

Data-Over-Cable Service Interface Specifications

Downstream RF Interface Specification

CM-SP-DRFI-I07-081209

ISSUED

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Contents

1	SCOPE AND PURPOSE	1
1.1	SCOPE.....	1
1.2	PURPOSE OF DOCUMENT	2
1.3	ORGANIZATION OF DOCUMENT	2
1.4	REQUIREMENTS.....	2
2	REFERENCES.....	3
2.1	NORMATIVE REFERENCES	3
2.2	INFORMATIVE REFERENCES.....	3
2.3	REFERENCE ACQUISITION	4
3	TERMS AND DEFINITIONS	5
4	ACRONYMS AND ABBREVIATIONS	7
5	FUNCTIONAL ASSUMPTIONS	8
5.1	BROADBAND ACCESS NETWORK.....	8
5.2	EQUIPMENT ASSUMPTIONS.....	8
5.2.1	<i>Frequency Plan.....</i>	8
5.2.2	<i>Compatibility with Other Services.....</i>	8
5.2.3	<i>Fault Isolation Impact on Other Users.....</i>	9
5.3	DOWNSTREAM PLANT ASSUMPTIONS.....	9
5.3.1	<i>Transmission Levels.....</i>	9
5.3.2	<i>Frequency Inversion.....</i>	9
5.3.3	<i>Analog and Digital Channel Line-up.....</i>	9
5.3.4	<i>Analog Protection Goal.....</i>	9
6	PHYSICAL MEDIA DEPENDENT SUBLAYER SPECIFICATION.....	10
6.1	SCOPE.....	10
6.2	EDGEQAM (EQAM) DIFFERENCES FROM CMTS	10
6.3	DOWNSTREAM.....	11
6.3.1	<i>Downstream Protocol.....</i>	11
6.3.2	<i>Spectrum Format</i>	11
6.3.3	<i>Scaleable Interleaving to Support Video and High-Speed Data Services.....</i>	11
6.3.4	<i>Downstream Frequency Plan</i>	12
6.3.5	<i>DRFI Output Electrical</i>	12
6.3.6	<i>CMTS or EQAM Clock Generation.....</i>	18
6.3.7	<i>Downstream Symbol Clock Jitter for Synchronous Operation.....</i>	19
6.3.8	<i>Downstream Symbol Clock Drift for Synchronous Operation.....</i>	19
6.3.9	<i>Timestamp Jitter</i>	19
7	DOWNSTREAM TRANSMISSION CONVERGENCE SUBLAYER.....	21
7.1	INTRODUCTION.....	21
7.2	MPEG PACKET FORMAT	21
7.3	MPEG HEADER FOR DOCSIS DATA-OVER-CABLE.....	21
7.4	MPEG PAYLOAD FOR DOCSIS DATA-OVER-CABLE.....	22
7.4.1	<i>stuff_byte.....</i>	22
7.4.2	<i>pointer_field.....</i>	22
7.5	INTERACTION WITH THE MAC SUBLAYER	23
7.6	INTERACTION WITH THE PHYSICAL LAYER.....	24

ANNEX A	ADDITIONS AND MODIFICATIONS FOR EUROPEAN SPECIFICATION.....	25
A.1	SCOPE AND PURPOSE	25
A.2	REFERENCES	25
A.2.1	<i>Normative References</i>	25
A.3	TERMS AND DEFINITIONS	25
A.4	ACRONYMS AND ABBREVIATIONS.....	25
A.5	FUNCTIONAL ASSUMPTIONS.....	25
A.5.1	<i>Broadband Access Network</i>	26
A.5.2	<i>Equipment Assumptions</i>	26
A.5.3	<i>Downstream Plant Assumptions</i>	26
A.6	PHYSICAL MEDIA DEPENDENT SUBLAYER SPECIFICATION	27
A.6.1	<i>Scope</i>	27
A.6.2	<i>EdgeQAM (EQAM) differences from CMTS</i>	27
A.6.3	<i>Downstream</i>	27
A.7	DOWNSTREAM TRANSMISSION CONVERGENCE SUBLAYER	34
A.7.1	<i>Introduction</i>	34
A.7.2	<i>MPEG Packet Format</i>	34
A.7.3	<i>MPEG Header for DOCSIS Data-Over-Cable</i>	34
A.7.4	<i>MPEG Payload for DOCSIS Data-Over-Cable</i>	34
A.7.5	<i>Interaction with the MAC Sublayer</i>	34
A.7.6	<i>Interaction with the Physical Layer</i>	34
ANNEX B	DOCS-DRF-MIB (NORMATIVE).....	35
APPENDIX I	ACKNOWLEDGEMENTS (INFORMATIVE).....	51
APPENDIX II	REVISION HISTORY (INFORMATIVE).....	52
II.1	ENGINEERING CHANGES FOR CM-SP-DRFI-I02-051209.....	52
II.2	ENGINEERING CHANGES FOR CM-SP-DRFI-I03-060106.....	52
II.3	ENGINEERING CHANGE FOR CM-SP-DRFI-I04-061222	52
II.4	ENGINEERING CHANGE FOR CM-SP-DRFI-I05-070223	52
II.5	ENGINEERING CHANGE FOR CM-SP-DRFI-I06-080215	52
II.6	ENGINEERING CHANGE FOR CM-SP-DRFI-I07-081209	53

Figures

FIGURE 6–1 - LOGICAL VIEW OF MODULAR CMTS AND INTERFACES	10
FIGURE 7–1 - EXAMPLE OF INTERLEAVING MPEG PACKETS IN DOWNSTREAM	21
FIGURE 7–2 - FORMAT OF AN MPEG PACKET	21
FIGURE 7–3 - PACKET FORMAT WHERE A MAC FRAME IMMEDIATELY FOLLOWS THE POINTER FIELD	23
FIGURE 7–4 - PACKET FORMAT WITH MAC FRAME PRECEDED BY STUFFING BYTES	23
FIGURE 7–5 - PACKET FORMAT SHOWING MULTIPLE MAC FRAMES IN A SINGLE PACKET	23
FIGURE 7–6 - PACKET FORMAT WHERE A MAC FRAME SPANS MULTIPLE PACKETS	23

Tables

TABLE 6–1 - LOW LATENCY INTERLEAVER DEPTHS	11
TABLE 6–2 - LONG DURATION BURST NOISE PROTECTION INTERLEAVER DEPTHS.....	12
TABLE 6–3 - RF OUTPUT ELECTRICAL REQUIREMENTS	13
TABLE 6–4 - DRFI DEVICE OUTPUT POWER	14
TABLE 6–5 - EQAM OR CMTS OUTPUT OUT-OF-BAND NOISE AND SPURIOUS EMISSIONS REQUIREMENTS	17
TABLE 6–6 - DOWNSTREAM SYMBOL RATES & PARAMETERS FOR SYNCHRONIZATION WITH MASTER CLOCK.....	19
TABLE 7–1 - MPEG HEADER FORMAT FOR DOCSIS DATA-OVER-CABLE PACKETS	22
TABLE A–1 - INTERLEAVER CHARACTERISTICS.....	27
TABLE A–2 - OUTPUT ELECTRICAL REQUIREMENTS PER RF PORT	28
TABLE A–3 - DRFI DEVICE OUTPUT POWER	29
TABLE A–4 - EQAM OR CMTS OUTPUT OUT-OF-BAND NOISE AND SPURIOUS EMISSIONS REQUIREMENTS	31
TABLE A–5 - DOWNSTREAM SYMBOL RATES & PARAMETERS FOR SYNCHRONIZATION WITH THE MASTER CLOCK.....	33

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1 SCOPE AND PURPOSE

1.1 Scope

This document defines the downstream radio-frequency interface [DRFI] specifications for:

- an edgeQAM (EQAM) modular device, or
- an integrated Cable Modem Termination System [CMTS] with multiple downstream channels per RF port, or
- an integrated CMTS beyond DOCSIS 2.0.

There are differences in the cable spectrum planning practices adopted for different networks in the world. Therefore two options for physical layer technology are included, which have equal priority and are not required to be interoperable. One technology option is based on the downstream multi-program television distribution that is deployed in North America using 6 MHz channeling. The other technology option is based on the corresponding European multi-program television distribution. Both options have the same status, notwithstanding that the document structure does not reflect this equal priority. The first of these options is defined in Sections 5, 6, 7, whereas the second is defined by replacing the content of those sections with the content of Annex A.

Correspondingly, [ITU-T J.83-B] and [CEA-542-B] apply only to the first option, and [EN 300 429] only to the second. Compliance with this document requires compliance with the one or the other of these implementations, not with both. It is not required that equipment built to one option shall interoperate with equipment built to the other.

A DRFI-compliant device may be a single-channel only device, or it may be a multiple-channel device capable of generating one or multiple downstream RF carriers simultaneously on one RF output port. An EQAM may be a module of a modular cable modem termination system (M-CMTS) and be used for delivering a high-speed data service or it may serve as a component of a digital video or video-on-demand (VOD) system, delivering high quality digital video to subscribers. These specifications are crafted to enable an EQAM to be used without restriction in either or both service delivery scenarios simultaneously. “Simultaneous” in the early deployments means that if a RF output port has multiple QAM channels, some channel(s) may be delivering high-speed data while some other channel(s) may be delivering digital video. This specification enables future uses, wherein a single QAM channel may share bandwidth between high-speed data and digital video in the same MPEG transport stream.

Conceptually, an EQAM will accept input via an Ethernet link, integrate the incoming data into an MPEG transport stream, modulate one of a plurality of RF carriers, per these specifications, and deliver the carrier to a single RF output connector shared in common with all modulators. Conceivably, a single EQAM RF channel could be used for data and video simultaneously. The reason that an EQAM RF channel can be used for either is that both digital video and DOCSIS data downstream channels are based on ITU-T J.83 Annex B [ITU-T J.83-B] for cable networks in North America and EN 300 429 [EN 300 429] for cable networks deployed in Europe. On downstream channels complying to ITU-T J.83, Annex B, typically, the only difference between an EQAM RF channel operating in a video mode and an EQAM RF channel operating in DOCSIS data mode is the interleaver depth (see Sections 6.3.1 and 6.3.3). DOCSIS data runs in a low latency mode using a shallow interleaver depth at the cost of some burst protection. DOCSIS data can do this because if a transmission error occurs, the higher layer protocols will request re-transmission of the missing data. For video, the sequence of frames in the program is both time sensitive and order sensitive and cannot be re-transmitted. For this reason, video uses a deeper interleaver depth to provide more extensive burst protection and deliver more of the program content without loss. The penalty video pays is in latency. The entire program content is delayed by a few milliseconds, typically, and is invisible to the viewers of the program. The conflicting demands for interleaver depth are what prevent a single EQAM RF channel from being used optimally for video and DOCSIS data simultaneously. A traditional integrated CMTS, however, is used solely for DOCSIS data.

The specifications were developed by Cable Television Laboratories (CableLabs) for the benefit of the cable industry. These specifications are mostly comprised of contributions from operators and vendors throughout the world.

1.2 Purpose of Document

The purpose of this document is to define the RF characteristics required in the downstream transmitter(s) of CMTSs and EQAMs, sufficiently enough to permit vendors to build devices that meet the needs of CableLabs multiple system operators (MSOs) around the world. Such devices implementing the first technology option can be submitted to CableLabs for qualification testing in conjunction with one or several vendor's compatible components, while a certification scheme for devices compliant to the second technology option is managed by EuroCableLabs. This level of multi-vendor interoperability is a critical measure of our ability to achieve the purpose of this document.

1.3 Organization of Document

This document will not attempt to wholly replicate the normative references provided in the document. However, it will use extracted portions of said documents where it adds clarity to this document. For fuller understanding of this document, the most recent versions of [ITU-T J.83-B] Annex B or [EN 300 429], respectively, as well as [DOCSIS2] should be available for reference.¹

1.4 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

“MUST” or “SHALL”	This word or the adjective “REQUIRED” means that the item is an absolute requirement of this specification.
“MUST NOT” or “SHALL NOT”	This phrase means that the item is an absolute prohibition of this specification.
“SHOULD”	This word or the adjective “RECOMMENDED” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
“SHOULD NOT”	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
“MAY”	This word or the adjective “OPTIONAL” means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

¹ Text modified per ECN DRFI-N-05.0263.3 by KN on 2/21/07

2 REFERENCES

2.1 Normative References²

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

- [DOCSIS2] Data-Over-Cable Service Interface Specifications, Radio Frequency Interface Specification v2.0, CM-SP-RFIV2.0-C01-081104, November 4, 2008, Cable Television Laboratories, Inc.
- [CEA-542-B] CEA-542-B: "CEA Standard: Cable Television Channel Identification Plan," July 2003.
- [ANSI/SCTE 02] ANSI/SCTE 02 2006, "Specification for F Port, Female, Indoor."
- [ITU-T J.83-B] Annex B to ITU-T Rec. J.83 (12/07), "Digital multi-programme systems for television sound and data services for cable distribution."
- [ISO 13818] ISO/IEC 13818-1, "Information Technology – Generic Coding of Moving Pictures and Associated Audio: Systems / ITU-T Rec. H.222.0," 2007.

2.2 Informative References

This specification uses the following informative references.

- [NSI] CMTS Network Side Interface, SP-CMTS-NSI-I01-960702, July 2, 1996, Cable Television Laboratories, Inc.
- [M-OSSI] Modular CMTS Operation Support System Interface, CM-SP-M-OSSI-I08-081209, December 9, 2008, Cable Television Laboratories, Inc.
- [CMCI] Cable Modem CPE Interface, CM-SP-CMCI-C01-081104, November 4, 2008, Cable Television Laboratories, Inc.
- [DEPI] Downstream External-PHY Interface, CM-SP-DEPI-I06-081209, December 9, 2008, Cable Television Laboratories, Inc.
- [DTI] DOCSIS Timing Interface, CM-SP-DTI-I06-081209, December 9, 2008, Cable Televisions Laboratories, Inc.
- [ERMI] Edge Resource Manager Interface, CM-SP-ERMI-I03-081107, November 7, 2008, Cable Television Laboratories, Inc.

² Section modified per 07.0576-2 on 1/16/08 by KN and per 08.0697-2 by JS.

2.3 Reference Acquisition

- Cable Television Laboratories, Inc., <http://www.cablelabs.com/>
- EIA: Electronic Industries Alliance, http://www.eia.org/new_contact/
- ETSI: European Telecommunications Standards Institute, http://www.etsi.org/services_products/freestandard/home.htm
- ITU: International Telecommunication Union (ITU), <http://www.itu.int/home/contact/index.html>
- ISO: International Organization for Standardization (ISO), <http://www.iso.org/iso/en/xsite/contact/contact.html>
- SCTE: Society of Cable Telecommunications Engineers, <http://www.scte.org>

3 TERMS AND DEFINITIONS

This specification uses the following terms:³

Ceiling (ceil)	Returns the first integer that is greater than or equal to a given value.
CM	Cable Modem. A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.
CPE	Customer Premises Equipment. Equipment at the end user's premises; may be provided by the service provider.
Carrier-to-Noise Ratio (C/N or CNR)	Carrier-to-Noise Ratio. The ratio of signal power to noise power in a defined measurement bandwidth. For digital modulation, $CNR = E_s/N_o$, the energy-per symbol to noise-density ratio; the signal power is measured in the occupied bandwidth, and the noise power is normalized to the modulation-rate bandwidth. For analog NTSC video modulation, the noise measurement bandwidth is 4 MHz.
Decibels (dB)	Ratio of two power levels expressed mathematically as $dB = 10\log_{10}(P_{OUT}/P_{IN})$.
Decibel-Millivolt (dBmV)	Unit of RF power expressed in decibels relative to 1 millivolt over 75 ohms, where $dBmV = 20\log_{10}(\text{value in mV}/1 \text{ mV})$.
Electronic Industries Alliance (EIA)	A voluntary body of manufacturers which, among other activities, prepares and publishes standards.
EQAM	EdgeQAM modulator. A head end or hub device that receives packets of digital video or data. It re-packetizes the video or data into an MPEG transport stream and digitally modulates the digital transport stream onto a downstream RF carrier using quadrature amplitude modulation (QAM).
FEC	Forward Error Correction. A class of methods for controlling errors in a communication system. FEC sends parity information with the data which can be used by the receiver to check and correct the data.
Gigahertz (GHz)	A unit of frequency; 1,000,000,000 or 10^9 Hz.
Hertz (Hz)	A unit of frequency; formerly cycles per second.
HRC	Harmonic Related Carriers. A method of spacing channels on a cable television system with all carriers related to a common reference.
HFC	Hybrid Fiber/Coax System. A broadband bidirectional shared-media transmission system using optical fiber trunks between the head-end and the fiber nodes, and coaxial cable distribution from the fiber nodes to the customer locations.
IRC	Incremental Related Carriers. A method of spacing NTSC television channels on a cable television system in which all channels are offset up 12.5 kHz with respect to the [CEA-542-B] standard channel plan except for channels 5 and 6.
kilohertz (kHz)	Unit of frequency; 1,000 or 10^3 Hz; formerly kilocycles per second.
Media Access Control (MAC)	Used to refer to the layer 2 element of the system which would include DOCSIS framing and signaling.
Megahertz (MHz)	A unit of frequency; 1,000,000 or 10^6 Hz; formerly megacycles per second.
MER	Modulation Error Ratio. The ratio of the average symbol power to average error power.

³ Revised Terms and Definitions, (Ceiling) per ECN DRFI-N-06.0285-2 by GO on 10/9/06.

M/N	Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate.
Multiple System Operator (MSO)	A corporate entity that owns and/or operates more than one cable system.
NTSC	National Television Systems Committee. Committee which defined the analog, color television, broadcast standards in North America. The standards television 525-line video format for North American television transmission is named after this committee.
NGNA LLC	Company formed by cable operators to define a next-generation network architecture for future cable industry market and business requirements.
Physical Media Dependent Sublayer (PMD)	A sublayer of the Physical layer which is concerned with transmitting bits or groups of bits over particular types of transmission link between open systems and which entails electrical, mechanical and handshaking procedures.
QAM channel (QAM ch)	Analog RF channel that uses quadrature amplitude modulation (QAM) to convey information.
Quadrature Amplitude Modulation (QAM)	A modulation technique in which an analog signal's amplitude and phase vary to convey information, such as digital data.
Radio Frequency (RF)	A portion of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light.
Radio Frequency Interface (RFI)	Term encompassing the downstream and the upstream radio frequency interfaces.
Root Mean Square (RMS)	Square root of the mean value squared a function.
Self-Aggregation	Method used to compute the headend noise floor by summing measured noise from a single device over a specified output frequency range.
Standard Channel Plan (STD)	Method of spacing NTSC television channels on a cable television system defined in [CEA-542-B].
Upstream Channel Descriptor (UCD)	The MAC Management Message used to communicate the characteristics of the upstream physical layer to the cable modems.
Video on Demand (VoD)	System that enables individuals to select and watch video content over a network through an interactive television system.

4 ACRONYMS AND ABBREVIATIONS

This specification uses the following terms:

CMCI	Cable Modem CPE Interface
CMTS	Cable Modem Termination System
CW	Continuous Wave
dBc	Decibels relative to carrier power
DEPI	Downstream External-PHY Interface
DOCSIS	Data-Over-Cable Service Interface Specifications
DRFI	Downstream Radio Frequency Interface
DTI	DOCSIS Timing Interface
ERMI	Edge Resource Manager Interface
FCC	Federal Communications Commission
ISO	International Standards Organization
ITU	International Telecommunications Union
ITU-T	Telecommunication Standardization Sector of the ITU
M-CMTS	Modular Cable Modem Termination System
Ms	Millisecond. 10^{-3} second
MPEG	Moving Picture Experts Group
Ns	Nanosecond. 10^{-9} second
NGNA	Next Generation Network Architecture, see <i>NGNA LLC</i>
OSSI	Operations System Support Interface
PHY	Physical Layer
ppm	Parts per Million
Q	Quadrature modulation component
S-CDMA	Synchronous Code Division Multiple Access.

5 FUNCTIONAL ASSUMPTIONS

This section describes the characteristics of a cable television plant, assumed to be for the purpose of operating a data-over-cable system. It is not a description of EQAM or CMTS parameters. The data-over-cable system **MUST** be interoperable within the environment described in this section.

Whenever there is a reference in this section to frequency plans or compatibility with other services, or conflicts with any legal requirement for the area of operation, the latter shall take precedence. Any reference to NTSC analog signals in six MHz channels does not imply that such signals are physically present.

5.1 Broadband Access Network

A coaxial-based broadband access network is assumed. This may take the form of either an all-coax or hybrid fiber/coax (HFC) network. The generic term “cable network” is used here to cover all cases.

A cable network uses a shared-medium, “tree-and-branch” architecture, with analog transmission. The key functional characteristics assumed in this document are the following:

- Two-way transmission
- A maximum optical/electrical spacing between the DRFI-compliant device and the most distant CM of 100 miles in each direction, although typical maximum separation may be 10-15 miles
- A maximum differential optical/electrical spacing between the DRFI-compliant device and the closest and most distant modems of 100 miles in each direction, although this would typically be limited to 15 miles

At a propagation velocity in fiber of approximately 1.5 ns/ft, 100 miles of fiber in each direction results in a round-trip delay of approximately 1.6 ms. For further information, see [DOCSIS2], Appendix VIII.

5.2 Equipment Assumptions

5.2.1 Frequency Plan

In the downstream direction, the cable system is assumed to have a pass band with a lower edge between 50 and 54 MHz and an upper edge that is implementation-dependent but is typically in the range of 300 to 870 MHz. Within that pass band, NTSC analog television signals in six-MHz channels are assumed present on the Standard (STD), HRC, or IRC frequency plans of [CEA-542-B], as well as other narrowband and wideband digital signals.

5.2.2 Compatibility with Other Services

The CM and EQAM or CMTS **MUST** coexist with the other services on the cable network, for example:

1. They **MUST** be interoperable in the cable spectrum assigned for EQAM or CMTS-CM interoperation, while the balance of the cable spectrum is occupied by any combination of television and other signals, and
2. They **MUST NOT** cause harmful interference to any other services that are assigned to the cable network in spectrum outside of that allocated to the EQAM or CMTS. The latter is understood as:
 - No measurable degradation (highest level of compatibility),
 - No degradation below the perceptible level of impairments for all services (standard or medium level of compatibility), or
 - No degradation below the minimal standards accepted by the industry (for example, FCC for analog video services) or other service provider (minimal level of compatibility).

5.2.3 Fault Isolation Impact on Other Users

As downstream transmissions are on a shared-media, point-to-multipoint system, fault-isolation procedures should take into account the potential harmful impact of faults and fault-isolation procedures on numerous users of the data-over-cable, video, and other services.

For the interpretation of harmful impact, see Section 5.2.2 above.

5.3 Downstream Plant Assumptions

The DRFI specifications have been developed with the downstream plant assumptions of this section.

5.3.1 Transmission Levels

The nominal power level of the downstream RF signal(s) within a six-MHz channel (average power) is targeted to be in the range: -10 dBc to -6 dBc, relative to analog video carrier level (peak power) and will normally not exceed analog video carrier level.

5.3.2 Frequency Inversion

There will be no frequency inversion in the transmission path in either the downstream or the upstream directions (*i.e.*, a positive change in frequency at the input to the cable network will result in a positive change in frequency at the output).

5.3.3 Analog and Digital Channel Line-up

In developing this specification, it was assumed that a maximum of 119 digital channels would be deployed in a headend. For the purposes of calculating CNR, protection for analog channels, it was assumed that analog channels are placed at lower frequencies in the channel line-up, versus digital channels.

5.3.4 Analog Protection Goal

One of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 60 dB for systems deploying up to 119 DRFI-compliant QAM channels.

The specification assumes that the transmitted power level of the digital channels will be 6 dB below the peak envelope power of the visual signal of analog channels, which is the typical condition for 256 QAM transmission. It is further assumed that the channel lineup will place analog channels at lower frequencies versus digital channels. An adjustment of $10 \cdot \log_{10}(6 \text{ MHz} / 4 \text{ MHz})$ is used to account for the difference in noise bandwidth of digital channels versus analog channels. With the assumptions above, for a 119 QAM channel system, the specification in Item 5 of Table 6-5 equates to an analog CNR protection of 60dB.

6 PHYSICAL MEDIA DEPENDENT SUBLAYER SPECIFICATION

6.1 Scope

This section applies to the first technology option referred to in Section 1.1. For the second option, refer to Annex A.

This specification defines the electrical characteristics of the Downstream Radio Frequency Interface (DRFI) of a cable modem termination system (CMTS) or an edgeQAM (EQAM). It is the intent of this specification to define an interoperable DRFI-compliant device, such that any implementation of a CM can work with any EQAM or CMTS. It is not the intent of this specification to imply any specific implementation. Figure 6–1 shows the M-CMTS structure and interfaces.

Whenever a reference in this section to spurious emissions conflicts with any legal requirement for the area of operation, the latter shall take precedence.

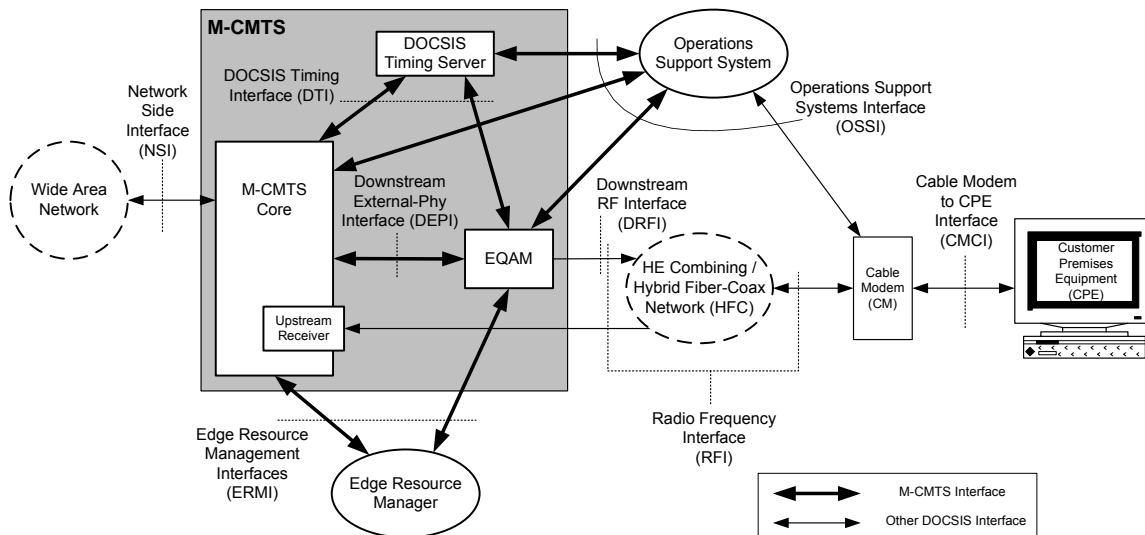


Figure 6–1 - Logical View of Modular CMTS and Interfaces

The CMTS Network Side Interface [NSI], Modular CMTS Operation Support System Interface [M-OSSI], Radio Frequency Interface [RFI], and the Cable Modem CPE Interface [CMCI] are documented in existing DOCSIS specifications (see Section 2.2). The DOCSIS Timing Interface [DTI], Downstream External-PHY Interface [DEPI], Downstream Radio Frequency Interface (this specification), and Edge Resource Manager Interface [ERMI] require new specifications specific to the M-CMTS in a Next Generation Network Architecture [NGNA] environment.

6.2 EdgeQAM (EQAM) differences from CMTS

The EQAM is primarily the RF modulation and transmission module extracted from a consolidated CMTS. Because the CMTS has been divided into constituent parts into the modules, the EQAM needs to have a new interface to the Modular-CMTS (M-CMTS) MAC module. That new interface is an Ethernet interface, as specified in the [DEPI], needed to communicate with the now remote EQAM. DEPI constructs, semantics, and syntax, as well as any new EQAM components and processing, are defined in the DEPI documentation.

EQAMs may also interface to video servers, via the Ethernet interface, and provide a downstream RF transmission to deliver digital video services. The protocols necessary to implement video services over EQAMs are out of the scope of this document.

Several new features are supported in this specification. The DOCSIS 1.x and 2.0 specifications do not reflect the ability of vendors to support multiple RF channels per physical RF port. This document presents the requirements and optional functions that enable an EQAM, or a CMTS, with multiple channels per RF port to be tested, measured and, if successful, qualified.

For an M-CMTS, module synchronization is not as easy as with an integrated CMTS. A DRFI-compliant EQAM has a timing port on it that enables a high precision (DTI) to be used to distribute a common clock and timing signals. This permits the EQAM to be used in all modes, including S-CDMA mode, because of the high stability and low jitter of the external clock and distribution system. The DOCSIS Timing Interface is defined in the [DTI] specification.

6.3 Downstream

6.3.1 Downstream Protocol

The downstream PMD sublayer MUST conform to ITU-T Recommendation J.83 Annex B [ITU-T J.83-B], except for Section B.6.2. Interleaver depths are defined in Section 6.3.3 of this document. The applicability of a particular interleaver depth depends on the data service provided on a particular QAM RF channel. Applicability of interleaver depths for service delivery, other than DOCSIS high-speed data, is beyond the scope of this document.

6.3.2 Spectrum Format

The downstream modulator for each QAM channel of the EQAM, or CMTS, MUST provide operation with the RF signal format of $S(t) = I(t) \cdot \cos(wt) + Q(t) \cdot \sin(wt)$, where t denotes time, w denotes RF angular frequency, and where $I(t)$ and $Q(t)$ are the respective Root-Nyquist filtered baseband quadrature components of the constellation, as specified in ITU-T Recommendation J.83, Annex B [ITU-T J.83-B].

6.3.3 Scaleable Interleaving to Support Video and High-Speed Data Services

The CMTS or EQAM downstream PMD sublayer MUST support a variable-depth interleaver. [ITU-T J.83-B] defines the variable interleaver depths in “Table B.2/J.83 – Level 2 interleaving.”

A CMTS or EQAM MUST support the set of interleaver depths described in Table 6–1 and Table 6–2. Requirements for operational availability of interleaver depths are given in Section 6.3.5.1.2, Sub-section 1.

Table 6–1 - Low Latency Interleaver Depths

Control Word	Interleaver Taps	Interleaver Increment	64QAM 5.056941 Msym/sec 6 bits per symbol		256QAM 5.360537 Msym/sec 8 bits per symbol	
			Burst Protection	Latency	Burst Protection	Latency
Four Bits	I	J				
1001	8	16	5.9 uSec	0.22 mSec	4.1 uSec	0.15 mSec
0111	16	8	12 uSec	0.48 mSec	8.2 uSec	0.33 mSec
0101	32	4	24 uSec	0.98 mSec	16 uSec	0.68 mSec
0011	64	2	47 uSec	2.0 mSec	33 uSec	1.4 mSec
0001	128	1	95 uSec	4.0 mSec	66 uSec	2.8 mSec

Table 6–2 - Long Duration Burst Noise Protection Interleaver Depths

Control Word	Interleaver Taps	Interleaver Increment	64QAM 5.056941 Msym/sec 6 bits per symbol		256QAM 5.360537 Msym/sec 8 bits per symbol	
			Burst Protection	Latency	Burst Protection	Latency
Four Bits	I	J				
0000	128	1	95 uSec	4.0 mSec	66 uSec	2.8 mSec
0010	128	2	190 uSec	8.0 mSec	132 uSec	5.6 mSec
0100	128	3	285 uSec	12 mSec	198 uSec	8.4 mSec
0110	128	4	380 uSec	16 mSec	264 uSec	11 mSec
1000	128	5	475 uSec	20 mSec	330 uSec	14 mSec
1010	128	6	570 uSec	24 mSec	396 uSec	17 mSec
1100	128	7	664 uSec	28 mSec	462 uSec	20 mSec
1110	128	8	759 uSec	32 mSec	528 uSec	22 mSec

The interleaver depth, which is coded in a 4-bit control word contained in the FEC frame synchronization trailer, always reflects the interleaving in the immediately following frame. In addition, errors are allowed while the interleaver memory is flushed after a change in interleaving is indicated.

Refer to [ITU-T J.83-B] for the control bit specifications required to specify which interleaving mode is used.

6.3.4 Downstream Frequency Plan

The downstream frequency plan SHOULD comply with a Harmonic Related Carrier (HRC); Incremental Related Carrier (IRC), or Standard (STD) North American frequency plans, per [CEA-542-B] for digital QAM carriers. Operational frequencies MAY include all channels between, and including center frequencies of 57 MHz to 999 MHz. Operational frequencies MUST include at least 91 MHz to 867 MHz.

6.3.5 DRFI Output Electrical

EQAMs and CMTSs may be available in two distinct versions:

- Single channel devices that can only generate one RF channel per physical RF port.
- Multiple channel devices capable of generating more than one channel simultaneously per physical RF port. A multiple channel device could be used to generate a single channel; even so, it is still defined as a multiple channel device.

An N -channel per RF port device MUST comply with all requirements operating with all N channels on the RF port, and MUST comply with all requirements for an N' -channel per RF port device operating with N' channels on the RF port for all even values of N' less than N , and for $N' = 1$. A single channel device MUST comply with all requirements for an N -channel device with $N = 1$.

These specifications assume that the DRFI device will be terminated with a 75 Ohm load.

If more than one CMTS or EQAM is packaged in a chassis, each CMTS or EQAM MUST meet the appropriate parameters and definitions in this specification, regardless of the number of other CMTSs or EQAMs, their location in the chassis, or their configuration.

6.3.5.1 CMTS or EQAM Output Electrical

A CMTS or EQAM MUST output an RF modulated signal with the characteristics defined in Table 6–3, Table 6–4 and Table 6–5. The condition for these requirements is all N combined channels, commanded to the same average power, except for the Single Channel Active Phase Noise and Diagnostic Carrier Suppression (Table 6–4) requirements.

Table 6–3 - RF Output Electrical Requirements⁴

Parameter	Value
Center Frequency (fc) of any RF channel of a CMTS or EQAM	MAY be 57 MHz to 999 MHz \pm 30 kHz (Note 1) MUST be at least 91 MHz to 867 MHz \pm 30 kHz
Level	Adjustable. See Table 6–4.
Modulation Type	64QAM , 256QAM
Symbol Rate (nominal) 64QAM 256QAM	5.056941 Msym/sec 5.360537 Msym/sec
Nominal Channel Spacing	6 MHz
Frequency response 64QAM 256QAM	~ 0.18 Square Root Raised Cosine Shaping ~ 0.12 Square Root Raised Cosine Shaping
Inband Spurious, Distortion, and Noise	Unequalized MER (Note 2) > 35 dB Equalized MER > 43 dB
Inband Spurious and Noise	\leq -48dBc; where channel spurious and noise includes all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, and other undesired transmitter products. Spurious and noise within \pm 50 kHz of the carrier is excluded. When N > 1, noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	See Table 6–5.
Phase Noise Single Channel Active, N – 1 Channels Suppressed (see Section 6.3.5.1.2 (6)) 64QAM and 256QAM	1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power 50 kHz - 3 MHz: -51dBc double sided noise power
All N Channels Active, (see Section 6.3.5.1.2 (7)) 64QAM and 256QAM	1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power
Output Impedance	75 ohms
Output Return Loss (Note 3)	> 14 dB within an active output channel from 88 MHz to 750 MHz (Note 4) > 13 dB within an active output channel from 750 MHz to 870 MHz (Note 5) > 12 dB in every inactive channel from 54 MHz to 870 MHz > 10 dB in every inactive channel from 870 MHz to 1002 MHz
Connector	F connector per [ANSI/SCTE 02]

⁴ Table modified per 07.0576-2 on 1/16/08 by KN.

Parameter	Value
Notes to Table 6–3:	
1. 30 kHz includes an allowance of 25 kHz for the largest FCC frequency offset normally built into upconverters.	
2. MER (modulation error ratio) is determined by the cluster variance caused by the transmit waveform at the output of the ideal receive matched filter. MER includes all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, distortion, and other undesired transmitter products. Unequalized MER also includes linear filtering distortion, which is compensated by a receive equalizer. Phase noise up to ± 50 kHz of the carrier is excluded from inband specification, to separate the phase noise and inband spurious requirements as much as possible. In measuring MER, record length or carrier tracking loop bandwidth may be adjusted to exclude low frequency phase noise from the measurement. For equalized MER, receive equalizer coefficients are computed and applied with receiver operating with device under test. For unequalized MER, receive equalize coefficients may be computed to flatten receiver response, if necessary, then are held fixed when device under test is connected. MER requirements assume measuring with a calibrated test instrument with its residual MER contribution removed.	
3. Frequency ranges are edge-to-edge.	
4. If the EQAM or CMTS provides service to a center frequency of 57 MHz (see line 1 in table), then the EQAM or CMTS MUST provide a return loss of > 14 dB within an active output channel, from 54 MHz to 750 MHz (f_{edge}).	
5. If the EQAM or CMTS provides service to a center frequency of 999 MHz (see line 1 in table), then the EQAM or CMTS MUST provide a return loss of > 12 dB within an active output channel, from 870 MHz to 1002 MHz (f_{edge}).	

6.3.5.1.1 Power per Channel CMTS or EQAM

An EQAM or CMTS MUST generate an RF output with power capabilities as defined in Table 6–4. Channel RF power MAY be adjustable on a per channel basis with each channel independently meeting the power capabilities defined in Table 6–4. If the EQAM or CMTS has independent modulation capability on a per channel basis, then the channel RF power MUST be adjustable on a per channel basis, with each channel independently meeting the power capabilities defined in Table 6–4.

Table 6–4 - DRFI Device Output Power⁵

Parameter	Value
Range of commanded transmit power per channel	≥ 8 dB below required power level specified below maintaining full fidelity over the 8 dB range
Commanded power per channel step size	≤ 0.2 dB Strictly monotonic
Power difference between any two adjacent channels in a block (with commanded power difference removed if channel power is independently adjustable)	≤ 0.5 dB
Power difference between any two non-adjacent channels in a block (with commanded power difference removed if channel power is independently adjustable)	≤ 1 dB
Power per channel absolute accuracy	± 2 dB

⁵ Revised this table per ECN DRFI-N-05.0248-1 on 10/28/05.

Parameter	Value
Diagnostic carrier suppression (3 modes) Mode 1: One channel suppressed Mode 2: All channels suppressed except one Mode 3: All channels suppressed	1) ≥ 50 dB carrier suppression within the Nyquist bandwidth in any one 6 MHz channel in the block. This MUST be accomplished without discontinuity or detriment to the other channels in the block. 2) 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz channel in the block except one. This MUST be accomplished without discontinuity or detriment to the remaining channel in the block. 3) 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz channel in the block.
RF block muting	≥ 73 dB below the unmuted aggregate power of the block, in every 6 MHz channel in the block
Required power per channel for N channels combined onto a single RF port. ' N ' = number of combined channels:	Required power in dBmV per channel
$N = 1$	60 dBmV
$N = 2$	56 dBmV
$N = 3$	54 dBmV
$N = 4$	52 dBmV
$N > 4$	$60 - \text{ceil}[3.6 * \log_2(N)]$ dBmV

6.3.5.1.2 Independence of individual channel within the multiple channels on a single RF port

A potential use of a CMTS or an EQAM is to provide a universal platform that can be used for high-speed data services or for video services. For this reason, it is essential that interleaver depth be set on a per channel basis to provide a suitable transmission format for either video or data as needed in normal operation. Any N -channel block of a CMTS or EQAM MUST be configurable with at least two different interleaver depths, using any of the interleaver depths shown in Table 6-1 and Table 6-2. Although not as critical as per-channel interleaver depth control, there are strong benefits for the operator if the EQAM is provided with the ability to set RF power, center frequency, and modulation type on a per-channel basis.

1. A multiple-channel CMTS or EQAM MUST be configurable with at least two different interleaver depths among the N channels on an RF output port, with each channel using one of the two (or more) interleaver depths, on a per channel basis, see Table 6-1 - Low Latency Interleaver Depths and Table 6-2 for information on interleaver depths.
2. A multiple-channel CMTS or EQAM MUST provide for 3 modes of carrier suppression of RF power for diagnostic and test purposes, see Table 6-4, Item 6 for mode descriptions and carrier RF power suppression level.⁶
3. A multiple-channel CMTS or EQAM MAY provide for independent adjustment of RF power in a per channel basis with each RF carrier independently meeting the requirements defined in Table 6-4.
4. A multiple-channel CMTS or EQAM MAY provide for independent selection of center frequency on a per channel basis, thus providing for non-contiguous channel frequency assignment with each channel independently meeting the requirements in Table 6-3.
5. A multiple-channel CMTS or EQAM MAY provide for independent selection of modulation order, either 64 QAM or 256 QAM, on a per channel basis, with each channel independently meeting the requirements in Table 6-3.

⁶ Revised this statement per ECN DRFI-N-05.0248-1 on 10/28/05.

6. A CMTS or EQAM MUST provide a test mode of operation, for out-of-service testing, configured for N channels but generating one-CW-per-channel, one channel at a time at the center frequency of the selected channel; all other combined channels are suppressed. One purpose for this test mode is to support one method for testing the phase noise requirements of Table 6–3. As such, the generation of the CW test tone SHOULD exercise the signal generation chain to the fullest extent practicable, in such manner as to exhibit phase noise characteristics typical of actual operational performance; for example, repeated selection of a constellation symbol with power close to the constellation RMS level would seemingly exercise much of the modulation and up-conversion chain in a realistic manner. The test mode MUST be capable of generating the CW tone over the full range of Center Frequency in Table 6–3.
7. A CMTS or EQAM MUST provide a test mode of operation, for out-of-service testing, generating one-CW-per-channel, at the center frequency of the selected channel, with all other $N - 1$ of the combined channels active and containing valid data modulation at operational power levels. One purpose for this test mode is to support one method for testing the phase noise requirements of Table 6–3. As such, the generation of the CW test tone SHOULD exercise the signal generation chain to the fullest extent practicable, in such manner as to exhibit phase noise characteristics typical of actual operational performance. For example, a repeated selection of a constellation symbol, with power close to the constellation RMS level, would seemingly exercise much of the modulation and upconversion chain in a realistic manner. For this test mode, it is acceptable that all channels operate at the same average power, including each of the $N - 1$ channels in valid operation, and the single channel with a CW tone at its center frequency. The test mode MUST be capable of generating the CW tone over the full range of Center Frequency in Table 6–3.

If either center frequency 4) or modulation type 5), or both are independently adjustable on a per channel basis, then the CMTS or EQAM MUST provide for independent adjustment of RF power (3) on a per channel basis, with each RF carrier independently meeting the requirements defined in Table 6–3.

6.3.5.1.3 Out-of-Band Noise and Spurious Requirements for CMTS or EQAM

One of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 60 dB for systems deploying up to 119 DRFI-compliant QAM channels.

The specification assumes that the transmitted power level of the digital channels will be 6 dB below the peak envelope power of the visual signal of analog channels, which is the typical condition for 256 QAM transmission. It is further assumed that the channel lineup will place analog channels at lower frequencies than digital channels. An adjustment of $10 \cdot \log_{10} (6 \text{ MHz} / 4 \text{ MHz})$ is used to account for the difference in noise bandwidth of digital channels, versus analog channels. With the assumptions above, for a 119 QAM channel system, the specification in item 5 of Table 6–5 equates to an analog CNR protection of 60dB.

Table 6–5 lists the out-of-band spurious requirements. In cases where the N combined channels are not commanded to the same power level, “dBc” denotes decibels relative to the strongest carrier in the channel block. The out-of-band spurious emissions requirements assume a test condition with a contiguous block of N combined channels commanded to the same power level, and for this test condition “dBc” should be interpreted as the average channel power, averaged over the block, to mitigate the variation in channel power across the block (see Table 6–4), which is allowed with all channels commanded to the same power.

Items 1 through 4 list the requirements in channels adjacent to the commanded channels.

Item 5 lists the requirements in all other channels further from the commanded channels. Some of these “other” channels are allowed to be excluded from meeting the Item 5 specification. All the exclusions, such as 2nd and 3rd harmonics of the commanded channel, are fully identified in the table.

Item 6 lists the requirements on the $2N$ 2nd harmonic channels and the $3N$ 3rd harmonic channels.

Table 6-5 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements⁷

Item	Band	N, Number of Combined Channels per RF Port				
		1	2	3	4	N > 4 All Equations Are Ceiling(Power, 0.5) dBc ¹
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<-58 dBc	<-58 dBc	$<10 \cdot \log_{10} [10^{-58/10} + (0.75/6) \cdot (10^{-65/10} + (N-2) \cdot 10^{-73/10})]$
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	<-62 dBc	<-60 dBc	<-60 dBc	<-60 dBc	$<10 \cdot \log_{10} [10^{-62/10} + (5.25/6) \cdot (10^{-65/10} + (N-2) \cdot 10^{-73/10})]$
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	<-65 dBc	<-64 dBc	<-63.5 dBc	<-63 dBc	$<10 \cdot \log_{10} [10^{-65/10} + (N-1) \cdot 10^{-73/10}]$
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge).	<-73 dBc	<-70 dBc	<-67 dBc	<-65 dBc	For N=5: -64.5 dBc; For N=6: -64 dBc; For N≥7: $<-73 + 10 \cdot \log_{10}(N)$ dBc
5	Noise in other channels (47 MHz to 1000 MHz) Measured in each 6 MHz channel excluding the following: a) Desired channel(s) b) 1 st , 2 nd , and 3 rd adjacent channels (see Items 1, 2, 3, 4 in this table) c) Channels coinciding with 2 nd and 3 rd harmonics (see Item 6 in this table)	<-73 dBc	<-70 dBc	<-68 dBc	<-67 dBc	$<-73 + 10 \cdot \log_{10}(N)$
6	In each of 2N contiguous 6 MHz channels or in each of 3N contiguous 6 MHz channels coinciding with 2 nd harmonic and with 3 rd harmonic components respectively (up to 1000 MHz)	$<-73 + 10 \cdot \log_{10}(N)$, or -63 dBc, whichever is greater				

Table Note 1. Use "Ceiling(2*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values.

6.3.5.2 CMTS or EQAM Master Clock Jitter for Asynchronous Operation

An EQAM MUST implement a DTI client and client interface per the [DTI] specification. The Master Clock specifications are defined in the [DTI] specification. The DTI client provides the Master Clock. An integrated CMTS not actively serviced by a DTI server MUST include a Master Clock with the specifications as follows:

The 10.24 MHz Master Clock MUST have, over a temperature range of 0 to 40 degrees C and for up to ten years from date of manufacture (see Note below):

- A frequency accuracy of $\leq \pm 5$ ppm
- A drift rate $\leq 10^{-8}$ per second, and
- An edge jitter of ≤ 10 nSec peak-to-peak (± 5 nSec)

Note: This specification MAY also be met by synchronizing the DRFI device Master Clock oscillator to an external frequency reference source. If this approach is used, the internal DRFI device Master Clock MUST have a frequency accuracy of ± 20 ppm over a temperature range of 0 to 40 degrees C, up to 10 years from date of manufacture, when no frequency reference source is connected. The drift rate and edge jitter MUST be as specified above.⁸

The drift rate and jitter requirements on the DRFI device Master Clock implies that the duration of two adjacent segments of 10,240,000 cycles will be within 30 nSec, due to 10 nSec jitter on each segments' duration, and 10 nSec due to frequency drift. Durations of other counter lengths also may be deduced: adjacent 1,024,000 segments, ≤ 21 nSec; 1,024,000 length segments separated by one 10,240,000-cycle segment, ≤ 30 nSec; adjacent 102,400,000

⁷ Added footnote to Table 6-5 per ECN DRFI-N-06.0285-2 by GO on 10/9/06.

⁸ Revised per ECN DRFI-N-06.0285-2 by GO on 10/9/06.

segments, ≤ 120 nSec. The DRFI device Master Clock MUST meet such test limits in 99% or more measurements.

6.3.5.3 CMTS or EQAM Master Clock Jitter for Synchronous Operation

In addition to the requirements in Section 6.3.5.2, the 10.24 MHz CMTS Master Clock MUST meet the following double sideband phase noise requirements over the specified frequency ranges:

- $< [-50 + 20 \cdot \log(f_{MC}/10.24)]$ dBc (*i.e.*, < 0.05 nSec RMS) 10 Hz to 100 Hz
- $< [-58 + 20 \cdot \log(f_{MC}/10.24)]$ dBc (*i.e.*, < 0.02 nSec RMS) 100 Hz to 1 kHz
- $< [-50 + 20 \cdot \log(f_{MC}/10.24)]$ dBc (*i.e.*, < 0.05 nSec RMS) 1 kHz to 10 kHz
- $< [-50 + 20 \cdot \log(f_{MC}/10.24)]$ dBc (*i.e.*, < 0.05 nSec RMS) 10 kHz to $f_{MC}/2$

f_{MC} is the frequency of the measured master clock in MHz. The value of f_{MC} MUST be either an integral multiple or divisor of 10.24 MHz. For example, if a 20.48 MHz oscillator is used as the master clock frequency source, and there is no explicit 10.24 MHz clock to test, the 20.48 MHz clock may be used with f_{MC} equal to 20.48 in the above expressions.

Specifications for EQAM Master Clock jitter in synchronous operation are contained in the [DTI] specification.

6.3.5.4 CMTS or EQAM Master Clock Frequency Drift for Synchronous Operation

The frequency of the CMTS Master Clock MUST NOT drift more than 10^{-8} per second.

Specifications for EQAM Master Clock frequency drift in synchronous operation is contained in the DTI specification.

6.3.6 CMTS or EQAM Clock Generation

When the 10.24 MHz Master Clock is provided by the DTI interface, a DRFI-compliant device MUST lock the Downstream Symbol Clock to the 10.24 MHz Master Clock using the M/N divisors provided in Table 6–6.

6.3.6.1 CMTS Clock Generation

The CMTS MUST lock the Downstream Symbol Clock to the CMTS Master Clock using the M/N divisors provided in Table 6–6.

6.3.6.2 EQAM Clock Generation

Because it operates with an active DTI interface, an EQAM MUST lock the Downstream Symbol Clock to the Master Clock using the M/N divisors provided in Table 6–6.

6.3.6.3 Downstream Symbol Rate⁹

Let f_b' represent the rate of the Downstream Symbol Clock which is locked to the Master Clock and let f_m' represent the rate of the Master Clock locked to the Downstream Symbol Clock. Let f_b represent the nominal specified downstream symbol rate and let f_m represent the nominal Master Clock rate (10.24 MHz). With the Downstream Symbol Clock locked to the Master Clock, the following equation MUST hold:

$$f_b' = f_m \cdot M/N$$

With the Master Clock locked to the Downstream Symbol Clock, the following equation MUST hold:

$$f_m' = f_b \cdot N/M$$

Note that M and N in Table 6–6 are unsigned integer values, each representable in 16 bits and result in a value of f_b' or f_m' that is not more than ± 1 ppm from its specified nominal value.

The standard deviation of the timing error of the EQAM/CMTS RF symbol clock, referenced to the DTI Server Master Clock, MUST be less than 1.5 ns measured over 100 seconds.

Table 6–6 lists the downstream modes of operation, their associated nominal symbol rates, f_b , values for M and N, the resulting synchronized clock rates and their offsets from their nominal values.

⁹ Revised this section per ECN DRFI-N-05.0249-1 on 10/28/05.

Table 6–6 - Downstream symbol rates & parameters for synchronization with Master Clock

Downstream mode	Nominal Specified Symbol Rate, fb (MHz)	M/N	Master Clock Rate, fm' (MHz)	Downstream Symbol Rate, fb' (MHz)	Offset from Nominal
Annex B, 64QAM	5.056941	401/812	10.239990...	5.056945...	0.95 ppm
Annex B, 256QAM	5.360537	78/149	10.240000...	5.360536...	0.02 ppm

6.3.7 Downstream Symbol Clock Jitter for Synchronous Operation

The downstream symbol clock MUST meet the following double sideband phase noise requirements over the specified frequency ranges:

- $< [-53 + 20 \cdot \log(f_{DS}/5.057)]$ dBc (*i.e.*, < 0.07 nSec RMS) 10 Hz to 100 Hz
- $< [-53 + 20 \cdot \log(f_{DS}/5.057)]$ dBc (*i.e.*, < 0.07 nSec RMS) 100 Hz to 1 kHz
- $< [-53 + 20 \cdot \log(f_{DS}/5.057)]$ dBc (*i.e.*, < 0.07 nSec RMS) 1 kHz to 10 kHz
- $< [-36 + 20 \cdot \log(f_{DS}/5.057)]$ dBc (*i.e.*, < 0.5 nSec RMS) 10 kHz to 100 kHz
- $< [-30 + 20 \cdot \log(f_{DS}/5.057)]$ dBc (*i.e.*, < 1 nSec RMS) 100 kHz to $(f_{DS}/2)$

f_{DS} is the frequency of the measured clock in MHz. The value of f_{DS} MUST be an integral multiple or divisor of the downstream symbol clock. For example, an $f_{DS} = 20.227764$ MHz clock may be measured if there is no explicit 5.056941 MHz clock available.

A DRFI-compliant device MUST provide a means for clock testing in which:

- The device provides test points for direct access to the master clock and the downstream symbol clock.

Alternatively, a DRFI conformant device MUST provide a test mode in which:

- The downstream QAM symbol sequence is replaced with an alternating binary sequence (1, -1, 1, -1, 1, -1...) at nominal amplitude, on both I and Q.
- The device generates the downstream symbol clock from the 10.24 MHz reference clock as in normal synchronous operation.

If an explicit downstream symbol clock, which is capable of meeting the above phase noise requirements, is available (e.g., a smooth clock without clock domain jitter), this test mode is not required.

6.3.8 Downstream Symbol Clock Drift for Synchronous Operation

The frequency of the downstream symbol clock MUST NOT drift more than 10^{-8} per second.

6.3.9 Timestamp Jitter¹⁰

The DOCSIS timestamp jitter MUST be less than 500 nsec peak-to-peak at the output of the Downstream Transmission Convergence Sublayer. This jitter is relative to an ideal Downstream Transmission Convergence Sublayer that transfers the MPEG packet data to the Downstream Physical Media Dependent Sublayer with a perfectly continuous and smooth clock at the MPEG packet data rate. Downstream Physical Media Dependent Sublayer processing MUST NOT be considered in timestamp generation and transfer to the Downstream Physical Media Dependent Sublayer.

Thus, any two timestamps N1 and N2 ($N2 > N1$) which were transferred to the Downstream Physical Media Dependent Sublayer at times T1 and T2 respectively must satisfy the following relationship:

$$|(N2-N1)/f_{CMTS} - (T2-T1)| < 500 \times 10^{-9}$$

¹⁰ Added this section per ECN DRFI-N-06.0333-1 by GO on 1/16/07.

In the equation, the value of $(N2-N1)$ is assumed to account for the effect of rollover of the timebase counter, and $T1$ and $T2$ represent time in seconds. f_{CMTS} is the actual frequency of the CMTS master timebase and may include a fixed frequency offset from the nominal frequency of 10.24 MHz. This frequency offset is bounded by a requirement further below in this section.

The jitter includes inaccuracy in timestamp value and the jitter in all clocks. The 500 nsec allocated for jitter at the Downstream Transmission Convergence Sublayer output **MUST** be reduced by any jitter that is introduced by the Downstream Physical Media Dependent Sublayer.

Note: Jitter is the error (*i.e.*, measured) relative to the CMTS Master Clock. (The CMTS Master Clock is the 10.24 MHz clock used for generating the timestamps.)

7 DOWNSTREAM TRANSMISSION CONVERGENCE SUBLAYER

7.1 Introduction

The downstream transmission convergence layer used in the M-CMTS is defined as a continuous series of 188-byte MPEG [ISO 13818] packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the Data-Over-Cable MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the CMTS.

Figure 7–1 illustrates the interleaving of DOCSIS MAC bytes with other digital information (digital video in the example shown).

header=DOC	DOC MAC payload
header=video	digital video payload
header=video	digital video payload
header=DOC	DOC MAC payload
header=video	digital video payload
header=DOC	DOC MAC payload
header=video	digital video payload
header=video	digital video payload
header=video	digital video payload

Figure 7–1 - Example of Interleaving MPEG Packets in Downstream

7.2 MPEG Packet Format

The format of an MPEG Packet carrying DOCSIS data is shown in Figure 7–2. The packet consists of a 4-byte MPEG Header, a pointer_field (not present in all packets), and the DOCSIS Payload.

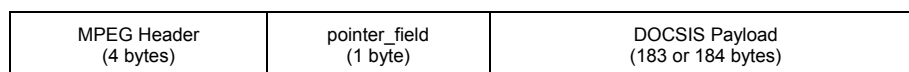


Figure 7–2 - Format of an MPEG Packet

7.3 MPEG Header for DOCSIS Data-Over-Cable

The format of the MPEG Transport Stream header is defined in Section 2.4 of [ISO 13818]. The particular field values that distinguish Data-Over-Cable MAC streams are defined in Table 7–1. Field names are from the ITU specification.

The MPEG Header consists of 4 bytes that begin the 188-byte MPEG Packet. The format of the header for use on a DOCSIS Data-Over-Cable PID MUST be as shown in Table 7–1. The header format conforms to the MPEG standard, but its use is restricted in this specification to not allow inclusion of an adaptation_field in the MPEG packets.

Table 7-1 - MPEG Header Format for DOCSIS Data-Over-Cable Packets

Field	Length (bits)	Description
sync_byte	8	0x47; MPEG Packet Sync byte.
transport_error_indicator	1	Indicates that an error has occurred in the reception of the packet. This bit is reset to zero by the sender, and set to one whenever an error occurs in the transmission of the packet.
payload_unit_start_indicator	1	A value of one indicates the presence of a pointer_field as the first byte of the payload (fifth byte of the packet).
transport_priority	1	Reserved; set to zero.
PID	13	DOCSIS Data-Over-Cable well-known PID (0x1FFE).
transport_scrambling_control	2	Reserved, set to '00'.
adaptation_field_control	2	'01'; use of the adaptation_field is not allowed on the DOCSIS PID.
continuity_counter	4	Cyclic counter within this PID.

7.4 MPEG Payload for DOCSIS Data-Over-Cable

The MPEG payload portion of the MPEG packet will carry the DOCSIS MAC frames. The first byte of the MPEG payload will be a 'pointer_field' if the payload_unit_start_indicator (PUSI) of the MPEG header is set.

7.4.1 stuff_byte

This standard defines a stuff_byte pattern having a value (0xFF) that is used within the DOCSIS payload to fill any gaps between the DOCSIS MAC frames. This value is chosen as an unused value for the first byte of the DOCSIS MAC frame. The 'FC' byte of the MAC Header will be defined to never contain this value. (FC_TYPE = '11' indicates a MAC-specific frame, and FC_PARM = '11111' is not currently used and, according to this specification, is defined as an illegal value for FC_PARM.)

7.4.2 pointer_field

The pointer_field is present as the fifth byte of the MPEG packet (first byte following the MPEG header) whenever the PUSI is set to one in the MPEG header. The interpretation of the pointer_field is as follows:

The pointer_field contains the number of bytes in this packet that immediately follow the pointer_field that the CM decoder will skip past before looking for the beginning of an DOCSIS MAC Frame. A pointer field **MUST** be present if it is possible to begin a Data-Over-Cable MAC Frame in the packet, and **MUST** point to either:

- the beginning of the first MAC frame to start in the packet, or
- to any stuff_byte preceding the MAC frame.

7.5 Interaction with the MAC Sublayer

MAC frames may begin anywhere within an MPEG packet. MAC frames may span MPEG packets, and several MAC frames may exist within an MPEG packet.

The following figures show the format of the MPEG packets that carry DOCSIS MAC frames. In all cases, the PUSI flag indicates the presence of the pointer_field as the first byte of the MPEG payload.

Figure 7–3 shows a MAC frame that is positioned immediately after the pointer_field byte. In this case, the pointer_field is zero, and the DOCSIS decoder will begin searching for a valid FC byte, at the byte immediately following the pointer_field.

MPEG Header (PUSI = 1)	pointer_field (= 0)	MAC Frame (up to 183 bytes)	stuff_byte(s) (0 or more)
---------------------------	------------------------	--------------------------------	------------------------------

Figure 7–3 - Packet Format where a MAC Frame Immediately Follows the Pointer Field

Figure 7–4 shows the more general case, where a MAC Frame is preceded by the tail of a previous MAC Frame and a sequence of stuffing bytes. In this case, the pointer_field still identifies the first byte after the tail of Frame #1 (a stuff_byte) as the position where the decoder should begin searching for a legal MAC sublayer FC value. This format allows the multiplexing operation in the CMTS to immediately insert a MAC frame that is available for transmission if that frame arrives after the MPEG header and pointer_field have been transmitted.

In order to facilitate multiplexing of the MPEG packet stream carrying DOCSIS data with other MPEG-encoded data, the CMTS SHOULD NOT transmit MPEG packets with the DOCSIS PID which contain only stuff_bytes in the payload area. MPEG null packets SHOULD be transmitted instead.

Note: There are timing relationships implicit in the DOCSIS MAC sublayer, which must also be preserved by any MPEG multiplexing operation.

MPEG Header (PUSI = 1)	pointer_field (= M)	Tail of MAC Frame #1 (M bytes)	stuff_byte(s) (0 or more)	Start of MAC Frame #2
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Figure 7–4 - Packet Format with MAC Frame Preceded by Stuffing Bytes

Figure 7–5 shows that multiple MAC frames may be contained within the MPEG packet. The MAC frames may be concatenated one after the other or be separated by an optional sequence of stuffing bytes.

MPEG Header (PUSI = 1)	pointer_field (= 0)	MAC Frame #1	MAC Frame #2	stuff_byte(s) (0 or more)	MAC Frame #3
---------------------------	------------------------	-----------------	-----------------	------------------------------	-----------------

Figure 7–5 - Packet Format Showing Multiple MAC Frames in a Single Packet

Figure 7–6 shows the case where a MAC frame spans multiple MPEG packets. In this case, the pointer_field of the succeeding frame points to the byte following the last byte of the tail of the first frame.

MPEG Header (PUSI = 1)	pointer_field (= 0)	stuff_byte(s) (0 or more)	Start of MAC Frame #1 (up to 183 bytes)	
MPEG Header (PUSI = 0)	Continuation of MAC Frame #1 (184 bytes)			
MPEG Header (PUSI = 1)	pointer_field (= M)	Tail of MAC Frame #1 (M bytes)	stuff_byte(s) (0 or more)	Start of MAC Frame #2 (M bytes)

Figure 7–6 - Packet Format where a MAC Frame Spans Multiple Packets

The Transmission Convergence sublayer must operate closely with the MAC sublayer in providing an accurate timestamp to be inserted into the Time Synchronization message.

7.6 Interaction with the Physical Layer

The MPEG-2 packet stream **MUST** be encoded according to [ITU-T J.83-B], including MPEG-2 transport framing using a parity checksum as described in [ITU-T J.83-B].

Annex A Additions and Modifications for European Specification¹¹

This annex applies to the second technology option referred to in Section 1.1. For the first option, refer to Sections 5, 6, and 7.

This annex describes the physical layer specifications required for the EuroDOCSIS integrated CMTS and EuroDOCSIS EQAM. This is an optional annex and in no way affects certification of equipment adhering to the North American technology option described in the sections referenced above.

The numbering of the paragraphs has been maintained such that the suffix after the letter for the annex refers to the part of the specification where the described changes apply. As a consequence, some heading numbers might be missing in this annex, since no change is required to the relevant paragraph in the main body of the document.

A.1 Scope and purpose

See Section 1.

A.2 References

A.2.1 Normative References¹²

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

- | | |
|----------------|--|
| [DOCSIS2] | Data-Over-Cable Service Interface Specifications, Radio Frequency Interface Specification v2.0, CM-SP-RFIV2.0-C01-081104, November 4, 2008, Cable Television Laboratories, Inc. |
| [IEC-61169-24] | IEC 61169-24 Revision: 02 Chg: Date: 00/00/02 Radio-Frequency Connectors - Part 24: Sectional Specification - Radio Frequency Coaxial Connectors With Screw Coupling, Typically For Use In 75 Ohm Cable Distribution Systems (Type F). |
| [ISO 13818] | ISO/IEC 13818-1, "Information Technology – Generic Coding of Moving Pictures and Associated Audio: Systems / ITU-T Rec. H.222.0", 2007. |
| [EN 300 429] | ETSI EN 300 429 V1.2.1: Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems", April 1998. |

A.3 Terms and Definitions

See Section 3.

A.4 Acronyms and Abbreviations

See Section 4.

A.5 Functional Assumptions

This section describes the characteristics of a cable television plant, assumed to be for the purpose of operating a data-over-cable system. It is not a description of EQAM or CMTS parameters. The data-over-cable system **MUST** be interoperable within the environment described in this section.

Whenever a reference to frequency plans or to compatibility with other services in this section conflicts with a legal requirement for the area of operation, the latter shall take precedence. Any reference to analog TV signals in a particular frequency band does not imply that such signals are physically present.

¹¹ Added Annex A per ECN DRFI-N-05.0263-3 by GO on 1/3/06.

¹² Section added per 07.0576-2, #1 on 1/16/08 by KN.

A.5.1 Broadband Access Network

A coaxial-based broadband access network is assumed. This may take the form of either an all-coax or hybrid fiber/coax (HFC) network. The generic term “cable network” is used here to cover all cases.

A cable network uses a shared-medium, “tree-and-branch” architecture, with analog transmission. The key functional characteristics assumed in this document are the following:

- Two-way transmission
- A maximum optical/electrical spacing between the DRFI-compliant device and the most distant CM of 160 km (route meters) in each direction
- A maximum differential optical/electrical spacing between the DRFI-compliant device and the closest and most distant modems of 160 km (route meters) in each direction

At a propagation velocity in fiber of approximately 5 ns/m, 160 km of fiber in each direction results in a round-trip delay of approximately 1.6 ms. For further information, see [DOCSIS2], Appendix VIII.

A.5.2 Equipment Assumptions

A.5.2.1 Frequency Plan

In the downstream direction, the cable system is assumed to have a pass band with a typical lower edge between 47 and 87.5 MHz, and an upper edge that is implementation-dependent, but is typically in the range of 300 to 862 MHz. Within that pass band, PAL/SECAM analog television signals in 7/8 MHz channels and FM radio signals are assumed to be present, as well as other narrowband and wideband digital signals. 8 MHz channels are used for data communication.

A.5.2.2 Compatibility with Other Services

The CM and EQAM or CMTS MUST coexist with the other services on the cable network, for example:

- a. They MUST be interoperable in the cable spectrum assigned for EQAM- or CMTS-CM interoperation while the balance of the cable spectrum is occupied by any combination of television and other signals; and
- b. They MUST NOT cause harmful interference to any other services that are assigned to the cable network in spectrum outside of that allocated to the EQAM or CMTS. The latter is understood as:
 - No measurable degradation (highest level of compatibility),
 - No degradation below the perceptible level of impairments for all services (standard or medium level of compatibility), or
 - No degradation below the minimal standards accepted by the industry or other service provider (minimal level of compatibility).

A.5.2.3 Fault Isolation Impact on Other Users

See Section 5.2.3.

A.5.3 Downstream Plant Assumptions

See Section 5.3.

A.5.3.1 Transmission Levels

The nominal average power level of the downstream RF signal(s) within an 8 MHz channel is targeted to be in the range of -13 dBc to 0 dBc, relative to analog peak video carrier level and will normally not exceed analog peak video carrier level, (typically between -10 to -6 dBc for 64 QAM and between -6 to -4 dBc for 256 QAM).

A.5.3.2 Frequency Inversion

See Section 5.3.2.

A.5.3.3 Analog and Digital Channel Line-up

In developing this technology option, it was assumed that a maximum of 85 digital channels would be deployed in a headend. For the purposes of calculating CNR protection for analog channels, it was assumed that analog channels are placed at lower frequencies in the channel line-up than digital channels.

A.5.3.4 Analog Protection Goal

One of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 59 dB measured in a 5.08 MHz wide frequency band for systems deploying up to 85 DRFI-compliant QAM channels.

For purposes of calculation, it is assumed that the transmitted power level of the digital channels will be 5 dB below the peak envelope power of the visual signal of analog channels, which is within the range of typical conditions for 256QAM transmission. It is further assumed, for the purpose of calculation, that the channel line-up will place analog channels at lower frequencies than digital channels. An adjustment of $10 \cdot \log_{10}(8 \text{ MHz} / 5.08 \text{ MHz})$ is used to account for the difference in bandwidth used to define the noise requirements for DRFI-compliant digital QAM channels, versus analog PAL channels. With the assumptions above, for an 85 QAM channel system, the specification in item 5 of Table A-4 equates to an analog CNR protection of 59 dB.

A.6 Physical Media Dependent Sublayer Specification

A.6.1 Scope

This section applies to the second technology option referred to in Section 1.1. In cases where the requirements for both technology options are identical, a reference is provided to the main text.

For the remainder of this section see Section 6.1.

A.6.2 EdgeQAM (EQAM) differences from CMTS

See Section 6.2.

A.6.3 Downstream

A.6.3.1 Downstream Protocol

The downstream PMD sublayer MUST conform to [EN 300 429].

A.6.3.2 Spectrum Format

The downstream modulator for each QAM channel of the EQAM or CMTS MUST provide operation with the RF signal format of $S(t) = I(t) \cdot \cos(\omega t) + Q(t) \cdot \sin(\omega t)$, where t denotes time, ω denotes RF angular frequency and where $I(t)$ and $Q(t)$ are the respective Root-Nyquist filtered baseband quadrature components of the constellation, as specified in [EN 300 429].

A.6.3.3 Scaleable Interleaving to Support Video and High-Speed Data Services

The CMTS or EQAM downstream PMD sublayer MUST support the interleaver with the characteristics defined in Table A-1. This interleaver mode fully complies with [EN 300 429].

Table A-1 - Interleaver characteristics

Interleaver Taps	Interleaver Increment	64QAM 6.952 Msym/sec 6 bits per symbol		256QAM 6.952 Msym/sec 8 bits per symbol	
		Burst Protection	Latency	Burst Protection	Latency
I	J				
12	17	18 μ s	0.43 ms	14 μ s	0.32 ms

A.6.3.4 Downstream Frequency Plan

It is up to the operator to decide which frequencies to use to meet national and network requirements.

A.6.3.5 DRFI Output Electrical

See Section 6.3.5.

A.6.3.5.1 CMTS or EQAM Output Electrical

A CMTS or EQAM MUST output an RF-modulated signal with the characteristics defined in Table A–2, Table A–3, and Table A–4.

A.6.3.5.1.1 Output Electrical per RF Port

The condition for the requirements in Table A–2 is that all N channels delivered to the RF port are commanded to the same average power. That condition does not apply to the requirement on Single Channel Active phase noise.

Table A–2 - Output Electrical Requirements per RF Port¹³

Parameter	Value
Center Frequency (f_c) of any RF channel of a CMTS or EQAM	MAY be 85 MHz to 999 MHz \pm 30 kHz at 250 kHz increments MUST be 112 MHz to 858 MHz \pm 30 kHz at 250 kHz increments
Level	Adjustable. See Table A–3.
Modulation Type	64QAM, 256QAM
Symbol Rate (nominal) 64QAM 256QAM	6.952 Msym/sec 6.952 Msym/sec
Nominal Channel Spacing	8 MHz
Frequency response 64QAM 256QAM	\sim 0.15 Square Root Raised Cosine Shaping \sim 0.15 Square Root Raised Cosine Shaping
Inband Spurious, Distortion, and Noise Inband Spurious and Noise ($f_c \pm 4$ MHz)	Unequalized MER (Note 1) > 35 dB Equalized MER > 43 dB ≤ -46.7 dBc; where channel spurious and noise includes all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, and other undesired transmitter products. Spurious and noise within ± 50 kHz of the carrier is excluded. When $N > 1$, noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	See Table A–4.
Phase Noise Single Channel Active, $N - 1$ Channels Suppressed (see Section (0), 64QAM and 256QAM)	01 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power 50 kHz - 3 MHz: -51dBc double sided noise power
All N Channels Active (see Section (0), 64QAM and 256QAM)	1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power
Output Impedance	75 ohms
Output Return Loss	> 14 dB within an active output channel in the frequency range from 108 MHz to 862 MHz (Note 2) > 12 dB in every inactive channel from 81 MHz to 862 MHz > 10 dB in every inactive channel above 862 MHz
Connector	F connector per [IEC-61169-24]

¹³ Table modified per 07.0576-2 on 1/16/08 by KN.

Parameter	Value
Table A–2 Notes:	
<p>1. MER (modulation error ratio) is determined by the cluster variance caused by the transmit waveform at the output of the ideal receive matched filter. MER includes all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, distortion, and other undesired transmitter products. Unequalized MER also includes linear filtering distortion, which is compensated by a receive equalizer. Phase noise up to ± 50 kHz of the carrier is excluded from inband specification, to separate the phase noise and inband spurious requirements as much as possible. In measuring MER, record length or carrier tracking loop bandwidth may be adjusted to exclude low frequency phase noise from the measurement. For equalized MER, receive equalizer coefficients are computed and applied with receiver operating with device under test. For unequalized MER, receive equalize coefficients may be computed to flatten receiver response, if necessary, then are held fixed when device under test is connected. MER requirements assume measuring with a calibrated test instrument with its residual MER contribution removed.</p> <p>2. If the EQAM or CMTS provides service to a center frequency of 85 MHz (see line 1 in table) and above then the EQAM or CMTS MUST provide a return loss > 14 dB within an active output channel in the frequency range from 81 MHz to 108 MHz. If the EQAM or CMTS provides service to a center frequency of 999 MHz (see line 1 in table) and below then the EQAM or CMTS MUST provide a return loss > 14 dB within an active output channel in the frequency range from 862 MHz to 1003 MHz.</p>	

A.6.3.5.1.2 Power per Channel CMTS or EQAM

An EQAM or CMTS MUST generate an RF output with power capabilities as defined in Table A–3. Channel RF power MAY be adjustable on a per channel basis with each channel independently meeting the power capabilities defined in Table A–3. If the EQAM or CMTS has independent modulation capability on a per channel basis, then the channel RF power MUST be adjustable on a per channel basis with each channel independently meeting the power capabilities defined in Table A–3.

Table A–3 - DRFI Device Output Power

Parameter	Value
Range of commanded transmit power per channel	≥ 8 dB below required power level specified below maintaining full fidelity over the 8 dB range.
Commanded power per channel step size	≤ 0.2 dB strictly monotonic
Power difference between any two adjacent channels in a block (with commanded power difference removed if channel power is independently adjustable)	≤ 0.5 dB
Power difference between any two non-adjacent channels in a block (with commanded power difference removed if channel power is independently adjustable)	≤ 1 dB
Power per channel absolute accuracy	± 2 dB
Diagnostic carrier suppression (3 modes)	
Mode 1: One channel suppressed	≥ 50 dB carrier suppression within the Nyquist bandwidth in any one 8 MHz channel in the block. This MUST be accomplished without discontinuity or detriment to the other channels in the block.
Mode 2: All channels suppressed except one	≥ 50 dB carrier suppression within the Nyquist bandwidth in every 8 MHz channel in the block except one. This MUST be accomplished without discontinuity or detriment to the remaining channel in the block.
Mode 3: All channels suppressed	≥ 50 dB carrier suppression within the Nyquist bandwidth in every 8 MHz channel in the block.

Parameter	Value
RF block muting	≥ 71.5 dB below the unmuted aggregate power of the block, in every 8 MHz channel in the block
Required power per channel for N channels combined onto a single RF port:	Required power in dBmV per channel
N = 1	60 dBmV
N = 2	56 dBmV
N = 3	54 dBmV
N = 4	52 dBmV
N > 4	60 – ceil [3.6*log ₂ (N)] dBmV

A.6.3.5.1.3 Independence of individual channel within the multiple channels on a single RF port

A potential use of a CMTS or an EQAM is to provide a universal platform that can be used for high-speed data services or for video services. There are strong benefits for the operator if the multiple-channel CMTS or the EQAM is provided with the ability to set RF power, center frequency and modulation type on a per-channel basis.

1. A multiple-channel CMTS or EQAM **MUST** provide for 3 modes of carrier suppression of RF power for diagnostic and test purposes. See Table A–3 for mode descriptions and carrier RF power suppression levels.
2. A multiple-channel CMTS or EQAM **MAY** provide for independent adjustment of RF power in a per channel basis with each RF carrier independently meeting the requirements defined in Table A–3.
3. A multiple-channel CMTS or EQAM **MAY** provide for independent selection of center frequency on a per channel basis, thus providing for non-contiguous channel frequency assignment, with each channel independently meeting the requirements in Table A–3.
4. A multiple-channel CMTS or EQAM **MAY** provide for independent selection of modulation order, either 64QAM or 256QAM, on a per channel basis, with each channel independently meeting the requirements in Table A–2.
5. A CMTS or EQAM **MUST** provide a test mode of operation, for out-of-service testing, configured for N channels, but generating one-CW-per-channel, one channel at a time at the center frequency of the selected channel; all other of the combined channels are suppressed. One purpose for this test mode is to support one method for testing the phase noise requirements of Table A–2. As such, the generation of the CW test tone **SHOULD** exercise the signal generation chain to the fullest extent practicable, in such manner as to exhibit phase noise characteristics typical of actual operational performance; for example, repeated selection of a constellation symbol with power close to the constellation RMS level would seemingly exercise much of the modulation and up-conversion chain in a realistic manner. The test mode **MUST** be capable of generating the CW tone over the full range of Center Frequency in Table A–2.
6. A CMTS or EQAM **MUST** provide a test mode of operation for out-of-service testing, generating one-CW-per-channel, at the center frequency of the selected channel, with all other $N - 1$ of the combined channels active and containing valid data modulation at operational power levels. One purpose for this test mode is to support one method for testing the phase noise requirements of Table A–2. As such, the generation of the CW test tone **SHOULD** exercise the signal generation chain to the fullest extent practicable, in such manner as to exhibit phase noise characteristics typical of actual operational performance. For example, a repeated selection of a constellation symbol, with power close to the constellation RMS level, would seemingly exercise much of the modulation and up conversion chain in a realistic manner. For this test mode, it is acceptable that all channels operate at the same average power, including each of the $N - 1$ channels in valid operation, and the single channel with a CW tone at its center frequency. The test mode **MUST** be capable of generating the CW tone over the full range of Center Frequency in Table A–2.

If either center frequency 0 or modulation type 0, or both are independently adjustable on a per channel basis, then the CMTS or EQAM MUST provide for independent adjustment of RF power 0 on a per channel basis, with each RF carrier independently meeting the requirements defined in Table A–2.

A.6.3.5.1.4 Out-of-Band Noise and Spurious Requirements for CMTS or EQAM

One of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 59 dB measured in a 5.08 MHz wide frequency band for systems deploying up to 85 DRFI-compliant QAM channels.

For purposes of calculation, it is assumed that the transmitted power level of the digital channels will be 5 dB below the peak envelope power of the visual signal of analog channels, which is within the range of typical conditions for 256QAM transmission. It is further assumed, for the purpose of calculation, that the channel lineup will place analog channels at lower frequencies than digital channels. An adjustment of $10 \cdot \log_{10}(8 \text{ MHz} / 5.08 \text{ MHz})$ is used to account for the difference in bandwidth used to define the noise requirements for DRFI-compliant digital QAM channels, versus analog PAL channels. With the assumptions above, for a 85 QAM channel system, the specification in item 5 of Table A–4 equates to an analog CNR protection of 59 dB.

Table A–4 lists the out-of-band spurious requirements. In cases where the N combined channels are not commanded to the same power level, “dBc” denotes the logarithmic power ratio relative to the strongest carrier in the channel block. The out-of-band spurious emissions requirements assume a test condition with a contiguous block of N combined channels commanded to the same power level, and for this test condition "dBc" should be interpreted as the average channel power, averaged over the block, to mitigate the variation (see Table A–3) in channel power across the block, which is allowed with all channels commanded to the same power.

Items 1 through 4 list the requirements in channels adjacent to the commanded channels.

Item 5 lists the requirements in all other channels further from the commanded channels. Some of these “other” channels are allowed to be excluded from meeting the Item 5 specification. All the exclusions, such as 2nd and 3rd harmonics of the commanded channel, are fully identified in the table.

Item 6 lists the requirements on the 2N 2nd harmonic channels and the 3N 3rd harmonic channels.

Table A–4 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements ¹⁴

Item	Band	N, Number of Combined Channels per RF Port					N >4 All Equations Are Ceiling(Power, 0.5) dBc1.
		1	2	3	4		
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<-58 dBc	<-58 dBc	$<10 \cdot \log_{10} [10^{-58/10} + (0.75/8)^* (10^{-63.5/10} + (N-2) \cdot 10^{-71.5/10})]$	
2	Adjacent channel (750 kHz from channel block edge to 8 MHz from channel block edge)	<-60.5 dBc	<-59 dBc	<-58.5 dBc	<-58.5 dBc	$<10 \cdot \log_{10} [10^{-60.5/10} + (7.25/8)^* (10^{-63.5/10} + (N-2) \cdot 10^{-71.5/10})]$	
3	Next-adjacent channel (8 MHz from channel block edge to 16 MHz from channel block edge)	<-63.5 dBc	<-63 dBc	<-62.5 dBc	<-62 dBc	$<10 \cdot \log_{10} [10^{-63.5/10} + (N-1) \cdot 10^{-71.5/10}]$	
4	Third-adjacent channel (16 MHz from channel block edge to 24 MHz from channel block edge).	<-71.5 dBc	<-68.5 dBc	<-65.5 dBc	<-64 dBc	For N=5: <-63 dBc; For N=6: <-62.5 dBc; For N≥7: <-71.5 + 10*log ₁₀ (N) dBc	

¹⁴ Added footnote to Table A-4; editorial corrections, per ECN DRFI-N-06.0285-2 by GO on 10/9/06.

Item	Band	N, Number of Combined Channels per RF Port				
		1	2	3	4	N > 4 All Equations Are Ceiling(Power, 0.5) dBc1.
5	Noise in other channels (80 MHz to 1003 MHz) Measured in each 8 MHz channel excluding the following: a) Desired channel(s) b) 1st, 2nd, and 3rd adjacent channels (see Items 1, 2, 3, 4 in this table) c) Channels coinciding with 2nd and 3rd harmonics (see Item 6 in this table)	<-71.5 dBc	<-68.5 dBc	<-66.5 dBc	<-65.5 dBc	<-71.5 + 10*log ₁₀ (N) dBc
6	In each of 2N contiguous 8 MHz channels or in each of 3N contiguous 8 MHz channels coinciding with 2nd harmonic and with 3rd harmonic components respectively (up to 1000 MHz)	< -71.5 + 10*log ₁₀ (N), or -63 dBc, whichever is greater				

1. Use “Ceiling(2*Power) / 2” to get 0.5 steps from ceiling functions that return only integer values.

A.6.3.5.2 CMTS or EQAM Master Clock Jitter for Asynchronous Operation

See Section 6.3.5.2.

A.6.3.5.3 CMTS or EQAM Master Clock Jitter for Synchronous Operation

See Section 6.3.5.3.

A.6.3.5.4 CMTS or EQAM Master Clock Frequency Drift for Synchronous Operation

See Section 6.3.5.4.

A.6.3.6 CMTS or EQAM Clock Generation

When the 10.24 MHz Master Clock is provided by the DTI interface, a DRFI-compliant device MUST lock the Downstream Symbol Clock to the 10.24 MHz Master Clock using the M/N divisors provided in Table A-5.

A.6.3.6.1 CMTS Clock Generation

The CMTS MUST lock the Downstream Symbol Clock to the CMTS Master Clock using the M/N divisors provided in Table A-5.

A.6.3.6.2 EQAM Clock Generation

Because it operates with an active DTI interface, an EQAM MUST lock the Downstream Symbol Clock to the Master Clock using the M/N divisors provided in Table A-5.

A.6.3.6.3 Downstream Symbol Rate

Let f_b' represent the rate of the Downstream Symbol Clock, which is locked to the Master Clock, and let f_m' represent the rate of the Master Clock locked to the Downstream Symbol Clock. Let f_b represent the nominal specified downstream symbol rate and let f_m represent the nominal Master Clock rate (10.24 MHz). With the Downstream Symbol Clock locked to the Master Clock, the following equation MUST hold:

$$f_b' = f_m * M/N$$

With the Master Clock locked to the Downstream Symbol Clock, the following equation MUST hold:

$$f_m' = f_b * N / M$$

Note that M and N in Table A-5 are unsigned integer values, each representable in 16 bits, and result in a value of f_b' or f_m' that is not more than ± 1 ppm from its specified nominal value.

The standard deviation of the timing error of the EQAM/CMTS RF symbol clock, referenced to the DTI Server Master Clock, MUST be less than 1.5 ns measured over 100 seconds.

Table A-5 lists the downstream modes of operation, their associated nominal symbol rates, f_b , values for M and N, the resulting synchronized clock rates and their offsets from their nominal values.

Table A-5 - Downstream symbol rates & parameters for synchronization with the Master Clock

Downstream mode	Nominal Specified Symbol Rate, f_b (MHz)	M/N	Master Clock Rate, f_m' (MHz)	Downstream Symbol Rate, f_b' (MHz)	Offset from Nominal
EN 300 429, 64QAM	6.952	869/1280	10.240...	6.952	0 ppm
EN 300 429, 256QAM	6.952	869/1280	10.240...	6.952	0 ppm

A.6.3.7 Downstream Symbol Clock Jitter for Synchronous Operation

The downstream symbol clock MUST meet the following double sideband phase noise requirements over the specified frequency ranges:

- $< [-53 + 20 * \log(f_{DS}/6.952)]$ dBc (*i.e.*, < 0.07 ns RMS) 10 Hz to 100 Hz
- $< [-53 + 20 * \log(f_{DS}/6.952)]$ dBc (*i.e.*, < 0.07 ns RMS) 100 Hz to 1 kHz
- $< [-53 + 20 * \log(f_{DS}/6.952)]$ dBc (*i.e.*, < 0.07 ns RMS) 1 kHz to 10 kHz
- $< [-36 + 20 * \log(f_{DS}/6.952)]$ dBc (*i.e.*, < 0.5 ns RMS) 10 kHz to 100 kHz
- $< [-30 + 20 * \log(f_{DS}/6.952)]$ dBc (*i.e.*, < 1 ns RMS) 100 kHz to ($f_{DS}/2$)

f_{DS} is the frequency of the measured clock in MHz. The value of f_{DS} MUST be an integral multiple or divisor of the downstream symbol clock. For example, an $f_{DS} = 27.808$ MHz clock may be measured if there is no explicit 6.952 MHz clock available.

A DRFI-compliant device MUST provide a means for clock testing in which:

- The device provides test points for direct access to the master clock and the downstream symbol clock.

Alternatively, a DRFI-conformant device MUST provide a test mode in which:

- The downstream QAM symbol sequence is replaced with an alternating binary sequence (1, -1, 1, -1, 1, -1...) at nominal amplitude, on both I and Q.
- The device generates the downstream symbol clock from the 10.24 MHz reference clock as in normal synchronous operation.

If an explicit downstream symbol clock, which is capable of meeting the above phase noise requirements, is available (e.g., a smooth clock without clock domain jitter), this test mode is not required.

A.6.3.8 Downstream Symbol Clock Drift for Synchronous Operation

See Section 6.3.8.

A.6.3.9 *Timestamp Jitter*¹⁵

See Section 6.3.9.

A.7 Downstream Transmission Convergence Sublayer**A.7.1 Introduction**

See Section 7.1.

A.7.2 MPEG Packet Format

See Section 7.2.

A.7.3 MPEG Header for DOCSIS Data-Over-Cable

See Section 7.3.

A.7.4 MPEG Payload for DOCSIS Data-Over-Cable

See Section 7.4.

A.7.5 Interaction with the MAC Sublayer

See Section 7.5.

A.7.6 Interaction with the Physical Layer

The MPEG-2 packet stream **MUST** be encoded according to [EN 300 429].

¹⁵ Added this Annex per ECN DRFI-N-06.0333-1 by GO on 1/16/07.

Annex B DOCS-DRF-MIB (normative)¹⁶

```

DOCS-DRF-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY,
    OBJECT-IDENTITY,
    OBJECT-TYPE,
    Unsigned32
        FROM SNMPv2-SMI

    TruthValue,
    AutonomousType
        FROM SNMPv2-TC

    OBJECT-GROUP,
    MODULE-COMPLIANCE
        FROM SNMPv2-CONF

    PhysicalIndexOrZero,
    PhysicalIndex
        FROM ENTITY-MIB

    ifIndex,
    InterfaceIndexOrZero
        FROM IF-MIB

    docsIfDownstreamChannelEntry
        FROM DOCS-IF-MIB

    clabProjDocsis
        FROM CLAB-DEF-MIB;

docsDrfMib MODULE-IDENTITY
    LAST-UPDATED      "200812090000Z" -- December 9, 2008
    ORGANIZATION      "Cable Television Laboratories, Inc"
    CONTACT-INFO
        "Postal: Cable Television Laboratories, Inc.
        858 Coal Creek Circle
        Louisville, Colorado 80027-9750
        U.S.A.
        Phone: +1 303-661-9100
        Fax:   +1 303-661-9199
        E-mail: mibs@cablelabs.com"

    DESCRIPTION
        "This MIB module contains the management objects for the
        management of the Downstream RF Interface specification.
        Copyright 1999-2008 Cable Television Laboratories, Inc.
        All rights reserved."

    REVISION "200812090000Z" -- December 9, 2008
    DESCRIPTION
        "Revised Version includes ECN DRFI-N-08.0697-2 and
        and published as CM-SP-DRFI-I07-081209."

    REVISION "200712060000Z" -- December 6, 2007
    DESCRIPTION
        "Initial version, published as part of the CableLabs
        M-OSSI specification, CM-SP-M-OSSI-I07-071206, via ECN
        M-OSSI-N-07.0562-5."

    ::= { clabProjDocsis 23 }

-----
-- Textual Conventions
-----

-----
-- Main Groups
-----

```

¹⁶ Annex added per ECN DRFI-N-08.0697-2 on 12/08/08 by JS.

```

docsDrfNotifications OBJECT IDENTIFIER ::= { docsDrfMib 0 }
docsDrfObjects        OBJECT IDENTIFIER ::= { docsDrfMib 1 }

-----
-- DOCSIS DRF objects
-----

-----
--
-- PHY Parameters dependencies OBJECT-IDENTITY definitions
--
-----

docsDrfRegistry OBJECT-IDENTITY
  STATUS      current
  DESCRIPTION
    "Registration point for M-CMTS characterization of PHY
    parameters dependencies."
  ::= { docsDrfObjects 1 }

docsDrfPhyParamFixValue OBJECT-IDENTITY
  STATUS      current
  DESCRIPTION
    "Indicates that this PHY parameter is fixed and cannot
    be changed."
  ::= { docsDrfRegistry 1 }

docsDrfPhyParamSameValue OBJECT-IDENTITY
  STATUS      current
  DESCRIPTION
    "Indicates that the PHY parameter value is the same for
    the elements in a dependency group; thus, a change in
    the PHY parameter of an element in the group will change
    the PHY parameter value in the other elements of the
    dependency group."
  ::= { docsDrfRegistry 2 }

docsDrfPhyParamAdjacentValues OBJECT-IDENTITY
  STATUS      current
  DESCRIPTION
    "Indicates that the PHY parameter has an adjacency or
    sequence pattern for the elements in a dependency group
    e.g., A group of channels all using J.83 Annex A, may set
    frequencies in the group by setting a 6 MHz spacing
    between the channels in the group. Vendors may rather
    use a more detailed vendor-specific OBJECT-IDENTITY or a
    table pointer to describe this type of PHY parameter
    dependency."
  ::= { docsDrfRegistry 3 }

docsDrfPhyParamFrequencyRange OBJECT-IDENTITY
  STATUS      current
  DESCRIPTION
    "This object indicates that the frequency in a TSID Group
    is constrained to a frequency range. Vendors may extend
    the MIB construct containing this reference to detail such
    constraints or rather use a more detailed vendor-specific
    OBJECT-IDENTITY or a table pointer to describe the
    frequency range supported."
  ::= { docsDrfRegistry 4 }

```

```
-----
-- DOCSIS DRF Interface Extension objects
-----
```

```
docsDrfDownstreamTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF DocsDrfDownstreamEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "Extensions for the DOCSIS RFI Downstream
        docsIfDownstreamChannelTable."
    ::= { docsDrfObjects 2 }

docsDrfDownstreamEntry OBJECT-TYPE
    SYNTAX      DocsDrfDownstreamEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "A conceptual row for this table.
        There is a corresponding entry for each entry of
        docsIfDownstreamChannelTable."
    AUGMENTS { docsIfDownstreamChannelEntry }
    ::= { docsDrfDownstreamTable 1 }

DocsDrfDownstreamEntry ::= SEQUENCE
{
    docsDrfDownstreamPhyDependencies      BITS
}

docsDrfDownstreamPhyDependencies OBJECT-TYPE
    SYNTAX  BITS {
        frequency(0),
        bandwidth(1),
        power(2),
        modulation(3),
        interleaver(4),
        j83Annex(5),
        symbolRate(6),
        mute(7)
    }
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The summary of the Downstream Interface
        dependencies based on the constraints of
        docsDrfGroupDependencyEntry.
        A BIT position set to '1' indicates the PHY parameter
        belongs to a dependency group.
        A BIT position set to '0', indicates the PHY parameter
        does not belong to a dependency group.

        For Interfaces configured via DEPI this information is
        reflected in the DEPI session as DEPI TSID group
        dependencies.

        If this object value is the zero-length string, it indicates
        this interface is configurable via DEPI but no session is
        currently active."
    ::= { docsDrfDownstreamEntry 1 }
```

```
-----
-- DRF Downstream Interface Capabilities
-----
```

```
docsDrfDownstreamCapabilitiesTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF DocsDrfDownstreamCapabilitiesEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This table contains the QAM channel capabilities
        for the Downstream Interface PHY parameters."
    ::= { docsDrfObjects 3 }

docsDrfDownstreamCapabilitiesEntry OBJECT-TYPE
    SYNTAX      DocsDrfDownstreamCapabilitiesEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "A conceptual row for this table."
    INDEX { ifIndex }
    ::= { docsDrfDownstreamCapabilitiesTable 1 }

DocsDrfDownstreamCapabilitiesEntry ::= SEQUENCE
{
    docsDrfDownstreamCapabFrequency          BITS,
    docsDrfDownstreamCapabBandwidth         BITS,
    docsDrfDownstreamCapabPower             BITS,
    docsDrfDownstreamCapabModulation        BITS,
    docsDrfDownstreamCapabInterleaver       BITS,
    docsDrfDownstreamCapabJ83Annex         BITS,
    docsDrfDownstreamCapabConcurrentServices BITS,
    docsDrfDownstreamCapabServicesTransport BITS,
    docsDrfDownstreamCapabMuting            BITS
}

docsDrfDownstreamCapabFrequency OBJECT-TYPE
    SYNTAX      BITS {
        qamDependency(0),
        adjacentChannel(1),
        adjacentChannelOrder(2)
    }
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The QAM channel frequency capabilities.
        'qamDependency' BIT set to '1' indicates the QAM channel
        frequency value has dependencies with other QAM channels
        and an entry that includes this QAM channel is in
        in docsDrfGroupDependencyTable for the PHY
        parameter 'frequency'.

        'adjacentChannel' BIT set to '1' indicates the QAM channel
        frequencies in the dependency group (DEPI TSID group) are
        adjacent and constrained in a frequency range based on
        the number of QAM channels in the dependency group.

        'adjacentChannelOrder' BIT set to '1' indicates the QAM
        channel frequency adjacency is based in the QAM channel
        sequence like entPhysicalParentRelPos in EntPhysicalTable
        or other vendor sequence.

        e.g., a dependency group of four QAM channels
        with 'adjacentChannelOrder' BIT set to '1':
        The 4th QAM channel in the sequence gets a frequency
        assignment  $f + 1 \times \text{bandwidth}$  when the frequency value of
        the 3rd QAM channel in the sequence is set to  $f$ ."

```

Similarly the 1st QAM channel in the sequence gets a frequency assignment of $f - 2 * \text{bandwidth}$ and the 2nd QAM channels gets a frequency of $f - 1 * \text{bandwidth}$.

'adjacentChannel' 'adjacentChannelOrder' BITS may be set to '1' when a dependency group includes the QAM channel of this M-CMTS Downstream interface and the value of the object docsDrfGroupDependencyType is docsDrfPhyParamAdjacentValues.

'adjacentChannel' BIT may be set to '1' if 'qamDependency' BIT is set to '1'. The same way, 'adjacentChannelOrder' BIT may be set to '1' and implies 'adjacentChannel' BIT is set to '1'."

```
::= { docsDrfDownstreamCapabilitiesEntry 1 }
```

docsDrfDownstreamCapabBandwidth OBJECT-TYPE

```
SYNTAX      BITS {
    qamDependency(0),
    chan6Mhz(1),
    chan8Mhz(2)
}
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The QAM channel Bandwidth capabilities.

'qamDependency' BIT set to '1' indicates the QAM channel bandwidth value has dependencies with other QAM channels as indicated in docsDrfGroupDependencyTable.

'chan6Mhz' set to '1' indicates 6 MHz channel width support.

'chan8Mhz' set to '1' indicates 8 MHz channel width support.

When 'qamDependency' BIT is set to '1', a set to the channel bandwidth PHY parameter of a QAM channels in a dependency group (with docsDrfGroupDependencyType set to docsDrfPhyParamSameValue), sets the same channel bandwidth value to all QAM channels in the dependency group."

```
::= { docsDrfDownstreamCapabilitiesEntry 2 }
```

docsDrfDownstreamCapabPower OBJECT-TYPE

```
SYNTAX      BITS {
    qamDependency(0)
}
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The QAM channel Power capabilities.

'qamDependency' BIT set to '1' indicates the QAM channel power value has dependencies with other QAM channels as indicated in docsDrfGroupDependencyTable.

When 'qamDependency' BIT is set to '1', a set to the power level PHY parameter of a QAM channels in a dependency group (with docsDrfGroupDependencyType set to docsDrfPhyParamSameValue), sets the same power level to all QAM channels in the dependency group."

```
::= { docsDrfDownstreamCapabilitiesEntry 3 }
```

docsDrfDownstreamCapabModulation OBJECT-TYPE

```

SYNTAX      BITS {
    qamDependency(0),
    qam64(1),
    qam256(2)
}
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "The QAM channel Modulation capabilities.
    'qamDependency' BIT set to '1' indicates the QAM channel
    modulation value has dependencies with other QAM channels
    as indicated in docsDrfGroupDependencyTable.

    'qam64' set to '1' indicates 64 QAM modulation support.
    'qam256' set to '1' indicates 256 QAM modulation support.

    When 'qamDependency' BIT is set to '1', a set to the
    modulation PHY parameter of a QAM channels in a
    dependency group (with docsDrfGroupDependencyType
    set to docsDrfPhyParamSameValue), sets the same modulation
    type to all QAM channels in the dependency group."
 ::= { docsDrfDownstreamCapabilitiesEntry 4 }

```

docsDrfDownstreamCapabInterleaver OBJECT-TYPE

```

SYNTAX      BITS {
    qamDependency(0),
    taps8Increment16(1),
    taps16Increment8(2),
    taps32Increment4(3),
    taps64Increment2(4),
    taps128Increment1(5),
    taps128increment17(6),
    taps128increment2(7),
    taps128increment3(8),
    taps128increment4(9),
    taps128increment5(10),
    taps128increment6(11),
    taps128increment7(12),
    taps128increment8(13)
}
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "The QAM channel Interleaver capabilities.
    'qamDependency' BIT set to '1' indicates the QAM channel
    interleave value has dependencies with other QAM channels
    as indicated in docsDrfGroupDependencyTable.

    'taps8Increment16' set to '1' indicates the support of
    j = 8, i = 16 interleave.

    'taps16Increment8' set to '1' indicates the support of
    j = 16, i = 8 interleave.

    'taps32Increment4' set to '1' indicates the support of
    j = 32, i = 4 interleave.

    'taps64Increment2' set to '1' indicates the support of
    j = 64, i = 2 interleave.

    'taps128Increment1' set to '1' indicates the support of
    j = 128, i = 1 interleave.

```

'taps12increment17' set to '1' indicates the support of
j = 12, i = 17 interleave.

'taps128increment2' set to '1' indicates the support of
j = 128, i = 2 interleave.

'taps128increment3' set to '1' indicates the support of
j = 128, i = 3 interleave.

'taps128increment4' set to '1' indicates the support of
j = 128, i = 4 interleave.

'taps128increment5' set to '1' indicates the support of
j = 128, i = 5 interleave.

'taps128increment6' set to '1' indicates the support of
j = 128, i = 6 interleave.

'taps128increment7' set to '1' indicates the support of
j = 128, i = 7 interleave.

'taps128increment8' set to '1' indicates the support of
j = 128, i = 8 interleave.

When 'qamDependency' BIT is set to '1', a set to the
interleave PHY parameter of a QAM channels in a
dependency group (with docsDrfGroupDependencyType
set to docsDrfPhyParamSameValue), sets the same Interleave
value to all QAM channels in the dependency group."

```
::= { docsDrfDownstreamCapabilitiesEntry 5 }
```

docsDrfDownstreamCapabJ83Annex OBJECT-TYPE

```
SYNTAX      BITS {
    qamDependency(0),
    annexA(1),
    annexB(2),
    annexC(3)
}
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The QAM channel J.83 Annex Capabilities.

'qamDependency' BIT set to '1' indicates the QAM channel
J.83 Annex value has dependencies with other QAM channels
as indicated in docsDrfGroupDependencyTable.

'annexA' set to '1' indicates J.83 Annex A support.

'annexB' set to '1' indicates J.83 Annex B support.

'annexC' set to '1' indicates J.83 Annex C support.

When 'qamDependency' BIT is set to '1', a set to the
J.83 Annex PHY parameter of a QAM channels in a
dependency group (with docsDrfGroupDependencyType
set to docsDrfPhyParamSameValue), sets the same J.83 Annex
value to all QAM channels in the dependency group."

```
::= { docsDrfDownstreamCapabilitiesEntry 6 }
```

docsDrfDownstreamCapabConcurrentServices OBJECT-TYPE

```
SYNTAX      BITS {
    qamDependency(0),
    videoAndDocsis(1)
}
```

```

MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "The QAM channel Concurrent Services Capabilities.
    'qamDependency' BIT set to '1' indicates the QAM channel
    is part of a dependency group that supports concurrent
    services mode as indicated in
    docsDrfGroupDependencyTable.

    'videoAndDocsis' BIT set to '1' indicates video transport
    and DOCSIS transport can be supported simultaneously.

    Video and DOCSIS transport service types are described in
    docsDrfDownstreamCapabServicesTransport."
 ::= { docsDrfDownstreamCapabilitiesEntry 7 }

```

docsDrfDownstreamCapabServicesTransport OBJECT-TYPE

```

SYNTAX BITS {
    qamDependency(0),
    mpeg2OverIP(1),
    dmpt(2),
    psp(3)
}
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "The QAM channel Services transports modes Capabilities.

    'qamDependency' BIT set to '1' indicates the QAM channel
    Service transport type has dependencies with other QAM
    channels as indicated in
    docsDrfGroupDependencyTable.

    'mpeg2OverIP' set to '1' indicates video transports as
    conventional VoD is supported (known as MPT mode, MPEG-2
    transport).
    'dmpt' set to 1 indicates DOCSIS MPT mode (D-MPT) support.
    'psp' set to 1 indicates DOCSIS Packet Streaming Protocol
    mode (PSP) support.

    When 'qamDependency' BIT is set to '1', a request to set
    a QAM channel to a service type in a dependency group
    (with docsDrfGroupDependencyType set to
    docsDrfPhyParamSameValue) may be rejected."
 ::= { docsDrfDownstreamCapabilitiesEntry 8 }

```

docsDrfDownstreamCapabMuting OBJECT-TYPE

```

SYNTAX BITS {
    qamDependency(0)
}
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "The QAM channel muting capabilities.
    'qamDependency' BIT set to '1' indicates the QAM Mute
    state has dependencies with other QAM channels as
    indicated in docsDrfGroupDependencyTable.

    When 'qamDependency' BIT is set to '1', a request to
    mute a QAM channels in a dependency group (with
    docsDrfGroupDependencyType set to
    docsDrfPhyParamSameValue), sets all QAM channels in the
    dependency group to mute."

```



```
::= { docsDrfDownstreamCapabilitiesEntry 9 }
```

```
-----
-- DRF Group Dependency of PHY parameters Definitions
-- Defines the group of QAM channels that may be impacted for
-- individual QAM channels PHY parameters changes. Extends ENTITY-MIB
-----
```

```
docsDrfGroupDependencyTable OBJECT-TYPE
```

```
SYNTAX SEQUENCE OF DocsDrfGroupDependencyEntry
```

```
MAX-ACCESS not-accessible
```

```
STATUS current
```

```
DESCRIPTION
```

"This table describes the rules that identify groups of QAM channels with PHY parameters dependencies.

A PHY parameter dependency group means that a set to a QAM channel parameter may affect the value of other QAM Channels in the group.

TSID is a broadcast term borrowed by the M-CMTS architecture to represent a unique identifier of QAM channels in the M-CMTS architecture.

TSID Group is the DEPI concept of a set of QAM channels with a PHY parameter dependency. This module refers to TSID group as a PHY dependency Group.

This table uses the ENTITY-MIB physical component structure to allow the managed system to describe the QAM channels' PHY parameters dependencies. A management entity can use the information from this table to generate the DEPI TSID Groups.

Examples of PHY dependencies could be usage of adjacent frequencies, or QAM channels of RF ports restricted, or same interleaver value, modulation and J.83 Annex value.

Additional details and rules to describe the PHY parameter dependency is indicated in docsDrfGroupDependencyType.

Vendors may extend via other MIB modules the usage of docsDrfGroupDependencyType."

```
::= { docsDrfObjects 4 }
```

```
docsDrfGroupDependencyEntry OBJECT-TYPE
```

```
SYNTAX DocsDrfGroupDependencyEntry
```

```
MAX-ACCESS not-accessible
```

```
STATUS current
```

```
DESCRIPTION
```

"A conceptual row of this table.

QAM channels are modeled as PhysicalClass 'port' from the ENTITY-MIB.

An QAM channel can be represented as part of an entity MIB containment tree as follows:

```
chassis(device)
  .container(Slot)
    .module(field-replaceable-module)
      .module ( Physical RF spigot)
        . port (QAM channel)
```

PhysicalClass 'stack' is left optional and not included as a reference or examples for this table.

Based on the hardware capabilities the Agent will create entries in this table including the entPhysicalEntry of the close element to the root (e.g., up to 'chassis' or 'stack') including the PHY parameter of the dependency as part of the entry index

The Aggregation is then defined as all the QAM channels (entity PhysicalClass = 'port') below the tree as indicated in entyPhysicalContainsTable.

Logical or software dependencies of the QAM channels PHY parameters in addition to the hardware dependency entries can be present and MUST persist during system re-initialization. The storage realization of hardware dependent entries are 'permanent' or 'readOnly'. The storage realization of logical dependency entries is 'nonVolatile'.

PHY parameter dependencies that are logically defined may be present in this table but its configuration is outside of the scope of this MIB Module, including the definition of simulated Physical components such backplane types or modules accomplish its logical grouping.

PHY parameters with no Physical entities associated in this table indicate no PHY dependencies for certain groups of QAM channels.

Administrative changes to the docsDrfGroupDependencyPhyParamLock are preserved in non-volatile memory upon system re-initialization.

Note that any change in the system due to the insertion or removal of components will reset to factory default the entries associated with those components.

An entry in this table is reflected in the MIB object docsIfMExtDownstreamTSIDGroupPhyParamFlag for individual QAM channels.

A recursive method to find the PHY dependency group of an QAM channel A, PHY parameter X is as follows:

The parent tree of QAM channel A is recursively calculated by navigating entyPhysicalContainsTable from bottom to top $P_i(P_1..P_n)$

The list M_j ($M_1..M_n$) of docsDrfGroupDependencyPhysicalIndex represents the values from this table with PHY parameter docsDrfGroupDependencyPhyParam X and/or 'all'

The list Q_i ($Q_1..n$) is the list of matches of M_i in P_i

Q_i with the lower position in the entyPhysicalContainsTable is selected Q_y and M_y is the group criteria selected.

All QAM channels B_i below M_y are candidates for inclusion in the dependency group.

Each B_i is verified as A for its own B_{P_i} parent tree to verify that in effect M_y is the lowest denominator in M_i

Bpi intersection to become part of the Dependency Group of A."

```

INDEX { docsDrfGroupDependencyPhyParam,
        docsDrfGroupDependencyPhysicalIndex }
 ::= { docsDrfGroupDependencyTable 1 }

DocsDrfGroupDependencyEntry ::= SEQUENCE
{
  docsDrfGroupDependencyPhyParam          INTEGER,
  docsDrfGroupDependencyPhysicalIndex     PhysicalIndexOrZero,
  docsDrfGroupDependencyGroupID          Unsigned32,
  docsDrfGroupDependencyType             AutonomousType
}

docsDrfGroupDependencyPhyParam OBJECT-TYPE
SYNTAX      INTEGER {
  noDependencies(0),
  all(1),
  frequency(2),
  bandwidth(3),
  power(4),
  modulation(5),
  interleave(6),
  annex(7),
  symbolRate(8),
  mute(9)
}
MAX-ACCESS not-accessible
STATUS      current
DESCRIPTION
  "This object represents the type of PHY parameter
  that may have dependencies when setting an individual
  object in the dependency group.
  The value 'all' may be used as a wildcard to indicate
  all PHY parameters have dependencies. The other
  enumeration values are common QAM PHY parameters.

  The opposite to 'all' is 'noDependencies', which indicates
  no dependencies in PHY parameters, but is only used to
  indicate no dependencies across all the device. Thus,
  when used, 'noDependencies' is accompanied by
  docsDrfGroupDependencyPhysicalIndex '0' as the only
  entry in the table.
  In this way it is clearly distinguished when a device
  has dependencies instead of an empty table."
 ::= { docsDrfGroupDependencyEntry 1 }

docsDrfGroupDependencyPhysicalIndex OBJECT-TYPE
SYNTAX      PhysicalIndexOrZero
MAX-ACCESS not-accessible
STATUS      current
DESCRIPTION
  "Indicates the physical element from where the PHY
  parameter dependency for QAM channels is derived.
  All the QAM channels elements under this Physical index
  will belong to a dependency group of the specified PHY
  parameter."
 ::= { docsDrfGroupDependencyEntry 2 }

docsDrfGroupDependencyGroupID OBJECT-TYPE
SYNTAX      Unsigned32 (1..127)
MAX-ACCESS read-only
STATUS      current

```

DESCRIPTION

"The internal ID assigned for the QAM channels in the dependency group.
The value of this object is unique in the scope of the PHY parameter being mapped."

```
::= { docsDrfGroupDependencyEntry 3 }
```

docsDrfGroupDependencyType OBJECT-TYPE

SYNTAX AutonomousType

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The description of the type of dependency associated with this dependency group.
Basic type of dependencies are docsDrfPhyParamSameValue, docsDrfPhyParamAdjacentValues, docsDrfPhyParamFrequencyRange. Vendors may define their own rules and policies to describe their implementation dependency definitions such as RowPointers to table entries or OBJECT-IDENTITY clauses. If the dependency is not described this object is set to zeroDotZero, although the dependency does exist."

```
::= { docsDrfGroupDependencyEntry 4 }
```

```
-----
-- DRF Channel Block configuration
-- Configuration and diagnostic of block Channels.
-- This table is only for Channels Blocks Physical containments
-- Other configuration parameters (PHY) applicable to all channels in a
-- QAM Channel Block are set through the DS (QAM) channel interface and
-- configuration objects
-----
```

docsDrfChannelBlockTable OBJECT-TYPE

SYNTAX SEQUENCE OF DocsDrfChannelBlockEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table configure attributes of block channels and Controls channel Block Tests.
A channel block is an ENTITY-MIB containment of PhysicalClass 'module' that represent an RF connector."

```
::= { docsDrfObjects 5 }
```

docsDrfChannelBlockEntry OBJECT-TYPE

SYNTAX DocsDrfChannelBlockEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"The conceptual row of this table.
Entries in this table are created at system Initialization for Block Channels compliant to DRFI Specification.
Sets in entries of this table persist after system initialization."

INDEX { docsDrfChannelBlockPhysicalIndex }

```
::= { docsDrfChannelBlockTable 1 }
```

DocsDrfChannelBlockEntry ::= SEQUENCE

```
{
  docsDrfChannelBlockPhysicalIndex      PhysicalIndex,
  docsDrfChannelBlockNumberChannels     Unsigned32,
  docsDrfChannelBlockCfGNumberChannels Unsigned32,
  docsDrfChannelBlockMute               TruthValue,
}
```

```

docsDrfChannelBlockTestType          INTEGER,
docsDrfChannelBlockTestIfIndex       InterfaceIndexOrZero
}

docsDrfChannelBlockPhysicalIndex OBJECT-TYPE
SYNTAX          PhysicalIndex
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
    "The Physical Index of the QAM Channel Block."
 ::= { docsDrfChannelBlockEntry 1 }

docsDrfChannelBlockNumberChannels OBJECT-TYPE
SYNTAX          Unsigned32
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
    "The Number of QAM Channels N associated with this entry.

    The value of this attribute corresponds to the number
    of channels that can be transmitted from this block"
 ::= { docsDrfChannelBlockEntry 2 }

docsDrfChannelBlockCfgNumberChannels OBJECT-TYPE
SYNTAX          Unsigned32
MAX-ACCESS      read-write
STATUS          current
DESCRIPTION
    "The Number of QAM Channels N' to configure for the
    QAM block.

    This number corresponds to the number of channels that
    are configured to be currently transmitted by the block.

    The maximum number of channels per block follows the
    consideration of maximum number of digital channels in
    a headend described in the DRFI specification.
    As a rule N' is valid if it is less than or equal to N.
    In addition N minimal requirements consist of even
    numbers and 1 (one QAM channel per Block Channel). Odd
    number of QAM channels per Block Channel are optional
    for implementation.
    A Set to an invalid value or not supported value returns
    Error 'wrongValue'."
 ::= { docsDrfChannelBlockEntry 3 }

docsDrfChannelBlockMute OBJECT-TYPE
SYNTAX          TruthValue
MAX-ACCESS      read-write
STATUS          current
DESCRIPTION
    "The Mute control object for the Block Channel.
    A set to this object to 'true' is reflected in
    ifOperStatus set to 'down' of the QAM channels
    associated to the block Channel.
    The opposite, a set to this object to 'false', is not
    necessarily reflected as ifOperStatus set to 'up' since
    other interface conditions might prevent such status."
 ::= { docsDrfChannelBlockEntry 4 }

```

```
docsDrfChannelBlockTestType OBJECT-TYPE
    SYNTAX      INTEGER {
                noTest(1),
                offOthersNormal(2),
                allOff(3),
                onOthersOff(4),
                cwOnOthersOff(5),
                cwOnOthersNormal(6),
                clockTest(7)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "A set of in-service and out-of-service test modes.
        The value 'noTest'(1) is the normal condition after
        reinitialization where the QAM channels are expected in
        operation.

        'noTest'
        It is also used to take out of testing mode
        a QAM channel within the block.

        In-service tests modes:
        'offOthersNormal'
        It is the condition where the QAM Channel indicated in
        docsDrfChannelBlockTestIfIndex has its carrier
        suppressed and the other channels in the
        Block Channel are operational.
        'allOff'
        All QAM channel carriers in the channel block are
        Suppressed.
        'onOthersOff'
        It is the condition where the QAM channel indicated in
        docsDrfChannelBlockTestIfIndex is in operation
        and the other QAM channels in the channel Block have
        their carriers suppressed.

        Out-of-service test modes:
        'cwOnOthersOff'
        It is the condition where the QAM channel indicated in
        docsDrfChannelBlockTestIfIndex transmits a
        continuous wave (CW) while the other QAM
        channels in the channel Block have their carriers
        suppressed.
        'cwOnOthersNormal'
        It is the condition where the QAM channel indicated
        in docsDrfChannelBlockTestIfIndex transmits a
        continuous wave (CW) while the other QAM channels in
        the channel Block are operational.

        'clockTest'
        It is the condition where the QAM channel indicated in
        docsDrfChannelBlockTestIfIndex transmits a sequence
        of alternating -1 and 1 symbols.

        This object value does not persist after system
        Reinitialization.
        The value of this object is meaningless if
        docsDrfChannelBlockTestIfIndex is set to zero."
 ::= { docsDrfChannelBlockEntry 5 }
```

```

docsDrfChannelBlockTestIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndexOrZero
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The ifIndex of the QAM channel to perform the QAM
        channel test.
        A Set to a value that does not correspond to a QAM
        Channel within the Block channel returns error
        'wrongValue'.
        A set to zero stops a current test execution."
    ::= { docsDrfChannelBlockEntry 6 }

-----
-- Conformance definitions
-----

docsDrfConformance OBJECT IDENTIFIER ::= { docsDrfMib 2 }
docsDrfCompliances OBJECT IDENTIFIER ::= { docsDrfConformance 1 }
docsDrfGroups OBJECT IDENTIFIER ::= { docsDrfConformance 2 }

docsDrfDeviceCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement DOCSIS DRFI compliant
        devices."

    MODULE -- this MODULE

-- conditionally mandatory groups

    MANDATORY-GROUPS {
        docsDrfGroup
    }
::= { docsDrfCompliances 1}

docsDrfCmtsCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for CMTS compliant
        devices."

    MODULE -- this MODULE

-- conditionally mandatory groups

    MANDATORY-GROUPS {
        docsDrfGroup,
        docsDrfCmtsGroup
    }

    ::= { docsDrfCompliances 2}

docsDrfGroup OBJECT-GROUP
    OBJECTS {
        docsDrfDownstreamCapabFrequency,
        docsDrfDownstreamCapabBandwidth,
        docsDrfDownstreamCapabPower,
        docsDrfDownstreamCapabModulation,
        docsDrfDownstreamCapabInterleaver,
        docsDrfDownstreamCapabJ83Annex,

```

```
docsDrfDownstreamCapabConcurrentServices,
docsDrfDownstreamCapabServicesTransport,
docsDrfDownstreamCapabMuting,
docsDrfGroupDependencyGroupID,
docsDrfGroupDependencyType,
docsDrfChannelBlockNumberChannels,
docsDrfChannelBlockCfgNumberChannels,
docsDrfChannelBlockMute,
docsDrfChannelBlockTestType,
docsDrfChannelBlockTestIfIndex
}
STATUS      current
DESCRIPTION
    "Group of objects implemented in M-CMTS compliant devices."
::= { docsDrfGroups 1 }

docsDrfCmtsGroup OBJECT-GROUP
OBJECTS {
    docsDrfDownstreamPhyDependencies
}
STATUS      current
DESCRIPTION
    "Group of objects specific for CMTS."
::= { docsDrfGroups 2 }

END
```


Appendix I Acknowledgements (Informative)

On behalf of the cable industry and our member companies, CableLabs would like to thank the following individuals and organizations for their contributions to the development of this specification.

Contributor	Company Affiliation
Kirk Ashby	Microtune, Inc.
Scott Brown	ARRIS International, Inc.
Alberto Campos	Cable Television Laboratories, Inc.
Phillip Chang	Comcast Corporation
Bruce Currivan	Broadcom Corporation
Gerald Harron	Vcom Inc.
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Hal Roberts	BigBand Networks
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Greg Taylor	Cisco Systems, Inc.
Robert Thompson	Motorola, Inc.

Appendix II Revision History (Informative)

II.1 Engineering Changes for CM-SP-DRFI-I02-051209

The following Engineering Changes were incorporated into CM-SP-DRFI-I02-051209:

ECN	ECN Date	Summary
DRFI-N-05.0248-1	10/12/05	Enhanced Diagnostic Suppression Modes
DRFI-N-05.0249-1	10/12/05	Editorially remove artifacts after restricting operation to M/N locked symbol clock to master clock.

II.2 Engineering Changes for CM-SP-DRFI-I03-060106

The following Engineering Changes were incorporated into CM-SP-DRFI-I03-060106:

ECN	ECN Date	Summary
DRFI-N-05.0263-3	12/28/05	Additions and modifications to specify a European technology option for DRFI.
N/A	N/A	Note: An incorporation error was corrected and the document was reposted on 2/13/06.

II.3 Engineering Change for CM-SP-DRFI-I04-061222

The following Engineering Change was incorporated into CM-SP-DRFI-I04-061222:

ECN	ECN Date	Summary
DRFI-N-06.0285-2	9/13/06	Ceiling and typo.

II.4 Engineering Change for CM-SP-DRFI-I05-070223

The following Engineering Change was incorporated into CM-SP-DRFI-I05-070223:

ECN	ECN Date	Summary
DRFI-N-06.0333-1	12/13/06	Move timestamp jitter specification and test case from DEPI to DRFI.

II.5 Engineering Change for CM-SP-DRFI-I06-080215

The following Engineering Change was incorporated into CM-SP-DRFI-I06-080215:

ECN	ECN Date	Summary
DRFI-N-07.0576-2	12/20/07	Separate references into Americas and European tables and update Euroline 3

II.6 Engineering Change for CM-SP-DRFI-I07-081209

The following Engineering Change was incorporated into CM-SP-DRFI-I07-081209:

ECN	ECN Date	Summary
DRFI-N-08.0697-2	12/3/08	Relocate DRFI MIB from Annex E in M-OSSI.