
**Information technology — Generic digital
audio-visual systems —**

**Part 4:
Lower-layer protocols and physical
interfaces**

*Technologies de l'information — Systèmes audiovisuels numériques
génériques —*

Partie 4: Protocoles et interfaces physiques de la couche inférieure

Reference number
ISO/IEC 16500-4:1999(E)



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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO/IEC 16500 may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 16500-4 was prepared by DAVIC (Digital Audio-Visual Council) and was adopted, under the PAS procedure, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in parallel with its approval by national bodies of ISO and IEC.

ISO/IEC 16500 consists of the following parts, under the general title *Information technology — Generic digital audio-visual systems*:

- *Part 1: System reference models and scenarios*
- *Part 2: System dynamics, scenarios and protocol requirements*
- *Part 3: Contours: Technology domain*
- *Part 4: Lower-layer protocols and physical interfaces*
- *Part 5: High and mid-layer protocols*
- *Part 6: Information representation*
- *Part 7: Basic security tools*
- *Part 8: Management architecture and protocols*
- *Part 9: Usage information protocols*

Introduction

ISO/IEC 16500 defines the minimum tools and dynamic behavior required by digital audio-visual systems for end-to-end interoperability across countries, applications and services. To achieve this interoperability, it defines the technologies and information flows to be used within and between the major components of generic digital audio-visual systems. Interoperability between these components and between individual sub-systems is assured through specification of tools and specification of dynamic systems behavior at defined reference points. A reference point can comprise one or more logical (non-physical) information-transfer interfaces, and one or more physical signal-transfer interfaces. A logical interface is defined by a set of information flows and associated protocol stacks. A physical interface is an external interface and is fully defined by its physical and electrical characteristics. Accessible reference points are used to determine and demonstrate compliance of a digital audio-visual subsystem with this international standard.

A summary of each part follows.

ISO/IEC 16500-1 (DAVIC 1.3.1a Part 2) defines the normative digital audio-visual systems technical framework. It provides a vocabulary and a Systems Reference Model, which identifies specific functional blocks and information flows, interfaces and reference points.

ISO/IEC 16500-2 (DAVIC 1.3.1a Part 12) defines system dynamic behavior and physical scenarios. It details the locations of the control functional entities along with the normative protocols needed to support the systems behavior. It is structured as a set of protocol walk-throughs, or “*Application Notes*”, that rehearse both the steady state and dynamic operation of the system at relevant reference points using specified protocols. Detailed dynamics are given for the following scenarios: video on demand, switched video broadcast, interactive broadcast, and internet access.

ISO/IEC 16500-3 (DAVIC 1.3.1a Part 14) provides the normative definition of DAVIC Technology Contours. These are strict sets of Applications, Functionalities and Technologies which allow compliance and conformance criteria to be easily specified and assessed. This part of ISO/IEC 16500 contains the full details of two contours. These are the Enhanced Digital Broadcast (EDB) and Interactive Digital Broadcast (IDB). ISO/IEC 16500-3 specifies required technologies and is a mandatory compliance document for contour implementations.

ISO/IEC 16500-4 (DAVIC 1.3.1a Part 8) defines the toolbox of technologies used for lower layer protocols and physical interfaces. The tools specified are those required to digitize signals and information in the Core Network and in the Access Network. Each tool is applicable at one or more of the reference points specified within the Delivery System. In addition a detailed specification is provided of the physical interfaces between the Network Interface Unit and the Set Top Unit and of the physical interfaces used to connect Set Top Boxes to various peripheral devices (digital video recorder, PC, printer). The physical Delivery System mechanisms included are copper pairs, coaxial cable, fiber, HFC, MMDS, LMDS, satellite and terrestrial broadcasting.

ISO/IEC 16500-5 (DAVIC 1.3.1a Part 7) defines the technologies used for high and mid-layer protocols for ISO/IEC 16500 digital audio-visual systems. In particular, this part defines the specific protocol stacks and requirements on protocols at specific interfaces for the content, control and management information flows.

ISO/IEC 16500-6 (DAVIC 1.3.1a Part 9) defines what the user will eventually see and hear and with what quality. It specifies the way in which monomedia and multimedia information types are coded and exchanged. This includes the definition of a virtual machine and a set of APIs to support interoperable exchange of program code. Interoperability of applications is achieved, without specifying the internal design of a set top unit, by a normative Reference Decoder Model which defines specific memory and behavior constraints for content decoding. Separate profiles are defined for different sets of multimedia components.

ISO/IEC 16500-7 (DAVIC 1.3.1a Part 10) defines the interfaces and the security tools required for an ISO/IEC 16500 system implementing security profiles. These tools include security protocols which operate across one or both of the defined conditional access interfaces CA0 and CA1. The interface CA0 is to all security and conditional access functions, including the high speed descrambling functions. The interface CA1 is to a tamper resistant device used for low speed cryptographic processing. This cryptographic processing function is implemented in a smart card.

ISO/IEC 16500-8 (DAVIC 1.3.1a Part 6) specifies the information model used for managing ISO/IEC 16500 systems. In particular, this part defines the managed object classes and their associated characteristics for managing the access network and service-related data in the Delivery System. Where these definitions are taken from existing standards, full reference to the required standards is provided. Otherwise a full description is integrated in the text of this part. Usage-related information model is defined in ISO/IEC 16500-9.

ISO/IEC 16500-9 (DAVIC 1.3.1a Part 11) specifies the interface requirements and defines the formats for the collection of usage data used for billing, and other business-related operations such as customer profile maintenance. It also specifies the protocols for the transfer of Usage Information into and out of the ISO/IEC 16500 digital audio-visual system. In summary, flows of audio, video and audio-visual works are monitored at defined usage data collection elements (e.g. servers, elements of the Delivery System, set-top boxes). Information concerning these flows is then collected, processed and passed to external systems such as billing or a rights administration society via a standardised usage data transfer interface.

Additional Information

ISO/IEC TR 16501 is an accompanying Technical Report. Further architectural and conformance information is provided in other non-normative parts of DAVIC 1.3.1a (1999). A summary of these documents is included here for information.

ISO/IEC TR 16501 (DAVIC 1.3.1a Part 1) provides a detailed listing of the functionalities required by users and providers of digital audio-visual applications and systems. It introduces the concept of a contour and defines the IDB (Interactive Digital Broadcast) and EDB (Enhanced Digital Broadcast) functionality requirements which are used to define the normative contour technology toolsets provided in ISO/IEC 16500-3.

DAVIC 1.3.1a Parts 3, 4 and 5 are DAVIC technical reports. They provide additional architectural and other information for the server, the delivery-system, and the Service Consumer systems respectively. Part 3 defines how to load an application, once created, onto a server and gives information and guidance on the protocols transmitted from the set-top user to the server, and those used to control the set-up and execution of a selected application. Part 4 provides an overview of Delivery Systems and describes instances of specific DAVIC networked service architectures. These include physical and wireless networks. Non-networked delivery (e.g. local storage physical media like discs, tapes and CD-ROMs) are not specified. Part 5 provides a Service Consumer systems architecture and a description of the DAVIC Set Top reference points defined elsewhere in the normative parts of the specification.

DAVIC 1.3.1a Part 13 is a DAVIC technical report, which provides guidelines on how to validate the systems, technology tools and protocols through conformance and / or interoperability testing.

Information technology — Generic digital audio-visual systems — Part 4: Lower layer protocols and physical interfaces

1. Scope

This part of ISO/IEC 16500 provides a toolbox consisting of lower layer protocols and physical interfaces. Each tool is applicable at one or more of the reference points within the delivery system. The physical delivery media that have been identified for this version of ISO/IEC 16500-4 are copper pairs, coaxial cable, microwave, fiber and satellite. Removable information carrying physical media (e.g. optical discs and tapes) are not covered. The tools listed address the three parts of the delivery system, namely, the core network, the access network and the access-network-independent interface to the Set Top Unit (STU). Tools are also identified for the STU dataport interface and for a service provider system (SPS) internal network and an SPS/SPS core network.

Clause 6 specifies in detail the tools provided to digitize the physical media in the core network. In the case of a broadband core network, all these tools support high speed ATM transport. Clause 7 specifies in detail the tools provided to digitize the physical media in the access network (copper pairs, coax, satellite, microwave, fiber). All these tools support high speed MPEG-2-TS transport and/or high speed ATM transport. Clause 8 concerns the access-network-independent interface to the STU and provides a detailed specification of the physical interfaces between the network interface unit (NIU) and the STU. This physical interface can be internal or external to the Set Top Box (STB) and is independent from the physical interface used in the access network. It supports the transport of MPEG-2-TS and ATM between NIU and STU. Clause 9 concerns the STU dataport interface and specifies the physical interfaces used to connect an STB to various peripheral devices. It defines normative STU multimedia dataport tools and interfaces and also includes informative specifications for both PC and parallel dataports. These interfaces support the transport of MPEG-2-TS or IP. Clause 10 defines the physical interfaces for interconnections between cascaded SPS entities with or without an intervening core network and the physical interfaces for networks used to connect various hosts within an SPS.

2. Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO/IEC 16500. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/IEC 16500 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau (TSB) maintains a list of currently valid ITU-T Recommendations.

2.1 IEC, ISO, ISO/IEC and ITU-T normative references

IEC 60801-4:1988 *Electromagnetic compatibility for industrial process measurement and control equipment.*

Part 4: Electrical fast transient/burst requirements

IEC 61883-1:1998, *Consumer audio/video equipment – Digital interface – Part 1: General.*

IEC 61883-4:1998, *Consumer audio/video equipment – Digital interface – Part 4: MPEG-2 TS data transmission.*

ISO/IEC 7816-3:1989, *Identification cards – Integrated circuit(s) cards with contacts – Part 3: Electronic signals and transmission protocols.*

ISO/IEC 8802-3:1996, *Information technology - Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.*

ISO/IEC 8877: 1987, *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.*

ISO/IEC 11801:1995, *Generic cabling for customer premises, standards for generic cabling for information technology.*

ISO/IEC 13818-1:1996, *Information technology – Generic coding of moving pictures and associated audio information: Systems*

- ISO/IEC 13818-9:1996, *Extension for real-time interface for systems decoders*.
- ITU General Secretariat, Radio Regulations (1990), Volume 1, Article 8, Frequency Allocations Chapter RR8.
- ITU-R Recommendation 656. *Recommendations of the ITU-R (formerly CCIR), 1990 -- CCIR 656, Part I*.
- ITU-T Recommendation G.117 [Blue Book], *Transmission aspects of unbalance about earth (definitions and methods)*, version CCITT PA 1988, published March 1990.
- ITU-T Recommendation G.652 [Rev. 1], *Characteristics of a single-mode optical fiber cable*, version WTSC 1993, published February 1994.
- ITU-T Recommendation G.704 [Rev. 2], *Synchronous frame structures used at levels of 1544, 6312, 2048, 8448 and 44736 kbit/s*, July 95.
- ITU-T Recommendation G.707 [Rev. 2], *Synchronous digital hierarchy bit rates*, version WTSC 1993, published August 1993.
- ITU-T Recommendation G.708, [Rev. 2], *Network node interface for synchronous digital hierarchy*, version WTSC 1993, published November 1993.
- ITU-T Recommendation G.709 [Rev. 2], *Digital transmission systems - Terminal Equipment - General*, version WTSC 1993, published December 1993.
- ITU-T Recommendation G.804 [New], *ATM cell mapping into plesiochronous digital hierarchy (PDH)*, version November 1993, published October 1994.
- ITU-T Recommendation G.832 (11/1995), *Transport of SDH elements on PDH networks: Frame and multiplexing structures*.
- ITU-T Recommendation G.957 (07/1995), *Optical interfaces for equipment and systems relating to the synchronous digital hierarchy*.
- ITU-T Recommendation G.981 [New], *PDH optical line systems for the local network*, version January 1994, published November 1994.
- ITU-T Recommendation I.361 (11/1995), *B-ISDN ATM layer specification*.
- ITU-T Recommendation I.363.5 (08/1996), *B-ISDN ATM adaptation layer (AAL) specification: Type 5 AAL*.
- ITU-T Recommendation I.413 [Rev. 1], *B-ISDN user-network interface*, version WTSC 1993, published December 1993.
- ITU-T Recommendation I.430 [Rev. 1], *Basic user-network interface - Layer 1 specification*, version WTSC 1993, published March 1994.
- ITU-T Recommendation I.432 [Rev. 1], *B-ISDN user-network interface - Physical layer specification*, version WTSC 1993, published January 1994.
- ITU-T Recommendation O.9 [Blue Book], *Measuring arrangements to assess the degree of unbalance about earth*, version CCITT PA 1988, published July 1990.
- ITU-T Recommendation V.22 [Blue Book], *1200 bits per second duplex modem standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits*, version CCITT PA 1988, published November 1989.
- ITU-T Recommendation V.22 bis [Blue Book], *2400 bits per second duplex modem using the frequency division technique standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits*, version CCITT PA 1988, published November 1989.
- ITU-T Recommendation V.32 [Rev.1], *A family of 2-wire, duplex modems operating at data signaling rates of up to 9600 bit/s for use on the general switched telephone network and on leased telephone-type circuits*, version WTSC 1993, published January 1994.
- ITU-T Recommendation V.32 bis [New], *A duplex modem operating at data signaling rates of up to 14400 bit/s for use on a general switched telephone network and on leased point-to-point 2-wire telephone-type circuits*, version February 1991, published May 1991.
- ITU-T Recommendation V.34 [New], *A modem operating at data signaling rates of up to 28800 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits*, version September 1994, published December 1994.

2.2 Other normative references

- 1394 Trade Association, *Specification for AV/C Digital Interface Command Set*, September 13, 1996. Figure 5-1.
- ADSL Forum TR-002, *ATM over ADSL Recommendations*, March 1997 http://www.adsl.com/adsl_atm.html.
- Scope Note: Sections B.2, 3 (except only a single latency path shall be implemented, see 3.2), 4, 6.2, and 7.
- ANSI Standard T1.105, *SONET Basic Description including Multiplex Structure, Rate and Formats*.
- ANSI Standard T1.105.01, *SONET Automatic Protection Switching*.
- ANSI Standard T1.105.02, *SONET Payload Mappings*.
- ANSI Standard T1.105.03, *SONET Jitter and Network Interfaces*.
- ANSI Standard T1.105.04, *SONET Data Communication Channel Protocols and Architectures*.
- ANSI Standard T1.105.05, *SONET Tandem Connection Maintenance*.

ANSI Standard T1.105.06, *SONET Physical Layer Specification*.
 ANSI Standard T1.105.07, *SONET Sub STS-1 Interface Rates and Formats Specifications*.
 ANSI Standard T1.105.08, *SONET Directory Service for TMN and SONET*.
 ANSI Standard T1.105.09, *SONET Timing and Synchronization*.
 ANSI Standard T1.413, *Network and customer installation interfaces - Asymmetrical Digital Subscriber Line (ADSL) Metallic Interface*, version March 95.
 ATM Forum, *Physical Interface Specification for 25.6 Mbit/s over Twisted Pair Cable*, November 1995.
 ATM Forum, *UTOPIA: an ATM-PHY Interface Specification*, Level 1, Version 2.01 March 21, 1994.
 Bellcore document GR-253 [Issue 02], *Set: Synchronous Optical Network (SONET) Transport; Systems: Common Generic Criteria*. December 1995.
 CENELEC EN 50083-9, *Cabled distribution systems for television, sound and interactive multimedia signals. Part 9: Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams*. March 1997.
 DIN Specification 41612-5, *Test Specification*, October 1987.
 ETSI specification ETS 300 421, *Digital broadcasting systems for television, sound and data services; Framing structure, channel coding and modulation for 11/12 GHz satellite services*, version December 1994.
 ETSI Technical Report 328 on ADSL, edition 1, December 1996.
 IEEE Standard 1284-1994, *Signaling Method for a Bidirectional Parallel Peripheral Interface for Personal Computers* (ISBN 1-55937-427-6) [SH17335-NXG] (Note: optional in ISO/IEC 16500- see Subclause 9.4 below)
 IEEE Standard 1394-1995, *IEEE Standard for a High Performance Serial Bus*.
 Philips Semiconductor Specification, *The I²C-bus and how to use it (including specifications)*, 1995 Update, released April 1995, by Philips Semiconductor. Document number 9398-393-40011.

3. Definitions

This clause defines new terms, and the intended meaning of certain common terms, used in this part of ISO/IEC 16500. Annex A of ISO/IEC 16500-1 defines additional terms and, in some cases, alternative interpretations that are appropriate in other contexts. For convenience, the normative definitions below are included in the annex.

- 3.1. Access network (AN):** a part of the Delivery system consisting of a collection of equipment and infrastructures, that link a number of Service Consumer Systems to the rest of the Delivery system through a single (or a limited number of) common port(s).
- 3.2. Access node:** The element of the Access network containing centralized functions responsible for processing information flows in preparation for transport through the selected distribution network.
- 3.3. block:** a part of a system or parent block that is the container for one or more processes of one block substructure. A block is a scope unit and provides a static interface. When used by itself, block is a synonym for block instance.
- 3.4. cable modem:** a device that interfaces between an A4 reference point and an Hybrid Fiber Coax plant, or between an A0 reference point and that plant, such that the whole comprises a physical layer tool.
- 3.5. channel:** a connection conveying signals between two blocks (the conveyed signals represent information). Channels also convey signals between a block and the environment. Channels may be unidirectional or bi-directional.
- 3.6. client:** a service consuming object or system (block); (a synonym for **user**).
- 3.7. connect:** indicates the connection of a channel to one or more signal routes or the interconnection of signal routes.
- 3.8. connection:** an association of transmission channels or circuits, switching and other functional units set up to provide a means for a transfer of user, control and management information between two or more end points (blocks) in a telecommunications network.
- 3.9. connection service:** provides basic functions to create, maintain, and tear down connections.
- 3.10. Control Plane (CP):** a classification for objects that interact to establish, maintain, and release resources and provide session, transport, and connection control functions that facilitate transparent information transfers between ISP clients.

3.11. Core network: a portion of the Delivery system composed of networks, systems, equipment and infrastructures, connecting the Service providers to the Access networks.

NOTE: The term Core network, in the DAVIC use, is *wide sense* as it includes the notion of the access networks that are needed to link the Service providers Systems to the core network in strict sense (i.e., exclusive of any access network). This kind of access networks are not under consideration within DAVIC.

3.12. Delivery system (DS): The portion of the DAVIC System that enables the transfer of information between DS-users.

3.13. Distribution network: a collection of equipment and infrastructures that delivers information flows from the Access node to the Network termination elements of the Access network.

3.14. downstream: information flow direction is from an End Service provider System to an End Service Consumer System.

3.15. End-Service Consumer (ESC): a user, either human or machine, whose primary interaction with the system is through the STU.

3.16. End-Service Consumer System (ESCS): A system that (predominantly) consumes information. ESCSs are ISPS and ESPS clients. The ESCS includes the STU and the ESC.

3.17. End-Service provider (ESP): an entity with jurisdiction over a domain that contains a system that (predominantly) provides information to clients.

3.18. End-Service provider System (ESPS): a system that (predominantly) provides information to clients. ESPSs are ISP clients and may also be clients of other ESPSs. ESPSs consists of hardware and software sub-systems that use ISP services to provide video and multimedia services to ESCSs.

3.19. error: An error occurs during the interpretation of a valid specification of a system when one of the dynamic conditions of SDL is violated. Once an error has occurred, the subsequent behavior of the system is not defined.

3.20. interface: a point of demarcation between two blocks through which information flows from one block to the other. See logical and Physical Interface definitions for further details. A DAVIC interface may be physical-interface or a logical-interface.

3.21. interface definition: Interface definitions are the detailed physical definitions used to define the method of interaction between system entities. These definitions are provided for the various reference points. A finite set of interfaces may exist at each particular reference point.

3.22. Intermediate-Service provider (ISP): ISPs provide adjunct services and convey information among ESPs and ESCs.

3.23. layer: a collection of objects of the same hierarchical rank

3.24. logical information flow path: a sequence of information transfers from an initial information source object to a terminal information destination object either directly or through intermediate objects; different physical information may be associated with a logical information flow path segment or with the entire path in different implementations.

3.25. logical interface: an interface where the semantic, syntactic, and symbolic attributes of information flows is defined. Logical interfaces do not define the physical properties of signals used to represent the information. A logical interface can be an internal or external interface. It is defined by a set of information flows and associated protocol stacks.

3.26. Management Plane (MP): a plane that contains those interfaces and functions which support interactions which may be typified as being temporally disjoint from an off-hook interaction. Interactions among Management Plane objects may also occur concurrently with an off-hook interaction.

3.27. management-information: information exchanged by Management Plane objects; may be content-information or control-information.

3.28. network: a collection of interconnected elements that provides connection services to users

3.29. network control function: The Network Control Function is responsible for the error-free receipt and transmission of content flow information to and from the Server.

- 3.30. Network Interface Unit (NIU):** The NIU accepts network specific content-information flows from the Delivery system and provides a non-network specific interface to the Connectivity Entity in the STU. (additional definitions of the NIU may exist).
- 3.31. Network Related Control:** The Network Related Control entity provides control functions for network configuration, connection establishment and termination and information routing in a network instance of a Delivery system.
- 3.32. Network termination (NT):** the element of the Access network performing the connection between the infrastructure owned by the Access network operator and the Service Consumer System (ownership decoupling). The NT can be passive or active, transparent or not.
- 3.33. physical information flow path:** a channel or a sequence of channels that constitutes a real or virtual connection between an information source object and an information destination object.
- 3.34. Physical Interface:** An interface where the physical characteristics of signals used to represent information and the physical characteristics of channels used to carry the signals are defined. A Physical Interface is an external interface. It is fully defined by its physical and electrical characteristics. Logical information flows map to signal flows that pass through Physical Interfaces.
- 3.35. plane:** a category that identifies a collection of related objects, e.g., objects that execute similar or complementary functions; or peer objects that interact to use or to provide services in a class that reflects authority, capability, or time period. Management-plane service objects, for example, may authorize ISP-clients' access to certain control-plane service objects that in turn may allow the clients to use services provided by certain user-plane objects.
- 3.36. process:** a communicating extended finite state machine. Communication can take place via signals or shared variables. The behavior of a process depends on the order of arrival of signals in its input port
- 3.37. process instance:** an instance of a process created at system creation time or dynamically as a result of a create [request].
- 3.38. protocol:** set of message formats (semantic, syntactic, and symbolic rules) and the rules for message exchange between peer layer entities (which messages are valid when)
- 3.39. randomization:** the process of removing auto-correlation from a signal, i.e. white noise spectrum shaping at the transmitter side to ease symbol or bit timing recovery at the receiver side.
- 3.40. reference point:** a set of interfaces between any two related blocks through which information flows from one block to the other. A reference point comprises one or more logical (non-physical) information-transfer interfaces, *and* one or more physical signal-transfer interfaces.
- 3.41. S1:** content-information flow, from a source to a destination object on the User plane of any service layer.
- 3.42. S2:** control-information flow from a source to a destination object on the Control Plane of the Application Service Layer (SL1).
- 3.43. S3:** control-information flow from a source to a destination object on the Control Plane of the Session and Transport Service Layer (SL2).
- 3.44. S4:** control-information flow from a source to a destination object on the Control Plane of the Network Service Layer (SL3).
- 3.45. S5:** management-information flow from a source to a destination object on the Management Plane of the container object: the objects may be peers (service layer is known), or the service layer may be unspecified.
- 3.46. scrambling:** The process of making a signal unintelligible at the transmission point in order that it can only be received if an appropriate descrambling system is in place at the point of reception. Scrambling can be applied to audio, video or data signals
- 3.47. server:** any service providing system.
- 3.48. Service provider:** an entity that provides a service to a client.
- 3.49. Service Related Control:** an entity that provides all control functions for the services that are offered by a network instance of the Delivery system. The DSRM allows for SL0, SL1 and SL2 Service Related Control subsets.

3.50. session: an interval during which a logical, mutually agreed correspondence between two objects exists for the transfer of related information. A session defines a relationship between the participating users in a service instance.

3.51. Session Control Function: This entity, in a Service provider System, is responsible for establishing and terminating the environment in which an application will operate. This environment includes the quality of service requirements for both the application and product entities.

3.52. session services: provide basic functions to create, modify, maintain, and tear down sessions (negotiate and allocate network resources).

3.53. signal: an instance of a defined signal type representing information meaningful to a process instance.

3.54. signal route: indicates the flow of signals between a process type and either another process type in the same block or the channels connected to the block.

3.55. specification: a definition of the requirements of a system. A specification consists of general parameters required of the system and the functional specification of its required behavior. Specification may also be used as a shorthand for *specification and/or description*, e.g., in SDL specification or system specification.

3.56. symbol: a bit or a defined sequence of bits.

3.57. system: a collection of interacting objects that serves a useful purpose; typically, a primary subdivision of an object of any size or composition (including domains).

3.58. Time Division Multiple Access (TDMA): method to access a shared transmission medium where time is divided into slots and the nodes connected to the medium are synchronized by assigning each one of them one or more specific time slots to transmit

3.59. transparent information: information that is not significant semantically to an object used to transport the information.

3.60. type: a set of properties for instances. Examples of types in SDL include blocks, processes, services, signals, and systems.

3.61. upstream: information flow direction is from an ESC System to an ESP System.

3.62. user: a service consuming object or system (block).

3.63. User plane (UP): A classification for objects whose principal function is to provide transfer of (end) user information: user information may be user-to-user content (e.g., a movie), or private user-to-user data.

3.64. Value Added Service provider (VASP): This provider offers, for example, a Video-on-Demand Service to the end-user. Within the Systems Reference Model this is the ESP.

3.65. virtual channel: communication channel that provides for the sequential unidirectional transport of ATM cells

4. Acronyms and abbreviations

This clause defines the acronyms and abbreviations used in this part of ISO/IEC 16500. Annex B of ISO/IEC 16500-1 defines acronyms and abbreviations used within ISO/IEC 16500.

ADSL	Asymmetrical Digital Subscriber Line
AII	Active Input Interface
AIS	Alarm Indication Signal
AOI	Active Output Interface
ATM	Asynchronous Transfer Mode
AWG	American Wire Gauge
BER	Bit Error Ratio
BW	Bandwidth
CATV	Community Antenna TeleVision
CBD	Connection Block Descriptor
CMB	CRC Message Block
CRC	Cyclic Redundancy Check
DFP	Downstream Frame Period
DS	Downstream

EL-FEXT	Equal Level - Far End Cross Talk
ESF	Extended SuperFrame
ETSI	European Telecommunications Standards Institute
FEC	Forward Error Correction
FEXT	Far End Cross Talk
FIFO	First In First Out
FTTB	Fiber To The Building
FTTC	Fiber To The Curb
GSM	Global System for Mobile communications
HDTV	High Definition TeleVision
HEC	Header Error Control
HFC	Hybrid Fiber Coax
HRM	High Reliability Marker
ID	Identification
ISDN	Integrated Services Digital Network
IWU	InterWorking Unit Functionality
LFSR	Linear Feedback Shift Register
LSB	Least Significant Bit
MAC	Media Access Control
MPEG	Moving Pictures Experts Group
MSB	Most Significant Bit
MUX	Multiplex
NIU	Network Interface Unit
NRC	Network Related Control
NRZ	Non-Return-to-Zero
NSAP	Network Service Access Point
OSB	Output Signal Balance
PDH	Plesiochronous Digital Hierarchy
PDU	Packet Data Unit
PHY	Physical Layer Interface
PID	Packet Identifier
PLMN	Public Land Mobile Network
PM	Phase Modulation
PMD	Physical Medium Dependent
PON	Passive Optical Network
POTS	Plain Old Telephone System
PPM	Pulses Per Million
PRBS	Pseudo Random Binary Sequence
PSK	Phase Shift Keying
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
RF	Radio Frequency
RL	Return Loss
RS	Reed-Solomon
SDH	Synchronous Digital Hierarchy
SDL	Syntax Description Language
SDU	Service Data Unit
SFP	SuperFrame Period
SFSC	SuperFrame Synchronization Control
SL-ESF	Signaling Link - Extended Superframe
SMATV	Satellite Master Antenna Television
SONET	Synchronous Optical Network
STP	Shielded Twisted Pair
STS	Satellite Transmission System
TC	Transmission Convergence
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TE	Terminal Equipment

ISO/IEC 16500-4:1999(E)

TS	Transport Stream
TV	TeleVision
UD	User Data
UNI	User-Network Interface
UPI	User Premises Interface
US	Upstream
UTP	Unshielded Twisted Pair
VDSL	Very high-speed Digital Subscriber Line

5. Conventions

The style of this part of ISO/IEC 16500 follows the *Guide for ITU-T and ISO/IEC JTC 1 cooperation. Appendix II: Rules for presentation of ITU-T | ISO/IEC common text (March 1993)*.

6. Tools for Digitizing the Core network

DAVIC supports physical layer interfaces for both narrowband and broadband core networks.

6.1 The Broadband Core network

For a broadband network, DAVIC supports interfaces for which a mapping of ATM cells has been standardized by international bodies such as ITU, ETSI and the ATM Forum. The ATM Forum makes a distinction between private and public UNI interfaces. For the broadband core network, only public UNI interfaces are considered. The allowable physical layer protocols for the broadband core network are given in detail below.

The recommendation to support SDH/SONET as the broadband core network physical layer may be viewed as offering a single solution. A near-term option of PDH is presented to accommodate for legacy networks; and a recommendation is given to review the applicability of PDH as a physical layer option for this part of ISO/IEC 16500 upon future revisions.

Though many Physical Interfaces exist that are able to carry ATM cells, it is important to limit the number of possible interfaces to prevent requirements that servers have to be equipped with a wide variety of Physical Interfaces. At the moment PDH plays an important role in transport networks and therefore PDH can not be ruled out for short term deployment of DAVIC services. This is because network operators who will be transporting DAVIC specified services will not be able to avoid using multiple physical layer technologies for the time being. However in the long term PDH equipment will be replaced, e.g. by SDH or SONET transmission equipment. The broadband core network shall be digitized by transporting ATM on one or more of the tools listed in Table 6-1. Each of these tools shall comply to the corresponding references listed in Table 6-1.

Table 6-1 - Broadband Core network Physical Interfaces.

Physical Interface		Bit Rate	References
SDH	STM-1	155.52 Mbit/s	[ITU-T G.652], [ITU-T G.957], [ITU-T G.707], [ITU-T G.708], [ITU-T G.709] [ITU-T I.413], [ITU-T I.432]
	STM-4	622.08 Mbit/s	[ITU-T G.652], [ITU-T G.957], [ITU-T G.707], [ITU-T G.708], [ITU-T G.709], [ITU-T I.413], [ITU-T I.432]
SONET	OC-3c	155.52 Mbit/s	[ANSI T1.105], [ANSI T1.105.01] through [ANSI T1.105.09] [BELLCORE GR-253]
	OC-12	622.08 Mbit/s	[ANSI T1.105], [ANSI T1.105.01] through [ANSI T1.105.09] [BELLCORE GR-253]
PDH	J2	6.312 Mbit/s	[ITU-T G.981], [ITU-T G.704], [ITU-T G.804]
	E3	34.368 Mbit/s	[ITU-T G.981], [ITU-T G.832], [ITU-T G.804]
	DS3	44.736 Mbit/s	[ITU-T G.981], [ITU-T G.804]
	E4	139.264 Mbit/s	[ITU-T G.981], [ITU-T G.832], [ITU-T G.804]

Part 4 specifies an enhanced broadcast scenario where the core network between the downstream delivery network and the originating SPS may not exist (i.e. A9 and A4 are coincident). In this case, DVB ASI shall be used for delivering the MPEG-2 Transport Stream from the SPS into the access network.

Table 6-2 - SPS/SPS core network and SPS internal network interfaces.

Physical Interface		Bit Rate	References
DVB	ASI	270 Mbit/s	[CENELEC EN50083-9]

6.2 The Narrowband Core network

A characteristic of Enhanced Broadcast Services is that a different delivery systems may be used for carrying the downstream broadcast signal and the interaction channel. The downstream broadcast may use a broadband core network, while the interaction channel may use a narrowband core network. In that case, carrying ATM is not mandatory for the interaction channel. DAVIC supports PSTN, ISDN and PLMN as physical layer tools for use in

a narrowband core network as listed in Table 6-3. These tools shall be the same as those defined for digitizing the access network in subclauses 7.1, 7.2, and 7.3, respectively.

Table 6-3 - Narrowband Core network Physical Interfaces.

Physical Interface		Bit Rate	References
PSTN	modem interface	2.4 bit/s	[ITU-T V22bis]
		9.6 kbit/s	[ITU-T V32]
		14.4 kbit/s	[ITU-T V32bis]
		28.8 kbit/s	[ITU-T V34]
ISDN	ISDN interface	144 kbit/s	[ITU-T I.430]
PLMN	mobile interface	1.2 kbit/s	[ITU-T V22]
		2.4 kbit/s	[ITU-T V22bis]
		4.8 kbit/s	[ITU-T V32]
		9.6 kbit/s	[ITU-T V32]

7. Tools for Digitizing the Access network

7.1 Low-Speed Symmetrical PHY on the PSTN

The PSTN is considered as a physical medium, a physical layer interface and a network which can be used to establish a bi-directional communication path in the end-to-end delivery system by making use of a modem.

Transmission performance levels are defined as follows:

- 1) Full duplex terrestrial path at up to 2.4 kbits/s
- 2) Full duplex terrestrial path at up to 9.6 kbit/s
- 3) Full duplex terrestrial path at up to 14.4 kbits/s
- 4) Full duplex terrestrial path at up to 28.8 kbits/s

The performance level 1 shall comply with [ITU-T V22 bis].

The performance level 2 shall comply with [ITU-T V32].

The performance level 3 shall comply with [ITU-T V32 bis].

The performance level 4 shall comply with [ITU-T V34].

The modem in the set top box shall at least support the auto mode selection [ITU-T V.22bis] transmission protocol (performance level 1).

Independently of the performance level the modem is operating at, asynchronous working with one or two stop bits and with or without parity shall be possible.

7.2 Low-Speed Symmetrical PHY on the ISDN

The ISDN is considered as a physical medium, a physical layer interface and a network which can be used to establish a bi-directional communication path in the end-to-end delivery system.

The ISDN interface shall comply to the [ITU-T I.430] specification.

7.3 Low-Speed Symmetrical PHY on Public Land Mobile Networks

The public land mobile network (PLMN) is considered as a physical medium, a physical layer interface and a network which can be used to establish a bi-directional communication path in the end-to-end delivery system by making use of a mobile terminal equipment, radio network, interworking functionality and PSTN/ISDN network. The type of the mobile network depends on the local mobile network operator. For example, GSM, PCS 1900, or DCS 1800 can be used according to the respective standards.

ISDN access from the PLMN provides faster connection establishment than PSTN access from the PLMN.

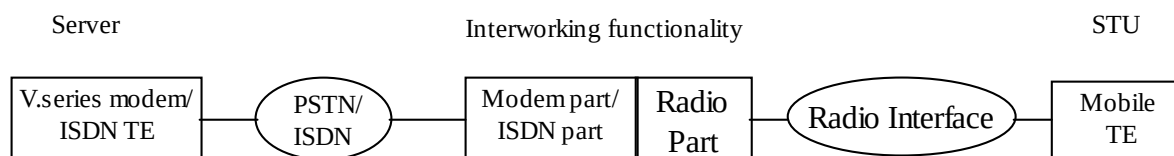


Figure 7.3-1 - Public Land Mobile Network (PLMN) PSTN/ISDN interworking for circuit switched calls

Transmission performance levels are defined as follows:

- 1) Full duplex terrestrial path at up to 1.2 kbits/s
- 2) Full duplex terrestrial path at up to 2.4 kbits/s
- 3) Full duplex terrestrial path at up to 4.8 kbits/s
- 4) Full duplex terrestrial path at up to 9.6 kbits/s

The performance level 1 shall comply with [ITU-T V22].

The performance level 2 shall comply with [ITU-T V22bis].

The performance level 3 shall comply with [ITU-T V32].

The performance level 4 shall comply with [ITU-T V32].

The Interworking functionality shall at least support the auto mode selection [ITU-T V22] transmission protocol (performance level 1). Independently of the performance level the interworking functionality is operating at, asynchronous working with one or two stop bits and with or without parity shall be possible.

In case of ISDN, the ISDN interface in the interworking functionality shall comply to the [ITU-T I.430] specification.

In the radio interface, the non-transparent data transmission (including error correction) is recommended, because it provides a better BER performance on the radio path, and it does not require an additional protocol to carry out the error correction.

For the GSM networks the IWU is specified in ETSI GSM standards, (e.g. GSM 09.07 ver 3.7.1 General Requirements on Interworking between PLMN and the ISDN or PSTN).

7.4 Long-Range Baseband Asymmetrical PHY on copper

This Physical Layer Interface specification supports transmission over long range (>1500 meters) unshielded twisted pair (UTP) cabling at bit rates up to 7 Mbit/s in the downstream direction and up to 640 kbit/s in the upstream direction.

Work on a long-range asymmetrical physical layer interface on copper pairs has been completed in the ANSI T1E1.4 and ETSI TM3. It is referred to as ADSL (Asymmetrical Digital Subscriber Line).

The Long-Range Asymmetrical Physical Layer Interface on copper pairs shall comply to the [ANSI T1.413] ADSL specification and additionally meet the performance requirements contained in the ETSI Technical Report [ETR 328].

The bit rate and interleaving depth shall be set at start-up according to the network operators service requirements by network management (reference [ANSI T1.413] section 12 "Initialization" sub-section 12.6.2 "C-RATES1").

The ATM transmission convergence layer specifications shall be implemented according to ADSL Forum recommendations described in [ADSLF TR-002], with the following restrictions:

- 1 Only the following sections of [ADSLF TR-002] are mandatory (as restricted in 2 below), other text is informative:
 - B.2 Relationship to other reference models: DAVIC
 - 3 Transport of ATM on ADSL
 - 4 Quality of Service
 - 6.2 Description of functional blocks: Transmission Convergence
 - 7 Management
- 2 In ISO/IEC 16500 only a single latency path shall be implemented. This is a restriction on the full flexibility of the [ADSLF TR-002] recommendation subclause 3.2.

7.5 Medium-Range Baseband Asymmetrical PHY on copper

This section is included for information only.

See DAVIC 1.3.1a Part 4 (1999) for more details on architectures able to support the Medium Range Baseband Asymmetrical PHY on copper.

7.6 Short-Range Baseband Asymmetrical PHY on copper and coax

This Physical Layer Interface supports transmission over short range (<300 meters) unshielded copper pairs, shielded copper pairs and coaxial cable (up to 40 MHz bandwidth), partly located in the outside distribution plant, partly located inside the premises. It is referred to as FTTB or FTTC (Fiber To The Building or Fiber To The Curb).

The PMD sublayer section specifies the electrical characteristics of the physical medium (e.g. propagation loss, crosstalk, impedance matching), the modulation schemes and reference loops over which this PHY is operating. The physical medium can be a copper pair, a coax or a combination of both and connects the network device to one or more user devices in a point-to-multipoint environment, as shown in Figure 7.6-1.

The TC sublayer section specifies the framing of downstream and upstream ATM cells (e.g. forward error correction, transport frame synchronization, network device to user device lower layer protocols and upstream TDMA control).

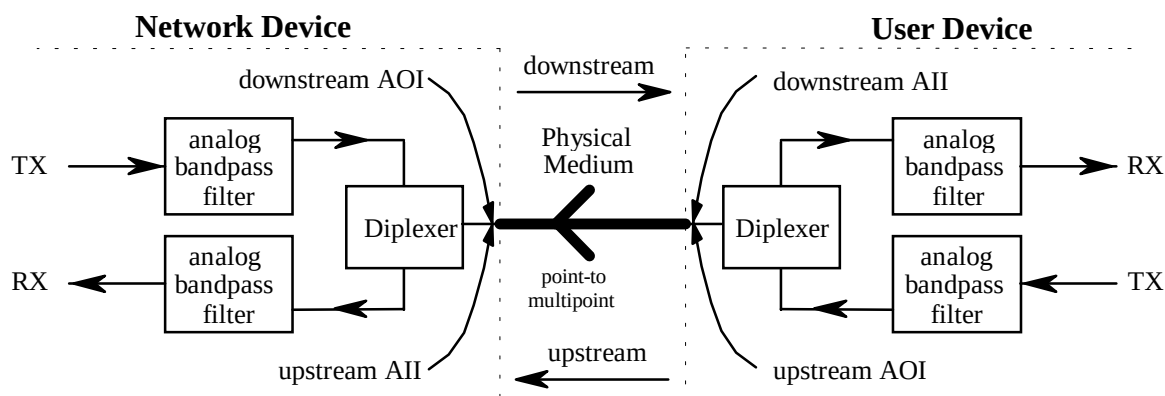


Figure 7.6-1 - Definition of active interfaces in the network and user device.

The PMD and TC sublayer sections specify the characteristics of the Network Device and the User device at the Active Input and Output Interfaces as shown in Figure 7.6-1. The network device shall be the device generating the downstream signal, typically located in the optical network termination (in the access network). The user device shall be the device generating the upstream signal, typically located in the Network Interface Unit (in the set top box).

On the physical medium, other signals can be carried in overlay (e.g. POTS or RF signals). The signal splitter/combiners to overlay these signals on the physical medium shall not be considered as part of the Network Device, nor as part of the User Device. They shall not affect compliance of the short-range baseband asymmetrical PHY signal to the PMD and TC sublayer specification.

7.6.1 Physical Medium Dependent (PMD) Sublayer Specification

7.6.1.1 Bit Rates

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

The downstream and upstream bit rate are scaleable. The downstream and upstream bit rate shall correspond to one of the valid bit rate combinations shown in Table 7-1.

Table 7-1 - Valid downstream and upstream bit rate combinations.

Bit Rate	Downstream	Upstream
A	51.84 Mbit/s	19.44 Mbit/s
B	51.84 Mbit/s	1.62 Mbit/s
C	25.92 Mbit/s	1.62 Mbit/s
D	12.96 Mbit/s	1.62 Mbit/s

All bit rate combinations shall use the same downstream and upstream TC layer frame format (downstream and upstream). The network device shall transmit downstream frames at the downstream bit rate as defined in Table 7-1. The user device shall transmit upstream frames at the upstream bit rate as defined in Table 7-1.

The network device shall support at least one of the bit rate settings A, B, C or D.

The network device shall support connection to copper pair or coax, as required by a particular access network wiring.

A user device shall support the A+B+C+D or B+C+D or C+D or D bit rate setting(s). This assures a level of portability of user devices between areas where different bit rate settings are being used by the network devices and is in line with common modem practice, where a modem also supports all the bit rate setting lower than its maximum performance.

A user device shall support connection to copper pair or coax, as required by a particular in-premises wiring.

For profiles with the option of having the upstream signal in the lower frequencies or having the upstream signal in the higher frequencies (i.e. B, C and D), the user device shall support both upstream signal transmissions, while the network device can choose to support upstream reception in the lower or higher frequencies. It is the responsibility of the user device to determine how to transmit upstream properly.

7.6.1.2 Bit Error Rate

The user device received white noise random bit error rate after error correction shall be lower than 10^{-12} . With this assumption, a 10 Mbit/s downstream stream flow will be corrupted less than once a day, which is considered to be acceptable for interactive multimedia services.

The network device received white noise random bit error rate after error correction shall be less than 10^{-10} . With this assumption, a 100 kbit/s upstream data stream will be corrupted less than once a day, which is considered to be acceptable for interactive multimedia services.

The network device is receiving bursty data from the various user devices connected to it. If the network device cannot receive a burst (e.g. because of burst synchronization acquisition failure), the data will be completely corrupted and the ATM cell is lost.

The network device upstream burst loss under white noise conditions shall be less than 10^{-9} . This is in line with the cell loss ratio commonly used for ATM networks.

7.6.1.3 Timing

The transmitter in the network device shall use a transmit clock which is derived from the network clock (e.g. SONET clock, SDH clock, PON clock, ...) to allow end-to-end network synchronization. In the absence of a network clock, the network device shall use a locally generated clock with a maximum tolerance of 50 ppm.

The transmitter in the user device shall use a transmit clock which is derived from its received data clock, i.e. the user device is loop timed. In the absence of a valid clock derived from the received data clock, the user device shall not perform any upstream access on the media.

7.6.1.4 Jitter

The jitter of the network device (downstream jitter τ_D) transmitter shall be obtained by continuously transmitting the symbol (b0b1b2b3=0111) (see Figure 7.6-4) at the output of the byte-to-symbol mapping and measure the variation of the zero-crossings of the resulting sine-waveform (as shown in Figure 7.6-2) at the network device active output interface. For the network device jitter measurement, the network device transmitter clock shall be used as the reference clock.

The jitter of the user device transmitter (upstream jitter τ_U) shall be obtained by continuously transmitting the symbol (b1b0=11) (see Figure 7.6-11) output of the byte-to-symbol mapping and measure the variation of the zero-crossings of the resulting sine-waveform (as shown in Figure 7.6-2) at the user device active output interface. For the user device jitter measurement, the network device transmitter clock shall be used as the reference clock.

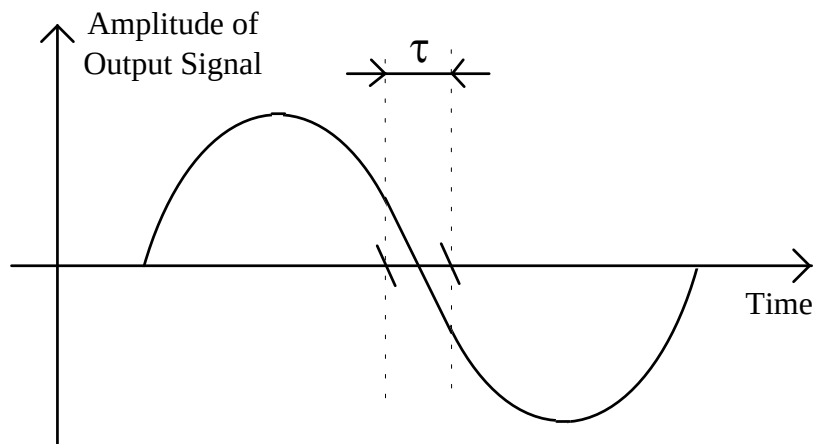


Figure 7.6-2 - Illustration of Transmission Jitter.

The network device transmitter shall be capable of continuously transmitting the symbol (b3b2b1b0=0111), as observed at the output of the byte-to-symbol mapping.
The user device transmitter shall be capable of continuously transmitting the symbol (b1b0=11), as observed at the output of the byte-to-symbol mapping.
The network device and user device jitter shall be less than the maximum values shown in Table 7-2. All the jitter values shall be peak-to-peak values at frequencies above 1 kHz.

Table 7-2 - Maximum peak-to-peak jitter values.

Bit rate setting	Downstream jitter	Upstream Jitter
A	1.5 ns	2.0 ns
B	1.5 ns	2.0 ns
C	3.0 ns	4.0 ns
D	6.0 ns	8.0 ns

7.6.1.5 Downstream Modulation

This PMD sublayer specification provides bit transmission capability and bit timing in the downstream direction (from the network device to any user device).
The sublayer includes functions to generate and receive waveforms suitable for the media, and the insertion and extraction of symbol timing information. The implementation of the PMD sublayer receives a byte stream from the TC sublayer, encodes, and transmits the signal to the adjacent PMD sublayer. The receiving implementation of the PMD sublayer decodes the signal and delivers it as a byte stream to the TC sublayer. These operations are described below.

7.6.1.5.1 Transmit functionality

The PMD sublayer shall be comprised of transmit functionality obtained from the blocks shown in Figure 7.6-3. Any implementation that produces the same functional behavior at the network device Active Output Interface is equally valid. The transmit function encodes the byte stream received from the TC layer into an equivalent encoded symbol stream and then into a modulated signal for presentation to the media at the network device Active Output Interface.

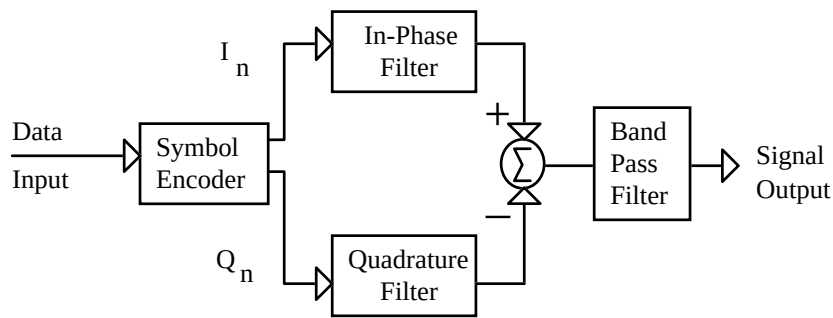


Figure 7.6-3 - Block diagram of digital transmitter functionality.

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

7.6.1.5.2 Encoding

The amplitudes of the I_n and Q_n components in the constellations shall maintain the relative values 1 and 3, with a tolerance of ± 0.06 relative to these values, as depicted in the constellation diagram of Figure 7.6-5.

For operation at 51.84 Mbit/s, the encoding used shall be the code in Figure 7.6-4 with a symbol rate equal to 12.96 Mbaud.

For operation at 25.92 Mbit/s, the encoding used shall be the code in Figure 7.6-4 with a symbol rate equal to 6.48 Mbaud.

For operation at 12.96 Mbit/s, the encoding used shall be the code in Figure 7.6-4 with a symbol rate equal to 3.24 Mbaud.

The encoder shall map four data bits into a symbol as shown in Figure 7.6-4. Bytes shall be mapped from the TC layer into two four bit symbols. The first bit out of the TC layer into a given symbol shall be b_0 .

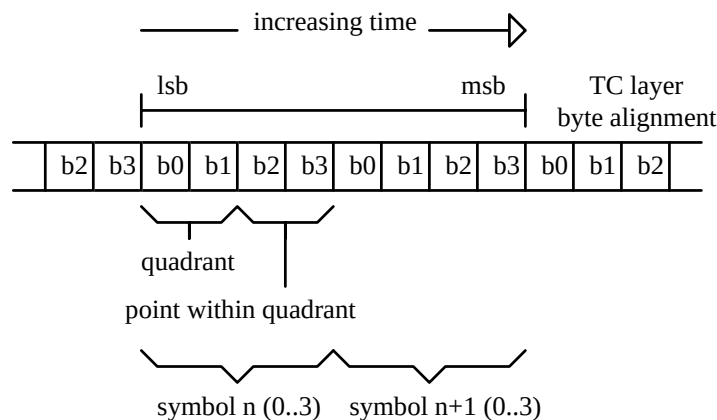


Figure 7.6-4 - Byte-to-symbol mapping

The signal constellation shall be as shown in Figure 7.6-5.

Each incoming group of 4 bits $b(0..3)$ shall be differentially encoded into a symbol. The relative levels of the amplitude of the symbols in each dimension shall be proportional to the four different levels, ± 1 and ± 3 . The differential encoding shall be done by first determining the current state as a function of the past state and bits b_0 and b_1 . Once the current state is obtained, the output symbols I_n and Q_n shall be generated from the current state and bits b_2 and b_3 . Symbol generation shall be as shown in Table 7-3.

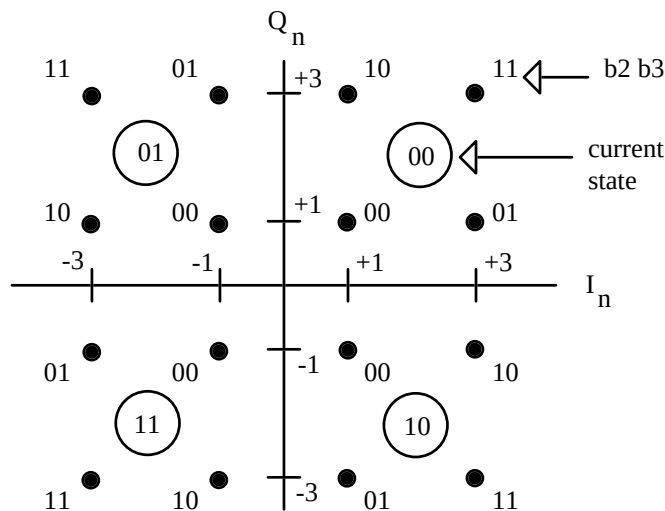


Figure 7.6-5 - Signal constellation.

Table 7-3 - State diagram for differential encoding.

b0 b1	previous state	current state and phase rotation	
00	00	01	$+\pi/2$
00	01	11	$+\pi/2$
00	10	00	$+\pi/2$
00	11	10	$+\pi/2$
01	00	00	$+0$
01	01	01	$+0$
01	10	10	$+0$
01	11	11	$+0$

b0 b1	previous state	current state and phase rotation	
10	00	11	$+\pi$
10	01	10	$+\pi$
10	10	01	$+\pi$
10	11	00	$+\pi$
11	00	10	$+3\pi/2$
11	01	00	$+3\pi/2$
11	10	11	$+3\pi/2$
11	11	01	$+3\pi/2$

7.6.1.5.3 Network Device Active Output Interface

This section specifies the

- impulse response for the transmit filters
- transmitted signal power spectrum
- transmitter signal power level
- transmitter return loss
- transmitter signal balance

7.6.1.5.3.1 Impulse Response for the Transmit Filters

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin[\frac{\pi}{T}(1-\alpha)] + \frac{4\alpha t}{T} \cos[\frac{\pi}{T}(1+\alpha)]}{\frac{\pi}{T}[1-(\frac{4\alpha t}{T})^2]}$$

The impulse response of the in-phase and quadrature filters shall have an excess bandwidth of $\alpha = 0.2$. The square-root raised-cosine pulse response shall therefore be defined as (Figure 7.6-6):

$$g(t) = \frac{\sin(\pi \frac{4t}{5T}) + (\frac{4t}{5T}) \cos(\pi \frac{6t}{5T})}{(\pi \frac{t}{T}) [1 - (\frac{4t}{5T})^2]}$$

where T is the symbol period.

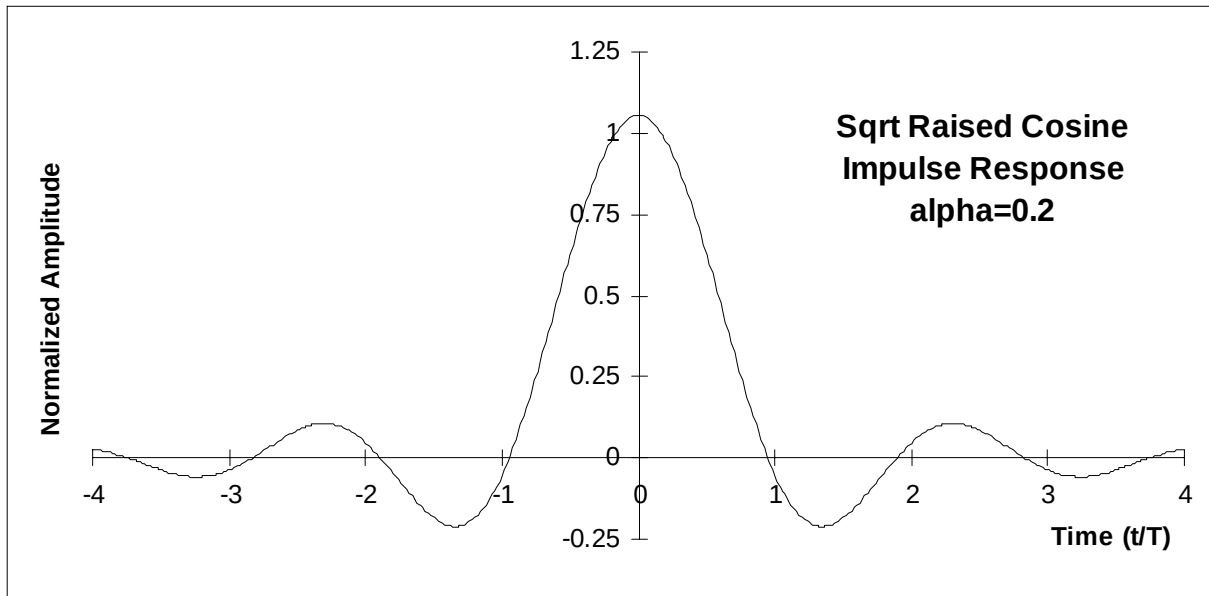


Figure 7.6-6 - Sqrt Raised Cosine Impulse Response $g(t)$ of the transmit filters.

The in-phase filter impulse response shall be defined as

$$f(t) = g(t) \bullet \cos(2\pi f_c t)$$

and the quadrature filter impulse shall be defined as

$$f'(t) = g(t) \bullet \sin(2\pi f_c t)$$

where T is the symbol period ($T=1/f_s$), and f_c the modulator's center frequency.

The output signal shall be defined as

$$S(t) = \sum_n [I_n \bullet f(t - nT) - Q_n \bullet f'(t - nT)]$$

with I_n and Q_n equal to ± 1 or ± 3 , independently from each other.

The in-phase and quadrature impulse response of the transmit filters are shown in Figure 7.6-7.

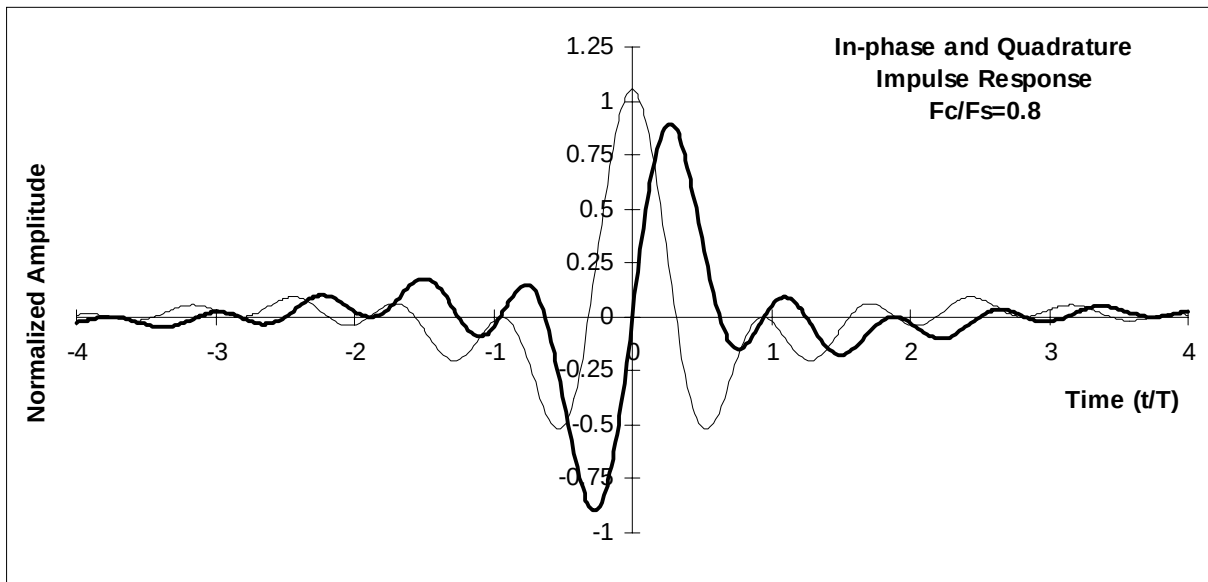


Figure 7.6-7 - In-phase and Quadrature Impulse Response of the transmit filters
(example for 51.84 Mbit/s downstream bit rate with $f_c/f_s=0.8$).

Because of the transmit filters' impulse response being an infinite time response (finite bandwidth), the actual impulse responses of the transmitter will be an approximation of the above equations over a fixed interval. For a 20% excess bandwidth system, a filter span of $[-4T, +4T]$ (informative value) can be considered adequate (32 taps filter in a 4 times oversampling implementation).

7.6.1.5.3.2 Transmitted Signal Power Spectrum

The Network Device Active Output interface shall have a power spectrum equivalent to the square root of a raised-cosine shaping with symbol frequency f_s , center frequency f_c , and 20% excess bandwidth. The symbol frequency and the center frequency depend upon the bit rate setting and shall comply to the values in Table 7-4.

Table 7-4 - Downstream spectrum allocation.

Bit rate setting	Downstream						
	Bit rate <i>Mbit/s</i>	Symbol rate f_s	Lowest freq. f_l	Center freq. f_c	Highest freq. F_h	c/s ratio f_c/f_s	roll-off α
A	51.84	12.96	11.6640	19.4400	27.2160	1.50	0.20
B	51.84	12.96	2.5920	10.3680	18.1440	0.80	0.20
C	25.92	6.48	2.5920	6.4800	10.3680	1.00	0.20
D	12.96	3.24	2.5920	4.5360	6.4800	1.40	0.20

The transmitted signal power spectrum, as measured at the Active Output Interface of the network device, shall meet the power spectrum template (as defined in Table 7-5) with lower and upper limits for attenuation at several points in the downstream signal bandwidth (as defined in Table 7-4). In-between these points, linear interpolation shall be applied.

The power spectrum template puts requirements on the implementation accuracy of the square-root raised cosine 20% roll-off filters and the analog filtering. The power spectrum template is defined as a function of the normalized frequency x , where

$$x = \frac{f - f_c}{f_s / 2}$$

Table 7-5 - Downstream power spectrum template.

Normalized frequency x	Spectral Lower Bound	Theoretical Value	Spectral Upper Bound
$\leq -1-5\alpha/2$	NA	NA	-50 dB
$-1-2\alpha$	NA	NA	-40 dB
$-1-3\alpha/2$	NA	NA	-40 dB
$-1-\alpha$	NA	NA	-30 dB
$-1-\alpha/2$	-10.0 dB	-8.3 dB	-7.0 dB
-1	-4.0 dB	-3.0 dB	-2.0 dB
$-1+\alpha/2$	-1.7 dB	-0.7 dB	+0.3 dB
$-1+\alpha$	-1.0 dB	0 dB	+1.0 dB
0	-1.0 dB	0 dB	+1.0 dB
$+1-\alpha$	-1.0 dB	0 dB	+1.0 dB
$+1-\alpha/2$	-1.7 dB	-0.7 dB	+0.3 dB
+1	-4.0 dB	-3.0 dB	-2.0 dB
$+1+\alpha/2$	-10 dB	-8.3 dB	-7.0 dB
$+1+\alpha$	NA	NA	-30 dB
$+1+3\alpha/2$	NA	NA	-40 dB
$+1+2\alpha$	NA	NA	-40 dB
$\geq +1+5\alpha/2$	NA	NA	-50 dB

Note: NA means the value is not applicable.

The group delay distortion seen at the Active Output Interface, which is introduced on the downstream signal by the network device analog output stage, shall be lower than 1/2 symbol period. This assumes that the delay distortion is attributed to the analog filters only.

7.6.1.5.3.3 Transmitted Signal Power Level

A minimum and a maximum network device output power is defined.

The network device total output power spectrum density, measured over the spectrum mask defined in Table 7-4, shall be lower than the maximum value of +15dBm.

The network device total output power spectrum density, measured over the spectrum mask defined in Table 7-4, shall be higher than the minimum value of -15dBm.

If the network device is driving copper pairs, the test load shall consist of a single $110 \Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

If the network device is driving coax, the test load shall consist of a single $75 \Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

7.6.1.5.3.4 Transmitter Return Loss

The Active Output Interface Return Loss specifies the amount of differential signal incident (for copper pair and coax) upon the AOI that is reflected.

$$RL = 20 \log \left| \frac{Z_L + Z_C}{Z_L - Z_C} \right|,$$

where Z_L is the termination impedance and Z_C is the characteristic impedance of the wiring.

More information about Return Loss can be found in [ITU-T G.117], section 4.1.1.

The AOI return loss, measured at the active output interface of the network device shall be at least 16 dB in the passband and at least 8 dB in the transition band of the downstream signal bandwidth as defined in Table 7-4. The network device AOI return loss mask is shown in Figure 7.6-8.

The return loss shall be measured for a resistive test load range of $Z_C=85$ to $135\ \Omega$ when driving copper pairs and $Z_C=65$ to $85\ \Omega$ when driving coax. The return loss shall be measured while the implementation of the PMD sublayer is powered.

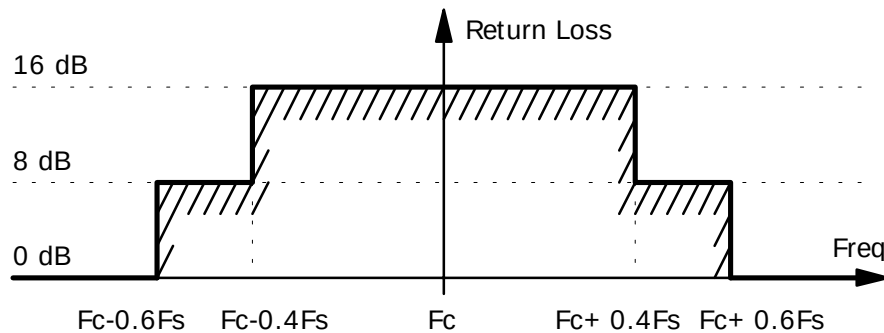


Figure 7.6-8 - Return loss mask of the network device AOI.

Note: The termination impedance of the network device must be chosen such that the return loss requirement is met over the specified impedance range. However, this does not preclude the use of cabling with a higher impedance tolerance.

7.6.1.5.3.5 Transmitter Signal Balance

This section only applies when the AOI of the network device is driving copper pairs. OSB is a measure of unwanted longitudinal signals at the output of the network device. The longitudinal output voltage (V_{cm}) is monitored to the differential output voltage (V_{diff}), while the generator in the device is active.

$$OSB = 20 \log \left| \frac{V_{diff}}{V_{cm}} \right|$$

The OSB, measured at the active output interface of the network device shall be minimum 40 dB over the frequency range equal to the downstream signal bandwidth as defined in Table 7-4. The OSB shall be measured in accordance with [ITU-T G.117] and [ITU-T O.9].

7.6.1.5.4 Receive Functionality

The receiver decodes the incoming signal stream received from the user device Active Input Interface and converts it into an equivalent bit stream for presentation to the TC sublayer.

The receiver shall require no more than 500 ms to reach a state that achieves the BER specified in section 7.6.1.2 from the time presented with a valid signal transmitted through the cable plant specified in sections 7.6.1.8, 7.6.1.9, 7.6.1.10 and 7.6.1.11.

7.6.1.5.5 Decoding

The decoding process shall be matched to the encoding process:

- constellation

7.6.1.5.6 User Device Active Input Interface

This section specifies the

- impulse response for the receive filters
- received signal power level
- receiver return loss

7.6.1.5.6.1 Impulse Response for the Receive Filters

The receive filters shall be matched to the transmit filters to avoid intersymbol interference.

The receive filters shall have the same impulse response as the transmit filters.

The receive filters shall have the same excess bandwidth as the transmit filters.

7.6.1.5.6.2 Received Signal Power Level

A minimum user device input power is defined.

The user device total input power spectral density, measured over the spectrum mask in Table 7-4, shall be at least -35dBm.

If the user device is driven from copper pairs, the test load shall consist of a single $110\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

If the user device is driven from coax, the test load shall consist of a single $75\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

A downstream total power spectrum density, measured over the spectrum mask defined in Table 7-4, of -20dBm (informative value) at the home side of the network termination (home boundary) is considered appropriate.

7.6.1.5.6.3 Receiver Return Loss

The Return Loss of the user device Active Input Interface specifies the amount of differential signal incident upon the AII that is reflected.

The Active Input Interface Return Loss specifies the amount of differential signal incident (for copper pair and coax) upon the AII that is reflected.

$$RL = 20 \log \left| \frac{Z_L + Z_C}{Z_L - Z_C} \right|,$$

where Z_L is the termination impedance and Z_C is the characteristic impedance of the wiring.

More information about Return Loss can be found in [ITU-T G.117], section 4.1.1.

The AII return loss, measured at the active input interface of the user device shall be at least 16 dB in the passband and at least 8 dB in the transition band of the downstream signal bandwidth as defined in Table 7-4. The user device AII return loss mask is shown in Figure 7.6-9.

The return loss shall be measured for a resistive test load $Z_C = 85$ to 135Ω when driven from copper pairs and $Z_C = 65$ to 85Ω when driven from coax. The return loss shall be measured while the implementation of the PMD sublayer is powered.

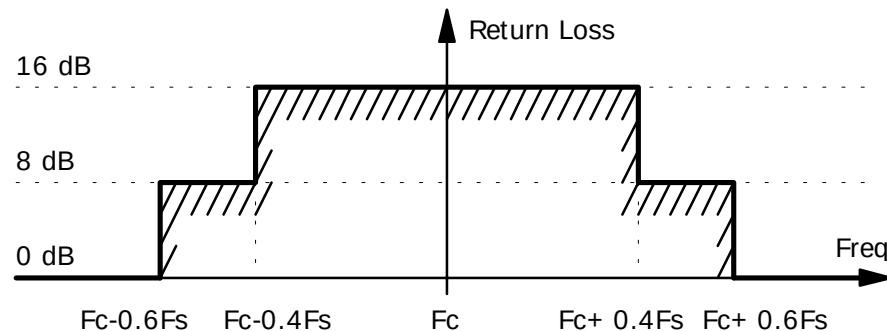


Figure 7.6-9 - Return loss mask of the user device AII.

Note: The termination impedance of the user device must be chosen such that the return loss requirement is met over the specified impedance range. However, this does not preclude the use of cabling with a higher impedance tolerance.

7.6.1.6 Upstream QPSK Modulation

This PMD sublayer specification uses the Quadrature Phase Shift Keying Modulation (QPSK) technique to provide bit transmission capability and bit timing in the upstream direction (from the user device to the network device).

The sublayer includes functions to generate and receive waveforms suitable for the media, and the insertion and extraction of symbol timing information. The implementation of the PMD sublayer receives a byte stream from the TC sublayer, encodes and transmits the signal to the adjacent PMD sublayer. The receiving implementation of

the PMD sublayer decodes the signal and delivers it as a byte stream to the TC sublayer. These operations are described below.

7.6.1.6.1 Transmit functionality

The PMD sublayer shall be comprised of transmit functionality obtained from the blocks shown in Figure 7.6-10. Any implementation that produces the same functional behavior at the network device Active Output Interface is equally valid. The transmit function encodes the byte stream received from the TC layer into an equivalent QPSK encoded symbol stream and then into a modulated signal for presentation to the media at the user device Active Output Interface.

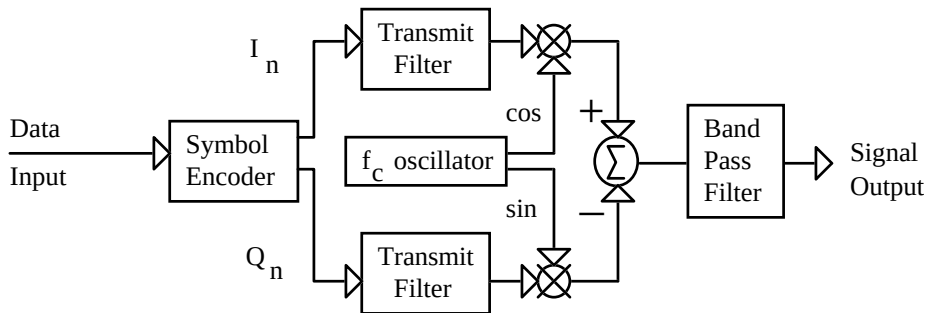


Figure 7.6-10- Block diagram of digital QPSK transmitter functionality.

The symbol stream from the encoder is divided into two paths, I_n and Q_n , where n designates the n^{th} symbol period. The two symbol streams are sent to pulse-shaping half-Nyquist filters before quadrature modulation of the I and Q signal. The output of the cosine modulator and the negative of the output of the sine modulator are summed into a single signal, the result passed through a band-pass filter, and then transmitted onto the media.

7.6.1.6.2 Encoding

The amplitudes of the I_n and Q_n components in the QPSK constellations shall maintain the relative value 1, with a tolerance of ± 0.06 relative to this value, as depicted in the constellation diagram of Figure 7.6-12. For operation at 19.44 Mbit/s, the encoding used shall be the QPSK code with a symbol rate equal to 9.72 Mbaud. For operation at 1.62 Mbit/s, the encoding used shall be the QPSK code with a symbol rate equal to 0.81 Mbaud. For QPSK, the encoder shall map two data bits into a symbol as shown in Figure 7.6-11. Bytes shall be mapped from the PMD sublayer data input (TC sublayer data output) into four two bit symbols. The first bit out of the PMD sublayer data input into a given symbol shall be b_0 .

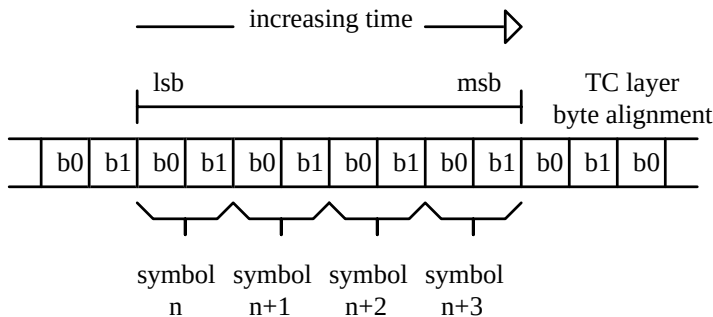


Figure 7.6-11- Byte-to-symbol mapping for QPSK.

As an example of the byte-to-symbol mapping, the I and Q values for the ramp-up, preamble and sync bytes are shown in Table 7-6. These bytes have fixed values, as defined in section 7.6.2.2.3. Therefore, the symbol sequence as shown in Table 7-6 is always present at the start of each upstream frame.

Table 7-6 - Mapping of Ramp-up, Preamble and Sync bytes into QPSK symbols.

	Symbol n		Symbol n+1		Symbol n+2		Symbol n+3		Byte value
	I	Q	I	Q	I	Q	I	Q	(hex)
Ramp-up	1	1	1	1	1	1	1	-1	40H
Preamble 1	1	1	1	-1	1	1	1	-1	44H
Preamble 2	-1	-1	-1	1	1	1	1	-1	4BH
Preamble 3	-1	-1	1	-1	-1	-1	1	-1	77H
Sync 1	-1	-1	-1	1	1	1	1	-1	4BH
Sync 2	-1	-1	1	-1	-1	-1	1	-1	77H

For QPSK, the signal constellation shall be as shown in Figure 7.6-12.

Each incoming group of 2 bits $b(0..1)$ shall be encoded into a QPSK symbol. The relative levels of the amplitude of the symbols in each dimension shall correspond to the levels ± 1 . The output symbols I_n and Q_n shall be generated from the bits b_0 and b_1 as shown in Figure 7.6-12.

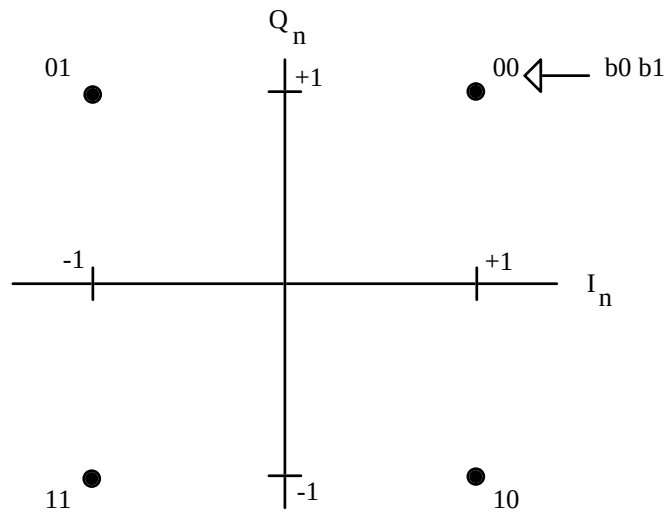


Figure 7.6-12 - QPSK signal constellation.

7.6.1.6.3 User Device Active Output Interface

This section specifies the

- impulse response for the transmit filters
- transmitted signal power spectrum
- transmitter signal power level
- transmitter ramp-up and ramp-down timing
- transmitter return loss
- transmitter signal balance

7.6.1.6.3.1 Impulse Response for the Transmit Filters

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin\left[\frac{\pi t}{T}(1-\alpha)\right] + \frac{4\alpha t}{T} \cos\left[\frac{\pi t}{T}(1+\alpha)\right]}{\frac{\pi t}{T} \left[1 - \left(\frac{4\alpha t}{T}\right)^2\right]}$$

The impulse response of the transmit filters shall use an excess bandwidth of $\alpha=0.35$ for bit rate setting A and $\alpha=0.5$ for bit rate settings B, C and D (see Table 7-7 and Table 7-8). In the latter case ($\alpha=0.5$), the square-root raised-cosine pulse is therefore defined as (Figure 7.6-13):

$$g(t) = \frac{\sin(\pi \frac{t}{2T}) + (\frac{2t}{T}) \cos(\pi \frac{3t}{2T})}{(\pi \frac{t}{T}) [1 - (\frac{2t}{T})^2]}$$

where T is the symbol period.

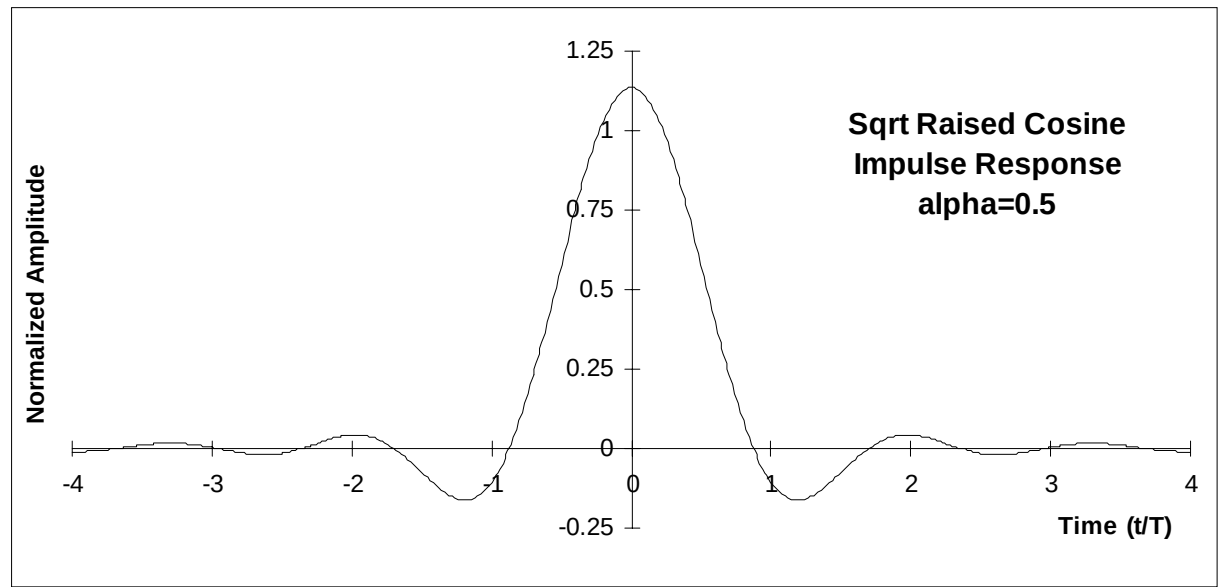


Figure 7.6-13 - Sqrt Raised Cosine Impulse Response $g(t)$ of the $\alpha=0.5$ transmit filter.

The output signal shall be defined as

$$S(t) = \sum_n [I_n \bullet g(t - nT) \bullet \cos(2\pi f_c t) - Q_n \bullet g(t - nT) \bullet \sin(2\pi f_c t)]$$

with I_n and Q_n equal to ± 1 , independently from each other, and f_c the QPSK modulator's center frequency. Because of the transmit filters' impulse response being an infinite time response (finite bandwidth), the actual impulse responses of the transmitter will be an approximation of the above equations over a fixed interval. For a 50% excess bandwidth QPSK system, a filter span of $[-2T, +2T]$ (informative value) can be considered adequate (16 taps filter in a 4 times oversampling implementation).

7.6.1.6.3.2 Transmitted Signal Power Spectrum

The User Device Active Output interface shall have a power spectrum equivalent to the square root of a raised-cosine shaping with symbol frequency f_s and center frequency f_c .

The symbol frequency, the center frequency and the excess bandwidth depend upon the bit rate setting and shall comply to the values in Table 7-7 and Table 7-8. The upstream signal can be transmitted in the lower part of the spectrum (below the downstream signal) or in the higher part of the spectrum (above the downstream signal).

Table 7-7 - Upstream Spectrum Allocation (higher frequencies)

Profile	Upstream in Higher Frequencies (above Downstream)						
	Bit rate <i>Mbit/s</i>	Symbol rate f_s	Lowest freq. f_l	Center freq. f_c	Highest freq. f_h	c/s ratio f_c/f_s	roll-off α
A	19.44	9.24	32.3190	38.8800	45.4410	4.00	0.35
B	1.62	0.81	22.0725	22.6800	23.2875	28.00	0.50
C	1.62	0.81	12.3525	12.9600	13.5675	16.00	0.50
D	1.62	0.81	7.4925	8.1000	8.7075	10.00	0.50

Table 7-8 - Upstream Spectrum Allocation (lower frequencies)

Profile	Upstream in Lower Frequencies (below Downstream)						
	Bit rate <i>Mbit/s</i>	Symbol rate f_s	Lowest freq. f_l	Center freq. f_c	Highest freq. f_h	c/s ratio f_c / f_s	roll-off α
A	-	-	-	-	-	-	-
B	1.62	0.81	0.6075	1.2150	1.8225	1.50	0.50
C	1.62	0.81	0.6075	1.2150	1.8225	1.50	0.50
D	1.62	0.81	0.6075	1.2150	1.8225	1.50	0.50

The transmitted signal power spectrum, as measured at the Active Output Interface of the user device, shall meet the power spectrum template (as defined in Table 7-9) with lower and upper limits for attenuation at several points in the upstream signal bandwidth (as defined in Table 7-7 or Table 7-8). In-between these points, linear interpolation shall be applied. The power spectrum template shall also be met during ramp-up and ramp-down of the bursty upstream transmitter.

The power spectrum template puts requirements on the implementation accuracy of the square-root raised cosine filters and the analog filtering. The power spectrum template is defined as a function of the normalized frequency x ,

$$x = \frac{f - f_c}{f_s / 2}$$

where

Table 7-9 - Upstream power spectrum template.

Normalized frequency x	Spectral Lower Bound	Theoretical value	Spectral Upper Bound
$\leq -1.5\alpha/2$	NA	NA	-50 dB
-1.2α	NA	NA	-40 dB
$-1.3\alpha/2$	NA	NA	-40 dB
$-1-\alpha$	NA	NA	-30 dB
$-1-\alpha/2$	-10.0 dB	-8.3 dB	-7.0 dB
-1	-4.0 dB	-3.0 dB	-2.0 dB
$-1+\alpha/2$	-1.7 dB	-0.7 dB	+0.3 dB
$-1+\alpha$	-1.0 dB	0 dB	+1.0 dB
0	-1.0 dB	0 dB	+1.0 dB
$+1-\alpha$	-1.0 dB	0 dB	+1.0 dB
$+1-\alpha/2$	-1.7 dB	-0.7 dB	+0.3 dB
$+1$	-4.0 dB	-3.0 dB	-2.0 dB
$+1+\alpha/2$	-10 dB	-8.3 dB	-7.0 dB
$+1+\alpha$	NA	NA	-30 dB
$+1+3\alpha/2$	NA	NA	-40 dB
$+1+2\alpha$	NA	NA	-40 dB
$\geq +1.5\alpha/2$	NA	NA	-50 dB

Note: NA means the value is not applicable.

The group delay distortion seen at the Active Output Interface, which is introduced on the upstream signal by the user device analog output stage, shall be lower than 1/8 symbol period. This assumes that the delay distortion is attributed to the analog filters only.

7.6.1.6.3.3 Transmitter Power Level

A minimum upper bound of the user device output power range is defined.

The upper bound of the user device total output power spectrum density range, measured over the spectrum mask defined in Table 7-7 or Table 7-8, shall be equal to +15dBm (active transmitter).

The mechanism to adapt the user device output power to the loop characteristics is described in the TC layer section.

During the guard time (as defined in section 7.6.2.2.3), the user device's bursty transmitter shall have a total output power spectrum density less than -40dBm, measured over the spectrum mask defined in Table 7-7 or Table 7-8 (silent transmitter).

If the user device is driving copper pairs, the test load shall consist of a single $110\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

If the user device is driving coax, the test load shall consist of a single $75\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

An upstream total power spectrum density, measured over the spectrum mask defined in Table 7-7 or Table 7-8, of 0 dBm (informative value) at the premises side of the network termination (premises boundary) is considered appropriate.

7.6.1.6.3.4 Transmitter Ramp-up and Ramp-down Timing

Ramp-up shall be defined as the transition from silent to active transmitter.

Ramp-down shall be defined as the transition from active to silent transmitter.

The ramp-up byte as defined in section 7.6.2.2.3, is mapped into 4 QPSK ramp-up symbols, according to the byte-to-symbol mapping shown in Figure 7.6-11. Ramp-up of the transmitter shall be performed in the time period necessary for the transmission of the first, second and third ramp-up symbol. Before the first ramp-up symbol, the transmitter shall be silent. During and after the fourth ramp-up symbol, the transmitter shall be active (see Figure 7.6-14).

The ramp-down byte as defined in section 7.6.2.2.3, is mapped into 4 QPSK ramp-down symbols, according to the byte-to-symbol mapping shown in Figure 7.6-11. Ramp-down of the transmitter shall be performed in the time period necessary for the transmission of the second, third and fourth ramp-down symbol. Before and during the first ramp-down symbol, the transmitter shall be active. After the fourth ramp-down symbol, the transmitter shall be silent (see Figure 7.6-14).

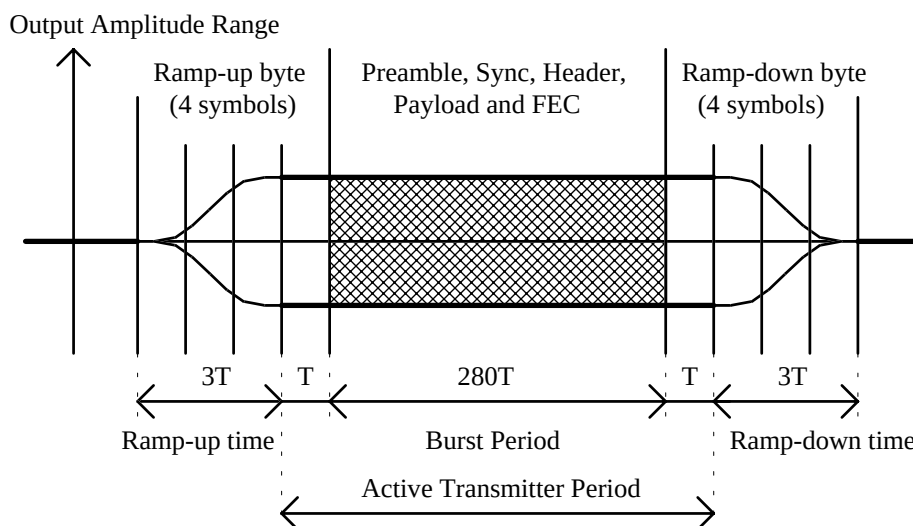


Figure 7.6-14 - Ramp-up and Ramp-down Timing.

7.6.1.6.3.5 Transmitter Return Loss

The Active Output Interface Return Loss specifies the amount of differential signal incident (for copper pair and coax) upon the AOI that is reflected.

$$RL = 20 \log \left| \frac{Z_L + Z_C}{Z_L - Z_C} \right|,$$

where Z_L is the termination impedance and Z_C is the characteristic impedance of the wiring.

More information about Return Loss can be found in [ITU-T G.117], section 4.1.1.

The AOI return loss, measured at the active output interface of the user device shall be at least 16 dB in the passband and at least 8 dB in the transition band of the upstream signal bandwidth as defined in Table 7-7 or Table 7-8. The user device AOI return loss mask is shown in Figure 7.6-15.

The return loss shall be measured for a resistive test of $Z_C=85$ to 135Ω when driving copper pairs and $Z_C=65$ to 85Ω when driving coax. The return loss shall be measured while the implementation of the PMD sublayer is powered.

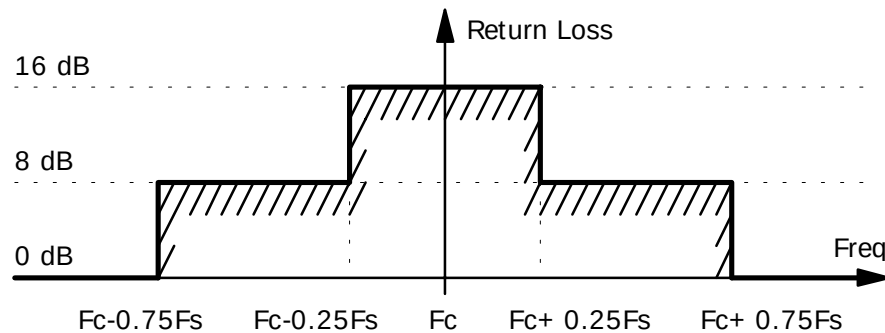


Figure 7.6-15 - Return loss mask of the user device AOI.

7.6.1.6.3.6 Transmitter Signal Balance

This section only applies when the AOI of the user device is driving copper pairs.

OSB is a measure of unwanted longitudinal signals at the output of the network device. The longitudinal output voltage (V_{cm}) is monitored to the differential output voltage (V_{diff}), while the generator in the device is active.

$$OSB = 20 \log \left| \frac{V_{diff}}{V_{cm}} \right|$$

The OSB, measured at the output of the network device shall be minimum 40 dB over the frequency range equal to the upstream signal bandwidth as defined in Table 7-7 or Table 7-8. The OSB shall be measured in accordance with [ITU-T G.117] and [ITU-T O.9].

7.6.1.6.4 Receive Functionality

The QPSK receiver decodes the incoming QPSK signal stream received from the network device Active Input Interface and converts it into an equivalent bit stream for presentation to the TC sublayer.

7.6.1.6.5 Decoding

The decoding process shall be matched to the encoding process:

- QPSK constellation

7.6.1.6.6 Network Device Active Input Interface

This section specifies the

- impulse response for the receive filters
- receiver return loss

7.6.1.6.6.1 Impulse Response for the Receive Filters

The receive filters shall be matched to the transmit filters to avoid intersymbol interference.

The receive filters shall have the same impulse response as the transmit filters.

The receive filters shall have the same excess bandwidth as the transmit filters.

7.6.1.6.6.2 Receiver Return Loss

The Return Loss of the network device Active Input Interface specifies the amount of differential signal incident upon the AII that is reflected.

The Active Input Interface Return Loss specifies the amount of differential signal incident (for copper pair and coax) upon the AII that is reflected.

$$RL = 20 \log \left| \frac{Z_L + Z_C}{Z_L - Z_C} \right|$$

where Z_L is the termination impedance and Z_C is the characteristic impedance of the wiring. More information about Return Loss can be found in [ITU-T G.117], section 4.1.1.

The AII return loss, measured at the active input interface of the network device shall be at least 16 dB in the passband and 8 dB in the transition band of the upstream signal bandwidth as defined in Table 7-7 or Table 7-8. The network device AII return loss mask is shown in Figure 7.6-16.

The return loss shall be measured with a resistive test load of $Z_C=85$ to 135Ω when driven from copper pairs and $Z_C=65$ to 85Ω when driven from coax.. The return loss shall be measured while the implementation of the PMD sublayer is powered.

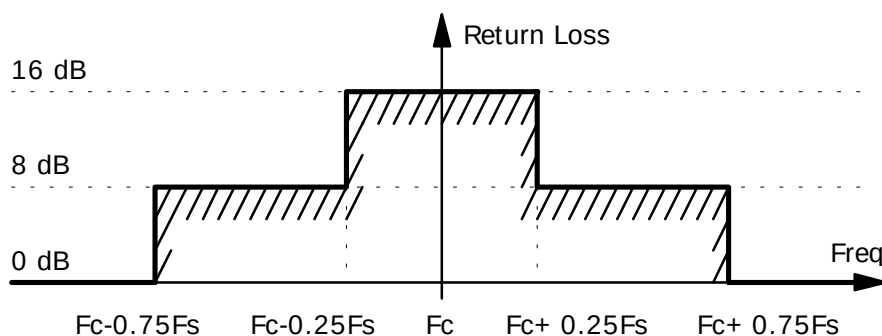


Figure 7.6-16 - Return loss mask of the network device AII.

7.6.1.7 Media Interface Connectors

At the user device, copper pairs shall be terminated with a Media Interface Connector as specified in Section 4 and Figure 1 of [ISO 8877]. This connector is an 8-pin Modular Plug RJ45-8 and shall meet or exceed the [ISO/IEC 11801] Category 3 or higher copper pair connecting hardware. An example of a Media Interface Connector Modular plug is shown in Figure 7.6-17.

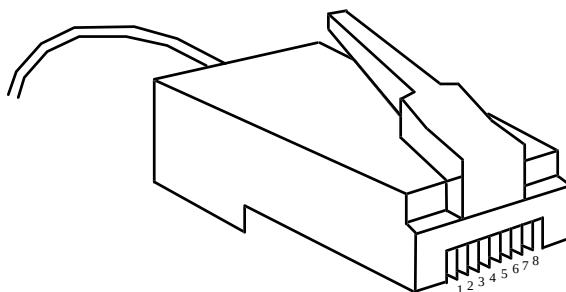


Figure 7.6-17 - Example of a MIC Modular Plug.

The Jack/Socket shall be a connector as specified in Section 4 and Figure 2 of [ISO 8877]. The connector hardware used within this implementation of the PMD sublayer shall be an unshielded 8-contact jack and meet or exceed the electrical requirements of [ISO/IEC 11801] Category 3 or higher copper pair. An example of a Media Interface Connector Jack is shown in Figure 7.6-18.

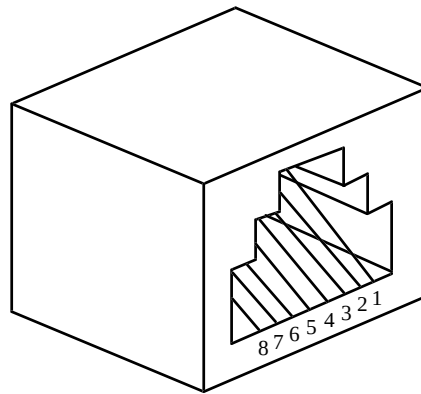


Figure 7.6-18 - Example of a MIC Jack.

The pins 4 and 5 of the RJ45-8 shall be used to connect the copper pairs, according to the [ISO/IEC 11801] pair grouping and pin assignment recommendation (see Figure 7.6-19).

When shielded copper pairs are used to connect the user device, the Media Interface Connector shall be shielded. However, the Jack/Socket shall not be shielded to avoid ground loops.

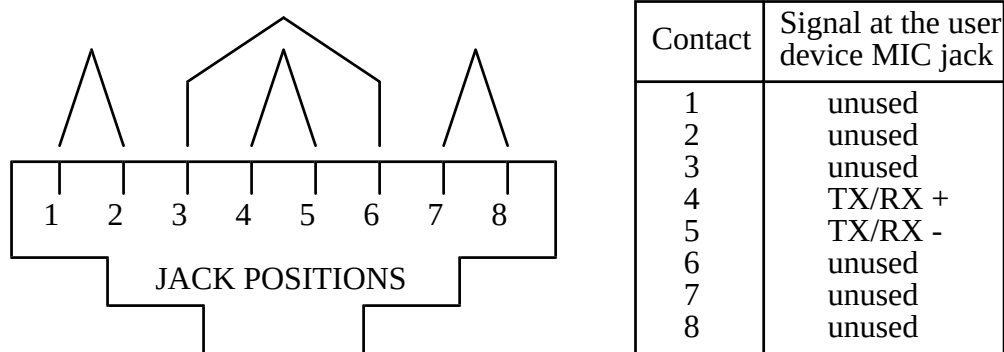


Figure 7.6-19 - Eight position jack pin and pair assignments
(This illustration is a front view of the jack connector).

A user device shall connect to coaxial cable using the F-type connector. The Media Interface Connector shall be of the male F-type. The Jack/Socket shall be of the female F-type.

7.6.1.8 Reference loops

The following reference loops (including copper pair and coax parts) define limiting conditions for the application of the Physical Interface (PMD and TC sublayer).

In case the Physical Medium is copper pairs, sections of multi-pair distribution cable shall be assumed to be 100% filled with UTP systems carrying the Physical Interface signals. These Physical Interface signals shall all be conveying the same data-rate (see section 7.6.1.1).

The reference loops are made up of two parts:

- The outside plant distribution cable section
- The in-premises distribution cable section

7.6.1.8.1 Reference Loop for Copper Pair outside plant distribution section

The reference loop shall be defined as the concatenation of the following elements:

- 70m overhead non-twisted copper pair 0.5 mm drop-wire
- 30m underground 5 pair 0.5 mm distribution cable
- 170m 20 pair 0.5 mm distribution cable

Note: 0.5 mm is approximately equivalent to 24 AWG
0.4 mm is approximately equivalent to 26 AWG

The 0.5 mm non-twisted copper pair drop wire shall be characterized by R,L,G,C characteristics in Table 7-10 under the heading DW10.
All sizes of 0.5 mm distribution cable shall be characterized by R,L,G,C parameters in Table 7-11 under the heading DWUG.
A graphical representation of the propagation loss on the outside copper pair reference loop (200 m DWUG cable and 70 m DW10 cable) is given in Figure 7.6-20.

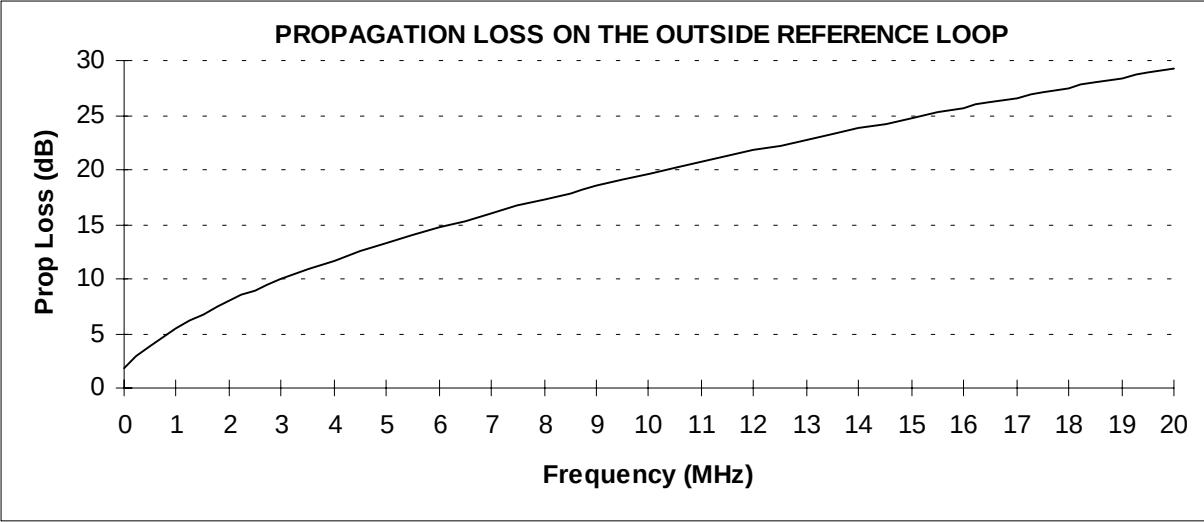


Figure 7.6-20 - Propagation loss on the outside copper pair reference loop.
(Source: British Telecom)

The cable balance of the aerial drop wire shall be no better than 30dB.
The Equal-Level far-end crosstalk (EL-FEXT) shall be characterized as:

$$EL - FEXT = 10 \log \frac{(49 / N)^{0.6}}{\Psi f^2 d}$$

- with N equal to the number of disturbers (N<50)
- Ψ constant equal to 2.623x10⁻⁷
- f equal to the frequency in MHz
- and d equal to the loop length in meters

Figure 7.6-21 shows the theoretical definition of EL-FEXT. Assume that the two sine-wave generators both transmit the same sine-wave with the same frequency f and amplitude V.

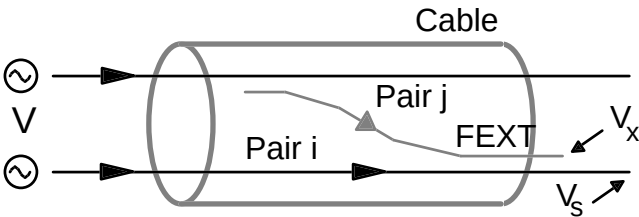


Figure 7.6-21 - Illustration of pair-to-pair FEXT.

Two signals appear at the end of the copper pair i. One is an attenuated version of the sine-wave transmitted on pair i and has amplitude Vs. The other is the interfering FEXT sine-wave from pair j with amplitude Vx. With N interfering pairs, the EL-FEXT power sum loss is defined as:

$$EL - FEXT = \frac{V_s^2}{V_x^2} \quad \text{with} \quad V_x^2 = \sum_{j=1}^N V_{xj}^2$$

A graphical representation of the EL-FEXT on the outside copper pair reference loop (170m 20-pair cable and 30m 5-pair cable) is given in Figure 7.6-22.

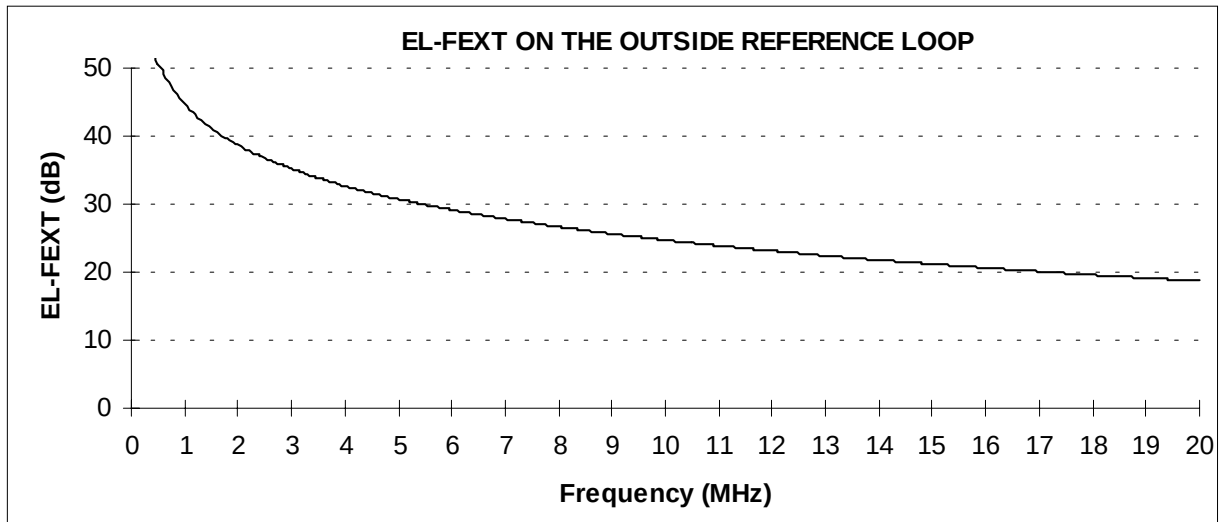


Figure 7.6-22 - EL-FEXT on the outside copper pair reference loop.

7.6.1.8.2 Reference Loop for Coax outside plant distribution section

The reference loop shall be defined as a single section of 100m coaxial cable of type RG59.

The cable loss at 600 MHz shall be less than 23 dB / 100 meters.

7.6.1.8.3 Reference Loop for Coax in-premises distribution

This section only applies to in-home distribution over coax.

A first reference loop shall be defined as (see Figure 7.6-23)

- 30m coax terminated by user device
- RF 1:2 splitter at 10m from entry point - terminated by user device at 10m
- RF 1:2 splitter at 20m from entry point - terminated by user device at 10m
- Any combination of 2 out of 3 user devices can be disconnected, leaving open-ended stubs.
- Bounce free connecting or disconnecting of a user device shall not cause a frame sync loss to the other user devices (see section 7.6.2.1.4).

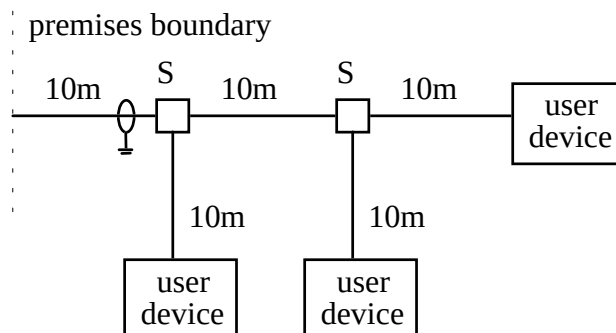


Figure 7.6-23 - In-premises coax reference loop 1.

A second reference loop shall be defined (see Figure 7.6-24)

- RF 1:4 splitter at 10m from entry point
- First splitter outlet terminated by user device at 10m
- Second splitter outlet terminated by user device at 20m
- Third splitter outlet terminated by user device at 30m
- Fourth splitter outlet terminated by user device at 30m
- Any combination of 2 out of 4 user devices can be disconnected, leaving open-ended stubs.
- Bounce free connecting or disconnecting of a user device shall not cause a frame sync loss to the other user devices (see section 7.6.2.1.4).

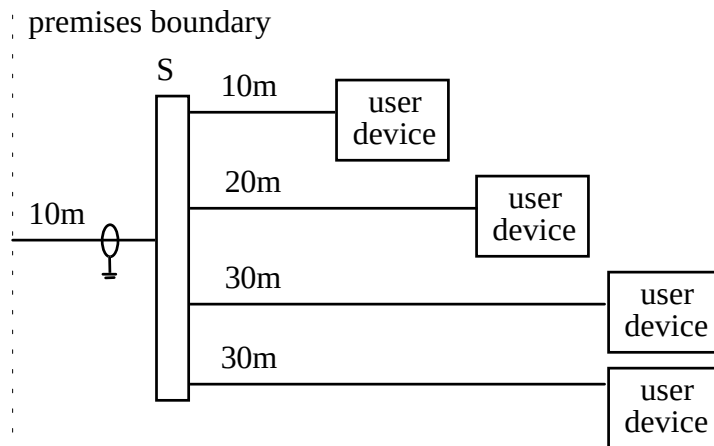


Figure 7.6-24 - In-premises coax reference loop 2.

For both reference loops, the coax cable characteristics shall be of the RG6 type.

The labels “input port” and “output port” shall be defined as applicable to the downstream signal.

The coax splitters in the first reference loop shall exhibit an insertion loss (input to output port and vice versa) less than 4 dB, measured on an RMS basis for each of the different bit rate settings, as shown in Table 7-4 and Table 7-7.

The coax splitter in the second reference loop shall exhibit an insertion loss (input to output port and vice versa) less than 8 dB, measured on an RMS basis for each of the different bit rate settings, as shown in Table 7-4 and Table 7-7.

Each of the coax splitters in both reference loops shall exhibit a notch of 15 dB depth in absolute propagation loss at any center frequency in the 1.5 to 4.5 MHz range.

The coax splitters in both reference loops shall have a port-to-port isolation between output ports of at least 3.0dB in the range of 1 to 5 MHz and of at least 12.0 dB in the range of 5 to 40 MHz.

The input port of the coax splitters in both reference loops shall have a return loss complying to the return loss definition of the Active Input Interface of the user device (Figure 7.6-9).

The output ports of the coax splitter in both reference loops shall have a return loss complying to the return loss definition of the Active Input Interface of the network device (Figure 7.6-15).

The return loss of a port shall be measured with the other ports properly terminated. The test load shall consist of a single $75\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20nH and the parallel capacitance shall be less than 2pF.

7.6.1.8.4 Reference Loops for Copper Pair in-premises distribution

This section only applies to in-home distribution over copper pairs.

The reference loop shall be defined (see Figure 7.6-25)

- RF 1:4 splitter implemented in the Network termination (NT)
- 4 point-to-point copper pairs in-premises
- First splitter outlet terminated by user device at 10m
- Second splitter outlet terminated by user device at 20m
- Third splitter outlet terminated by user device at 30m
- Fourth splitter outlet terminated by user device at 30m
- Any combination of 2 out of 4 user devices can be disconnected, leaving open-ended stubs.
- Bounce free connecting or disconnecting of a user device shall not cause a frame sync loss to the other user devices (see section 7.6.2.1.4).

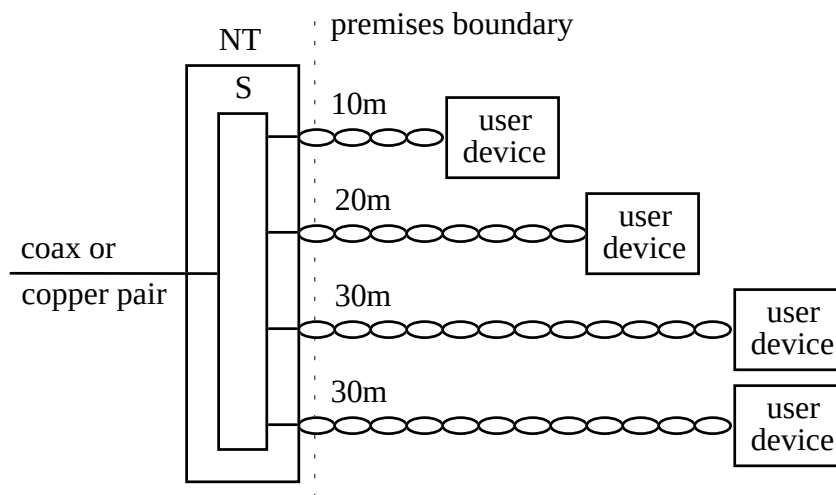


Figure 7.6-25 - In-premises copper pair reference loop.

The copper pairs shall have characteristics of the Category 3 type, as defined in [ISO/IEC 11801].

The labels “input port” and “output port” shall be defined as applicable to the downstream signal.

The copper pair splitter in the reference loop shall have a port-to-port isolation between output ports of at least 25 dB over the downstream and upstream frequency range as defined in Table 7-4, Table 7-7 and Table 7-8.

The copper pair splitter in the reference loop shall have an insertion loss (input to output port and vice versa) less than 8 dB, measured on an RMS basis over the downstream and upstream frequency range as defined in Table 7-4, Table 7-7 and Table 7-8.

The input port of the copper pair splitter shall have a return loss complying to the return loss definition of the Active Input Interface of the user device (Figure 7.6-9).

The output ports of the copper pair splitter shall have a return loss complying to the return loss definition of the Active Input Interface of the network device (Figure 7.6-15).

The return loss of a port shall be measured with the other ports properly terminated. The test load for a copper pair port shall consist of a single $110\Omega \pm 0.2\%$ resistor. The test load for a coax port shall consist of a single $75\Omega \pm 0.2\%$ resistor. For frequencies less than 100 MHz, the series inductance of the resistor shall be less than 20 nH and the parallel capacitance shall be less than 2 pF.

7.6.1.9 Rates and Reach

For Profiles A, the all-coax reference loop applies (100 m drop + 30 m in-home). For profiles B, C and D with the upstream signal in the higher frequencies, any mix of the outside coax or twisted-pair reference loop with the inside coax or twisted-pair reference loop applies. For profiles B, C and D with the upstream signal in the lower frequencies, any mix of the outside coax or twisted-pair reference loop with the inside twisted-pair reference loop applies. The all twisted-pair reference loops is 270 m drop + 30 m in-home.

This shall be confirmed by measuring at least 6 dB margin at a bit error rate after error correction of 10^{-7} . The measurement shall be performed in the presence of white Gaussian noise at the receiver input with power spectral density of -140 dBm/Hz.

7.6.1.10 Impulse Noise

The implementation of the PMD sublayer of the Physical Interface shall recover without operator intervention when subjected to a 0.5kV impulse noise (fast transient) as described in Level 2 of [IEC 801-4]. The implementation of the PMD sublayer shall be tested using the methods described in [IEC 801-4].

7.6.1.11 Electromagnetic Compatibility

7.6.1.11.1 Regulatory

The Physical Interface implementation shall meet regional regulatory constraints (e.g. FCC, ETSI).

7.6.1.11.2 Additional Susceptibility Constraints

The receiver shall meet all of the performance requirements set forth in this international standard in presence of a single interference signal with -14 dBm average power in the internationally agreed Ham radio bands as defined in the radio regulations [ITU RR8].

The interference signal shall have the following characteristics:

- Intermittent 5 sec on 10 sec off.
- Modulated with CCITT speech weighted noise interrupted at the syllabic rate with 1:3 on/off ration. The resultant base-band signal is band-limited to 4 kHz with 6 dB/octave pre-emphasis in-band.
- The center frequency shall change by at least 50 kHz every 2 minutes.

To meet the international standard in presence of higher power interferences, it might be necessary to choose appropriate wiring or to include additional equipment between the network device and the user device such as a common mode rejecter or a null inserter.

Table 7-10 - Characteristics of 0.5 mm UTP drop wires

Source: BT contribution TD55 of TM3 meeting in Rome in October 1994

DW10				
f (kHz)	R (Ω /km)	L (μ H/km)	C (nF/km)	G (mS/km)
5	191	724.63	74.72	0.13
10	191	721.82	72.89	0.92
50	195	707.05	69.15	0.99
100	207	694.78	67.75	1.70
500	342	648.79	64.88	6.73
1000	475	624.65	63.81	12.19
5000	1056	578.22	61.62	48.34
10000	1493	565.74	60.79	87.50
20000	2112	557.33	60.03	158.39
30000	2586	553.87	59.61	224.12

Table 7-11 - Characteristics of 0.5mm distribution cables

Source: BT contribution TD55 of TM3 meeting in Rome in October 1994

DWUG				
f (kHz)	R (Ω /km)	L (μ H/km)	C (nF/km)	G (mS/km)
5	179	694.81	55.43	0.003
10	179	694.56	55.40	0.007
50	183	692.06	55.34	0.036
100	193	688.47	55.32	0.073
500	316	661.64	55.27	0.385
1000	438	640.00	55.25	0.789
5000	974	598.93	55.21	4.16
10000	1376	591.53	55.20	8.51
20000	1947	587.94	55.19	17.42
30000	2384	586.83	55.18	26.48

7.6.2 Transmission Convergence (TC) PHY Sublayer Specification

The Transmission Convergence (TC) Sublayer deals with physical aspects which are independent of the transmission medium characteristics. Most of the functions comprising the TC sublayer are involved with generating and processing the overhead bytes contained in the data framing, as described in this section. The network device data framer maps ATM cells together with overhead data into downstream data frames for continuous downstream transmission. The user device data framer maps a single ATM cell together with overhead data into upstream data frames for bursty upstream transmission.

7.6.2.1 The Downstream Data Frame Format

7.6.2.1.1 Building a Downstream Frame

The downstream data frame format shall be as shown in Figure 7.6-26. The frame length shall be 810 bytes. The frame shall consist of header bytes and payload bytes. The frame payload shall consist of an integer number of Reed-Solomon code words. Each Reed-Solomon code word shall consist of ATM bytes and forward-error-correction (FEC) bytes. ATM bytes shall be mapped into the RS code words in the order they are passed from the ATM layer to the TC layer. No ATM cell alignment shall be considered in respect to the RS code words. The downstream bit rate available for mapping of 53-byte ATM cells is shown in Table 7-12.

RS code words shall have a length of 66 bytes: 58 ATM data bytes and 8 FEC bytes, calculated over the 58 ATM data bytes using the RS(66,58) code. The first ATM data byte shall be the most significant byte of the code word and shall be transmitted first. The last FEC byte shall be the least significant byte of the RS code word and shall be transmitted last.

The user device shall use the error correcting capability to correct up to 4 bytes per RS code word. In case an RS code word contains uncorrectable errors, the 58 ATM data bytes shall still be passed to the cell specific TC sublayer functions (see section 7.6.2.5).

The Reed-Solomon code generator polynomial and field generator polynomial shall be as described in section 7.6.2.3 with N and K set to implement an RS(66,58) code.

To increase the error correction performance, RS code words may be interleaved before mapping them into the downstream frame. When applying interleaving to the RS code words, long data erasures can be corrected by the RS decoder. The deinterleaver spreads the erased data over many RS code words, such that the number of corrupted bytes per code word remains within the correction power of the RS decoder. Depending on the physical medium, impulse noise conditions and end-to-end delay requirements, the Interleaving Depth (D) is set to an appropriate value by the network device (see definition of FEC format byte in downstream frame header).

Table 7-12 - Bit rate available for mapping of ATM cells.

Downstream frame bit rate	ATM pipe bit rate
51.84 Mbit/s	44.544 Mbit/s
25.92 Mbit/s	22.272 Mbit/s
12.96 Mbit/s	11.136 Mbit/s

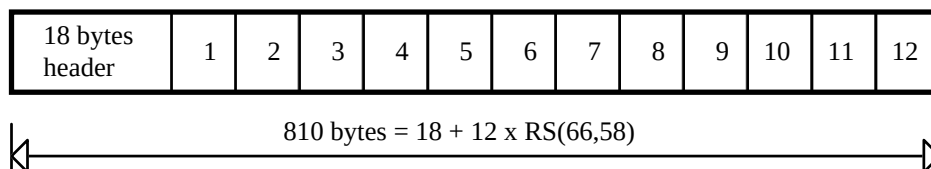


Figure 7.6-26 - Downstream frame format.

7.6.2.1.2 Downstream Data Randomization and Derandomization

A self-synchronizing randomizer/derandomizer shall be provided in the implementation of the TC layer. The randomizer shall be implemented in the network device, the derandomizer shall be implemented in the user device.

The network device randomization shall be performed before RS encoding and shall comply to (see Figure 7.6-27):

$$D_{out}^n = D_{in}^n \oplus D_{out}^{n-18} \oplus D_{out}^{n-23}$$

The user device derandomization shall be performed after RS decoding and shall comply to (see Figure 7.6-28):

$$D_{out}^n = D_{in}^n \oplus D_{in}^{n-18} \oplus D_{in}^{n-23}$$

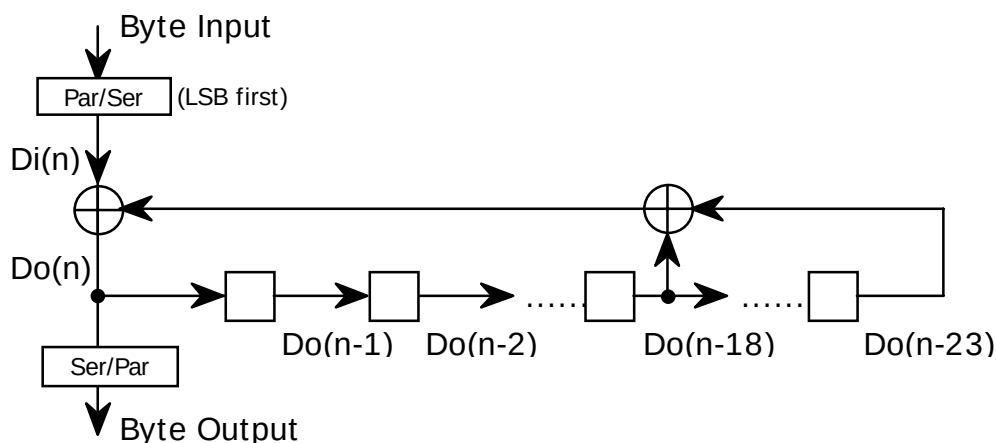


Figure 7.6-27 - Network Device Data Randomizer.

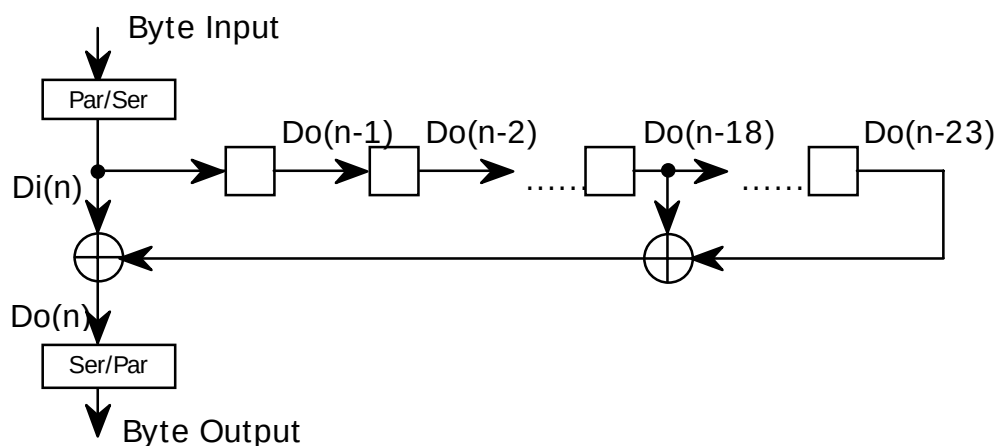


Figure 7.6-28 - User Device Data Derandomizer.

Both the downstream frame header and the downstream frame payload shall be randomized using the network device randomizer characterization (see Figure 7.6-27). However, the header randomizer and the payload randomizer shall be implemented separately. The header randomizer shall have 96 bit randomizing cycles per downstream frame by randomizing 12 header bytes (the whole header excluding the two SYNC bytes and the four FEC bytes). The payload randomizer shall have 5568 bit randomizing cycles per downstream frame by randomizing the 696 ATM cell data bytes (the whole payload excluding the 96 FEC bytes). Both header and payload randomization shall be continuous over all downstream frames.

Since a self-synchronizing (de)randomizer is used with a continuous (non-bursty) signal, the (de)randomizer can be initialized to a random value. The initialization of the (de)randomizer shall only be done at reset or power up. Initialization at a random value results in a better decorrelation of downstream signals, and thus, better FEXT performance when transmitted through a multi-pair copper cable.

Care shall be taken not to disturb the byte frame on the data traffic. The byte-parallel data stream shall first be converted in a serial stream with convention 'least-significant-bit-first' before it is applied to the randomizer. After randomization, the byte-parallel stream shall be restored with the same convention, so that bytes which are not randomized remain unchanged.

7.6.2.1.3 Definition of a Superframe

A superframe defines a period in time, during which an integer number of downstream frames and an integer number of upstream frames shall be transmitted. Superframe related definitions are shown in Figure 7.6-29.

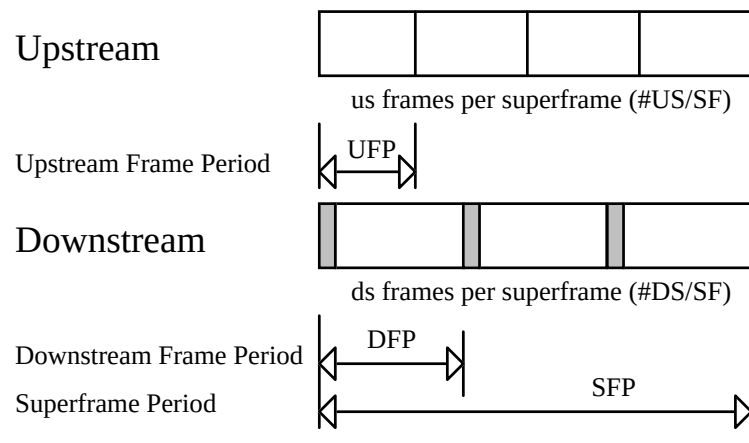


Figure 7.6-29- Superframe related definitions.

Depending on the bit rate setting, the superframe has a different transmission time. For each of the bit rate settings A, B, C and D, the timing diagram and the number of downstream and upstream frames carried in one superframe are shown in Figure 7.6-30.

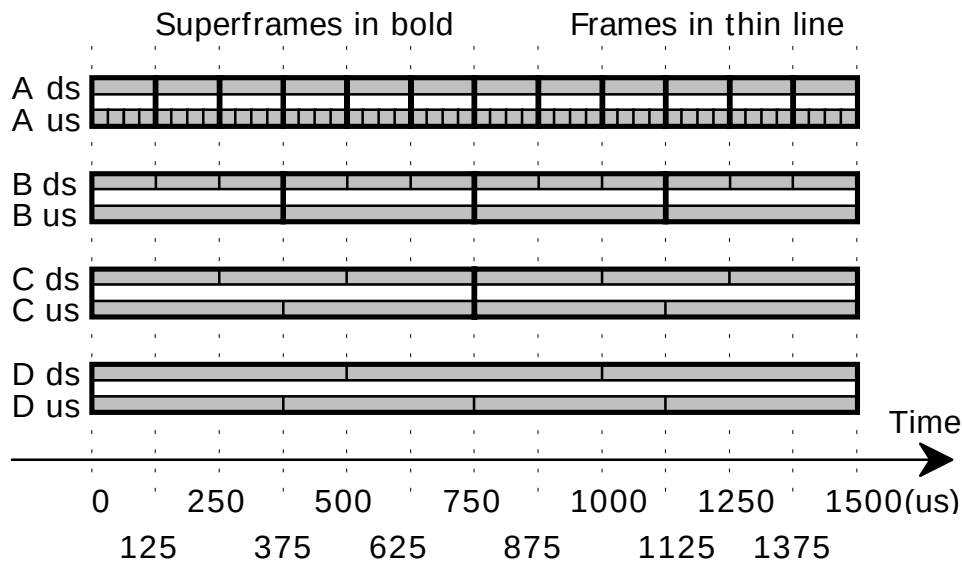


Figure 7.6-30 - Superframe and frame timing for bit rate settings A, B, C and D.

The network device shall align the downstream frame time alignment with its 8 kHz network clock as shown in Figure 7.6-31. This allows the user device to recover the 8 kHz network clock by upsampling the frame frequency (8, 4 or 2 kHz).

The user device shall derive the upstream frame time alignment from the downstream superframes, such that each upstream frame (as seen at the user device active output interface) starts 0 up to 4 upstream symbols after the start of the downstream superframe (as seen at the user device active input interface). The start of a downstream and upstream frame shall be defined as the center of its first symbol period. Downstream and upstream symbols are defined in Sections 7.6.1.5 and 7.6.1.6 respectively.

In case multiple upstream frames are transmitted per downstream superframe, these margins shall also apply at the following time intervals after the start of each downstream superframe (see Figure 7.6-31):

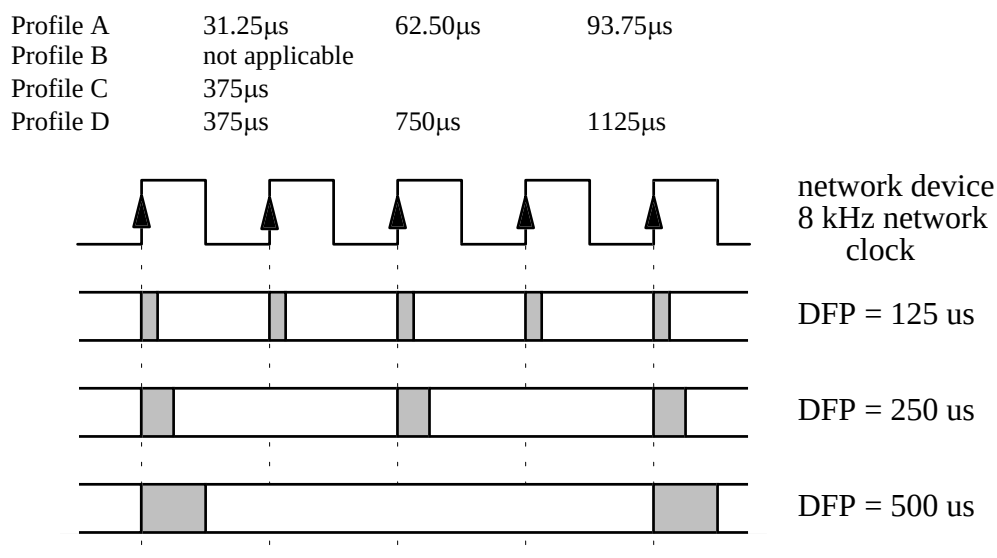


Figure 7.6-31 - Alignment of the downstream frames to the network device 8kHz clock.

7.6.2.1.4 Downstream Frame Header Byte Definition

The frame header shall consist of 18 bytes. All frames within the same superframe shall have the same header byte values (except the SFSC counter and the FEC bytes). The allocation of the header bytes shall be as shown in Table 7-13. Byte 0 shall be transmitted first.

Table 7-13- Allocation of the frame header bytes.

Byte	Name	Byte	Name
0	Sync 1	9	Control
1	Sync 2	10	Grant 1
2	User Data 1	11	Grant 2
3	User Data 2	12	Grant 3
4	Frame Format	13	Grant 4
5	FEC Format	14	FEC 1
6	Alarm	15	FEC 2
7	Data Link Address	16	FEC 3
8	Data Link Data	17	FEC 4

Byte 0-1: Sync 1 and Sync 2

The Sync 1 and Sync 2 bytes are the frame sync word and shall have fixed values.

Sync 1 = F6 hex, Sync 2 = 28 hex.

The frame sync word allows frame delineation in the user device. The frame delineation algorithm is based on the Sync_Event (Sync 1 and Sync 2) and shall be as shown in Figure 7.6-32:

- Transition of “Sync” to “Hunt” state when the frame sync word is not found at the expected location 7 times consecutively.
- Transition of “Presync” to “Sync” state when the frame sync word is found at the expected location 6 times consecutively.

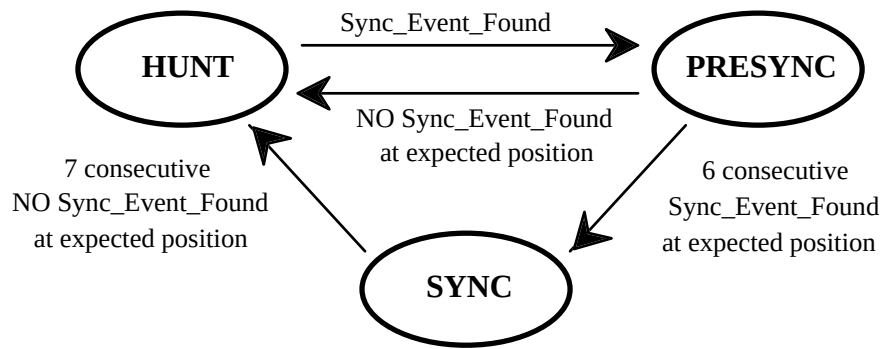


Figure 7.6-32 - Downstream frame synchronization state machine.

The frame delineation process is similar to the ATM cell delineation process described in section 7.6.2.5.3.

Byte 2-3: User Data 1 and User Data 2

Both User Data bytes shall be made available by the deframer implementation for further processing at the TC layer level in the user device. The operation of the PMD sublayer (including demodulator and symbol decoder) in the user device shall not depend upon the value of the User Data bytes.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
UD[7]	UD[6]	UD[5]	UD[4]	UD[3]	UD[2]	UD[1]	UD[0]

Byte 4: Frame Format

The Frame Format byte shall contain the superframe definition: superframe period (DFP), number of downstream frames per superframe (#DS/SF) and the number of upstream frames per superframe (#US/SF). The Frame Format byte value only depends upon the bit rate setting.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Reserved	Reserved	DFP 1	DFP 0	#DS/SF[1]	#DS/SF[0]	#US/SF[1]	#US/SF[0]
		00: DFP=125 us (8 kHz)		00: #DS/SF = 1		00: #US/SF = 1	
		01: DFP=250 us (4 kHz)		01: #DS/SF = 2		01: #US/SF = 2	
		10: DFP=500 us (2 kHz)		10: #DS/SF = 3		10: #US/SF = 3	
		11: not used		11: #DS/SF = 4		11: #US/SF = 4	

Reserved bits shall be set to 0.

The superframe definition for the possible bit rate settings shall be as given in Table 7-14.

Table 7-14- Frame Format settings depending on the bit rate.

Bit rate setting	DFP	SFP	#DS/SF	#US/SF
A	125 µs	125 µs	1	4
B	125 µs	375 µs	3	1
C	250 µs	750 µs	3	2
D	500 µs	1500 µs	3	4

Byte 5: FEC Format

The FEC byte shall contain the Reed-Solomon code word Interleaving Depth Parameter (M[4..0]) indication. The interleaving and deinterleaving process in network and user device shall be as described in section 7.6.2.3 with the interleaving depth (D) and block length (I) defined as:

$$I = (N/2)$$

$$D = M * (N/2) + 1$$

where N is the RS code word length and M=0..31.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Reserved	Reserved	Reserved	M[4]	M[3]	M[2]	M[1]	M[0]

The Interleaving Depth Parameter (M) value shall range from 0 to 31. The user device shall be able to deinterleave the complete set of interleaving depths corresponding with an Interleaving Depth Parameter (M) ranging from 0 to 31.

Byte 6: Alarm

The Alarm byte shall contain the frame payload alarm indication signal (AIS).

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
AIS	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

AIS = 0 shall indicate normal operation (valid frame payload).

AIS = 1 shall indicate alarm status (invalid frame payload).

Reserved bits shall be set to 0.

Byte 7: Data Link Address

The Data Link Address byte shall contain four command bits (COM[3..0]) and a user device identification (ID[3..0]).

The command bits interpretation shall be:

0		Idle command
1	→	Reset for Device ID[3..0]
2	→	Transmitter Shutdown for Device ID[3..0]
3		Data Link Byte = Network Device Transmit Power
4 to 14		Reserved
15		Data Link Byte = User Data

The reserved commands shall not be used by the network device.

The network device transmit power is encoded into a byte indicating 256 power levels. The upper level 255 shall correspond with the maximum transmit power of +15 dBm. The lower level 0 shall correspond with the minimum transmit power of -15 dBm. Linear interpolation shall be applied for the other levels. There shall be a maximum period of 250ms in-between consecutive transmissions of the network device output power.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
COM[3]	COM[2]	COM[1]	COM[0]	ID[3]	ID[2]	ID[1]	ID[0]

The Device ID value ranges from 0 to 15. If the Device ID is 0, the Data Link command shall be interpreted by all users devices (broadcast). If the Device ID is 15, the Data Link command shall not be interpreted by any user device. For other Device ID values (1 to 14), the Data Link byte shall be interpreted by the user device to which this Device ID is allocated.

After a reset command is sent to a particular user device, grants shall no longer be allocated to this user device.

The user device shall restart the procedure to get a Device ID allocated, just as it does after power up (sign-on cycle), to get grants allocated again.

After a transmitter shutdown is sent to a particular device, grants shall no longer be allocated to this user device.

The user device shall no longer output any upstream data (silent transmitter) until it is reset through the command described above (resulting in a sign-on procedure) or until it is going through a sign-on cycle for any other reason (e.g. through user intervention). After sign-on, the user device gets grants allocated again.

Byte 8: Data Link Byte

The Data Link Data byte shall be made available by the deframer implementation for further processing at the TC layer level in case the Data Link Address is broadcast (value 0) or matches the user device's Device ID.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
DL[7]	DL[6]	DL[5]	DL[4]	DL[3]	DL[2]	DL[1]	DL[0]

Byte 9: Control Byte

The Control Byte shall contain the Grant Control (GC1, GC2, GC3 and GC4) and the superframe Synchronization Control SFSC[1..0].

The GC bits indicate whether the corresponding grant byte is a grant which is already allocated to a user device or not. In case the grant is not allocated yet, the corresponding time slot can be used for sign-on of new user devices (see also sign-on section).

GC bit = 0 not open for sign-on

GC bit = 1 open for sign-on

There shall not be more than 50ms between two consecutive grants opened for sign-on. Only grant values ranging from 1 to 14 may have the GC bit set to 1. Grant values 0 and 15 shall always have the GC bit set to 0.

The superframe synchronization control bits indicate the sequence number of the frame within the superframe. The SFSC[1..0] bits shall take values from 0 to ($\#DS/SF-1$) and shall be 0 for the first frame within a superframe.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
GC1	GC2	GC3	GC4	Reserved	Reserved	SFSC[1]	SFSC[0]

Byte 10-13: Grants

The Grant bytes shall be used to control the upstream TDMA access. A superframe consists of up to 4 upstream frames. Each of these upstream frames may be transmitted by a different user device. Through the 4 grant bytes, the network devices shall indicate which user device is allowed to transmit which upstream frame.

Per superframe, 4 grant bytes shall be transmitted downstream. The first grant byte shall correspond to the first upstream frame, the second grant byte shall correspond to the second upstream frame, etc. If for example, the superframe contains only 2 upstream frames, the third and fourth grant bytes shall contain a user device ID equal to 15 (closed grant).

The Device ID value ranges from 0 to 15.

If the device ID = 0, the upstream frame may be transmitted by any user device (optional upstream response for all user devices, collision possible).

If the device ID = 15, no upstream frame shall be transmitted by any user device (closed grant).

If the Device ID is in the 1 to 14 range and it is not opened for sign-on, a valid upstream frame shall be transmitted by the user device to which this Device ID has been allocated (mandatory upstream response for the granted user device). A valid upstream frame may contain an idle ATM cell. In case this Device ID has not been allocated to any user device, no upstream frame will be transmitted.

If the Device ID is in the 1 to 14 range and it is opened for sign-on (through the GC bit=1), the upstream frame can be used by a new user device for sign-on (see section 7.6.2.4). If no new user device does so, no upstream frame will be transmitted.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
U_ERR	C_ERR	PLC1	PLC0	ID[3]	ID[2]	ID[1]	ID[0]

The granting and acknowledgment mechanism implemented in the bits ID[3..0] and U_ERR, C_ERR, PLC1 and PLC0 is shown in Figure 7.6-33 (bit rate setting A), Figure 7.6-34 (bit rate setting B), Figure 7.6-35 (bit rate setting C) and Figure 7.6-36 (bit rate setting D). Grants given in each of the downstream frames (DF) of the (n)th superframe (SF) are used for the upstream frames (US) of the (n+1)st superframe. These upstream frames of the (n+1)st superframe are acknowledged in each of the downstream frames of the (n+3)rd superframe.

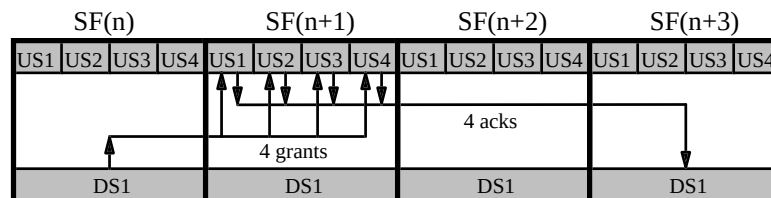


Figure 7.6-33 - Granting and acknowledgment of upstream access for bit rate setting A.

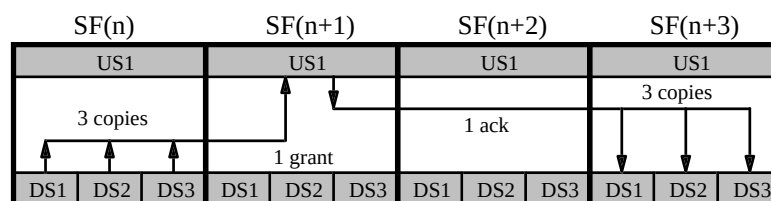


Figure 7.6-34 - Granting and acknowledgment of upstream access for bit rate setting B.

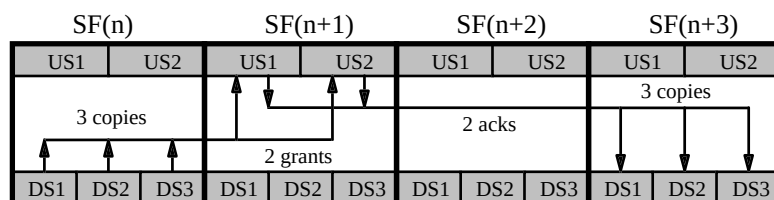


Figure 7.6-35 - Granting and acknowledgment of upstream access for bit rate setting C.

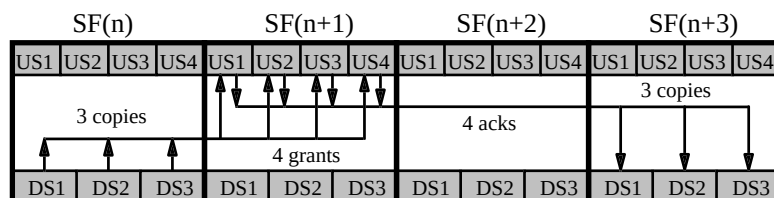


Figure 7.6-36 - Granting and acknowledgment of upstream access for bit rate setting D.

The U_ERR and C_ERR bits of the n^{th} ($n=1..4$) grant byte shall indicate the error status of the n^{th} upstream frame transmitted in the second previous superframe in the network device:

U_ERR = 0	C_ERR = 0	no errors detected
U_ERR = 0	C_ERR = 1	correctable errors
U_ERR = 1	C_ERR = 0	uncorrectable errors
U_ERR = 1	C_ERR = 1	no upstream frame received

If an upstream frame contains uncorrectable errors, the upstream frame shall be discarded by the network device. Whenever the upstream frame is discarded by the network device, the corresponding U_ERR bit shall be set to 1. The U_ERR bit being set to 1 shall correspond to a negative acknowledgment of the upstream frame reception (NACK).

If an upstream frame contains no errors or correctable errors, the upstream frame shall be accepted by the network device. Whenever the upstream frame is accepted by the network device, the corresponding U_ERR bit shall be set to 0. The U_ERR bit being set to 0 shall correspond to a positive acknowledgment of the upstream frame reception (ACK).

The Power Level Control (PLC1, PLC0) bits of the n^{th} ($n=1..4$) grant byte shall indicate the power level status of the n^{th} upstream frame transmitted in the second previous superframe in the network device:

00	the user device shall maintain the upstream power at the same level
10	the user device shall decrease the upstream power by one level
11	the user device shall increase the upstream power by 1 level
01	the user device can choose to perform one of the above actions

An increment or decrement of the power by one level shall correspond with a power increment or decrement between 0.75dB and 1.25 dB.

Byte 14-17: FEC bytes

The 4 FEC bytes are calculated over the bytes 2 to 13, using the Reed-Solomon RS(16,12) code. Bytes 2 to 17 of the downstream frame header shall compose an RS(16,12) code word, with byte 2 being the most significant byte of the code word and byte 17 being the least significant byte of the code word.

The user device shall use the error correcting capability to correct up to 2 bytes per downstream frame header.

The Reed-Solomon code generator polynomial and field generator polynomial shall be as described in section 7.6.2.3 with N and K set to implement an RS(16,12) code.

Except for the SFSC counter and the FEC bytes, all frame headers within a superframe shall be identical. This gives the user device multiple chances (if #DS/SF > 1) to receive the frame header. The header received with the lowest error level shall be processed in the user device i.e. correct headers shall be preferred over corrected headers.

In case all the frame headers received in a downstream superframe are uncorrectable, the user device is not able to extract the grant bytes from the downstream superframe. The user device shall therefore not perform any upstream access in the next superframe time period.