TP-PMD is a supporting document to FDDI PHY and FDDI PHY-2 which should be read in conjunction with it. The FDDI SMT document should be read for information pertaining to supported FDDI node and network configurations.

ISO/IEC 9314 specifies the interfaces, functions, and operations necessary to ensure interoperability between conforming FDDI implementations. This standard provides a functional description. Conforming implementations may employ any design technique that does not violate interoperability.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ANSI/EIA/TIA 568-1991, *Commercial building telecommunications wiring standard*

ECMA 97: 1985, *Local Area Networks Safety Requirements*

EIA/TIA TSB 36, *Technical systems bulletin additional cable specifications for unshielded twisted pair cables, November 1991*[1)]

EIA/TIA TSB 40, *Technical systems bulletin additional transmission specifications for unshielded twisted pair connecting hardware, 1992*[1)]

EIA/TIA 574: 1990, *9 Position non-synchronous interface between data terminal equipment and data circuit-terminating equipment employing serial binary data interchange*[1)]

IEC 60, *High-voltage test techniques*[2)]

IEC 950: 1991, *Safety of information technology equipment, including electrical business equipment*[2)]

ISO 8802-3: 1993, *Information technology – Local and metropolitan area networks– Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*[2)]

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1) Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80111-5704.

2) Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ISO 8802-5: 1992, *Information processing systems – Local and metropolitan area networks – Part 5: Token ring access method and physical layer specifications*[2)]

ISO/IEC 8877:1992, *Information technology – Telecommunications and information exchange between systems – Interface connector and contact assignments for ISDN Basic Access Interface located at reference points S and T*[2)]

ISO 9314-1: 1989, *Information processing systems – Fibre Distributed Data Interface (FDDI) – Part 1: Token Ring Physical Layer Protocol (PHY)*[2)]

ISO 9314-2: 1989, *Information processing systems – Fibre Distributed Data Interface (FDDI) – Part 2: Token Ring Media Access Control (MAC)*[2)]

ISO/IEC 9314-3: 1990, *Information processing systems – Fibre Distributed Data Interface (FDDI) – Part 3: Token Ring Physical Layer, Medium Dependent (PMD)*[2)]

ISO/IEC DIS 9314-6, *Information processing systems – Fibre Distributed Data Interface (FDDI) – Part 6: Token Ring Physical Layer, Station Management (SMT)*[2)]

3 Definitions

For the purposes of this standard, the following definitions apply. Other parts of FDDI, e.g., MAC and PHY, may contain additional definitions of interest.

3.1 baseline wander: Data dependent variations in the low frequency component of a signal.

3.2 bypass: The ability of a station to isolate itself from the FDDI network while maintaining the continuity of the cable plant.

3.3 code bit: The smallest signaling element used by the Physical Layer for transmission on the medium.

3.4 concentrator: An FDDI node that has additional PHY/PMD entities beyond those required for its own attachment to an FDDI network. These additional PHY/PMD entities are for the attachment of other FDDI nodes (including other concentrators) in a tree topology.

3.5 connector plug: A device used to terminate a cable.

3.6 connector receptacle: The fixed or stationary half of a connection that is mounted on a panel/bulkhead. Receptacles mate with plugs.

3.7 counter-rotating: An arrangement whereby two signal paths, one in each direction, exist in a ring topology.

3.8 dual attachment concentrator: A concentrator that offers two attachments to the FDDI network which are capable of accommodating a dual (counter-rotating) ring.

3.9 dual attachment station: A station that offers two attachments to the FDDI network which are capable of accommodating a dual (counter-rotating) ring.

3.10 dual ring (FDDI dual ring): Two FDDI rings that operate as (a pair of) counter-rotating logical rings.

3.11 entity: An active service or management element within an Open Systems Interconnection (OSI) layer, or sublayer.

3.12 fibre: Dielectric material that guides light; waveguide.

3.13 fibre optic cable: A cable containing one or more optical fibres.

3.14 interchannel isolation: The ability to prevent undesired energy from appearing in one signal path as a result of coupling from another signal path.

3.15 jitter: The variation in synchronization between bits in the FDDI signaling bit stream.

3.16 jitter, data dependent (DDJ): Jitter that is related to the transmitted symbol sequence. DDJ is caused by the limited bandwidth characteristics and imperfections in the channel components.

3.17 jitter, duty cycle distortion (DCD): Distortion usually caused by propagation delay differences between low-to-high and high-to-low transitions. DCD is manifested as a pulse width distortion of the nominal baud time.

3.18 jitter, random (RJ): RJ due to thermal noise may be modeled as a Gaussian process. Other sources of RJ include external noise and crosstalk. The peak-peak value of RJ is probabilistic in nature.

3.19 TP-MIC plug: The male part of the TP-MIC that terminates a twisted pair cable.

3.20 TP-MIC receptacle: The female part of the TP-MIC which is contained in an FDDI node.

3.21 logical ring: The set of MACs serially connected to form a single ring.

3.22 media interface connector (MIC): A mated connector pair that provides an attachment between an FDDI node and a cable plant. When referring to the original PMD's MIC, the term MIC is used. When referring to the TP-PMD MIC, the term TP-MIC is used. The TP-MIC consists of two parts; a TP-MIC plug and a TP-MIC receptacle.

3.23 network (FDDI network): A collection of FDDI nodes interconnected to form a trunk, or a tree, or a trunk with multiple trees. This topology is sometimes called a dual ring of trees.

3.24 node: A generic term applying to any FDDI ring attachment (station or concentrator).

3.25 original PMD: The first FDDI PMD standard developed that supports multi-mode fibre optic cable with an 11dB loss budget and is known as ANSI X3.166.

3.26 physical connection: The full-duplex physical layer association between adjacent PHY entities (in concentrators or stations) in an FDDI network, i.e., a pair of Physical Links.

3.27 physical link: The simplex path (via PMD and attached medium) from the transmit function of one PHY entity to the receive function of an adjacent PHY entity (in concentrators or stations) in an FDDI network.

3.28 primitive: An element of the services provided by one entity to another.

3.29 receiver (optical): An opto-electronic circuit that typically converts an optical signal to an electrical logic signal.

3.30 ring: A set of stations wherein information is passed sequentially between stations, each station in turn examining or copying the information, finally returning it to the originating station. In FDDI usage, the term "ring" or "FDDI ring" refers to the dual (counter-rotating) ring.

3.31 services: The FDDI services provided by one FDDI entity to another. Data services are provided to a higher layer entity; management services are provided to a management entity in the same or another layer.

3.32 single attachment concentrator: A concentrator that offers one attachment to the FDDI network.

3.33 single attachment station: A station that offers one attachment to the FDDI network.

3.34 station: An addressable node on an FDDI network capable of transmitting, repeating, and receiving information. A station has exactly one SMT and at least one MAC, one PHY, and one PMD.

3.35 transmitter (optical): An opto-electronic circuit that typically converts an electrical logic signal to an optical signal.

3.36 tree: A physical topology consisting of a hierarchy of master-slave connections between a concentrator and other FDDI nodes (including subordinate concentrators).

3.37 trunk: A physical loop topology, either open or closed, employing two signal paths, one in each direction (i.e., counter-rotating), forming a sequence of peer connections between FDDI nodes. When the trunk forms a closed loop it is sometimes called a trunk ring.

4 Conventions and abbreviations

4.1 Conventions

The terms SMT, MAC, PHY, and PMD, when used without modifiers, refer specifically to the local instances of these entities.

Low lines (e.g., control_action) are used as a convenience to mark the name of signals, functions, and the like, which might otherwise be misinterpreted as independent individual words if they were to appear in text.

The use of a period (e.g., PM_UNITDATA.request) is equivalent to the use of low lines except that a period is used as an aid to distinguish modifier words appended to an antecedent expression.

The use of a colon (e.g., N:PM_UNITDATA.request) distinguishes between two or more instances of the same signal where N designates the other source/destination entity.

In the presentation of diagrams, dashed lines are used to indicate optional entities, data paths, transitions and states. Dotted lines are used to indicate a functional unit that may be broken into other functional units.

Timers are given by a name of the form TXX, where XX are two capital letters. An example is the PCM timer, TPC.

This standard contains four kinds of documentation as follows:

1) Narrative text, including text associated with state machines;
2) State machine diagrams, including associated footnotes;
3) Pseudo code;
4) Examples, which are specifically noted as such.

If any discrepancies exist between the above, the following precedence shall be used to resolve those disprecancies and determine conformance:

1) State machine diagrams;
2) Pseudo code;
3) Narrative text.

Examples are provided only for clarification and shall not be used for determining conformance.

4.1.1 State machines

Some operations are defined using cooperating state machines. It is assumed that time elapses only in discrete states, with instantaneous transitions between the states.

State diagrams are expressed using vertical staffs to represent states and horizontal arrows to represent transitions.

Transitions are illustrated with the triggering condition located above the horizontal arrow and any actions on transition located below the transition arrow. Transition actions are performed while remaining in the previous state, before entry into the new state.

The following event-processing sequence is assumed:

1) Evaluate all transition conditions from the current state;

2) If a transition condition is satisfied, then

   a) Perform the associated transition actions in the current state;

   b) Enter the new state;

   c) Perform entry actions, if any, for the new state;

   d) If a transition condition from this new state is satisfied, then repeat the transition sequence steps a to d;

3) Perform any instate actions when their associated conditions are satisfied. Logical symbols are represented in state machines and pseudo code using l to represent the 'or' operator and & to represent the 'and' operator.

Footnotes are used in state diagrams to give precise detail on transition conditions, transition actions, entry actions, and instate actions.

4.2 Abbreviations

AII	Active Input Interface
AOI	Active Output Interface
ANS_Max	Maximum acquisition time (no signal)
AS_Max	Maximum acquisition time (signal)
BER	Bit Error Rate
BERT	Bit Error Rate Tester
BLW	Baseline Wander
DCD	Duty Cycle Distortion (jitter)
DDJ	Data Dependent Jitter
ECL	Emitter Coupled Logic
ILD	Insertion Loss Deviation
LED	Light Emitting Diode
LS_Max	Maximum line state change time
MIC	Media Interface Connector
MLT-3	Multi level transmit – 3 levels
NEXT	Near End Crosstalk
NRZ	Non Return to Zero
NRZI	Non Return to Zero, Invert on ones
OCL	Open Circuit Inductance
RJ	Random Jitter
SAE	Static Alignment Error (clock offset error)
SDU	Service Delivery Unit
STP	Shielded Twisted Pair
TL_Min	Minimum Line State Transmission Time
TP-MIC	TP-PMD MIC Connector
UTP	Unshielded Twisted Pair
VSDA	Signal Detect Assertion Voltage
VSDD	Signal Detect Deassertion Voltage

5 General description

5.1 Ring overview

A ring consists of a set of stations logically connected as a serial string of stations and transmission media to form a closed loop. Information is transmitted sequentially, as a stream of suitably encoded symbols, from one station to the next. Each station generally regenerates and repeats each symbol and serves as the means for attaching one or more devices to the ring for the purpose of communicating with other devices on the ring. The method of actual physical attachment to the FDDI ring may vary and is dependent on specific application requirements as described in subsequent paragraphs.

The basic building block of an FDDI ring is a physical connection as shown in figure 1. A physical connection consists of the Physical Layers (each composed of a PMD and a PHY entity) of two stations that are connected over the transmission medium by a Primary Link and a Secondary Link. A Primary Link consists of an output, called Primary Out, of a Physical Layer, communicating over a Primary medium to the input, called Primary In, of a second Physical Layer. The Secondary Link consists of the output, called Secondary Out, of the second Physical Layer communicating over a Secondary medium to the input, called Secondary In, of the first Physical Layer. Physical connections may be subsequently logically connected within stations, via attached MACs or other means, to create the network. As such, the function of each station is implementer-defined and is determined by the specific application or site requirements.

Two classes of stations are defined: dual (attachment) and single (attachment). FDDI trunk rings may be composed only of dual attachment stations which have two PMD entities (and associated PHY entities) to accommodate the dual ring. Concentrators provide additional PMD entities beyond those required for their own attachment to the FDDI network, for the attachment of single attachment stations which have only one PMD and thus should not directly attach to the FDDI trunk ring.

The example of figure 2 shows the concept of multiple physical connections used to create logical rings. As shown, the logical sequence of MAC connections is stations 1, 3, 5, 8, 9, 10, and 11. Stations 2, 3, 4, and 6 form an FDDI trunk ring. Stations 1, 5, 7, 10, and 11 are attached to this ring by lobes branching out from the stations that form it. Stations 8 and 9 are in turn attached by lobes branching out from station 7. Stations 2, 4, 6, and 7 are concentrators, serving as the means for attaching multiple stations to the FDDI ring. Concentrators may or may not have MAC entities and station functionality. The concentrator examples of figure 2 do not show any MACs although their presence is implied by the designation of these concentrators as stations.

Connection to the physical medium as established by PMD is controlled by the station insertion and removal algorithms of Station Management (SMT) which are beyond the scope of this standard.

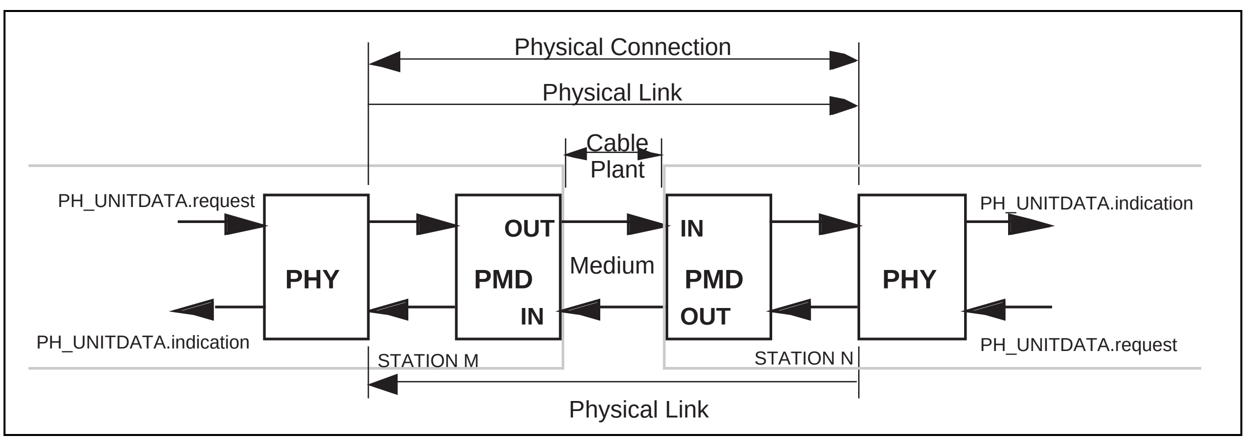

Figure 1 – FDDI links and connections

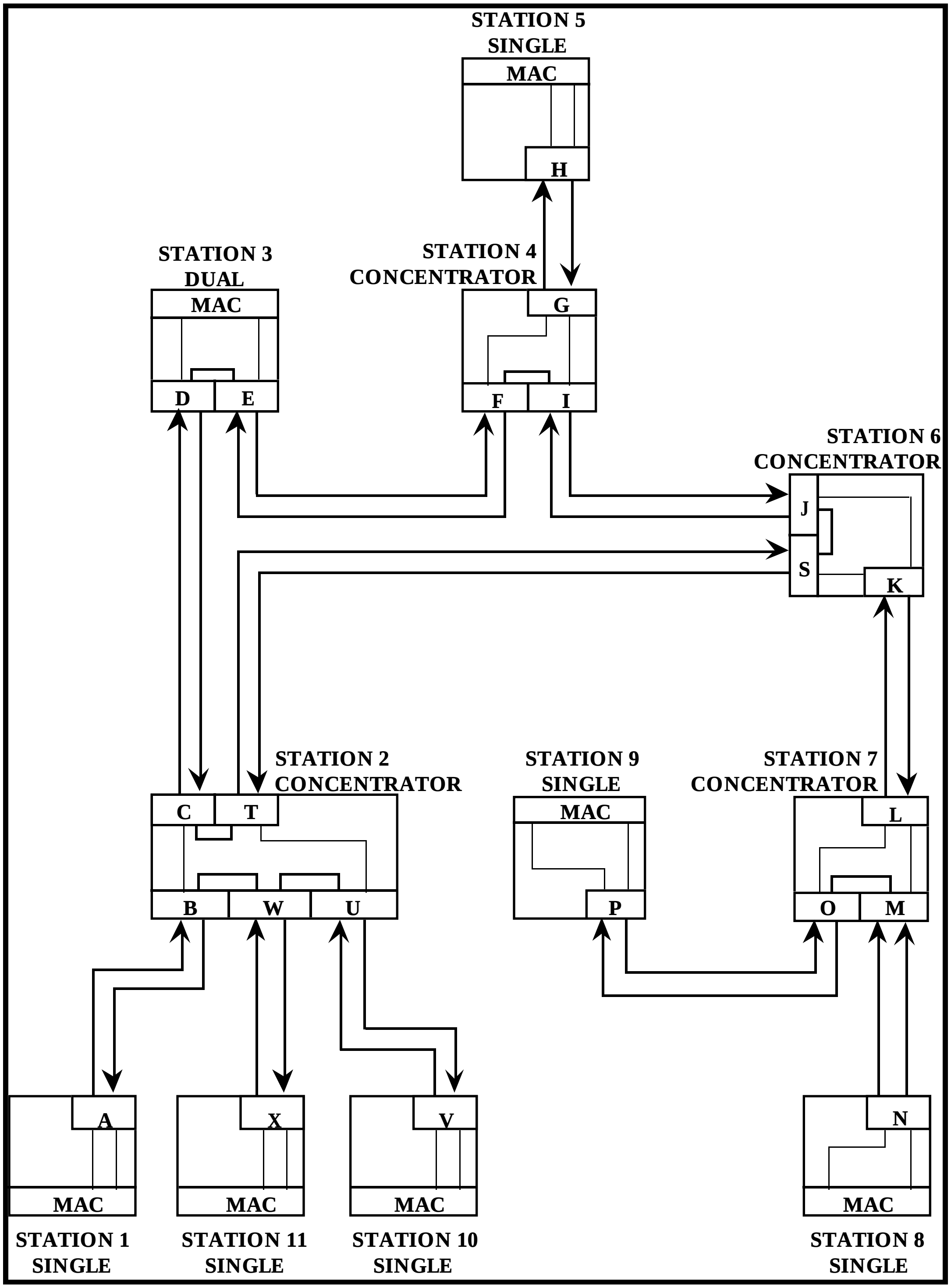

Figure 2 – FDDI topology example

5.2 Environment

As shown in figure 2 and as described in 5.1, an FDDI network consists of a virtually unlimited number of connected stations. SMT establishes the physical connections between stations, and the correct internal station configurations, to create an FDDI network. It is understood that restrictions of the transmission media as defined (i.e., dynamic range and bandwidth) may place limits on realizable physical configurations. Tradeoffs may be made within specific site applications, such as distance versus optical bypassing, consistent with these limitations.

While not intended to be limiting, FDDI has been defined to provide for a multi-level private network serving a campus or multi-building environment. The levels envisioned as typically useful in such an environment are an inter-building distribution environment, an intra-building distribution environment, and a workstation distribution environment. These are discussed in the following subclauses, and are shown in a sample form in figure 3.

5.2.1 Campus inter-building distribution environment

The campus environment is characterized by stations distributed across multiple buildings, utilizing underground fibre cable distribution plant, where the distances might be as short as several hundred metres and as long as tens of Kilometres. At the shortest distances, the FDDI LCF-PMD (Low-Cost Fibre) interface might possibly be used, but it would generally be expected that the original FDDI PMD interface would be used for inter-building distances up to 2 km.

At the longer distances, a campus environment might use private fibre, and thus rely on the FDDI SMF-PMD (Single-Mode Fibre), while connections that required public links could rely on an FDDI SONET physical mapping interface.

This environment would typically be expected to be implemented as a dual-trunk ring, though centralized concentrators with radial distribution to remote sites (buildings) can be used. Optical bypass is also a candidate for this environment as transmission link reliability considerations are paramount when underground fibre cable plant is utilized due to the great difficulty in restoring services if the link is physically damaged or lost.

5.2.2 Intra-building distribution environment

The intra-building environment is characterized by stations located throughout a building, utilizing standard intra-building cable distribution models, where the distances typically range from a few meters to a thousand meters. For more details on typical building premises wiring, refer to ANSI/EIA/TIA 568, the US commercial wiring standard, and the soon to be released ISO equivalent standard.

At the very shortest distances, the FDDI TP-PMD (Twisted-Pair) interface might be used but it would generally be expected that the FDDI LCF-PMD (Low-Cost Fibre) interface would be used for distances up to 500 m and the original FDDI PMD interface for intra-building distances above LCF-PMD limits.

This environment would typically consist of interconnections between concentrators located in building wiring distribution closets and facilities which are part of the standardized intra-building distribution plan. However, it would also be expected that some data centre to data centre interconnections would be implemented in this environment as well using dual attachment stations. Concentrators would be interconnected by either single or dual attachment. Optical bypass is also a candidate for this environment, but less likely given the protection provided by both dual rings and concentrators.

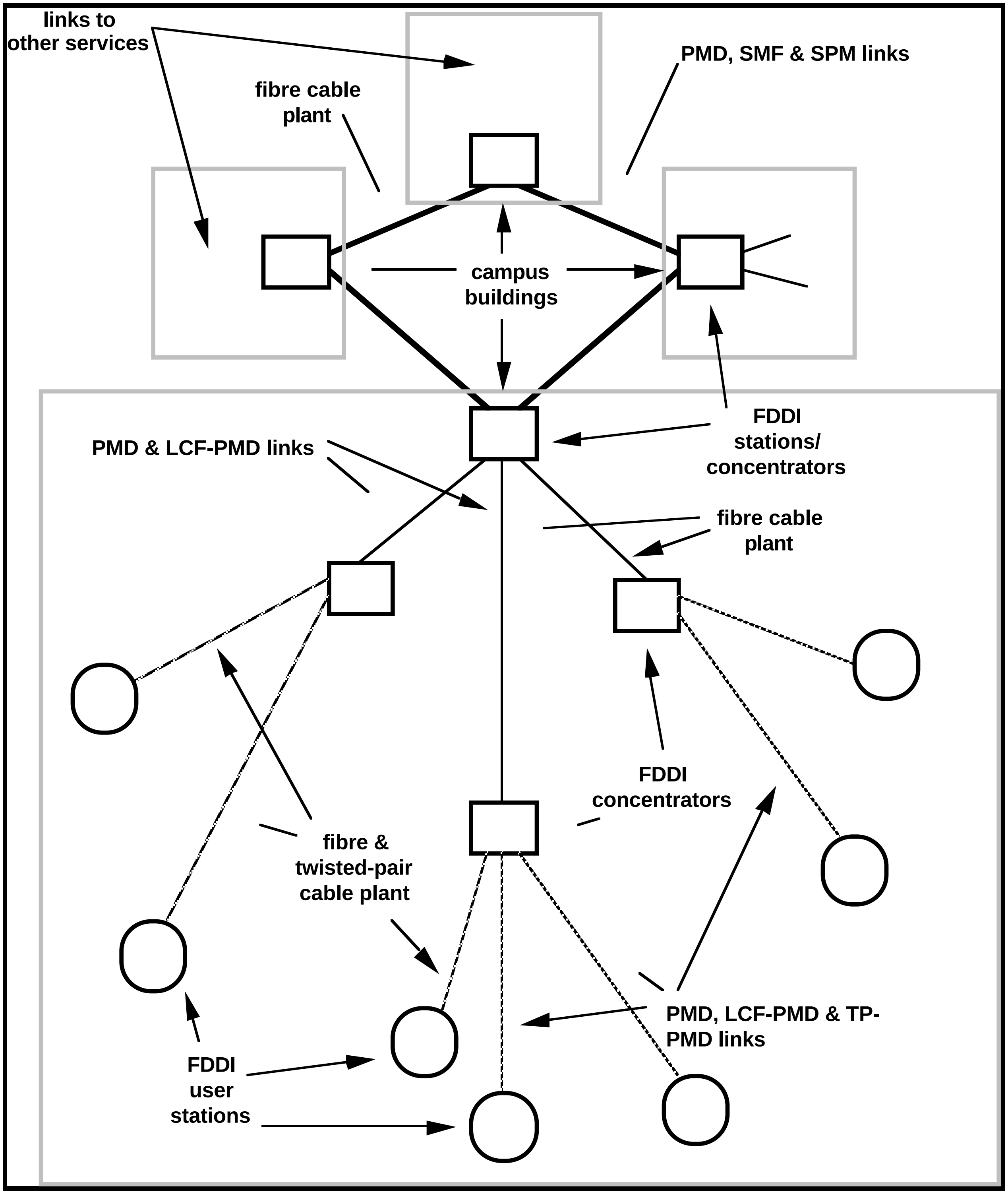

Figure 3 – FDDI representative distribution environment example

5.2.3 Workstation distribution environment

The workstation environment is characterized by stations located within a short distance of a building wiring distribution closet. It would typically utilize standard intra-building cable distribution models, where distances are typically less than 100 m, and distances between distribution closets are typically less than 500 m. For distribution from the workstation to the closest distribution closet, the FDDI TP-PMD and LCF-PMD interfaces would typically be used. For distribution where the workstation is more than one distribution closet away from the concentrator, the FDDI LCF-PMD interface would typically be used, with the original FDDI PMD only being used for distances above 500 m.

The environment would typically consist of single attachment interconnections from workstations in the office or laboratory, to concentrators located in building wiring distribution closets. Occasionally dual attachment stations might be served, but it is expected that the link distances as described above would still apply. Optical bypass is also a candidate for this environment, but less likely given the protection provided by both dual rings and concentrators.

6 Services

This clause specifies the services provided by the TP-PMD. These services do not imply any particular implementation or any interface. It should be noted that these services for TP-PMD are identical to those defined in the PMD; they are included here for completeness, and changes are purely editorial. Services described are:

a) TP-PMD services provided to the local Physical Protocol (PHY) entity (indicated by PM_ prefix).

b) TP-PMD services provided to the local Station Management (SMT) entity (indicated by SM_PM_ prefix).

An optional qualifier is sometimes needed to identify a signal unambiguously where there are multiple instances of the same signal within a service interface (indicated by the “(N:)” prefix). Thus, a prefix of (N:)PM_ or (N:)SM_PM_ indicates that a TP-PMD could duplicate a signal a number of times and identify each signal with a unique qualifier. For example, a TP-PMD in a dual station would use A:PM_ and B:PM_ as prefixes when required, whereas a TP-PMD in a single station may only use PM_ as a prefix. Concentrators may use other qualifiers, such as M1:PM_ through Mn:PM_, to uniquely identify a signal.

Figure 4 shows the block diagram organization of the FDDI Twisted Pair Physical Layer Medium Dependent (TP-PMD) including the separate functions, intended to show physical implementation or physical orientation of the components within an FDDI station. As described, the interfaces and signals between PMD, PHY, and SMT are examples and are intended to be logical rather than physical. Any other set of signals that causes the same physical behavior is equally valid.

6.1 TP-PMD-to-PHY services

This subclause specifies the services provided at the interface between the TP-PMD and the PHY entities of the Physical Layer, to allow PHY to exchange an NRZI code-bit stream with peer PHY entities. The TP-PMD parameters have been selected to be compatible with the encoding and decoding techniques provided by the FDDI PHY. TP-PMD translates the encoded data signals to and from signals suitable for the twisted pair medium. Additional detail is provided in clauses 7 and 10 concerning conditions that generate these primitives and TP-PMD actions upon receipt of PHY-generated primitives.

The following primitives are defined:

PM_UNITDATA.request

PM_UNITDATA.indication

PM_SIGNAL.indication

Each primitive includes the information that is passed between the TP-PMD and PHY entities.

6.1.1 PM_UNITDATA.request

This primitive defines the transfer of encoded NRZI data from PHY to TP-PMD.

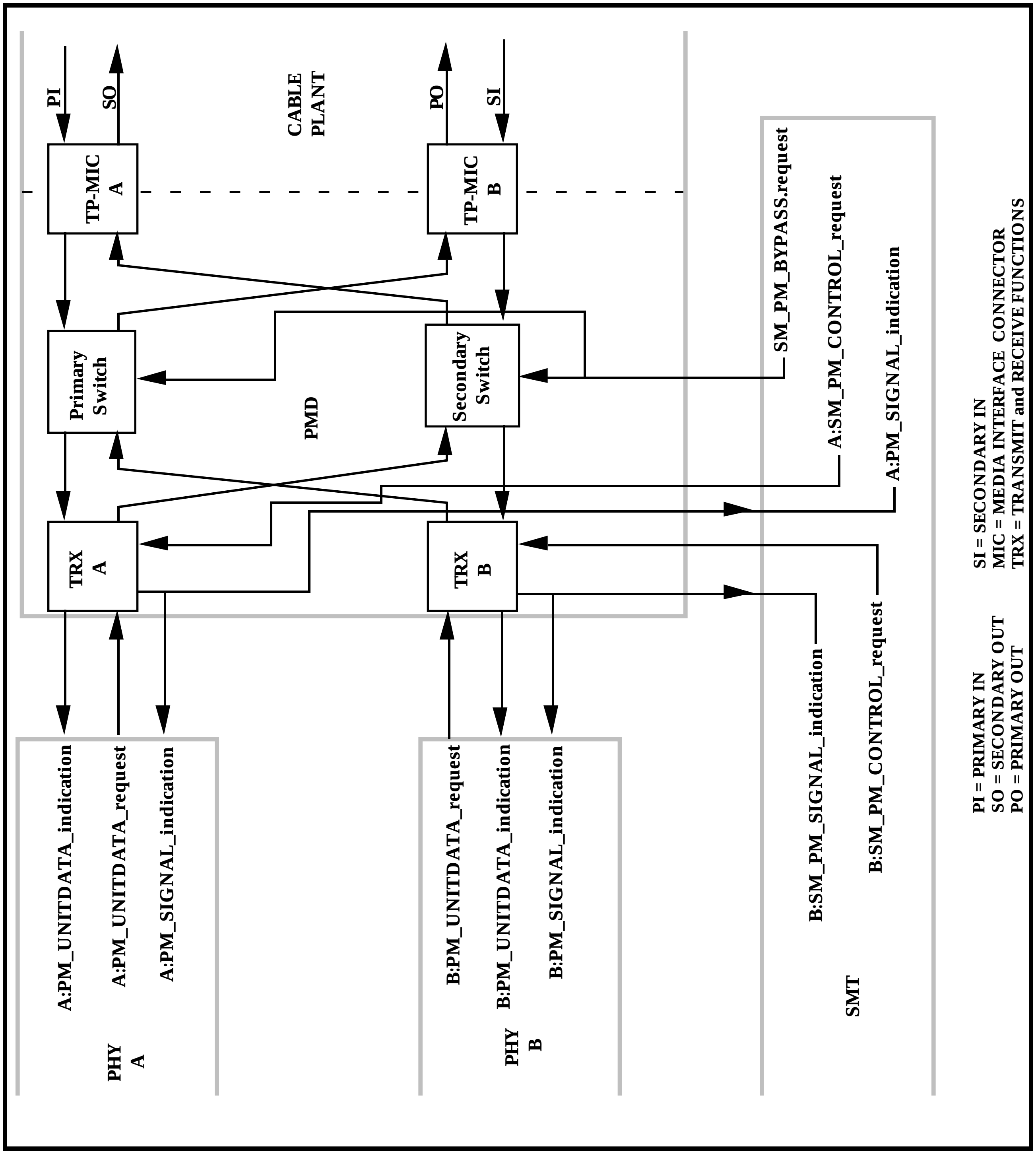

Figure 4 – Dual attachment TP-PMD services

6.1.1.1 Semantics of the primitive

(N:)PM_UNITDATA.request (
PM_Request (NRZI code)
)

The data conveyed by PM_Request shall be a continuous code-bit sequence.

6.1.1.2 When generated

PHY continuously sends the TP-PMD layer the current NRZI code polarity.

6.1.1.3 Effect of receipt

Upon receipt of this primitive and of SM_PM_CONTROL.request with a Control_Action parameter of Transmit_Enable, TP-PMD shall convert an electrical NRZI encoded code-bit sequence into the electrical domain of the interface medium.

6.1.2 PM_UNITDATA.indication

This primitive defines the transfer of encoded NRZI data from TP-PMD to PHY.

6.1.2.1 Semantics of the primitive

(N:)PM_UNITDATA.indication (
PM_Indication (NRZI code)
)

The data conveyed by PM_Indication shall be a continuous code-bit sequence.

6.1.2.2 When generated

TP-PMD shall continuously send the current encoded NRZI code to PHY.

6.1.2.3 Effect of receipt

In normal non-Loopback mode, PM_Indication is continuously sampled by the clock recovery and decode functions of the PHY entity.

6.1.3 PM_SIGNAL.indication

This primitive is generated by TP-PMD and asserted to PHY to indicate the status of the signal being received by TP-PMD.

6.1.3.1 Semantics of the primitive

(N:)PM_SIGNAL.indication (
Signal_Detect(status)
)

The Signal_Detect(status) parameter shall indicate whether the quality and level of the received signal is satisfactory (status = on) or unsatisfactory (status = off). When status = off, then PM_UNITDATA.indication is undefined but actions based on PM_SIGNAL.indication shall be interpreted as if PM_UNITDATA.indication is a continuous logic "0" code-bit sequence.

6.1.3.2 When generated

TP-PMD shall generate this primitive to indicate the status of the Signal_Detect.

6.1.3.3 Effect of receipt

The effect of PHY on receipt of this primitive is, when status = off, to enter Quiet Line State, and when status = on, to enable detection of other line states.

6.2 TP-PMD-to-SMT services

The services supplied by TP-PMD allow SMT to control the operation of TP-PMD. The TP-PMD shall perform the requested SMT services preemptively over any requested PHY services. Additional detail is provided in clauses 9 and 10 concerning conditions that generate these primitives and TP-PMD actions upon receipt of SMT-generated primitives. The following primitives are defined:

SM_PM_CONTROL.request

SM_PM_BYPASS.request

SM_PM_SIGNAL.indication

Each primitive includes the information that is passed between the TP-PMD and SMT entities.

6.2.1 SM_PM_CONTROL.request

This primitive is generated by SMT and asserted to TP-PMD to control the output of the transmit function.

6.2.1.1 Semantics of the primitive

```
(N:)SM_PM_CONTROL.request          (
                                   Control_Action
                                   )
```

The Control_Action parameter shall include the following: Transmit_Enable and Transmit_Disable.

6.2.1.2 When generated

SMT generates this primitive whenever it wants to enable or disable the TP-PMD transmitter.

6.2.1.3 Effect of receipt

Receipt of this primitive by TP-PMD with a Control_Action parameter of Transmit_Enable shall cause the TP-PMD to transmit the signal requested by the PM_UNITDATA.request primitive.

Receipt of this primitive with a Control_Action parameter of Transmit_Disable shall cause the TP-PMD to transmit a signal corresponding to the disabled condition preemptively over the PM_UNITDATA.request primitive as specified in 10.2.

Receipt of this primitive shall not affect PM_SIGNAL.indication or PM_UNITDATA.indication.

6.2.2 SM_PM_BYPASS.request

This primitive is generated by SMT and asserted to TP-PMD to indicate that SMT wants to join or leave the FDDI ring.

6.2.2.1 Semantics of the primitive

SM_PM_BYPASS.request (
Control_Action
)

The Control_Action parameter shall include the following: Insert, Deinsert.

6.2.2.2 When generated

SMT generates this primitive whenever it wants to activate or deactivate the bypass switches.

6.2.2.3 Effect of receipt

Upon receipt of this primitive with a Control_Action parameter of Insert, TP-PMD shall activate the switch such that the TP-MIC inbound signal from the cable plant is directed to the receiver (see figure 4). The output of the transmitter shall be directed to the TP-MIC output to the cable plant. Upon receipt of this primitive with a Control_Action parameter of Deinsert, TP-PMD shall deactivate the switch such that the TP-MIC inbound signal from the cable plant is directed through the switch to the TP-MIC output to the cable plant. The output of the transmitter shall be directed through the switch to the input of the receiver. This state is called the bypassed mode.

Optical bypass switches are optional in a FDDI ring. Stations that do not employ optical switches do not require this service.

6.2.3 SM_PM_SIGNAL.indication

This primitive is generated by TP-PMD and asserted to SMT to indicate the status of the signal level being received by TP-PMD.

6.2.3.1 Semantics of the primitive

(N:)SM_PM_SIGNAL.indication (
Signal_Detect(status)
)

The Signal_Detect(status) parameter shall indicate whether the quality and level of the inbound signal level is satisfactory (status = on) or unsatisfactory (status = off). When status = off, then SM_PM_UNITDATA.indication is undefined but actions based on SM_PM_SIGNAL.indication shall be interpreted as if PM_UNITDATA.indication is a continuous logic "0" code-bit sequence.

6.2.3.2 When generated

TP-PMD shall generate this primitive to indicate the status of the Signal_Detect.

6.2.3.3 Effect of receipt

The effect of receipt of this primitive on SMT is not defined.

7 Media independent operations

This clause describes operations which are independent of the UTP or STP media described herein.

The TP-PMD receives an NRZI code bit stream at the PHY-PMD interface, scrambles and encodes it, and transmits it to the adjacent TP-PMD over the physical link. The receiving TP-PMD decodes and descrambles the signal, and delivers it as an NRZI code bit stream at its PHY-PMD interface. These operations are described by the Transmit Function and the Receive Function. Figure 5 shows these functions and their details.

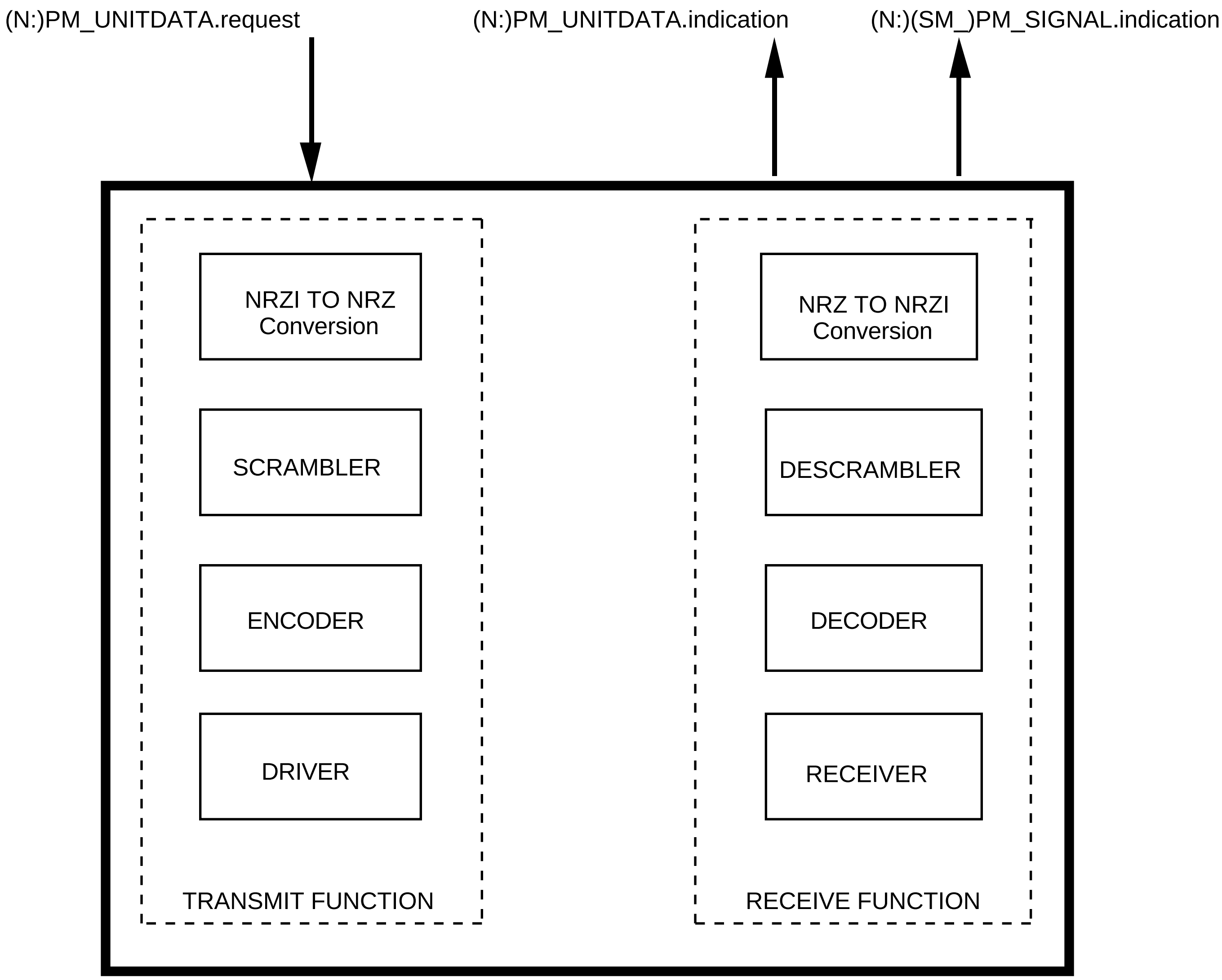

Figure 5 – TP-PMD functions

7.1 Transmit function

A TP-PMD implementation shall include a Transmit Function consisting of the four functional blocks described below. Any implementation that causes the same physical behavior is equally valid.

a) NRZI to NRZ conversion;

b) Scrambler;

c) Encoder;

d) Driver.

The Transmit Function shall scramble and encode the NRZI code bit stream received from the PHY via the (N:) PM_ UNITDATA.request primitive into an equivalent MLT-3 encoded signal stream for presentation to the medium at the Active Output Interface. The transmit function shall be able to correctly transmit any valid encoded bit stream.

7.1.1 Scrambler

The scrambler shall encode a plaintext NRZ bit stream derived from the (N:) PM_UNITDATA.request service primitive.

The plaintext bit stream shall be encoded by addition (modulo 2) of a key stream to produce a ciphertext bit stream. The key stream shall be the periodic sequence of 2047 bits generated by the recursive linear function X[n] = X[n-11] + X[n-9] (modulo 2). The scrambler shall generate the specified non-zero key stream whenever the Active Output Interface is required to transmit a scrambled data stream.

NOTES

1 The key stream sequence can be generated by an 11 bit Linear Feedback Shift Register (LFSR) whose input bit is the exclusive-OR of its 11th and 9th previous bits, and which contains at least one non-zero bit. If the LFSR contains all zeros it generates the constant zero sequence from the same recursive linear function. These two sequences are the only sequences generated by this function.

2 The addition of the key stream to valid FDDI plaintext streams produces NRZ ciphertext streams with an average run length of approximately two consecutive zeros and a maximum run length of approximately 60 consecutive zeros.

The scrambler shall present the ciphertext bit stream to the MLT-3 encoder.

Annex G contains an example of a scrambler design.

7.1.2 Encoder

The Encoder receives the scrambled NRZ data stream from the Scrambler and encodes the stream into MLT-3 for presentation to the Driver. MLT3 is similar to NRZI coding, but three levels are output instead of two.

7.1.2.1 Facilities

7.1.2.1.1 Variables

A variable shall take on one value from a limited set of possible values. When a variable is cleared, the value of the variable becomes "none." Variables may be exported outside of the Transmit Function.

Encoder_Input Indicates the value of each scrambled NRZ bit to be encoded. The variable Encoder_Input may take on a value of 0 or 1.

Encoder_Output Indicates the value from the encoder for each MLT-3 encoded bit. The variable Encoder_Output may take on a value of Positive_Voltage, Zero_Voltage, or Negative_Voltage.

7.1.2.1.2 Flags

A flag is a variable that shall take on one of two values: Set or Cleared. Flags are assigned values within the state machines by specifying a set or clear operation. Flags are tested within state machines by checking their status or the negation of their status. Transitions initiated by flags need only be checked upon initial entry into the state and upon change of the flag. The value of a flag may be exported outside of the Transmit Function.

7.1.2.1.2.1 Operational flags

LE_Flag Indicates whether the last non-zero value of Encoder_Output was Positive_Voltage. The flag LE_Flag is set upon entry to E0:Plus_V. The flag LE_Flag is cleared upon entry to E2:Minus_V.

NOTE – The value of LE_Flag does not need to be preserved while transmit disable is asserted and the output of the transmit function is continuously less than 30 mV p-p as specified in 10.2.

7.1.2.2 Detailed encoder description

See figure 6.

7.1.2.2.1 State E0:PLUS_V

In this state the Encoder_Output variable takes on the value Positive_Voltage.

E(01):ZERO: When the value of Encoder_Input equals 1 the state machine transitions to State E1.

7.1.2.2.2 State E1: ZERO_V

In this state the Encoder_Output variable takes on the value Zero_Voltage.

E(10):PLUS: When the value of Encoder_Input equals 1 and LE_Flag is Cleared the state machine transitions to State E0.

E(12):MINUS: When the value of Encoder_Input equals 1 and the LE_Flag is Set the state machine transitions to State E2.

7.1.2.2.3 State E2:MINUS_V

In this state the Encoder_Output variable takes on the value Negative_Voltage.

E (21):ZERO: When the value of Encoder_Input equals 1 the state machine transitions to State E1.

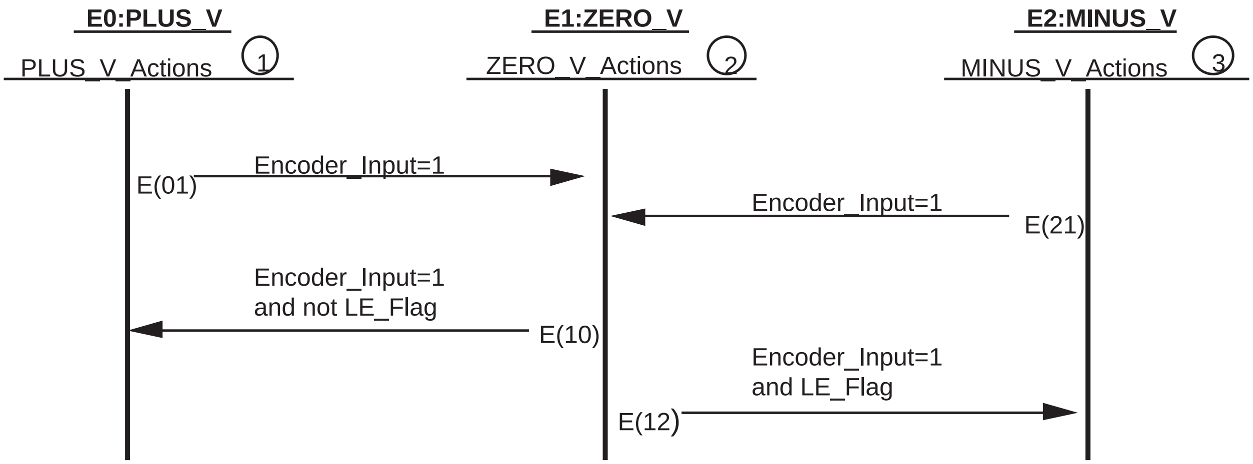

Figure 6 – Encoder state diagram

1) PLUS_V_Actions:

ON entry DO

Set LE_Flag

Encoder_Output (Positive Voltage)

2) ZERO_V_Actions:

ON entry DO

Encoder_Output (Zero Voltage)

3) MINUS_V_Actions:

ON entry DO

Clear LE_Flag

Encoder_Output (Negative Voltage)

7.1.3 Driver

The Driver shall convert the scrambled and encoded MLT-3 signal stream received from the Encoder to a differential signal which meets the requirements of the appropriate Active Output Interface of 9.1.

7.2 Receive function

A TP-PMD implementation shall include a Receive Function consisting of the four functional blocks described below. Any implementation that causes the same physical behavior is equally valid.

a) Receiver;

b) Decoder;

c) Descrambler;

d) NRZ to NRZI conversion.

The Receive Function shall decode the MLT-3 signal stream received from the appropriate Active Input Interface, descramble it, and convert it into an equivalent NRZI code bit stream for presentation to the PHY via the (N:) PM_UNITDATA.indication primitive. The receive function shall be able to receive correctly any valid encoded bit stream at the specified bit error rate.

7.2.1 Receiver

The Receiver shall convert the differential signal received from the Active Input Interface to an MLT-3 encoded waveform suitable for use by the decoder.

7.2.2 Decoder

The Decoder receives the MLT3 encoded bit stream from the Receiver, and decodes it into an NRZ encoded bit stream for presentation to the Descrambler.

7.2.2.1 Facilities

7.2.2.1.1 Variables

A variable shall take on one value from a limited set of possible values. When a variable is cleared, the value of the variable becomes "none." Variables may be exported outside of the Receive Function.

Decoder_Input — Indicates the value of the MLT-3 encoded bit from the Receiver. The variable Decoder_Input may take on a value of Zero and Non-zero.

Decoder_Output — Indicates the value of the NRZ encoded bit. The variable Decoder_Output may take on a value of 0 and 1.

Prev_Data — Indicates whether the last value of Decoder_Input was Zero or Non-zero. The variable Prev_Data takes on the value Non-zero when the last value of Decoder_Input was Non-zero. The variable Prev_Data takes on the value Zero when the last value of Decoder_Input was Zero.

7.2.2.2 Detailed decoder description

See figure 7.

7.2.2.2.1 State D0:ZERO

In this state the Decoder_Output variable takes on the value "0".

D(01):One: When the value of Decoder_Input does not equal the value of Prev_Data, the state machine transitions to state D1.

7.2.2.2.2 State D1:ONE

In this state the Decoder_Output variable takes on the value "1".

D(10):Zero: When the value of Decoder_Input does equal the value of Prev_Data, the state machine transitions to state D0.

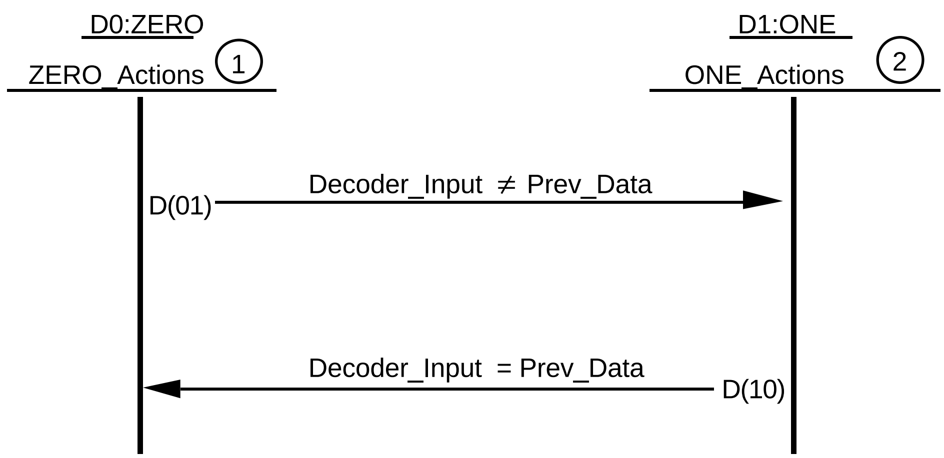

Figure 7 – Decoder state diagram

1) ZERO_Actions:

    FOR EACH Decoder_Input DO

        Prev_Data=Decoder_Input

        Decoder_Output(0)

2) ONE_Actions:

    FOR EACH Decoder_Input DO

        Prev_Data=Decoder_Input

        Decoder_Output(1)

7.2.3 Descrambler

The Descrambler shall descramble the decoded NRZ ciphertext bit stream from the MLT-3 decoder.

The ciphertext bit stream shall be decoded by addition (modulo 2) of a key stream to produce a plaintext bit stream. The key stream shall be the periodic sequence of 2047 bits generated by the recursive linear function X[n] = X[n-11] + X[n-9] (modulo 2). The descrambler shall generate the specified key stream while it is synchronized.

The descrambler is defined to be synchronized while the descrambler key stream added to a sequence of ciphertext bits is identical to the upstream scrambler key stream added to those bits. While the descrambler is synchronized, error free bits in the ciphertext stream decode as error free bits in the plaintext stream, and errored bits in the ciphertext stream decode as errored bits in the plaintext stream.

Annex G contains an example of a descrambler design.

The following subclauses specify detailed descrambler functional requirements related to various modes of operation of the physical link. The detailed requirements refer to aspects of the FDDI protocol that are defined in other clauses of this standard or in other FDDI standards. Signal_Detect is defined in 10.1.1.

The MLT-3 decoder is defined in 7.2.2. The FDDI standards on PHY and PHY-2 define the 4B/5B code symbols, the line states, PHY Service Data Units (SDU) (frames, tokens and cycles) and PH_Invalid. The FDDI standards on PHY-2 and HRC define hybrid mode operation.

7.2.3.1 Acquiring synchronization

7.2.3.1.1 Line state patterns

The descrambler shall acquire synchronization on receipt of 60 consecutive error-free ciphertext bits of each of the following line state patterns while Signal_Detect is asserted and the output of the MLT-3 decoder is valid:

a) Quiet Line State (QLS); or

b) Halt Line State (HLS); or

c) Master Line State (MLS); or

d) Idle Line State (ILS).

7.2.3.1.2 Service data units

If the optional hybrid mode of operation is supported, the descrambler shall acquire synchronization on receipt of 30 consecutive error-free ciphertext bits of the IIIIJK symbol sequence while Signal_Detect is asserted and the output of the MLT-3 decoder is valid.

NOTE – This requirement implies that, in hybrid mode, the descrambler must be capable of recognizing the starting delimiter pattern in the ciphertext stream to ensure reliable synchronization when a cycle is received. It does not imply that, in basic mode, the descrambler must be capable of recognizing the starting delimiter pattern in the ciphertext stream. In basic mode, the requirement given in 7.2.3.1.1 (d) ensures synchronization on the preamble pattern preceding a frame.

7.2.3.2 Maintaining synchronization

7.2.3.2.1 Line state patterns

After acquiring synchronization on one of the ciphertext line state patterns in 7.2.3.1.1, the descrambler shall maintain synchronization while receiving subsequent ciphertext bits of the same line state pattern with no error spanning more than two consecutive bits in any subsequent interval of 60 bits while Signal_Detect is asserted and the output of the MLT-3 decoder is valid.

NOTES

1 The requirement given in 7.2.3.1.1 combined with this requirement ensures reliable line state signaling at bit error rates less than 10^{-2}, which is the minimum Signal_Detect deassertion threshold.

2 The requirement given in 7.2.3.1.1 combined with this requirement permit loss of synchronization for up to 60 bit times (480 ns) when switching between these four line states. This transient condition does not affect reliable operation of PHY and SMT because it is less than one percent of the minimum line state duration during signaling, and less than two percent of the maximum permitted line state change detection time in PHY.

7.2.3.2.2 Service data units

After acquiring synchronization on one of the ciphertext patterns in 7.2.3.1.1 (d) or 7.2.3.1.2, the descrambler shall maintain synchronization after presenting 30 consecutive error-free plaintext bits of the start of SDU symbol sequence (IIIIJK) while Signal_Detect is asserted and the output of the MLT-3 decoder is valid, until any of the conditions for recovery in 7.2.3.3 exists.

> NOTE – This requirement implies that the descrambler must be capable of maintaining synchronization while receiving a SDU to avoid corrupting the SDU. It does not imply that the descrambler must be capable of recognizing the presence of a SDU in the ciphertext stream.

7.2.3.3 Loss of synchronization

While maintaining synchronization as specified in 7.2.3.2.2, the descrambler shall detect at least one of the following two synchronization error conditions, and shall be capable of reacquiring synchronization as specified in 7.2.3.1 after any of these conditions is detected:

a) The subsequent plaintext bit stream contains sufficient invalid code symbols to trigger a PHY standard's PH_Invalid condition; or

b) More than 1.5 ms elapse without presenting at least 20 consecutive plaintext idle pattern bits.

The descrambler is also not required to maintain synchronization as specified in 7.2.3.2.2 after any of the following five conditions occur, and shall be capable of reacquiring synchronization as specified in 7.2.3.2 after any of these conditions cause loss of synchronization:

c) Signal_Detect is deasserted; or

d) The output of the MLT-3 decoder is invalid; or

e) More than 722 µs (two maximum length SDUs plus three preambles) elapses without presenting at least 58 consecutive plaintext idle pattern bits;

f) More than 361 µs (one maximum length SDU plus two preambles) elapses without presenting at least 29 consecutive plaintext idle pattern bits;

g) More than 655 µs elapses without presenting at least 35 consecutive plaintext idle pattern bits in Basic Mode provided that a minimum of 46 bits is used to acquire synchronization in 7.2.3.1.1.

NOTE

Condition (c) will immediately cause condition (a). Condition (d) will eventually cause condition (a). Condition (a) will eventually cause conditions (b), (e), (f) and (g) if it persists.

7.2.4 NRZ to NRZI conversion

The NRZ signal stream from the descrambler shall be converted to NRZI code bits for presentation to the PHY via (N:) PM_UNITDATA.indication.

8 Media interface connector specifications

An FDDI station implementing the TP-PMD standard shall be attached to the twisted pair medium by a Twisted Pair Media Interface Connector (TP-MIC). The media connection between adjacent stations consists of a duplex cable assembly attached to the respective station’s TP-MIC. To ensure interconnectability between conforming FDDI stations, a TP-PMD mating interface is specified at the TP-MIC receptacle.

The term TP-MIC is a general term, as there are two TP-MICs. One is for shielded twisted pair cable, the second is for unshielded twisted pair cable.

8.1 Media interface connectors

8.1.1 UTP-MIC

The UTP-MIC shall have 8 poles and conform to the requirements of clause 4 and figures 1 to 5 of ISO/IEC 8877 as it relates to intermateability. It shall meet the requirements of EIA/TIA TSB 40, Section 4.1 as it applies to insertion loss. It shall meet the requirements of EIA/TIA TSB 40, Section 4.2 as it applies to near end crosstalk between the two balanced circuits.

8.1.1.1 UTP-MIC receptacle

The UTP-MIC receptacle shall be an 8-pole connector that is attached to the station. The contact assignment shall be as shown in table 1. Figure 8 is an example of a UTP-MIC receptacle.

Table 1 – UTP-MIC contact assignments

Contact	Signal
1	Transmit +
2	Transmit -
3	
4	
5	
6	
7	Receive +
8	Receive -

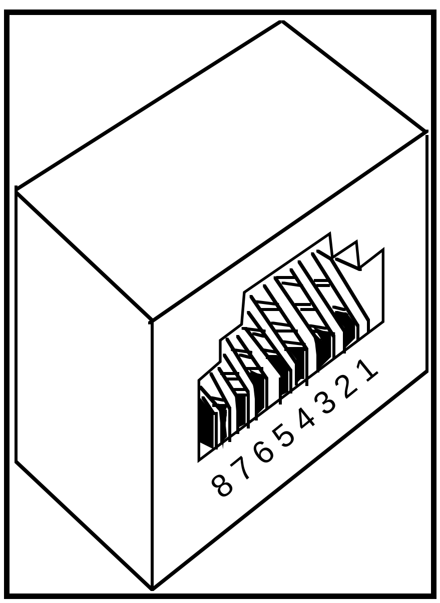

Figure 8 – Example of a UTP-MIC receptacle

8.1.1.2 UTP-MIC plug

The UTP-MIC plug shall mate with the receptacle defined in 8.1.1.1. Figure 9 is an example of a UTP-MIC plug.

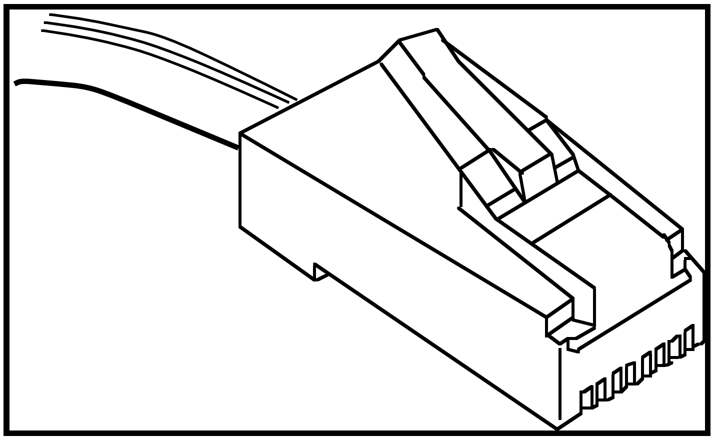

Figure 9 – Example of a UTP-MIC plug

8.1.2 STP-MIC

The STP-MIC shall have 9 poles and conform to the requirements of EIA/TIA 574, Section 2 as it relates to intermateability. It shall meet the requirements of 8.1.1 as it applies to insertion loss. It shall meet the requirements of 8.1.1 as it applies to near end crosstalk between the two balanced circuits.

8.1.2.1 STP-MIC receptacle

The STP-MIC receptacle shall be a 9-pole connector that is attached to the station. The contact assignment shall be as shown in table 2. Figure 10 is an example of a STP-MIC receptacle.

Table 2 – STP-MIC contact assignments

Contact	Signal
1	Receive +
2	
3	
4	
5	Transmit +
6	Receive -
7	
8	
9	Transmit -
Shell	Chassis

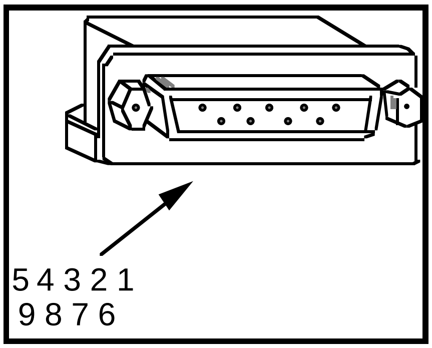

Figure 10 – Example of a STP-MIC receptacle

8.1.2.2 STP-MIC plug

The STP-MIC plug shall mate with the receptacle defined in 8.1.2.1. Figure 11 is an example of a STP-MIC plug.

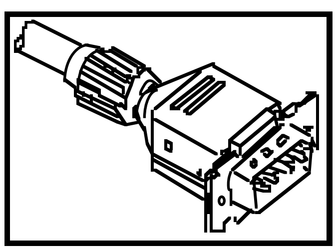

Figure 11 – Example of a STP-MIC plug

8.2 Testing recommendations

Test information will eventually be found in an FDDI Conformance standard that is under development.

8.3 Station labeling

To aid in preventing improper TP-MIC plug attachment, the TP-PMD station port should be marked (labeled). Recommended practices for station labeling are contained in annex D.

8.4 Isolation requirements

LAN cable systems described in this standard are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

1) Direct contact between LAN components and power, lighting, or communications circuits;
2) Static charge buildup on LAN cables and components;
3) High-energy transients coupled onto the LAN cable system;
4) Voltage potential differences between safety grounds to which various LAN components are connected.

Such electrical safety hazards shall be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures shall be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network.

8.4.1 UTP isolation requirements

The UTP-PMD shall provide isolation between frame ground and all leads of the UTP-MIC, including those not used by the AOI and AII. This electrical separation shall withstand at least one of the following electrical strength tests.

1) 1500 V rms at 50 to 60 Hz for 60 s, applied as specified in 5.3.2 of IEC 950.
2) 2250 VDC for 60 s, applied as specified in 5.3.2 of IEC 950.
3) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of these impulses shall be 1,2/50 µs (1,2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60.

There shall be no insulation breakdown, as defined in 5.3.2 of IEC 950, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 VDC.

8.4.2 STP isolation/coupling requirements

The STP cable plant consists of two distinct components, the twisted pair data path and the shielding system, which have different isolation/coupling requirements.

8.4.2.1 Data path isolation requirements

The 150 Ohm STP cable plant is consistent with the installed base Token Ring networks as described in of ISO 8802-5. As such, a voltage used for ring access control may exist in incomplete cabling systems. To protect against this and other hazards, the STP-PMD AOI and AII shall provide isolation which withstands the following electrical strength test.

1) 500 V rms for 60 s, applied as specified in 5.3.2 of IEC 950.

8.4.2.2 Shield coupling requirements

The STP cable plant relies on an equipotential bonded ground system to maintain system shield integrity. To ensure that excessive currents do not flow in the STP shield system, the potential difference across the shielding system shall be consistent with the applicable local safety codes.

9 Media signal interface

This clause defines the interfaces of the signal at the interconnect receptacles shown in figures 8 and 9. Each conforming FDDI attachment shall be compatible with the applicable interface to allow interoperability within an FDDI environment.

9.1 Active Output Interface

Characteristics of the Active Output Interface (AOI) are summarized in table 3.

There are two Active Output Interfaces defined by the TP-PMD standard. Unless specified otherwise, the AOI specifications are identical.

9.1.1 Shielded twisted pair active output interface

The shielded twisted pair active output interface shall exhibit the characteristics shown in table 3, figures 12 to 14 and the balance of this clause.

9.1.1.1 STP test load

For STP, the test load shall consist of a single 150Ω±0,2% resistor connected across the transmit pins of the AOI. For frequencies $\leq$ 100 MHz, the series inductance of the load shall not exceed 30 nH and the parallel capacitance shall not exceed 1,5 pF.

9.1.1.2 STP differential output voltage

For STP, the peak differential output voltage, V_{out} , as defined in 9.1.3 and figure 12 shall be:

$1165\ \text{mV} \leq V_{out} \leq 1285\ \text{mV}$

9.1.2 Unshielded twisted pair active output interface

The Unshielded Twisted Pair Active Output Interface shall exhibit the characteristics shown in table 3, figures 12 to 14 and the balance of this clause.

9.1.2.1 UTP test load

For UTP, the test load shall consist of a single 100Ω± 0,2% resistor connected across the transmit pins of the AOI. For frequencies $\leq$ 100 MHz, the series inductance of the load shall not exceed 20 nH and the parallel capacitance shall not exceed 2 pF.

9.1.2.2 UTP differential output voltage

For UTP, the differential output voltage, V_{out} , as defined in 9.1.3 and figure 12 shall be:

$950\ \text{mV} \leq V_{out} \leq 1050\ \text{mV}$

9.1.3 Waveform overshoot

For the purposes of 9.1, overshoot is defined as the percentage excursion of the differential signal transition beyond its final adjusted value, V_{out}, during the symbol interval following the signal transition. The adjusted value is obtained by performing a straight line best fit to an output waveform consisting of 14 bit times of no transition preceded by a transition from zero to either plus or minus V_{out} as shown in figure 12.

V_{out} is defined to be the intersection of the straight line best fit for amplitude with the vertical line indicating the start of the transition from 0 V to V_{out}.

The differential signal overshoot shall not exceed 5%. Any overshoot or undershoot transient shall have decayed to within 1% of the steady state voltage within 8,0 ns following the beginning of the differential signal transition.

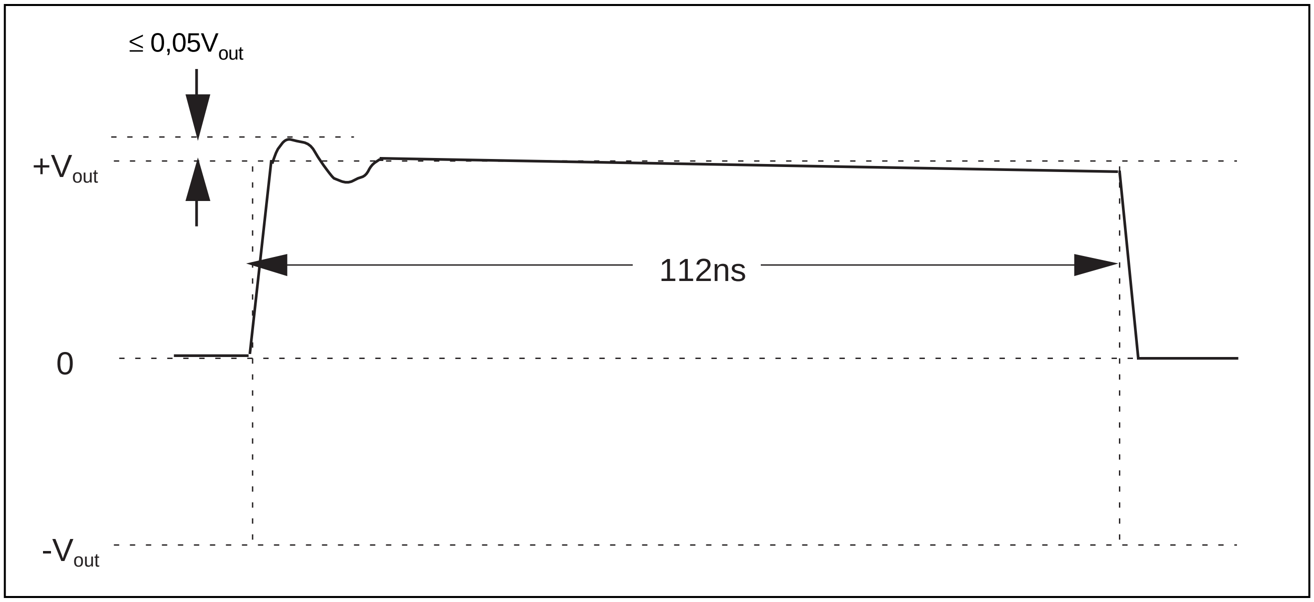

Figure 12 – Active Output Interface overshoot

9.1.4 Signal amplitude symmetry

The ratio of the $+V_{out}$ magnitude to $-V_{out}$ magnitude shall be between the limits:

$$0{,}98 \leq \frac{|+V_{out}|}{|-V_{out}|} \leq 1{,}02$$

9.1.5 Return loss

The UTP and STP Active Output Interface shall be implemented such that the following return loss characteristics are satisfied for each of the specified line impedances.

Greater than 16 dB from 2 MHz to 30 MHz

Greater than (16 – 20 log(f / 30 MHz)) dB from 30 MHz to 60 MHz

Greater than 10 dB from 60 MHz to 80 MHz

The impedance environment for the measurement of the UTP AOI return loss shall be 100 $\pm$ 15Ω; the environment for the STP AOI return loss shall be 150$\pm$15Ω. The impedance environments shall be nominally resistive, with a magnitude of phase angle less than 3° over the specified measurement frequency range.

9.1.6 Rise/fall times

For the purposes of 9.1, the AOI signal rise is defined as a transition from the baseline voltage (nominally zero) to either +V_{out} or -V_{out} . Signal fall is conversely defined as a transition from the + V_{out} or – V_{out} to the baseline voltage.

The rise and fall times of the waveform shall be determined as the time difference between the 10% and the 90% voltage levels of the signal transition, where 100% is represented by V_{out} of figure 12.

Measured rise and fall times shall be between the limits:

$3{,}0 \text{ ns} \leq t_{rise/fall} \leq 5{,}0 \text{ ns}$

The difference between the maximum and minimum of all measured rise and fall times shall be $\leq$ 0,5 ns.

9.1.7 Worst case droop of transformer

Baseline Wander tracking by the receiver is dependent on the worst case droop that can be produced by a transmitter. Droop is directly related to the Open Circuit Inductance (OCL) which varies with temperature, manufacturing tolerance, and bias current.

Worst case Baseline Wander Frames vary the transformer bias which causes the droop to change with data content. This variation must be accounted for by the receiver to track the Baseline Wander over long frames. Variation in inductance caused by bias of the transformer can be on the order of 2:1.

The minimum inductance measured at the transmit pins of the AOI shall be greater than or equal to 350 µH with any DC bias current between 0 mA and +8 mA injected as shown in figure 13.

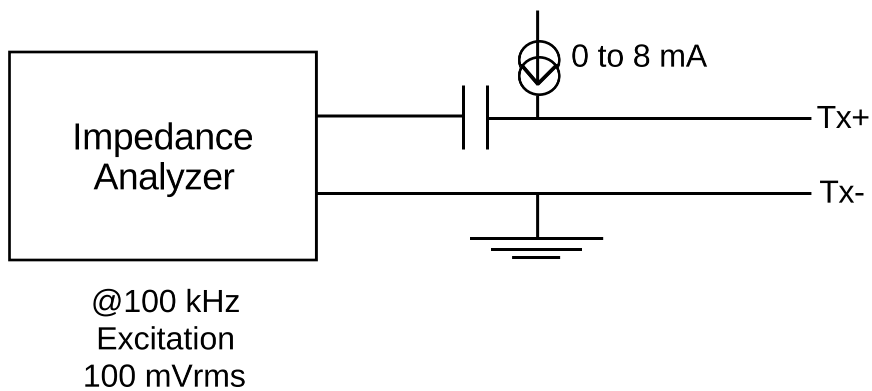

Figure 13 – Inductance measurement technique

9.1.8 Duty cycle distortion (DCD)

Duty cycle distortion shall be measured at the 50% voltage points on rise and fall transitions of the differential output waveform. The 50% times at the four successive MLT-3 transitions generated by a 01010101 NRZ bit sequence shall be used. The deviations of the 50% crossing times from a best fit to a time grid of 16 ns spacing shall not exceed $\pm$0,25ns as shown in figure 14.

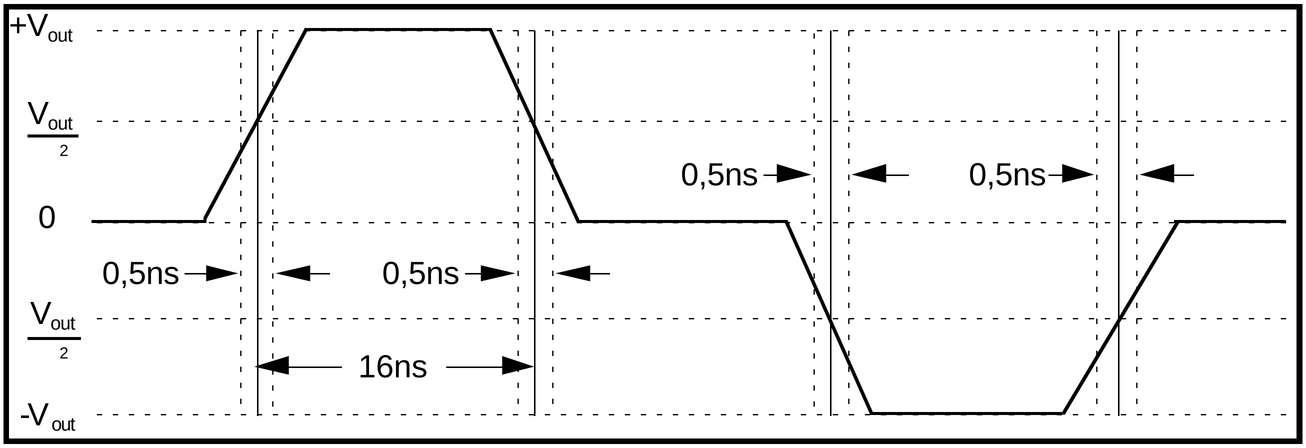

Figure 14 – Active Output Interface duty cycle distortion

9.1.9 Jitter

Peak to peak jitter shall be measured using scrambled HALT line state. Total transmit jitter, including contributions from duty cycle distortion and Baseline Wander, shall not exceed 1,4 ns peak-peak.

9.1.10 Characteristics of Active Output Interface

Table 3 summarizes the characteristics of the Active Output Interface.

Table 3 – Twisted Pair Active Output Interface characteristics

Characteristic	Minimum	Maximum	Units
Differential Signal, UTP, zero-peak	950	1050	mVpk
Differential Signal, STP, zero-peak	1165	1285	mVpk
Signal Amplitude Symmetry (positive/negative)	98	102	%
Rise and Fall Time	3,0	5,0	ns
Rise and Fall Time Symmetry	0	0,5	ns
Duty Cycle Distortion, peak-to-peak	0,0	0,5	ns
Transmit Jitter (HLS)	0,0	1,4	ns
Overshoot	0	5	%

9.2 Active Input Interface specifications

The TP_PMD shall provide the Receiver functions specified in 10.1 in accordance with the electrical specifications of this clause.

9.2.1 Differential input signals

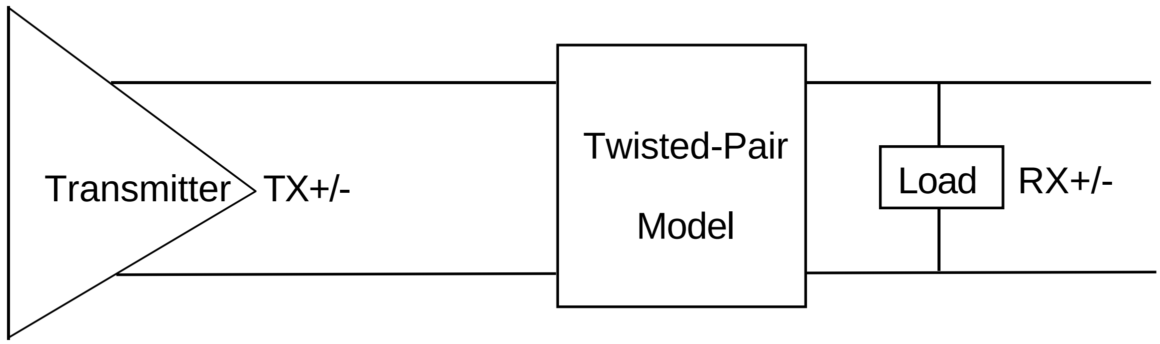

Figure 15 – Differential input signals

The differential input signals, RX +/-, are defined at the output of the twisted pair model of annex A as shown in figure 15. The differential transmitted signals on TX+/- meet the requirements of 9.1 (AOI).

9.2.2 Differential input impedance

The differential input impedance shall be such that the return loss is as shown below. The requirement is specified for any reflection due to differential signals incident upon RX+/- from a twisted pair having any impedance within the range specified in 11.1.1. The return loss shall be maintained when the receiver circuit is powered.

Greater than 16 dB from 2 MHz to 30 MHz

Greater than (16 – 20log(f/30 MHz)) dB from 30 MHz to 60 MHz

Greater than 10 dB from 60 MHz to 80 MHz

9.2.3 Common-mode rejection

Receiver shall deliver the proper value for PM_UNITDATA.indication, at the specified Bit Error Rate, for any signal meeting the requirements of 10.1. The receiver shall deliver the correct value for Ecm applied as shown in figure 16. E_{cm} shall be a 1,0 V peak-to-peak sine wave from 0 MHz to 125 MHz.

The impedance of the text equipment shall not disrupt the impedance of the channel.

NOTE – Implementers are encouraged to test to the applicable country EMC standards.

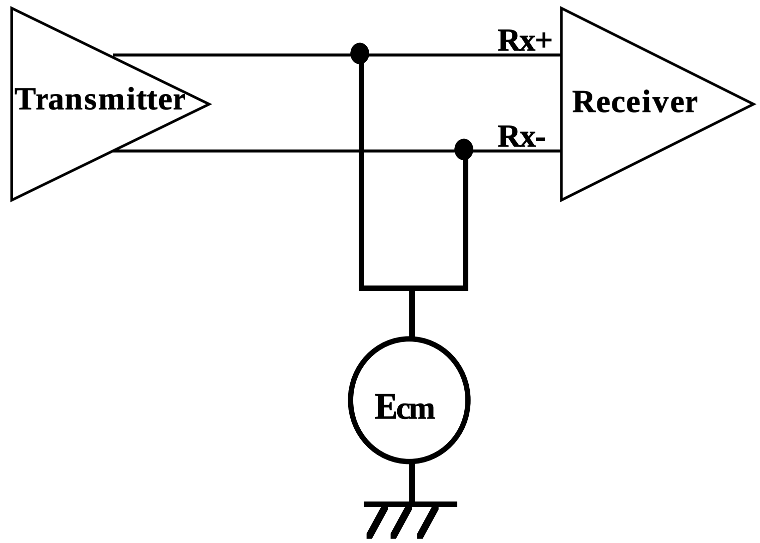

Figure 16 – Common mode rejection

10 Interface signals

This clause defines the interface of the signals between TP-PMD and SMT and also between TP-PMD and PHY. Each conforming FDDI attachment shall be compatible with this interface to allow interoperability within an FDDI environment. Conforming implementations may employ any design technique which does not violate interoperability.

10.1 Receiver

The receiver transforms the incoming differential voltage signal to an equivalent (translation from MLT-3 to NRZI and descrambling) signal that is presented to PHY.

A Signal_Detect parameter shall be presented to PHY to indicate the presence or absence of a differential signal. The data outputs of the Receiver are related to the Signal_Detect parameter and are described below.

10.1.1 Signal_Detect

Signal_Detect indicates the presence of a differential signal with sufficient quality to correctly identify a Line-State.

Signal_Detect is characterized by the threshold levels that it changes state on, by:

- the hysteresis between these levels;
- the timing of the Signal_Detect output relative to the Receiver data outputs, to allow:
  - a suitable quality of the received signal;
  - time for the equalization to converge.

10.1.1.1 Signal_Detect assertion threshold

Signal_Detect shall be asserted per 10.1.2 for any valid peak to peak signal, VSDA, of >1000 mV for UTP, and > 1225 mV for STP. Figure 17 illustrates this requirement. Signal_Detect shall remain asserted in the presence of valid signals with a low density of transitions.

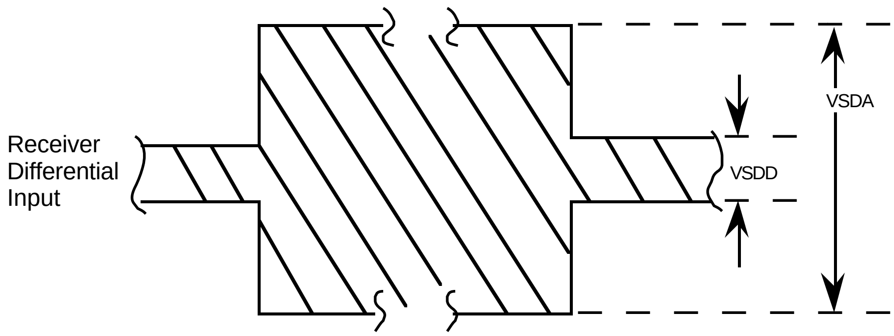

Figure 17 – Signal_Detect assertion threshold

10.1.1.2 Signal_Detect deassertion threshold

Signal_Detect shall be deasserted when the peak to peak received signal, VSDD, is < 200 mV for UTP, and < 245 mV for STP. Figure 17 illustrates this requirement.

10.1.2 Signal_Detect timing requirements on assertion

The Signal_Detect output shall be asserted within 1000 µs after a step increase in the differential (peak to peak) voltage exceeding the Signal_Detect assertion threshold. Figure 18 illustrates this requirement.

Moreover, the receiver data output shall reflect a bit error rate of less than 10^{-2} measured in an LS_Max interval after the assertion of Signal_Detect. The data pattern of the incoming symbol stream may be any valid scrambled symbol stream.

LS_Max	= 25 µs as defined in ISO/IEC DIS 9314-6, the FDDI SMT standard
AS_Max	Maximum acquisition time (signal). AS_Max is the maximum Signal_Detect assertion time for the station. AS_Max shall not exceed 1000 µs. The default value of AS_Max is 1000 µs.

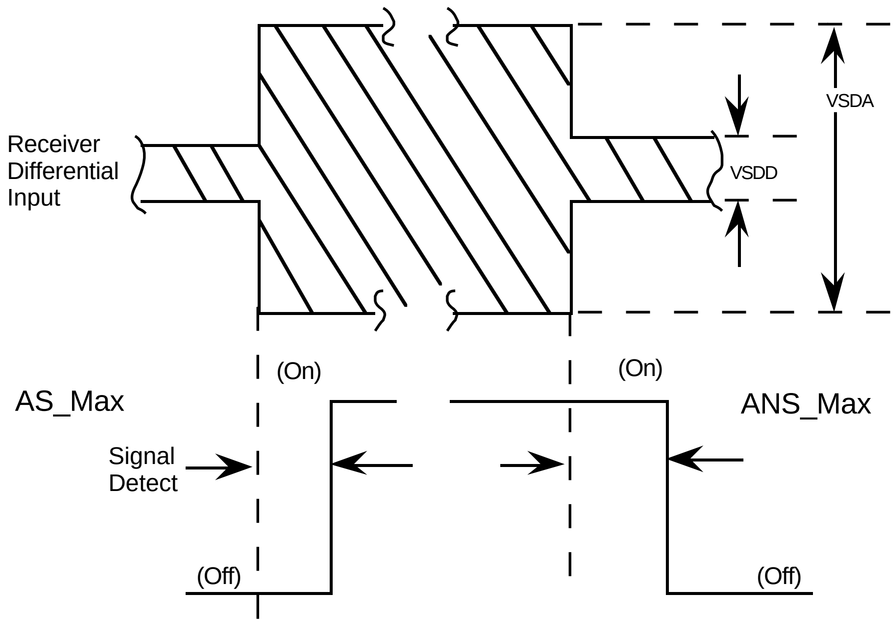

Figure 18 – Signal_Detect threshold and timing

10.1.3 Signal_Detect timing requirements on deassertion

The Signal_Detect output shall be deasserted within a maximum of 350 µs after a step decrease in the differential peak to peak input voltage from a value greater than the Signal_Detect Assertion Threshold to a differential signal level less than the Signal_Detect Deassertion Threshold. Signal_Detect shall also be deasserted within a maximum of 350 µs after the BER of the Receiver output degrades below 10^{-2} for a differential input data stream that decays with a negative ramp function instead of step function. The data pattern of the incoming differential signal stream may be any valid scrambled symbol stream. Figure 18 illustrates this requirement. See table 4 for Signal_Detect summary.

NOTE – Physical disconnection of the TP-PMD link may cause Link Error monitor errors.

ANS_Max Maximum acquisition time (no signal). ANS_Max is the maximum Signal_Detect deassertion time for a station. ANS_Max shall not exceed 350 µs. The default value of ANS_Max is 350 µs.

Table 4 – Signal_Detect summary

Characteristic	Minimum	Maximum
Assert time	-	1000 µs
Deassert time	-	350 µs
UTP assertion threshold VSDA		1000 mV p-p
UTP deassertion threshold VSDD	200 mV p-p	
STP assertion threshold VSDA		1225 mV p-p
STP deassertion threshold VSDD	245 mV p-p	

10.2 Transmitter

TP-PMD shall provide a service to SMT called SM_PM_CONTROL.request. When transmit disable is asserted, the output of the transmit function shall be scrambled Quiet Line State for a period of at least TL_Min. After TL_Min the output shall continue to be scrambled Quiet Line State or it shall be less than 30 mV p-p within 150 µs of assertion of Transmit_Disable. When SMT passes a Control_Action parameter of Transmit_Enable, the output shall transmit the current encoded value of the PM_UNITDATA.request primitive. The TP-PMD shall respond to the Transmit_Enable parameter within 1,0 µs after receipt of the parameter.

NOTE – Transmission for TL_Min allows for decoding of QLS by the receiving station, as defined in ISO/IEC DIS 9314-6, the FDDI SMT standard. SMT specifies TL_Min to have a minimum value of 50 µs, and a default value of 50 µs.

11 Cable plant interface specification

This clause defines the network requirements for FDDI twisted pair cable plants. The term "cable plant" encompasses all the components between the TP-MICs of any two communicating stations. The requirements specified herein apply to both dual and single attachments.

11.1 Cable plant specification

The specifications in 11.1.1 to 11.1.7 are intended to assure interoperability of FDDI conforming attachments and shall apply to all conforming twisted pair cable plant configurations. Subclauses 11.1.8 and 11.1.9 give example configurations of twisted pair cable plant compliant with 11.1.1 to 11.1.7.

11.1.1 Twisted pair types

The requirements of clause 9 are specified in terms of either 150 Ohm STP as defined by ANSI/EIA/TIA 568 or category 5 UTP as defined by EIA/TIA TSB-36. The Active Interface requirements were developed assuming worst case parameters for these cables; however, other cable types may also be used (see annex E).

11.1.2 Insertion loss definitions

The Insertion Loss of twisted pair cable plant is a function of frequency. The requirement for insertion loss is specified in two parts. The first is a Reference Insertion Loss, measured at a frequency of 16 MHz. The second is the Insertion Loss Deviation (ILD) which is a measure of the deviation from the expected insertion loss vs. frequency characteristics.

The Insertion Loss Deviation in dB is defined by:

$$\text{Insertion Loss Deviation} = \text{loss}(f) - A\sqrt{f} - C$$

Where f is in MHz, loss (f) is the transmission insertion loss in dB between nominal terminating impedances of the cable plant at frequency f and A and C are constants. The values of A and C are found which minimize the rms value of the Insertion Loss Deviation over the frequency range 0,2 MHz to 64 MHz, subject to the constraint that $-0{,}5$ dB < C < 0,5 dB.

11.1.3 Crosstalk definitions

The near end crosstalk of twisted pair cable plant is a highly variable function of frequency. A definition is used which allows this function to be referred to the reference frequency of 16 MHz.

The Reference Crosstalk Attenuation over the range of 1 MHz to 80 MHz is defined as follows:

Reference Crosstalk Attenuation = minimum value of (next(f) + 15log(f/16))

where f is the frequency in MHz, $1 < f < 80$

and next(f) is the crosstalk attenuation of the cable plant.

11.1.4 Reference insertion loss and reference crosstalk attenuation values

The range of values of Reference Insertion Loss (at 16 MHz) and Reference Crosstalk Attenuation (as defined in 11.1.3), which the cable plant is permitted to exhibit shall be constrained to the indicated region of figure 19.

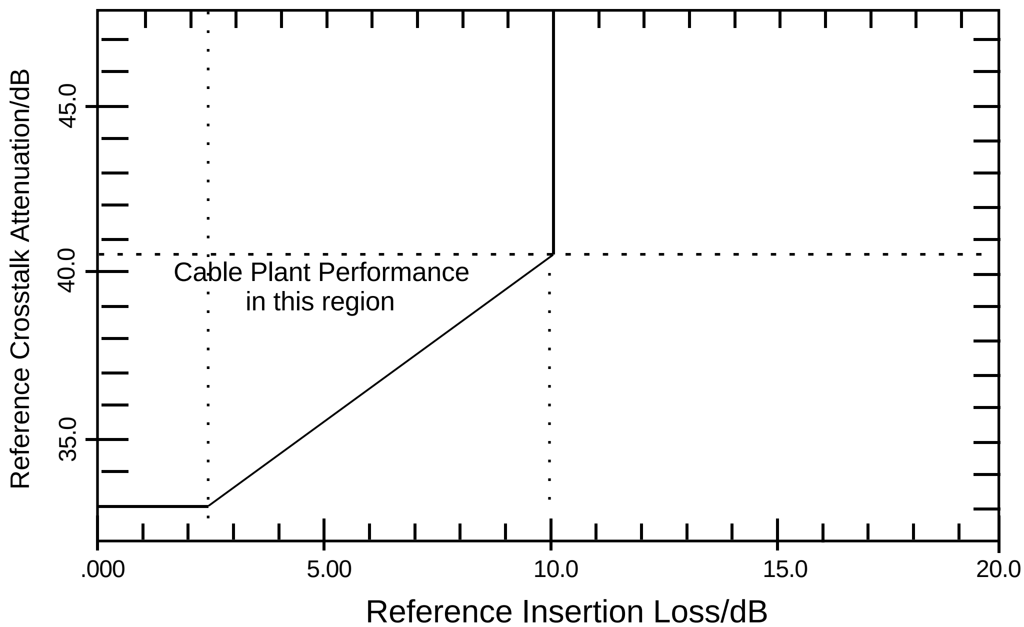

Figure 19 – Mask of permitted cable plant reference insertion loss and reference crosstalk attenuation

11.1.5 Insertion loss deviation value

The rms Insertion Loss Deviation shall not exceed 0,35 dB.

NOTE – This requirement is usually easily met by channels constructed of up to four separate cable elements of either category 5 UTP or Type 1 STP cabling components. For other cabling of interest, performance should be verified in the laboratory to ensure compliance.

11.1.6 Impedance considerations

The channel shall have a nominal impedance equal to the value specified for use with the TP-MIC plug in use for that channel.

Return Loss of the parts making up the channel shall be such that the resulting channel performance meets the Reference Insertion Loss, Crosstalk Attenuation and Insertion Loss Deviation requirements of 11.1.4 and 11.1.5.

11.1.7 Balance considerations

Cable plant balance does not directly constrain the interoperation of FDDI conforming attachments, but poor balance will cause the differential line signal to be partially converted to the common mode in the cable plant and the resulting common mode currents will result in electromagnetic emissions which may potentially violate statutory emissions requirements.

11.1.8 Example of compliant UTP channel configuration

Cable plant consisting of up to 90 m of EIA/TIA TSB 36 category 5 UTP cable and up to 10 m of EIA/TIA TSB 36 category 5 flexible cords along with category 5 connecting hardware as defined by EIA/TIA TSB 40 shall define one implementation of a compliant channel[3)]. This channel shall contain at most 4 connectors and shall be installed in accordance with the guidelines defined by ANSI/EIA/TIA 568 and EIA/TIA TSB 40.

11.1.9 Example of compliant STP channel configuration

Cable plant consisting of up to 90 m of 150 Ohm STP cable as described in ANSI/EIA/TIA 568 and up to 10 meters of cords terminated in a wall outlet used together with one cross-connect panel shall, if correctly installed in accordance with ANSI/EIA/TIA 568, define another implementation of a compliant channel.

11.2 Crossover function

A crossover function shall be implemented in every twisted pair Physical Connection. The crossover function connects the transmitter of each Physical Link to the receiver of that Physical Link. Explicit implementation details are beyond the scope of this standard. It is recommended that the crossover be implemented in a patch cable, so that conformance with in-wall wiring standards is maintained.

11.3 Connectors, cords, and cross-connect equipment

The TP-MIC plug for connection to an FDDI node shall be compatible with the requirements specified in clause 8.

Cords, connectors and cross-connect equipment used to make up the TP-PMD channel shall be of a quality sufficient to satisfy the Reference Insertion Loss, Crosstalk Attenuation and Insertion Loss Deviation requirements of 11.1.4 and 11.1.5. The number and quality of connections affect the performance of the cable plant and represent a design trade-off outside the scope of this standard. Some examples of conforming cable plant configurations are given in 11.1.8 and 11.1.9, and further information in annex E.

Cords, connectors, and crossconnect hardware compatible with the electrical characteristics of the twisted pair media should be used. It is recommended that connecting hardware be of the same or of a better category than the cable used for the link.

[3)] This assumes that the Structural Return Loss (SRL) of category 5 horizontal wiring cable is specified and that the attenuation/unit length of category 5 patch cord is constrained to be significantly less than that of category 3 horizontal cable. At the time of writing neither of these requirements is addressed by current issues of the referenced EIA/TIA documents.

Annex A
(normative)

Test procedures

A.1 Test channel requirements (twisted pair model)

This annex specifies the transmission characteristics for the STP and UTP test channels. All test channels and components used to build test channels shall meet the requirements of 11.1.

A.1.1 Attenuation of test channels

To ensure the receiver's adaptive equalizer (or conceptual equivalent) properly compensates for a wide range of attenuation and phase distortion of cabling, five test channels are defined for UTP and one additional test channel for STP. The test channels are intended to be representative of channels consisting of 5%, 25%, 50%, 75%, and 100% of the worst case attenuation at 16 MHz of the UTP and STP channels. The test channel insertion loss in dB at 16 MHz shall be as follows:

	UTP	STP	Tolerance
Test_chan_1	0,5	-	+-0,20 dB
Test_chan_2	2,5	-	+-0,20 dB
Test_chan_3	5,0	-	+-0,20 dB
Test_chan_4	7,5	-	+-0,20 dB
Test_chan_5	10,0	5,2	+-0,20 dB

NOTES

1 The recommended method to obtain the above test channel insertion loss values is to cut the nominal cabling to the appropriate length to meet the insertion loss requirement above.

2 The UTP Test_chan_5 value is based on three category 5 connectors (excluding both MICs) plus 90 m of category 5 cable at 60°C, plus 10 m of category 5 cordage at 60°C. The loss of the cordage is assumed to be 20% higher than the loss per meter of cable. In addition, the loss of the cables and cordage are assumed to be 12% higher (in dB) at 60°C than they are at 20°C.

The STP Test_chan_5 value is based on two Type 1 connectors (excluding both MICs) plus 90 m of Type 1 cable at 60°C, plus 10 m of Type 6 cordage at 60°C.

A.1.2 Insertion loss deviation of test channels

The worst case insertion loss deviation of the channel allowed by 11.1.5 is modeled by artificially inducing controlled deviation into test channels that inherently have minimal insertion loss deviation.

In order to minimize the inherent insertion loss deviation of the test channels, cables with good structural return loss performance should be used, such as category 5 UTP and type 1 STP.

Insertion loss deviation is then artificially induced in each of the test channels via two 18 pF +- 1 pF capacitors. Specifically, one capacitor is placed between the two conductors of the receive pair at one convenient location in each test channel. The other capacitor is placed between the two conductors of the receive pair 2 m apart from the first capacitor as shown in figure A.1.

A.1.3 Crosstalk of test channels

The crosstalk tolerance of the receiver is measured by inducing crosstalk as specified in A.1.4. To maximize repeatability of the crosstalk tolerance test, the crosstalk of the test channel shall be minimized. Specifically, the crosstalk of the test channel shall be at least 20 dB better than the requirements of 11.1.4. This usually implies that the transmit and receive pairs are in separate cables.

A.1.4 Test channel induced crosstalk

The crosstalk tolerance of the receiver is measured by inducing crosstalk energy onto the receive pair in a controlled artificial manner and monitoring the bit error rate. Figure A.1 illustrates, in block diagram form, a circuit used to induce the crosstalk energy. Other circuits that result in the equivalent induced noise in the test channel may also be used.

The MLT-3 encoder/driver should be a conformant transmit output or equivalent. The balanced differential coupler shall be designed to ensure disturbance of the channel is minimized. This can be verified by measuring insertion loss deviation before and after the introduction of the balanced differential coupler or it can be verified by other suitable methods.

The combination of the 15 dB per decade filter and the balanced differential coupler should result in a simulated crosstalk amplitude response that varies over frequency at the rate of 15 dB per decade. The spectral amplitude of the response shall deviate from the value at 16 MHz by no more than 2 dB over the frequency range of 4 MHz to 80 MHz when adjusted for frequency at the rate of 15 dB per decade. Furthermore, at any frequency below 4 MHz, the amplitude shall not be higher than the value at 4 MHz.

The balanced attenuator shall be adjusted so that the combined attenuation at 16 MHz of the 15 dB/decade filter, balanced attenuator, and balanced differential coupler meet the following requirements:

	UTP	STP
Test_chan_1	35,0	-
Test_chan_2	35,0	-
Test_chan_3	37,5	-
Test_chan_4	40,0	-
Test_chan_5	42,5	39,5

NOTE – The UTP Test_chan_5 value is based on 90 m of category 5 cable with two category 5 connectors at the measurement end of the cable, plus a 2 dB adjustment factor. The crosstalk values for the other UTP test channels are based on maintaining constant signal to crosstalk noise ratio at 16 MHz. The STP Test_chan_5 value is based on 90 m of Type 1 cable plus one Type 1 connector at the measurement end of the cable, plus a 2 dB adjustment factor. The values are further rounded to the nearest 1/2 dB.

The adjustment factor takes into account that a minimally compliant category 5 cable plant will not be minimally compliant over the entire frequency range of interest. Specifically, the 2 dB adjustment factor compensates for the pessimistic assumption inherent in this crosstalk test of worst case crosstalk over the entire frequency range of interest.

It may be advisable to ensure the crosstalk coupling circuit is capable of inducing higher levels of crosstalk than those listed above to facilitate determining the dB of margin available before the error rate degrades substantially.

The above crosstalk tolerance test shall be performed on UTP Test_channel_1, UTP Test_channel_2, UTP Test_channel_3, UTP Test_channel_4, UTP Test_channel _5, and STP Test_channel_5 while monitoring the error rate to ensure compliance with the bit error rate objectives.

In order to minimize test time for test channels 1 to 4, compliance with the error rate objective shall be assumed if error free performance is obtained over a five minute period with the crosstalk level adjusted to be 6 dB higher than specified above.

For all tests the balanced coupler shall be located at or near the end of the cable at which the error rate of the receiver is being evaluated.

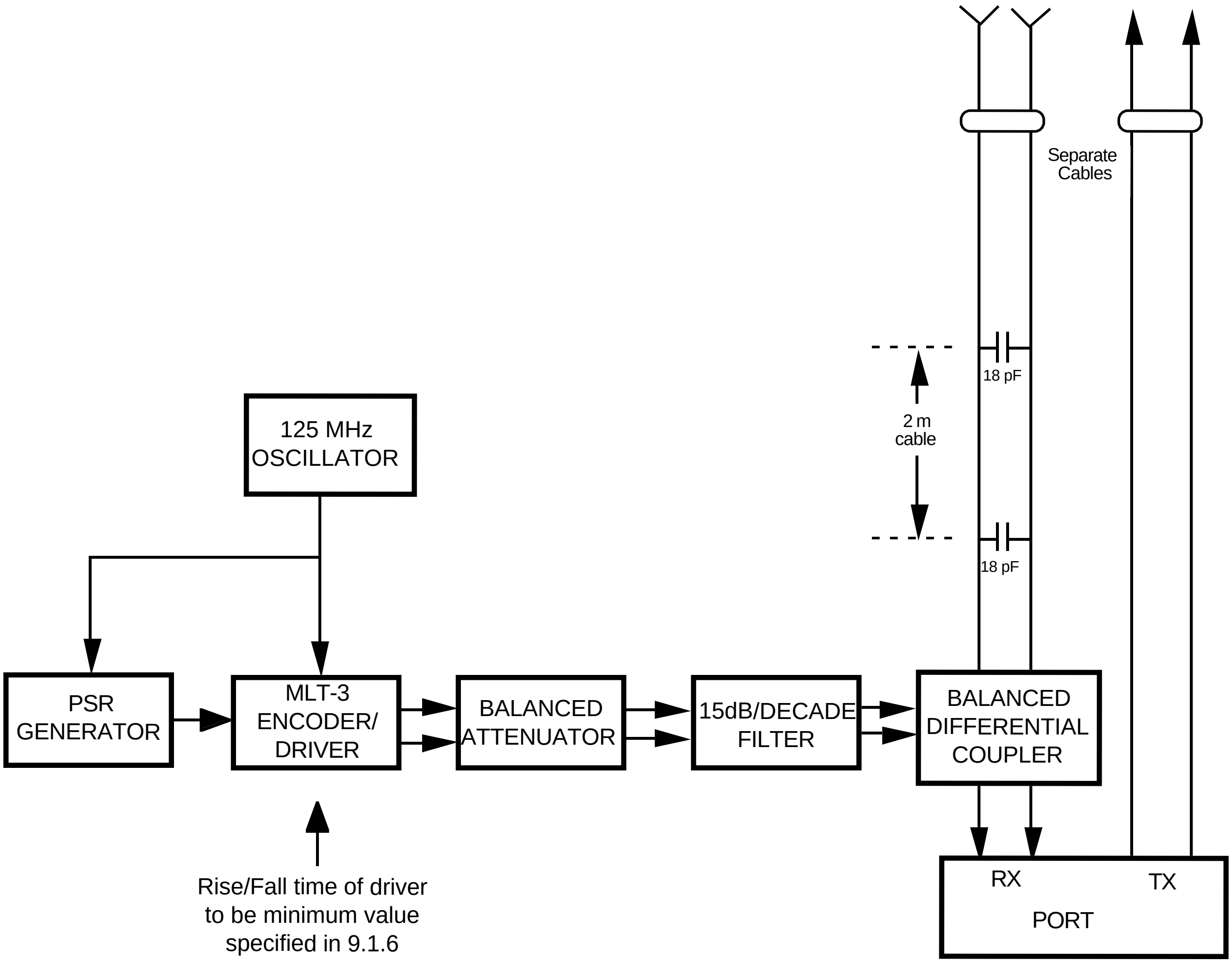

Figure A.1 – NEXT and ILD simulation test set-up

A.2 DDJ test pattern for baseline wander measurements

The symbol pattern provided below is used for testing TP_PMD components or physical links for Data Dependent Jitter. The 4B symbols used in the pattern are defined in ISO 9314-1.

This pattern produces a near worst case baseline wander condition. Other patterns will also produce baseline wander of varying amplitudes and durations. The receiver is expected to accommodate baseline wander phenomena, in order to minimize the chance of error in receipt of a transmitted frame.

The probability of generating large amounts of baseline wander depends on the PHY sending a bit sequence which matches the scrambler output for a period of time long enough to cause the AC coupled MLT-3 signal on the cable to accumulate a significant DC offset. Such sequences must last for a period on the order of greater than 100 symbol times for the offset to develop.

The following pattern can be used in its entirety to construct a 9000-symbol FDDI frame which is designed to produce a near worst case baseline wander condition of approximately 750 mV. It can also be truncated to various lengths to study the effects of both short and long sequences. Since baseline wander is a statistical phenomenon, the sequence should be sent often enough to make sure that the expected baseline wander is actually being produced. The pattern includes a period of 57 bit times at the start of the sequence which will appear when the scrambler seed is correct for generating this worst case pattern. This event can be useful for triggering measurement devices.

```
06 9c 61 db 43 12 b1 78 13 47 12 f8 1f 62 41
35 4c be 1e b1 3f 03 6b 4e 6b 15 ab 0f 83 e4
a1 71 3d 55 69 ba 2a 6b cf e5 a7 73 b3 a5 6f
51 9f a4 b1 31 2e ab 2e 08 4f 1e 32 16 89 e6
1d 6d 4d 0d 0c da d4 da 46 6d f5 be 32 68 ff
52 2d a8 c2 39 e5 a7 70 46 5d 5d e5 38 0e 51
90 6f d1 52 c0 f6 29 96 2c 82 4b 21 aa 5b af
42 a9 26 59 5b be 37 fb 3b 18 a7 11 e7 51 02
80 25 88 e8 a2 a0 05 f9 a0 a8 5f 7e 7a 26 ed
5d dc 41 0b d2 48 be a0 38 6f 62 bd 55 c8 7f
2f 93 0a 84 3b 13 95 b6 95 e1 a4 7a 15 ad 1d
0c 11 50 d8 ce bb f1 2c 5a 87 f3 35 46 2c 61
16 24 b4 a2 31 2b a2 cd bc 41 f7 51 cb 73 14
c3 31 58 64 d1 55 92 a4 76 1b 92 09 86 fc 35
26 24 53 64 85 f0 e0 b5 31 22 1e a2 58 75 1a
76 15 ae b1 3c 11 ac b8 37 01 6b 02 6c c3 ef
f3 52 01 25 61 8c f5 26 4d 6c 0e 2f af c9 1e
1a 47 f5 26 5a 94 73 48 22 90 ad ac a3 ae 6a
c5 16 04 96 6b cf b3 62 52 25 ab ce aa 34 22
10 9d 04 63 1c 0b 8f 82 71 12 2d 60 a8 22 bb
7f 5e db c2 78 21 84 53 1c c1 4a 57 22 5e 6e
6a 17 51 6e 54 9a 07 61 a7 bb 24 8e 2b 63 ba
27 8b ef b3 20 95 28 63 62 a0 a0 08 85 f0 fe
22 68 c3 52 77 14 00 80 28 6f 1e f7 2a 83 72
60 d6 d9 4e 2a 35 ce 14 aa a2 06 a1 ca ea b5
32 54 a8 08 92 06 51 93 52 01 9b 02 18 53 7e
4e 11 a0 19 67 50 86 3c 61 1a 36 05 09 06 c4
02 21 67 3e 9e fc 2e 9b 63 45 15 8b 2a 42 b9
7b 1f cf a2 58 a3 34 29 a6 65 d8 4f 63 01 68
44 3f d4 53 85 30 1f aa a5 b7 91 5a 67 db 45
32 d4 98 ae 1a 6c d8 56 94 74 19 72 44 2e c1
15 01 95 bb e9 af a3 a6 bf 3a 0a 5b 82 ef a1
b6 45 79 1b c8 10 b1 33 1b b3 e8 02 c6 e1 ab
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a5 b5 59 ba 4b ee ca 8b 22 6c f1 1a f0 35 23
52 8a e4 60 c5 19 17 e5 a0 75 1a 7d 05 68 0e
07 9b 09 9f 05 9a b5 33 19 04 9e a1 b9 f4 28
c2 eb fa e4 a1 bb 22 9f 7b a3 12 33 f5 19 c1
17 aa b3 12 d1 dc 5f 12 35 59 ba b6 ec b3 28
40 68 19 a9 bf 24 81 fb 43 03 7c a1 2b 91 7d
64 32 f1 2c 88 f2 f5 20 14 51 7e 13 b0 2d 9c
0a 93 66 47 33 5b 83 2e 5a 8a 5b 05 90 59 7c
1f 12 fd 34 92 52 24 8e 36 2c 41 f6 b4 51 a8
5f 7e 50 59 80 e8 b5 36 a5 28 98 76 a4 00 96
78 af 33 a3 dd 45 69 90 0e 95 7c 34 e3 b6 39
00 de d2 c9 b6 8d 24 01 0a aa 42 2b 11 01 99
b9 34 24 ef 92 98 fe 35 2f 03 d0 4c 51 60 9e
73 33 94 51 06 9c be 21 89 3f a3 c0 40 49 12
b6 f9 57 c2 66 c1 ab 73 72 54 72 25 e9 26 8c
51 27 51 b9 3a 87 03 8e 5a 5c 9e 0c 95 77 a4
c5 11 61 57 97 75 3a d7 51 6a b0 19 41 19 89
ff 52 bd fc 41 7a 57 4c 20 08 5f 84 f1 1a c6
ac 24 a3 4d 2e 6a fb 13 04 9e b2 58 59 94 74
18 87 41 96 85 08 1f 4e 0b 0e ea 1b 44 1e 9c
7f 72 54 4a 25 b8 4f e4 ae 0b 85 f5 2e 81 f4
e0 a4 be f2 39 47 95 7a 2d ac 71 0b 6f 42 58
53 54 63 15 a6 6a d3 ca 44 13 54 61 c8 ee bb
53 d6 58 ef 52 df da 4b b2 b5 e8 1f 4e 86 0c
83 ee 29 62 09 0a 1b 5f 3f 8e 7a ba f1 20 f9
57 0b 87 32 18 be 1a 47 ae d9 d9 55 96 c5 49
8b 74 13 b5 f6 e4 ab aa 72 b9 f6 55 49 07 be
af 23 4e 99 78 16 a4 13 8c 70 e7 51 70 79 21
86 9d f4 11 41 15 8b 2f f2 a9 17 2e 5e 00 69
67 a0 b4 38 ae 2b 0e dc de 45 36 45 08 de c1
18 66 dc c7 13 23 0c ae 58 97 71 15 a2 00 44
43 fc a7 b2 88 2e 07 41 6a 9a 6b c5 14 a5 b5
f6 fa 37 b4 b3 f4 28 d8 d7 da 55 9d 65 59 17
26 91 71 12 90 3a 1c 9a 71 1d 2c 41 e8 25 80
59 57 f1 bc 3e ab 4f 02 a9 4b 53 61 bb 43 5e
7e 3b e5 a0 69 c6 1d b4 31 2b 17 81 34 71 2f
81 f6 24 13 54 cb e1 eb 13 f0 36 b4 e6 b1 5a
b0 f8 3e 4a 17 13 d5 56 9b a2 a6 bc fe 5a 77
3b 3a 56 f5 19 fa 4b 13 12 ea b2 e0 84 f1 e3
21 68 9e 61 d6 d4 d0 d0 cd ad 4d a4 66 df 5b
e3 26 8f f5 22 da 8c 23 9e 5a 77 04 65 d5 de
53 80 e5 19 06 fd 15 2c 0f 62 99 62 c8 24 b2
1a a5 ba f4 2a 92 65 95 bb e3 7f b3 b1 8a 71
1e 75 10 28 02 58 8e 8a 2a 00 5f 9a 0a 85 f7
e7 a2 6e d5 dd c4 10 bd 24 8b ea 03 86 f6 2b
d5 5c 87 f2 f9 30 a8 43 b1 39 5b 69 5e 1a 47
a1 5a d1 d0 c1 15 0d 8c eb bf 12 c5 a8 7f 33
54 62 c6 11 62 4b 4a 23 12 ba 2c db c4 1f 75
1c b7 31 4c 33 15 86 4d 15 59 2a 47 61 b9 20
98 6f c3 52 62 45 36 48 5f 0e 0b 53 12 21 ea
25 87 51 a7 61 5a eb 13 c1 1a cb 83 70 16 b0
26 cc 3e ff 35 20 12 56 18 cf 52 64 d6 c0 e2
fa fc 91 e1 a4 7f 52 65 a9 47 34 82 29 0a da
ca 3a e6 ac 51 60 49 66 bc fb 36 25 22 5a bc
```

```
ea a3 42 21 09 d0 46 31 c0 b8 f8 27 11 22 d6
0a 82 2b b7 f5 ed bc 27 82 18 45 31 cc 14 a5
72 25 e6 e6 a1 75 16 e5 49 a0 76 1a 7b b2 48
e2 b6 3b a2 78 be fb 32 09 52 86 36 2a 0a 00
88 5f 0f e2 26 8c 35 27 71 40 08 02 86 f1 ef
72 a8 37 26 0d 6d 94 e2 a3 5c e1 4a aa 20 6a
1c ae ab 53 25 4a 80 89 20 65 19 35 20 19 b0
21 85 37 e4 e1 1a 01 96 75 08 63 c6 11 a3 60
50 90 6c 40 22 16 73 e9 ef c2 e9 b6 34 51 58
b2 a4 2b 97 b1 fc fa 25 8a 33 42 9a 66 5d 84
f6 30 16 84 43 fd 45 38 53 01 fa aa 5b 79 15
a6 7d b4 53 2d 49 8a e1 a6 cd 85 69 47 41 97
24 42 ec 11 50 19 5b be 9a fa 3a 6b f3 a0 a5
b8 2e fa 1b 64 57 91 bc 81 0b 13 31 bb 3e 80
2c 6e 1a ba 5b 55 9b a4 be ec a8 b2 26 cf 11
af 03 52 35 28 ae 46 0c 51 91 7e 5a 07 51 a7
d0 56 80 e0 79 b0 99 f0 59 ab 53 31 90 49 ea
1b 9f 42 8c 2e bf ae 4a 1b b2 29 f7 ba 31 23
3f 51 9c 11 7a ab 31 2d 1d c5 f1 23 55 9b ab
6e cb 32 84 06 81 9a 9b f2 48 1f b4 30 37 ca
12 b9 17 d6 43 2f 12 c8 8f 2f 52 01 45 17 e1
3b 02 d9 c0 a9 36 64 73 35 b8 32 e5 a8 a5 b0
59 05 97 c1 f1 2f d3 49 25 22 48 e3 62 c4 1f
6b 45 1a 85 f7 e5 05 98 0e 8b 53 6a 52 89 87
6a 40 09 67 8a f3 3a 3d d4 56 99 00 e9 57 c3
4e 3b 63 90 0d ed 2c 9b 68 d2 40 10 aa a4 22
b1 10 19 9b 93 42 4e f9 29 8f e3 52 f0 3d 04
c5 16 09 e7 33 39 45 10 69 cb e2 18 93 fa 3c
04 04 91 2b 6f 95 7c 26 6c 1a b7 37 25 47 22
5e 92 68 c5 12 75 1b 93 a8 70 38 e5 a5 c9 e0
c9 57 7a 4c 51 16 15 79 77 53 ad 75 16 ab 01
94 11 98 9f f5 2b df c4 17 a5 74 c2 00 85 f8
4f 11 ac 6a c2 4a 34 d2 e6 af b1 30 49 eb 25
85 99 47 41 88 74 19 68 50 81 f4 e0 b0 ee a1
b4 41 e9 c7 f7 25 44 a2 5b 84 fe 4a e0 b8 5f
52 e8 1f 4e 0a 4b ef 23 94 79 57 a2 da c7 10
b6 f4 25 85 35 46 31 5a 66 ad 3c a4 41 35 46
1c 8e eb b5 3d 65 8e f5 2d fd a4 bb 2b 5e 81
f4 e8 60 c8 3e e2 96 20 90 a1 b5 f3 f8 e7 ab
af 12 0f 95 70 b8 73 21 8b e1 a4 7a ed 9d 95
59 6c 54 98 b7 41 3b 5f 6e 4a ba a7 2b 9f 65
54 90 7b ea f2 34 e9 97 81 6a 41 38 c7 0e 75
17 07 92 18 69 df 41 14 11 58 b2 ff 2a 91 72
e5 e0 06 96 7a 0b 43 8a e2 b0 ed cd e4 53 64
50 8d ec 11 86 6d cc 71 32 30 ca e5 89 77 11
5a 20 04 44 3f ca 7b 28 82 e0 74 16 a9 a6 bc
51 4a 5b 5f 6f a3 7b 4b 3f 42 8d 8d 7d a5 59
d6 55 91 72 69 17 11 29 03 a1 c9 a7 11 d2 c4
1e 82 58 05 95 7f 1b c3 ea b4 f0 2a 94 b5 36
1b b4 35 e7 e3 be 5a 06 9c 61 db 43 12 b1 78
13 47 12 f8 1f 62 41 35 4c be 1e b1 3f 03 6b
4e 6b 15 ab 0f 83 e4 a1 71 3d 55 69 ba 2a 6b
cf e5 a7 73 b3 a5 6f 51 9f a4 b1 31 2e ab 2e
08 4f 1e 32 16 89 e6 1d 6d 4d 0d 0c da d4 da
```

46 6d f5 be 32 68 ff 52 2d a8 c2 39 e5 a7 70
46 5d 5d e5 38 0e 51 90 6f d1 52 c0 f6 29 96
2c 82 4b 21 aa 5b af 42 a9 26 59 5b be 37 fb
3b 18 a7 11 e7 51 02 80 25 88 e8 a2 a0 05 f9
a0 a8 5f 7e 7a 26 ed 5d dc 41 0b d2 48 be a0
38 6f 62 bd 55 c8 7f 2f 93 0a 84 3b 13 95 b6
95 e1 a4 7a 15 ad 1d 0c 11 50 d8 ce bb f1 2c
5a 87 f3 35 46 2c 61 16 24 b4 a2 31 2b a2 cd
bc 41 f7 51 cb 73 14 c3 31 58 64 d1 55 92 a4
76 1b 92 09 86 fc 35 26 24 53 64 85 f0 e0 b5
31 22 1e a2 58 75 1a 76 15 ae b1 3c 11 ac b8
37 01 6b 02 6c c3 ef f3 52 01 25 61 8c f5 26
4d 6c 0e 2f af c9 1e 1a 47 f5 26 5a 94 73 48
22 90 ad ac a3 ae 6a c5 16 04 96 6b cf b3 62
52 25 ab ce aa 34 22 10 9d 04 63 1c 0b 8f 82
71 12 2d 60 a8 22 bb 7f 5e db c2 78 21 84 53
1c c1 4a 57 22 5e 6e 6a 17 51 6e 54 9a 07 61
a7 bb 24 8e 2b 63 ba 27 8b ef b3 20 95 28 63
62 a0 a0 08 85 f0 fe 22 68 c3 52 77 14 00 80
28 6f 1e f7 2a 83 72 60 d6 d9 4e 2a 35 ce 14
aa a2 06 a1 ca ea b5 32 54 a8 08 92 06 51 93
52 01 9b 02 18 53 7e 4e 11 a0 19 67 50 86 3c
61 1a 36 05 09 06 c4 02 21 67 3e 9e fc 2e 9b
63 45 15 8b 2a 42 b9 7b 1f cf a2 58 a3 34 29
a6 65 d8 4f 63 01 68 44 3f d4 53 85 30 1f aa
a5 b7 91 5a 67 db 45 32 d4 98 ae 1a 6c d8 56
94 74 19 72 44 2e c1 15 01 95 bb e9 af a3 a6
bf 3a 0a 5b 82 ef a1 b6 45 79 1b c8 10 b1 33
1b b3 e8 02 c6 e1 ab a5 b5 59 ba 4b ee ca 8b
22 6c f1 1a f0 35 23 52 8a e4 60 c5 19 17 e5
a0 75 1a 7d 05 68 0e 07 9b 09 9f 05 9a b5 33
19 04 9e a1 b9 f4 28 c2 eb fa e4 a1 bb 22 9f
7b a3 12 33 f5 19 c1 17 aa b3 12 d1 dc 5f 12
35 59 ba b6 ec b3 28 40 68 19 a9 bf 24 81 fb
43 03 7c a1 2b 91 7d 64 32 f1 2c 88 f2 f5 20
14 51 7e 13 b0 2d 9c 0a 93 66 47 33 5b 83 2e
5a 8a 5b 05 90 59 7c 1f 12 fd 34 92 52 24 8e
36 2c 41 f6 b4 51 a8 5f 7e 50 59 80 e8 b5 36
a5 28 98 76 a4 00 96 78 af 33 a3 dd 45 69 90
0e 95 7c 34 e3 b6 39 00 de d2 c9 b6 8d 24 01
0a aa 42 2b 11 01 99 b9 34 24 ef 92 98 fe 35
2f 03 d0 4c 51 60 9e 73 33 94 51 06 9c be 21
89 3f a3 c0 40 49 12 b6 f9 57 c2 66 c1 ab 73
72 54 72 25 e9 26 8c 51 27 51 b9 3a 87 03 8e
5a 5c 9e 0c 95 77 a4 c5 11 61 57 97 75 3a d7
51 6a b0 19 41 19 89 ff 52 bd fc 41 7a 57 4c
20 08 5f 84 f1 1a c6 ac 24 a3 4d 2e 6a fb 13
04 9e b2 58 59 94 74 18 87 41 96 85 08 1f 4e
0b 0e ea 1b 44 1e 9c 7f 72 54 4a 25 b8 4f e4
ae 0b 85 f5 2e 81 f4 e0 a4 be f2 39 47 95 7a
2d ac 71 0b 6f 42 58 53 54 63 15 a6 6a d3 ca
44 13 54 61 c8 ee bb 53 d6 58 ef 52 df da 4b
b2 b5 e8 1f 4e 86 0c 83 ee 29 62 09 0a 1b 5f
3f 8e 7a ba f1 20 f9 57 0b 87 32 18 be 1a 47

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ae d9 d9 55 96 c5 49 8b 74 13 b5 f6 e4 ab aa
72 b9 f6 55 49 07 be af 23 4e 99 78 16 a4 13
8c 70 e7 51 70 79 21 86 9d f4 11 41 15 8b 2f
f2 a9 17 2e 5e 00 69 67 a0 b4 38 ae 2b 0e dc
de 45 36 45 08 de c1 18 66 dc c7 13 23 0c ae
58 97 71 15 a2 00 44 43 fc a7 b2 88 2e 07 41
6a 9a 6b c5 14 a5 b5 f6 fa 37 b4 b3 f4 28 d8
d7 da 55 9d 65 59 17 26 91 71 12 90 3a 1c 9a
71 1d 2c 41 e8 25 80 59 57 f1 bc 3e ab 4f 02
a9 4b 53 61 bb 43 5e 7e 3b e5 a0 69 c6 1d b4
31 2b 17 81 34 71 2f 81 f6 24 13 54 cb e1 eb
13 f0 36 b4 e6 b1 5a b0 f8 3e 4a 17 13 d5 56
9b a2 a6 bc fe 5a 77 3b 3a 56 f5 19 fa 4b 13
12 ea b2 e0 84 f1 e3 21 68 9e 61 d6 d4 d0 d0
cd ad 4d a4 66 df 5b e3 26 8f f5 22 da 8c 23
9e 5a 77 04 65 d5 de 53 80 e5 19 06 fd 15 2c
0f 62 99 62 c8 24 b2 1a a5 ba f4 2a 92 65 95
bb e3 7f b3 b1 8a 71 1e 75 10 28 02 58 8e 8a
2a 00 5f 9a 0a 85 f7 e7 a2 6e d5 dd c4 10 bd
24 8b ea 03 86 f6 2b d5 5c 87 f2 f9 30 a8 43
b1 39 5b 69 5e 1a 47 a1 5a d1 d0 c1 15 0d 8c
eb bf 12 c5 a8 7f 33 54 62 c6 11 62 4b 4a 23
12 ba 2c db c4 1f 75 1c b7 31 4c 33 15 86 4d
15 59 2a 47 61 b9 20 98 6f c3 52 62 45 36 48
5f 0e 0b 53 12 21 ea 25 87 51 a7 61 5a eb 13
c1 1a cb 83 70 16 b0 26 cc 3e ff 35 20 12 56
18 cf 52 64 d6 c0 e2 fa fc 91 e1 a4 7f 52 65
a9 47 34 82 29 0a da ca 3a e6 ac 51 60 49 66
bc fb 36 25 22 5a bc ea a3 42 21 09 d0 46 31
c0 b8 f8 27 11 22 d6 0a 82 2b b7 f5 ed bc 27
82 18 45 31 cc 14 a5 72 25 e6 e6 a1 75 16 e5
49 a0 76 1a 7b b2 48 e2 b6 3b a2 78 be fb 32
09 52 86 36 2a 0a 00 88 5f 0f e2 26 8c 35 27
71 40 08 02 86 f1 ef 72 a8 37 26 0d 6d 94 e2
a3 5c e1 4a aa 20 6a 1c ae ab 53 25 4a 80 89
20 65 19 35 20 19 b0 21 85 37 e4 e1 1a 01 96
75 08 63 c6 11 a3 60 50 90 6c 40 22 16 73 e9
ef c2 e9 b6 34 51 58 b2 a4 2b 97 b1 fc fa 25
8a 33 42 9a 66 5d 84 f6 30 16 84 43 fd 45 38
53 01 fa aa 5b 79 15 a6 7d b4 53 2d 49 8a e1
a6 cd 85 69 47 41 97 24 42 ec 11 50 19 5b be
9a fa 3a 6b f3 a0 a5 b8 2e fa 1b 64 57 91 bc
81 0b 13 31 bb 3e 80 2c 6e 1a ba 5b 55 9b a4
be ec a8 b2 26 cf 11 af 03 52 35 28 ae 46 0c
51 91 7e 5a 07 51 a7 d0 56 80 e0 79 b0 99 f0
59 ab 53 31 90 49 ea 1b 9f 42 8c 2e bf ae 4a
1b b2 29 f7 ba 31 23 3f 51 9c 11 7a ab 31 2d
1d c5 f1 23 55 9b ab 6e cb 32 84 06 81 9a 9b
f2 48 1f b4 30 37 ca 12 b9 17 d6 43 2f 12 c8
8f 2f 52 01 45 17 e1 3b 02 d9 c0 a9 36 64 73
35 b8 32 e5 a8 a5 b0 59 05 97 c1 f1 2f d3 49
25 22 48 e3 62 c4 1f 6b 45 1a 85 f7 e5 05 98
0e 8b 53 6a 52 89 87 6a 40 09 67 8a f3 3a 3d
d4 56 99 00 e9 57 c3 4e 3b 63 90 0d ed 2c 9b
```

```
68 d2 40 10 aa a4 22 b1 10 19 9b 93 42 4e f9
29 8f e3 52 f0 3d 04 c5 16 09 e7 33 39 45 10
69 cb e2 18 93 fa 3c 04 04 91 2b 6f 95 7c 26
6c 1a b7 37 25 47 22 5e 92 68 c5 12 75 1b 93
a8 70 38 e5 a5 c9 e0 c9 57 7a 4c 51 16 15 79
77 53 ad 75 16 ab 01 94 11 98 9f f5 2b df c4
17 a5 74 c2 00 85 f8 4f 11 ac 6a c2 4a 34 d2
e6 af b1 30 49 eb 25 85 99 47 41 88 74 19 68
50 81 f4 e0 b0 ee a1 b4 41 e9 c7 f7 25 44 a2
5b 84 fe 4a e0 b8 5f 52 e8 1f 4e 0a 4b ef 23
94 79 57 a2 da c7 10 b6 f4 25 85 35 46 31 5a
66 ad 3c a4 41 35 46 1c 8e eb b5 3d 65 8e f5
2d fd a4 bb 2b 5e 81 f4 e8 60 c8 3e e2 96 20
90 a1 b5 f3 f8 e7 ab af 12 0f 95 70 b8 73 21
8b e1 a4 7a ed 9d 95 59 6c 54 98 b7 41 3b 5f
6e 4a ba a7 2b 9f 65 54 90 7b ea f2 34 e9 97
81 6a 41 38 c7 0e 75 17 07 92 18 69 df 41 14
11 58 b2 ff 2a 91 72 e5 e0 06 96 7a 0b 43 8a
e2 b0 ed cd e4 53 64 50 8d ec 11 86 6d cc 71
32 30 ca e5 89 77 11 5a 20 04 44 3f ca 7b 28
82 e0 74 16 a9 a6 bc 51 4a 5b 5f 6f a3 7b 4b
3f 42 8d 8d 7d a5 59 d6 55 91 72 69 17 11 29
03 a1 c9 a7 11 d2 c4 1e 82 58 05 95 7f 1b c3
ea b4 f0 2a 94 b5 36 1b b4 35 e7 e3 be 5a 06
9c 61 db 43 12 b1 78 13 47 12 f8 1f 62 41 35
4c be 1e b1 3f 03 6b 4e 6b 15 ab 0f 83 e4 a1
71 3d 55 69 ba 2a 6b cf e5 a7 73 b3 a5 6f 51
9f a4 b1 31 2e ab 2e 08 4f 1e 32 16 89 e6 1d
6d 4d 0d 0c da d4 da 46 6d f5 be 32 68 ff 52
2d a8 c2 39 e5 a7 70 46 5d 5d e5 38 0e 51 90
6f d1 52 c0 f6 29 96 2c 82 4b 21 aa 5b af 42
a9 26 59 5b be 37 fb 3b 18 a7 11 e7 51 02 80
25 88 e8 a2 a0 05 f9 a0 a8 5f 7e 7a 26 ed 5d
dc 41 0b d2 48 be a0 38 6f 62 bd 55 c8 7f 2f
93 0a 84 3b 13 95 b6 95 e1 a4 7a 15 ad 1d 0c
11 50 d8 ce bb f1 2c 5a 87 f3 35 46 2c 61 16
24 b4 a2 31 2b a2 cd bc 41 f7 51 cb 73 14 c3
31 58 64 d1 55 92 a4 76 1b 92 09 86 fc 35 26
24 53 64 85 f0 e0 b5 31 22 1e a2 58 75 1a 76
15 ae b1 3c 11 ac b8 37 01 6b 02 6c c3 ef f3
52 01 25 61 8c f5 26 4d 6c 0e 2f af c9 1e 1a
47 f5 26 5a 94 73 48 22 90 ad ac a3 ae 6a c5
16 04 96 6b cf b3 62 52 25 ab ce aa 34 22 10
9d 04 63 1c 0b 8f 82 71 12 2d 60 a8 22 bb 7f
5e db c2 78 21 84 53 1c c1 4a 57 22 5e 6e 6a
17 51 6e 54 9a 07 61 a7 bb 24 8e 2b 63 ba 27
8b ef b3 20 95 28 63 62 a0 a0 08 85 f0 fe 22
68 c3 52 77 14 00 80 28 6f 1e f7 2a 83 72 60
d6 d9 4e 2a 35 ce 14 aa a2 06 a1 ca ea b5 32
54 a8 08 92 06 51 93 52 01 9b
```

Annex B
(informative)

Electrical interface considerations

This annex defines the electrical interface of the transmitters and receivers as shown in figures B.1 and B.2. This interface is intended to separate the development of components for PHY and TP-PMD and thus it provides an interface that may be used for the verification of the conformance of FDDI MAC and PHY entities. It is not intended to provide an interface for the interconnection of conforming FDDI attachments.

For interconnection of conforming FDDI attachments, the true requirement for interoperability is at the TP-MIC provided by each attachment. Therefore, the requirements specified in this annex need not be met if the interface supplied meets the applicable requirements as specified in clause 9.

In figures B.1 and B.2, RX+ and RX- form a differential input. They connect the TP-PMD Receive Function output to the PHY's Decode function input. The data is transferred as an NRZI pulse stream.

TX+ and TX- form a differential output. They connect the PHY's Encode function output to the TP-PMD Transmit function. The data is transferred as an NRZI pulse stream.

The differential input/output signals are shown dc-coupled in figure B.1. This dc coupling was assumed in the jitter allocation shown in annex C.

The differential input/output signals are shown ac-coupled in figure B.2 as this may be useful to allow for power supply mismatches between components. An implementation using the ac coupled scheme may need to provide for jitter induced due to base-line wander across the capacitors.

The differential interface signals between PHY and TP-PMD should be compatible with both the 10K and the 100K ECL logic families.

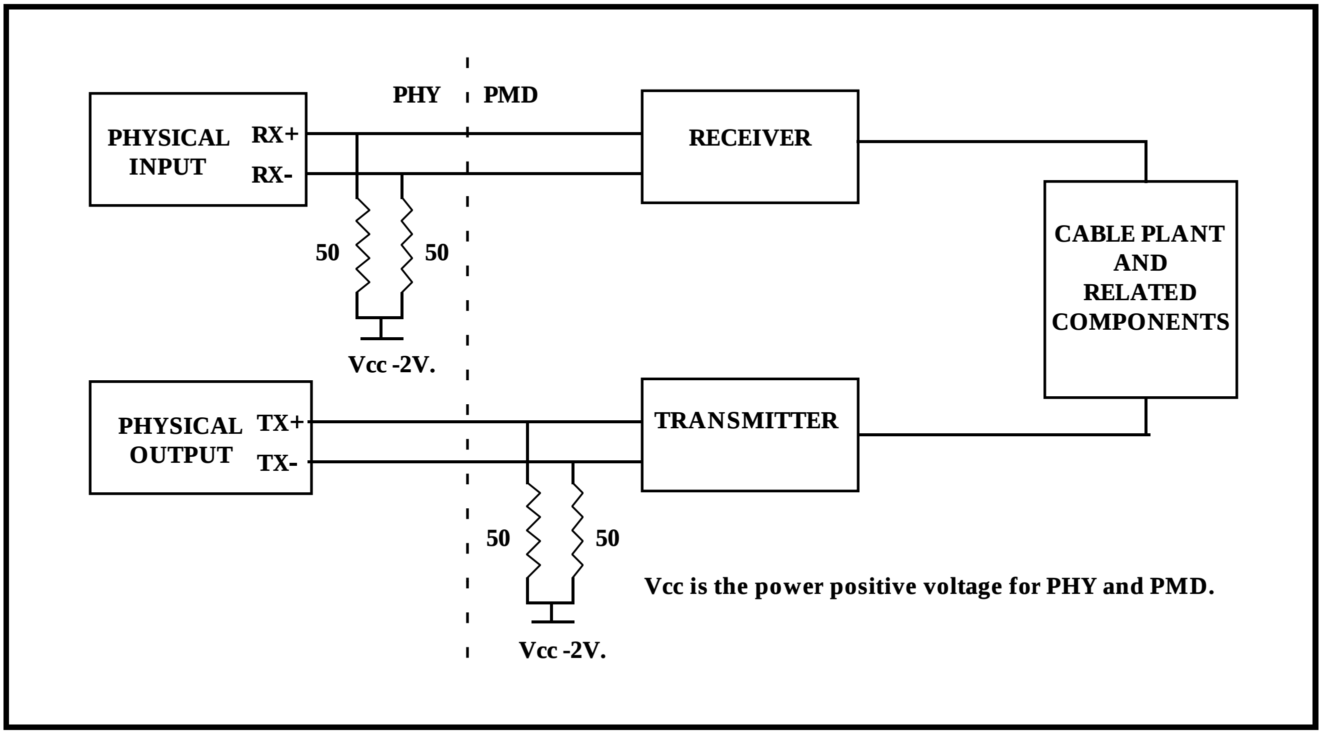

Figure B.1 – Test configuration for dc-coupled components

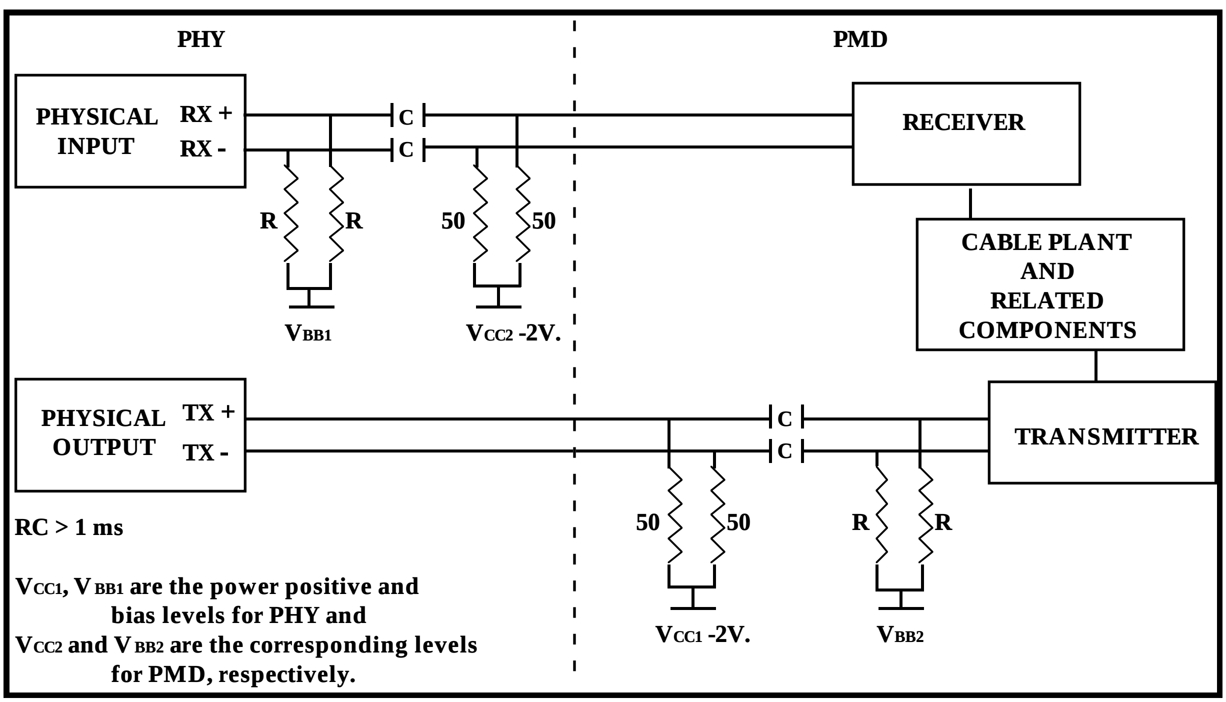

Figure B.2 – Test configuration for ac-coupled components

Annex C
(informative)

Example of system jitter allocation

This annex provides information on jitter in a TP-PMD link.

C.1 Jitter constraints

TP-PMD has been conceived and developed to work with existing PHY silicon. However, interoperability is defined at the MIC, so normative jitter specifications are defined at the MIC, not at internal interfaces. Specifications of jitter performance at internal interfaces are informative only.

The LCF-PMD optical jitter example (annex E of ANSI X3.237) showed a jitter budget with four components: Duty Cycle Distortion (DCD), Data Dependent Jitter (DDJ), Random Jitter (RJ), and Static Alignment Error. Refer to the PMD document for a detailed explanation of these components. Table C.1 is a recreation of the LCF-PMD jitter example.

Table C.1 – System jitter budget example

ITEM	**DCD** (p-p)	**DDJ** (p-p)	**RJ** (p-p)
PH_UNITDATA.request (PHY Out)	0,4 ns	0,0 ns	0,32 ns
AOI (PMD Out)	1,0	0,6	0,76
AII (PMD In)	1,0	0,6	0,76
PH_UNITDATA.indication (PHY In)	1,4	1,6	3,002

Clock recovery jitter: 1)

SAE and Clock DDJ (C_DDJ)	1,5 ns peak-peak
Clock RJ (C_RJ)	1,8 ns peak-peak (0,143 ns rms)

NOTES

Peak-peak RJ components are evaluated at a probability of 1,0 x 10^{-12}. For a Gaussian distribution, the peak-peak jitter is then 14,0 times the rms jitter.

1) SAE, C_DDJ, and C_RJ are implementation-dependent.

Jitter in the TP-PMD transmitters, receivers and cabling is allocated between Duty Cycle Distortion, Data Dependent Jitter, and Random Jitter, similar to the manner used for the optical PMDs. Jitter in the recovered clock consists of Static Alignment Error (SAE), DCD, DDJ, and RJ. SAE is an offset of the decision time slot (clock) from the optimal sampling position. When the clock coincides with the optimal sampling position the minimum bit error rate (BER) is achieved. See annex A of ISO/IEC 9314-3 (PMD) for additional information on jitter measurements and definitions.

DCD is often caused by propagation delay differences between the two differential signal paths. DCD is the deviation of the measured code bit duration from the nominal code bit duration of 8 ns. The measurement technique for this distortion is defined in 9.1.8.

DDJ is related to the transmitted symbol sequence. It is caused by the limited bandwidth characteristics of the channel components, and DC imbalance caused by the combination of encoding and scrambling techniques. DDJ results from deviation in the average value of the encoded pulse sequence, which may cause base line wander and a possible change in the decision threshold levels in the receiver. A test pattern useful for DDJ due to baseline wander is provided in clause A.2.

This jitter budget is provided to document the thinking underlying the TP-PMD specifications and to serve as guidance for the development of TP-PMD and PHY components. Conforming FDDI stations are required to comply only with the normative requirements expressed in the main body of this standard. For the interconnection of conforming FDDI attachments the true requirement for interoperability is at the TP-MIC provided by each attachment. These requirements are given in clauses 8, 9, and 10.

The TP-PMD jitter budget assumes that DCD contributions add linearly between PHY Out and PHY In. It also assumes tha RJ contributions add linearly between PHY Out and PHY In. DDJ is expressed as the resultant error after the receiver has compensated for the cable and the baseline wander of the transmitted signal. Table C.2 shows these values.

Table C.2 – TP-PMD jitter budget example

ITEM	**DCD** (p-p)	**DDJ** (p-p)	**RJ** (p-p)
PH_UNITDATA.request (PHY Out)	0,4 ns	0,0 ns	0,32 ns
AOI (PMD Out)	0,9	1)	0,32
AII (PMD In)	0,9	1)	2,30
PH_UNITDATA.indication (PHY In)	1,3	2,0	2,64 2)

Clock recovery jitter: 3)

SAE and Clock DDJ (C_DDJ) 1,5 ns peak-peak

Clock RJ (C_RJ) 1,8 ns peak-peak (0,143 ns rms)

NOTES

1) DDJ contributions are not characterized at each interface. They are expressed as a residual error contribution into the PHY.

2) Includes contributions from NEXT, cable noise, ILD, and receiver.

3) Total jitter is then calculated in a manner similar to the optical jitter example. The calculation is as follows:

(PHY In)DCD + (PHY In)DDJ + (SAE + C_DDJ) + (((PHY In)RJ)** 2 + (C_RJ)** 2)** 1/2

1,30 ns + 2,00 ns + 1,50 ns + 2,64 ns + 1,80 ns = 8,00 ns

Annex D
(informative)

Labeling considerations

This annex describes recommended practices for connector and cable labeling for FDDI equipment.

The original PMD standard (ISO/IEC 9314-3) defines the use of FDDI Media Interface Connectors (MIC). The MIC includes two types of keying. Polarity keying prevents the transmit and receive signal paths from being reversed. Port type keying prevents the establishment of undesirable connection paths that would result in an FDDI network topology violation.

This TP-PMD standard defines a Twisted Pair MIC (TP-MIC), that includes polarity keying, but not port type keying. Because port type keying was eliminated, it is now possible to inadvertently attempt to establish an illegal connection. Illegal connections are usually rejected by Station Management based on connection signaling. This situation, however, is not desirable, and can be minimized through the implementation of port type labeling on the equipment, the cabling, and the wall jack if appropriate.

D.1 FDDI station labeling

The FDDI station should be labeled in a location approximately close to or on the station port to identify it as an FDDI device, and provide information to assist in the proper network connection. The labeling system, described in table D.1, provides information on the connector type, PMD and port type.

On equipment with multiple station ports of the same classification, a single label may be used if it improves the identification of the station ports.

FDDI stations supporting field reconfiguration should also include field configurable labeling. As an example, an SAS station could be reconfigured to a DAS station. The original SAS port label should be changed to reflect the new port type. A less desirable alternative is to dual label those ports capable of field configuration. This should be done only in those cases where the proper port type is obvious based on the station configuration. The “S” type port could be dual marked as “S/B”, with the assumption that the port is “S” type when configured as an SAS station, and “B” when configured as a DAS station.

Table D.1 – FDDI station labeling recommendation

Code meaning	Code letter
Connector type	
MIC	M
LCF-MIC SC type	C
LCF-MIC ST type	T
UTP MIC	J
STP MIC	D
PMD type	
Original PMD	P
LCF-PMD	L
TP-PMD (STP)	S
TP-PMD (UTP)	U
SMF-PMD (rcv/xmt type 1)	1
SMF-PMD (rcv/xmt type 2)	2
SMF-PMD (rcv type 1, xmt type 2)	3
SMF-PMD (rcv type 2, xmt type 1)	4
SPM	H
Port type	
A port	A
B port	B
Master port	M
Slave port	S

The recommended label format is:

FDDI-XYZ, where

X=Connector type,

Y=PMD type,

Z=Port type

Some examples of this scheme are:

FDDI-CLS refers to an **SC** type connector on an **LCF-PMD** type interface, which is acting as a single attach **Slave** type port

FDDI-JUM refers to a **TP-MIC** type connector on a **TP-PMD UTP** type interface, which is acting as a single attach **Master** type port

Annex E
(informative)

Alternative cable plant usage

E.1 Alternative twisted pair types

Different twisted pair cable types exhibit various insertion loss, crosstalk, and insertion loss deviation characteristics. As a result, the choice of twisted pair type may affect the maximum achievable distance between stations.

In developing this standard, work focused on 100 ohm category 5 UTP cable and 150 ohm STP cable. Cable types other than those specified in the standard may have unacceptable performance over the required ranges, and be unsuitable for use with TP-PMD.

Cable balance, screening, and installation practices can affect Electromagnetic Compatibility (EMC) performance for both emissions and susceptibility. Testing may be required to ensure compliance with regulatory guidelines.

Annex F
(informative)

Impedance and insertion loss deviation

The Active Output Interface, the various items making up the cable plant and the Active Input Interface each have associated characteristic impedances which are in general frequency dependent. When connected together signals which are sent over the combined path will suffer from reflections at the interfaces between parts exhibiting different characteristic impedances. These reflections (and other effects) result in the path exhibiting deviations from its expected frequency response. As these deviations are not generally equalized they result in a degree of eye closure at the receiver. For this reason the value of these deviations is limited in the main body of the specification.

It has been shown that if the impedance of parts of the system differs excessively from some nominal impedance then there is a risk that the overall path will exhibit excessive frequency response deviations due to reflections. It is difficult to be precise about what constitutes excessive impedance mismatch as much depends on the sequence, number and proximity of the mismatches. For this reason the mixing of cable plant items of different characteristic impedance is not recommended.

Cable plant that has a nominal impedance different from that of the Active Input Interface and Active Output Interface may be used, provided that suitable media interface adapters (matching transformers) are used. In this case the media interface adapters must be considered to be part of the cable plant.

Annex G
(informative)

Stream cipher scrambling function

The purpose of scrambling is to spread the transmission spectrum to minimize electromagnetic compatibility problems.

The operation of the scrambling function is intended to be transparent to the other aspects of the FDDI protocol, including:

a) Transmission of PHY Service Data Units (SDUs, i.e. tokens and frames in basic mode and cycles in hybrid mode);

b) Transmission of line states during Connection Management signaling sequences and as preambles between PHY SDUs;

c) Clocking and smoothing functions of PHY;

d) Symbol code (i.e., 4B/5B code in the PHY standard);

e) Line code (i.e., MLT-3 for the TP-PMD standard);

f) Error detection and recovery mechanisms of PHY, HRC, MAC, and SMT.

In this context transparency means that the other aspects of the FDDI protocol are not affected by the behavior of the scrambling function; however, the behavior of other aspects of the FDDI protocol may affect the scrambling function. The effects of other aspects of the FDDI protocol on the scrambling function can be summarized for the modes of operation of a FDDI physical link:

g) Off – No signal is being transmitted. Transmit_Enable and Signal_Detect are deasserted;

h) Signaling – Continuous line state signals are being transmitted under control of Connection Management (CMT). Each line state has a minimum duration of 50 µs and a maximum duration of hundreds of milliseconds to many seconds;

i) Preamble – Idle Line State (ILS) is being transmitted between PHY SDUs. The smoothing function maintains, with a high probability, at least 60 bits of preamble between frames in basic mode and at least 20 bits of preamble between cycles in hybrid mode;

j) Active – A PHY SDU is being transmitted. Each SDU starts with an IIIIJK symbol sequence. The maximum frame length in basic mode (including the IIIIJK symbol sequence) is 360 µs. The maximum cycle length in hybrid mode (including the IIIIJK symbol sequence) is 125 µs;

k) Noise – None of the other modes are detected during a timed interval. After a few milliseconds CMT may attempt to restart the connection. After many milliseconds CMT may declare the link bad.

To be transparent to the other aspects of the FDDI protocol, the descrambler must be able to:

l) Acquire synchronization during the signaling and preamble modes of operation of the physical link;

m) Maintain synchronization during the signaling, preamble and active modes of operation of the physical link;

n) Detect potential loss of synchronization and attempt to resynchronize when loss of synchronization could trigger or aggravate the noise mode of operation of the physical link.

Transmit_Enable and Signal_Detect are described in 10.2 and 10.1.1, respectively. The FDDI standards on PHY (ISO 9314-1) and PHY-2 contain descriptions of the clocking and smoothing functions, the line states and the 4B/5B code symbols. The FDDI standards on MAC (ISO 9314-2) and MAC-2 contain descriptions of tokens and frames. The FDDI standard on HRC contains a description of cycles. The FDDI standards on SMT and SMT-2 contain descriptions of Connection Management.

The remainder of this annex explains the theory of stream cipher coding, followed by examples of stream cipher scrambler and descrambler designs that conform to the requirements in 7.1.2 and 7.2.3, respectively. These examples have been chosen to illustrate design techniques. They are not intended to define either a recommended or an optimal design. Other conforming designs have been developed and are not excluded by this standard.

The designs are described as Verilog modules.

G.1 Stream cipher scrambling

The stream cipher method of scrambling is used to minimize electromagnetic emissions from the TP-PMD physical link. Stream ciphering randomizes the data spectrum by the addition of a pseudorandom key sequence to the plaintext sequence transmitted by the PHY. The length of the pseudorandom sequence is chosen so as to reduce radiated emissions by approximately 20 dB when the station is transmitting the Idle Line State. Such reduction is necessary in order to meet regulatory requirements in many countries. The pseudorandom sequence is subtracted by the receiver in order to recover the transmitted data. Stream ciphering also has the desirable property that single bit errors in the received ciphertext bit stream decode as single bit errors in the recovered plaintext stream. Figure G.1 illustrates these concepts.

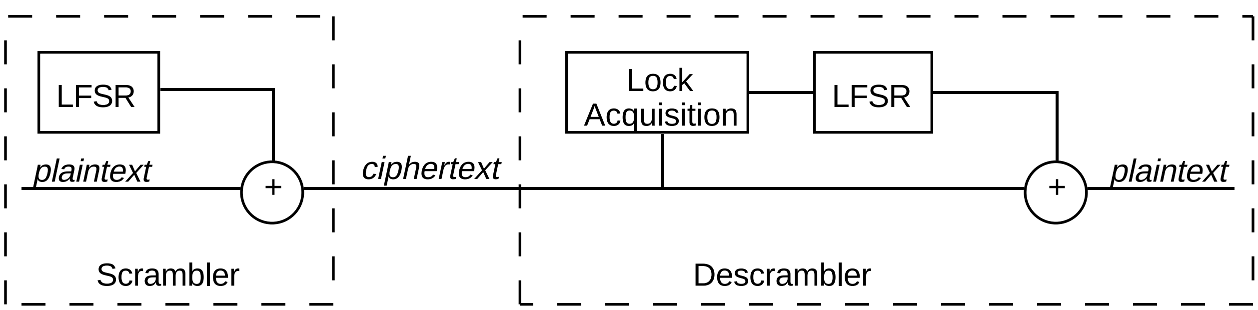

Figure G.1 – Cipher overview

For transmission, plaintext is scrambled by the modulo 2 addition of a pseudorandom sequence with the plaintext data to be transmitted. The pseudorandom sequence is generated by a Linear Feedback Shift Register (LFSR) which is then exclusive ORed with the plaintext data stream to produce the transmitted ciphertext. As noted above, the sequence length is chosen to minimize electromagnetic emissions. A sequence length of 11 bits has been shown to provide the necessary emissions reduction with a reasonable implementation complexity.

At the receiver, the plaintext is recovered by modulo 2 subtraction of the identical pseudorandom sequence from the ciphertext. This can only occur when the receiver's LFSR is synchronized with the transmitter's LFSR, so that the pseudorandom sequence applied to decode the ciphertext is the same sequence applied to encode the plaintext.

Synchronization of the descrambler can be achieved by using the FDDI line states. The line states produce patterns in the ciphertext which the descrambler uses to recognize the receipt of a line state. The descrambler uses this information to hypothesize a value for the LFSR's seed, and check the resulting plaintext output to determine if synchronization of the LFSRs has been achieved.

Clauses G.2 and G.3 show examples of a stream cipher implementation for scrambler and descramblers.

G.2 Stream Cipher Scrambler Example

```
//
// STREAM CIPHER SCRAMBLER
//
// for bit serial data path with parallel key stream load
//
// txclk:       transmit bit clock
// txen:        transmit enable (disables scrambler)
// tnrzdin:   unscrambled input NRZ data stream (plaintext)
// tnrzdout: scrambled output NRZ data stream (ciphertext)
//
module scrambler (txclk, txen, tnrzdin, tnrzdout);
input txclk, txen, tnrzdin;
output tnrzdout;
wire [11:0]s;          // descrambler key stream
reg [10:0]ds;          // key stream register
reg tnrzdout;          // ciphertext output bit
//
// KEY STREAM
//
assign s[11:1] = ds[10:0];      // shift previous bits
assign s[0] = s[11] ^ s[9];     // generate newest bit
always @(posedge txclk)
    if (!txen)
        ds[10:0] = #1 11'h0;        // reset key stream
    else if ( ds == 11'h0 )
        ds[10:0] = #1 11'h1;        // initialize key stream
    else
        ds[10:0] = #1 s[10:0]; // save current key stream
//
// CIPHERTEXT STREAM
//
always @(posedge txclk)
    tnrzdout = #1 s[0] ^ tnrzdin;          // scramble NRZ data bit
endmodule
```

G.3 Stream cipher descrambler example

```
//
// STREAM CIPHER DESCRAMBLER
//
// for bit serial data path with parallel key stream load
//
// rxclk:        recovered bit clock
// rxsd:         signal detect (disables descrambler)
// rxcd:         clock detect status (disables descrambler)
// rnrzdin:      scrambled input NRZ data stream (ciphertext)
// rnrzdout:     descrambled output NRZ data stream (plaintext)
// testmode:     enable test mode with short timeout
//
module descrambler (rxclk, rxsd, rxcd, rnrzdin, rnrzdout, testmode);
input rxclk, rxsd, rxcd, rnrzdin, testmode;
output rnrzdout;
wire [11:0]c;           // ciphertext input stream
reg [10:0]dc;           // ciphertext stream register
wire [10:0]h;           // descrambled hypothesis stream
reg [9:0]dh;            // hypothesis stream register
wire quiet;             // quiet pattern recognized in hypothesis stream
wire halt;              // halt pattern recognized in hypothesis stream
wire master;            // master pattern recognized in hypothesis
wire idle;              // idle pattern recognized in hypothesis stream
wire start;             // start pattern recognized in hypothesis stream
wire enable;            // enable descrambler
wire load;              // load descrambler from hypothesis stream
wire [10:0]hp;          // plaintext pattern derived from hypothesis stream
wire [11:0]u;           // descrambler key stream
reg [10:0]du;           // key stream register
reg rnrzdout;           // plaintext output bit
reg [4:0]idlecount;     // idle bit counter
wire idlestate;         // idle line state – at least 20 idle bits received
reg wasidle;            // idle pattern was recognized
wire active;            // active line state – IIIIJK received
reg [16:0]locktime;     // lock timer – time since idle line state received
reg locked;             // 1 = locked/synchronized, 0 = not synchronized
```

```
//
// CIPHERTEXT STREAM
//
assign c[11:1] = dc[10:0];              // shift previous bits
assign c[0] = rnrzdin;                  // get newest bit
always @(posedge rxclk)
        dc[10:0] = #1 c[10:0];          // save current bits
//
// HYPOTHESIS STREAM
//
assign h[10:1] = dh[9:0];                       // shift previous bits
assign h[0] = c[11] ^ c[9] ^ c[0];   // generate newest bit
always @(posedge rxclk)
        dh[9:0] = #1 h[9:0];            // save current bits
//
// HYPOTHESIS PATTERN RECOGNITION
//
assign quiet = ( h == 11'b0_00000_00000 )? 1'b1 :  1'b0;          // QQQ
assign halt = ( h == 11'b110_01110_011 )? 1'b1 :  1'b0;           // altered HHH
assign master = ( h == 11'b110_00000_011 )? 1'b1 :  1'b0;  // altered HQH
assign idle = ( h == 11'b1_11111_11111 )? 1'b1 :  1'b0;           // III
// the start pattern is needed to support hybrid mode
assign start = ( h == 11'b1_11000_10001 )? 1'b1 :  1'b0;          // IJK
assign enable = rxsd & rxcd;       // enable if signal detect and clock detect
assign load = (~locked) & (quiet | halt | master | idle);
assign hp = {            // generate plaintext bits for hypothesis patterns
        /* bit 10*/   idle | halt | master,
        /* bit 9*/    idle,
        /* bit 8*/    idle,
        /* bit 7*/    idle,
        /* bit 6*/    idle,
        /* bit 5*/    idle | halt,
        /* bit 4*/    idle,
        /* bit 3*/    idle,
        /* bit 2*/    idle,
        /* bit 1*/    idle,
        /* bit 0*/    idle | halt | master
        };
```

```
//
// KEY STREAM
//
assign u[11:1] = du[10:0];          // shift previous bits
assign u[0] = u[11] ^ u[9];         // generate newest bit
always @(posedge rxclk)
        if (!enable)
                du[10:0] = #1 11'h0;                // reset key stream
        else if (load)
                du[10:0] = #1 c[10:0] ^ hp[10:0];  // load new key stream
        else
                du[10:0] = #1 u[10:0];        // save current key stream
//
// PLAINTEXT STREAM
//
always @(posedge rxclk)
        rnrzdout = #1 u[0] ^ rnrzdin;              // descramble NRZ data bit
//
// IDLE LINE STATE DETECTOR
//
`define MINIDLE (5'd21)            // idle line state after 22 idle bits
always @(posedge rxclk)
        if ( (!enable) || (!rnrzdout) )
                idlecount = #1 5'h0;                            // reset
        else if (idlecount < `MINIDLE)
                idlecount = #1 idlecount + 5'h1;          // increment
        else
                idlecount = #1 `MINIDLE;                        // force expired
//
// alternatively, idlecount can be a shift register counter
// always @(posedge rxclk)
//              if ( (!enable) || (!rnrzdout) )
//                      idlecount = #1 5'h0E;                           // reset
//              else if ( !( idlecount == 5'h1F ) )
//                      idlecount = #1 { idlecount[3:0],           // increment
//                                                              idlecount[4] ^ locktime[2] };
//              else
//                      idlecount = #1 5'h1F;                           //force expired
```

```
//
assign idlestate = ( enable && rnrzdout && (idlecount == `MINIDLE) );
//
// IIIIJK DETECTOR
//
// this logic is needed to support hybrid mode
always @(posedge rxclk)
        if ( (!enable) || locked || (!h[10]) )
                wasidle = #1 1'b0;              // reset
        else if (load)
                wasidle = #1 idle;              // load
        else
                wasidle = #1 wasidle;           // remember
assign active = ( enable && wasidle && start );
//
// SYNCHRONIZATION STATE
//
`define MAXLOCK (17'h1FFFF)
                                        // timeout after 2^17 bits (1.048 milliseconds)
// the following definition causes shorter timeouts in test mode
`define MINTEST (`MAXLOCK – 17'd260)
                                        // timeout after 260 bits (1 claim frame)
always @(posedge rxclk)
        if ( idlestate || active )
                locktime = #1 (testmode)? `MINTEST :  17'h0;     // reset
        else if (locktime < `MAXLOCK)
                locktime = #1 locktime + 17'h1;                  // increment
        else
                locktime = #1 `MAXLOCK;                          // force expired
//
// alternatively, locktime can be a shift register counter
// always @(posedge rxclk)
//              if ( idlestate || active )
//                      locktime = #1 17'h1FFFE;                 // reset
//              else if ( !( locktime == 17'h1FFFF ) )
//                      locktime = #1 { locktime[15:0],          // increment
//                                      locktime[16] ^ locktime[2] };
//              else
```

```
//                  locktime = #1 17'h1FFFF;                    // force expired
//
always @(posedge rxclk)
        if ( idlestate || active )
                locked = #1 1'b1;                  // set
        else if ( (!enable) || (locktime == `MAXLOCK) )
                locked = #1 1'b0;                  // reset
        else
                locked = #1 locked;          // remember
//
endmodule
```

Annex H
(informative)

Equipment cabling in a structured cabling context

All connectors for TP-PMD are wired the same. The result of this is that the crossover from transmit to receive that must be provided somewhere in any point to point communication system has to be provided in the wiring system. To avoid confusion this must be done in a systematic way. LANs which are primarily designed for structured wiring situations are generally designed for cabling which is wired straight through, that is the conductors are wired to the same connector pin numbers at each end of the cabling and the connectors are wired differently in the hubs vs. end stations (or "up" port vs. "down" port); such is not the case in FDDI. Universal connector pinning was chosen in TP-PMD to be consistent with the rest of FDDI and to accommodate the wide variety of possible wiring schemes. Hub oriented structured wiring is only one of these schemes.

The following recommends a uniform practice for providing the crossover function for TP-PMD in a hub oriented, generic structured wiring context, e.g., that specified in ANSI/EIA/TIA 568 plus EIA/TIA TSB 36.

There are three different cabling sections in a generic wiring system. These are (1) the work area cabling which connects the DTE to the work area telecommunications outlet (2) the in-the-wall cabling as specified in the commercial building telecommunications cabling standard and (3) the cross-connect and equipment wiring that is in the telecommunications closet/equipment room.

It is recommended:

1) That there be only a single crossover in the wiring between the TP-MIC on the DTE and the TP-MIC on the hub.

NOTE – The actual requirement is that there be an odd number.

2) That the single crossover be in the telecommunications closet.

3) That, if the crossover is implemented in a connectorized patch cord, the patch cord have a distinctive color from other patch cords and work area cables. For example, a yellow color is sometimes used for crossover cords.

The purpose of this recommendation is to minimize the confusion associated with determining the type of patch cord required (straight or crossover) and to isolate cross-over considerations from less-expert end users. The above scheme allows for a single type of work area cable (4 pair, Category 5 100 ohm UTP wired straight through and terminated at each end in modular plugs) to serve as a universal work area cable in office areas served by the commercial building telecommunications cabling standard. It also provides for a centralized point for the usage of crossover cables and a uniform means for distinguishing them.

Annex I
(informative)

Common mode cable termination

This annex deals with methods of terminating the cable for improved EMC performance. Such improvements include reduction of radiated emissions and increased immunity to electromagnetic noise. Such techniques may prove useful in some implementations.

Work shown at the TP-PMD ad hoc working group indicated that such techniques have no impact on interoperability between TP-PMD implementations. That is to say, the presence or absence of such a technique in Station A did not affect the ability of Station B to interoperate with Station A.

Two techniques of terminating unused pairs of the cable were discussed. The first consisted of a scheme in which the common mode impedance of the cable pairs was resistively terminated at the station. Such a scheme could be implemented as shown in figure I.1.

The second technique involved the termination of one or more unused cable pairs to the chassis reference of the station. Such a scheme could be implemented as shown in figure I.2.

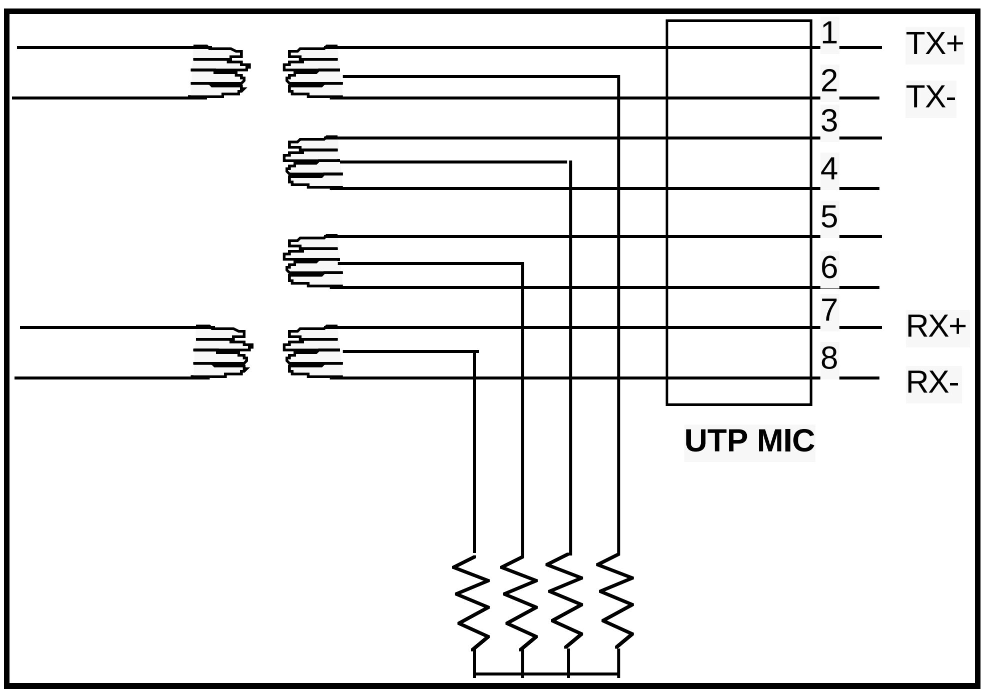

Figure I.1 – Example of a resistive termination of pairs

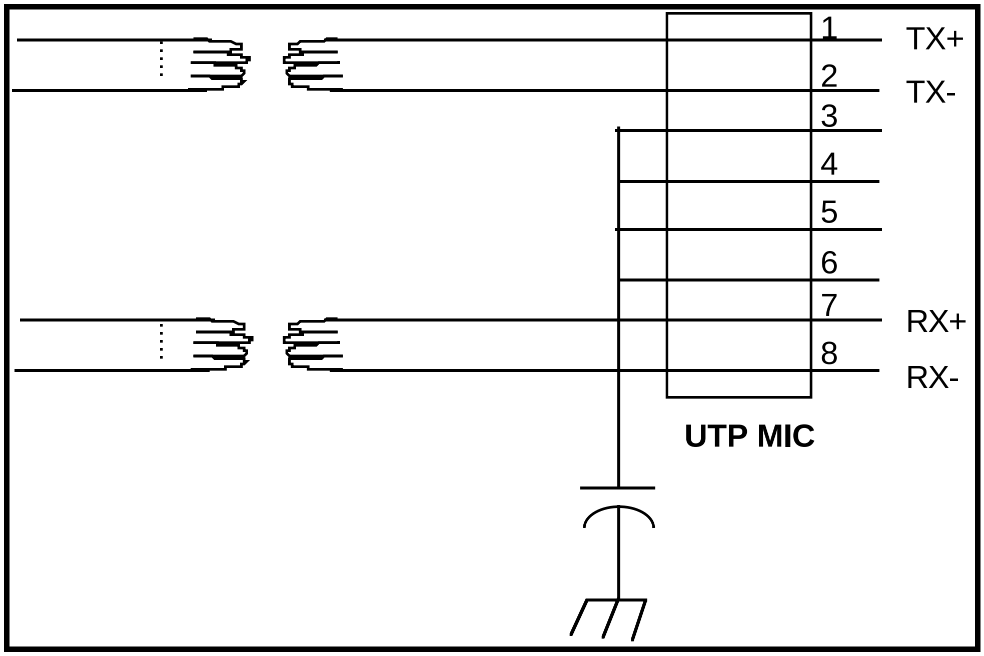

Figure I.2 – Example of a common mode termination to chassis reference

Annex J
(informative)

Twisted Pair Active Output Interface template

The normative requirements for the TP-PMD AOI are specified in clause 9. The following template is provided as a quick check on the output of a transmitting station.

A template for the eye pattern of the differential output voltage is shown in figure J.1. For the measurement, the AOI is transmitting scrambled Halt Line State into the test load specified in 9.1.1.1, or 9.1.2.1. The oscilloscope employed to make the eye pattern measurement is synchronized to the transmit clock or its equivalent (for example, a clock generated by a very narrow-bandwidth 125 MHz PLL phase locked to the transmit waveform).

The template is first centered vertically on the eye pattern baseline; it should be translated horizontally and scaled in amplitude for the best fit to the eye pattern. For UTP, the scaling factor is a minimum of 0,95 and a maximum of 1,05. For STP, the scaling factor is a minimum of 1,165 and a maximum of 1,285. The differential peak output voltage, V_{out}, as defined in 9.1.1.2 or 9.1.2.2 is the best fit multiplied by 1000 mV. The differential peak output voltage is defined as the average positive and the average negative differential output voltage extremes exclusive of any overshoot. The eye pattern resides entirely within the translated and best fit scaled template.

The mean voltage magnitudes in the windows A+ and A- should be measured using the mean voltage in window zero as a reference. The ratio of the positive voltage magnitude to the negative voltage magnitude should be 0,98 to 1,02.

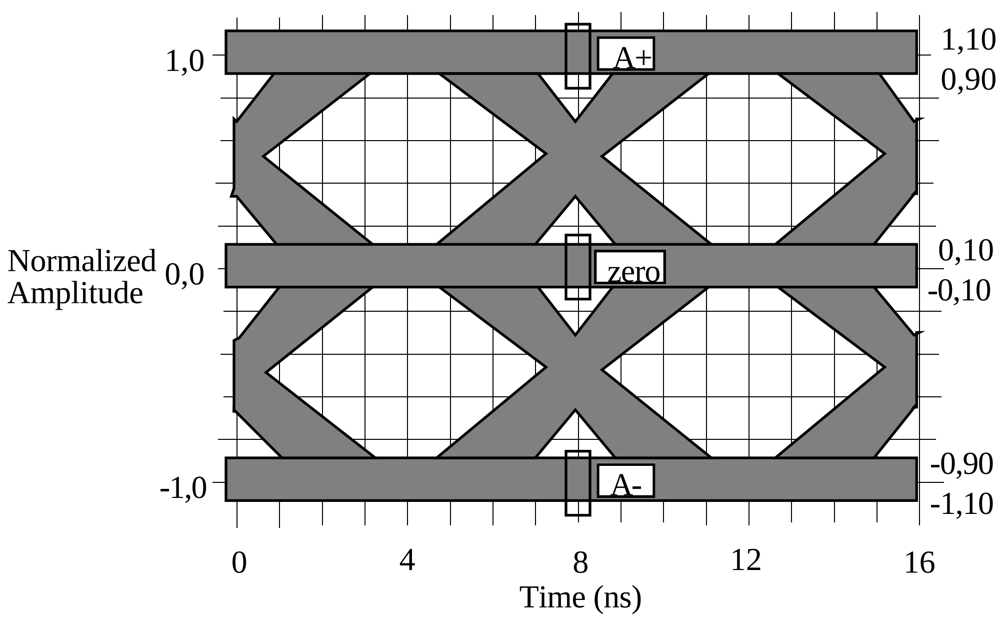

Figure J.1 – Twisted Pair Active Output Interface template

Annex K
(informative)

Bibliography

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