

# **Data-Over-Cable Service Interface Specifications**

## **Downstream RF Interface Specification**

**CM-SP-DRFI-I16-170111**

**ISSUED**

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# 1 SCOPE AND PURPOSE<sup>1</sup>

## 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 four 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 second technology option is based on the corresponding European multi-program television distribution. The third technology option is based on the corresponding Chinese multi-program television distribution. The fourth technology option is based on a Remote PHY Device (RPD) that describes the physical layer specifications required for the location and operation of a downstream modulator in an optical node. All four 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, and 7. The second is defined by replacing the content of those sections with the content of Annex A. The third is defined by replacing the content of those sections with the content in Annex C. The fourth is defined by replacing the content of those sections with the content of Annex D. Correspondingly, [ITU-T J.83-B] and [CTA-542-D] apply only to the first and fourth options, [EN 300 429] only to the second, third and fourth options; [GB 8898-2001] and [GB/T 11318.1-1996] apply only to the third. Compliance with this document requires compliance with the one or the other of these implementations, not with all four. 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] for cable networks deployed in Europe and China. On downstream channels complying to [ITU-T J.83-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.

<sup>1</sup> Text modified per DRFI-N-13.1112-4 on 8/1/13 by PO. Revised per DRFI-N-16.1615-2 on 12/6/16 by JB.

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.<sup>2</sup>

## 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.

<sup>2</sup> Text modified per DRFI-N-05.0263.3 by KN on 2/21/07.

## 2 REFERENCES

### 2.1 Normative References<sup>3</sup>

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.

- [ANSI/SCTE 02] ANSI/SCTE 02 2006, "Specification for F Port, Female, Indoor."
- [C-DOCSIS] Data-Over-Cable Interface Specifications, C-DOCSIS System Specification, CM-SP-CDOCSIS-I02-150305, March 5, 2015, Cable Television laboratories, Inc.
- [CTA-542-D] CTA-542-D: "CEA Standard: Cable Television Channel Identification Plan," June 2013.
- [DOCS-DRF-MIB] CableLabs DOCSIS DOCS-DRF-MIB SNMP MIB Module, DOCS-DRF-MIB, <http://www.cablelabs.com/MIBs/DOCSIS/>.
- [DOCSIS2] Data-Over-Cable Service Interface Specifications, Radio Frequency Interface Specification v2.0, CM-SP-RFIv2.0-C02-090422, April 22, 2009, Cable Television Laboratories, Inc.
- [ISO 13818] ISO/IEC 13818-1, "Information Technology – Generic Coding of Moving Pictures and Associated Audio: Systems / ITU-T Recommendation H.222.0," 2007.
- [ITU-T J.83-B] Annex B to ITU-T Recommendation J.83 (12/07), "Digital multi-programme systems for television sound and data services for cable distribution."
- [R-DTI] Remote DOCSIS Timing Interface Specification, CM-SP-R-DTI-I04-170111, January 11, 2017, Cable Television Laboratories, Inc.
- [R-PHY] Remote PHY Specification, CM-SP-R-PHY-I06-170111, January 11, 2017, Cable Television Laboratories, Inc.

### 2.2 Informative References

This specification uses the following informative references.

- [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-I08-100611, June 11, 2010, Cable Television Laboratories, Inc.
- [DTI] DOCSIS Timing Interface, CM-SP-DTI-I05-081209, December 9, 2008, Cable Television Laboratories, Inc.
- [ERMI] Edge Resource Manager Interface, CM-SP-ERMI-C01-140520, May 20, 2014, 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.
- [NSI] CMTS Network Side Interface, SP-CMTS-NSI-I01-960702, July 2, 1996, Cable Television Laboratories, Inc.

<sup>3</sup> Section modified per 07.0576-2 on 1/16/08 by KN and per 08.0697-2 by JS. Revised per DRFI-N-10.0969-1 on 1/25/11 by JB. Revised per DRFI-N-16.1615-2 on 12/6/16 by JB.

## 2.3 Reference Acquisition

- Cable Television Laboratories, Inc., <http://www.cablelabs.com/>
- EIA: Electronic Industries Alliance, [http://www.eia.org/new\\_contact/](http://www.eia.org/new_contact/)
- ETSI: European Telecommunications Standards Institute, [http://www.etsi.org/services\\_products/freestandard/home.htm](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:<sup>4</sup>

<b>Ceiling (ceil)</b>	Returns the first integer that is greater than or equal to a given value.
<b>CM</b>	Cable Modem. A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.
<b>CPE</b>	Customer Premises Equipment. Equipment at the end user's premises; may be provided by the service provider.
<b>Carrier-to-Noise Ratio (C/N or CNR)</b>	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.
<b>Decibels (dB)</b>	Ratio of two power levels expressed mathematically as $dB = 10\log_{10}(P_{OUT}/P_{IN})$ .
<b>Decibel-Millivolt (dBmV)</b>	Unit of RF power expressed in decibels relative to 1 millivolt over 75 ohms, where $dBmV = 20\log_{10}(\text{value in mV}/1 \text{ mV})$ .
<b>Encompassed Spectrum</b>	The spectrum ranging from the lower band-edge of the lowest active channel frequency to the upper band-edge of the highest active channel frequency on an RF output port.
<b>Electronic Industries Alliance (EIA)</b>	A voluntary body of manufacturers which, among other activities, prepares and publishes standards.
<b>EQAM</b>	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).
<b>FEC</b>	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.
<b>Gap Channel</b>	A channel within the encompassed spectrum which is not active; this occurs with non-contiguous channel frequency assignments on an RF output port.
<b>Gigahertz (GHz)</b>	A unit of frequency; 1,000,000,000 or $10^9$ Hz.
<b>Hertz (Hz)</b>	A unit of frequency; formerly cycles per second.
<b>HRC</b>	Harmonic Related Carriers. A method of spacing channels on a cable television system with all carriers related to a common reference.
<b>HFC</b>	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.
<b>IRC</b>	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 [CTA-542-D] standard channel plan except for channels 5 and 6.
<b>kilohertz (kHz)</b>	Unit of frequency; 1,000 or $10^3$ Hz; formerly kilocycles per second.

<sup>4</sup> Revised Terms and Definitions, (Ceiling) per DRFI-N-06.0285-2 by GO on 10/9/06. Revised per DRFI-N-10-0913-3 on 6/2/10 by JB.

<b>Media Access Control (MAC)</b>	Used to refer to the layer 2 element of the system which would include DOCSIS framing and signaling.
<b>Megahertz (MHz)</b>	A unit of frequency; 1,000,000 or $10^6$ Hz; formerly megacycles per second.
<b>MER</b>	Modulation Error Ratio. The ratio of the average symbol power to average error power.
<b>M/N</b>	Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate.
<b>Multiple System Operator (MSO)</b>	A corporate entity that owns and/or operates more than one cable system.
<b>Non-contiguous Channel Assignment</b>	The encompassed spectrum on an RF output port contains gap channels (inactive channels).
<b>NTSC</b>	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.
<b>NGNA LLC</b>	Company formed by cable operators to define a next-generation network architecture for future cable industry market and business requirements.
<b>Physical Media Dependent Sublayer (PMD)</b>	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.
<b>QAM channel (QAM ch)</b>	Analog RF channel that uses quadrature amplitude modulation (QAM) to convey information.
<b>Quadrature Amplitude Modulation (QAM)</b>	A modulation technique in which an analog signal's amplitude and phase vary to convey information, such as digital data.
<b>Radio Frequency (RF)</b>	A portion of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light.
<b>Radio Frequency Interface (RFI)</b>	Term encompassing the downstream and the upstream radio frequency interfaces.
<b>Root Mean Square (RMS)</b>	Square root of the mean value squared a function.
<b>Self-Aggregation</b>	Method used to compute the headend noise floor by summing measured noise from a single device over a specified output frequency range.
<b>Standard Channel Plan (STD)</b>	Method of spacing NTSC television channels on a cable television system defined in [ANSI/SCTE 02].
<b>Upstream Channel Descriptor (UCD)</b>	The MAC Management Message used to communicate the characteristics of the upstream physical layer to the cable modems.
<b>Video on Demand (VoD)</b>	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:

<b>CMCI</b>	Cable Modem CPE Interface
<b>CMTS</b>	Cable Modem Termination System
<b>CW</b>	Continuous Wave
<b>dBc</b>	Decibels relative to carrier power
<b>DEPI</b>	Downstream External-PHY Interface
<b>DOCSIS®</b>	Data-Over-Cable Service Interface Specifications
<b>DRFI</b>	Downstream Radio Frequency Interface
<b>DTI</b>	DOCSIS Timing Interface
<b>ERMI</b>	Edge Resource Manager Interface
<b>FCC</b>	Federal Communications Commission
<b>ISO</b>	International Standards Organization
<b>ITU</b>	International Telecommunications Union
<b>ITU-T</b>	Telecommunication Standardization Sector of the ITU
<b>M-CMTS</b>	Modular Cable Modem Termination System
<b>Ms</b>	Millisecond. $10^{-3}$ second
<b>MPEG</b>	Moving Picture Experts Group
<b>Ns</b>	Nanosecond. $10^{-9}$ second
<b>NGNA</b>	Next Generation Network Architecture, see <i>NGNA LLC</i>
<b>OSSI</b>	Operations System Support Interface
<b>PHY</b>	Physical Layer
<b>ppm</b>	Parts per Million
<b>RPD</b>	Remote PHY Device
<b>Q</b>	Quadrature modulation component
<b>S-CDMA</b>	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 [CTA-542-D], 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 <sup>5</sup>

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, and in systems deploying modulators capable of generating nine or more QAM channels on a single RF output port analog channels will be placed at center frequencies below 600 MHz. 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. With more QAM channels the analog protection is less. With the stated assumptions, the analog protection is:

$$\text{Analog Protection (dB)} = 80.76 - 10 \cdot \log_{10}(\text{Number of QAM Channels}).$$

For example, in a 143-QAM channel system, with the assumptions above, the specification equates to an analog CNR protection of 59.2 dB.

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<sup>5</sup> Revised per DRFI-N-10.0910-1 on 5/25/10 and per DRFI-N-10.0927-3 on 6/9/10 by JB.

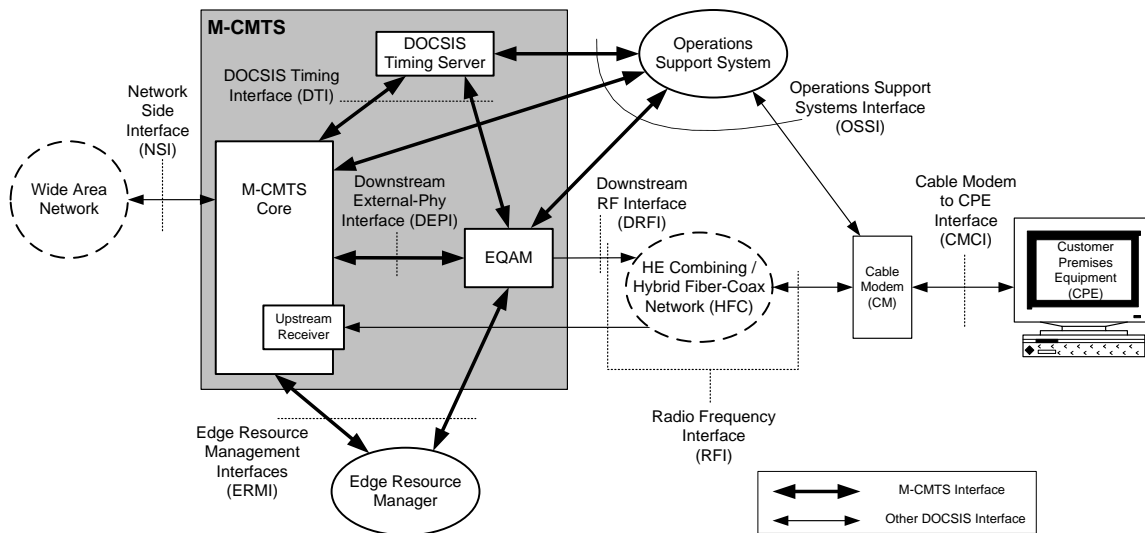
## 6 PHYSICAL MEDIA DEPENDENT SUBLAYER SPECIFICATION

### 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  $S(t) = I(t) \cdot \cos(\omega t) + Q(t) \cdot \sin(\omega t)$ , where  $t$  denotes time,  $\omega$  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 Scalable Interleaving to Support Video and High-Speed Data Services <sup>6</sup>

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. A multiple-channel CMTS or EQAM which is capable of producing up to  $N = 32$  RF channels on a single RF output port MUST be capable of providing up to the longest interleaver depth on all  $N$  channels. A multiple-channel CMTS or EQAM which is capable of producing  $N > 32$  RF channels on a single RF output port MUST be capable of providing interleaver depth  $I = 128$ ,  $J = 8$  on at least 32 channels, and up to  $I = 128$ ,  $J = 4$  on the remaining number of channels. \* Further requirements for operational availability of interleaver depths are given in Section 6.3.5.1.2, Sub-section 1.

\* This requirement provides that a DRFI modulator capable of producing  $N > 32$  RF channels on a single RF output port is allowed to be limited in the total amount of interleaver depth it must support, where it must support no more than maximum interleaving depth on 32 channels and half that depth on the other  $N - 32$  channels. This amount of required interleaving depth is less than that which is required for all channels to be interleaved with the maximum depth for a single channel, on all  $N$  channels.

**Table 6–1 - Low Latency Interleaver Depths**

Control Word	Interleaver Taps	Interleaver Increment	64-QAM 5.056941 Msym/sec 6 bits per symbol		256-QAM 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

<sup>6</sup> Revised per DRFI-N-10.0911-1 on 6/2/10 by JB.

Control Word	Interleaver Taps	Interleaver Increment	64-QAM 5.056941 Msym/sec 6 bits per symbol		256-QAM 5.360537 Msym/sec 8 bits per symbol	
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	64-QAM 5.056941 Msym/sec 6 bits per symbol		256-QAM 5.360537 Msym/sec 8 bits per symbol	
Four Bits	I	J	Burst Protection	Latency	Burst Protection	Latency
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 [CTA-542-D] 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<sup>7</sup>

EQAMs and CMTs may be available in three distinct versions. The terminology "multiple channel device" will apply to either of the latter two versions; requirements that apply to only one of the latter two versions will be clearly delineated in each case:

- Single channel devices that can only generate one RF channel per physical RF port.
- Multiple channel devices capable of generating more than one channel, but no more than eight, 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.

<sup>7</sup> Revised per DRFI-N-10.0891-2 and per DRFI-N-09.0892-2 on 6/2/10 by JB.

- Multiple channel devices capable of generating more than eight channels simultaneously per physical RF port. Such a multiple channel device could be used to generate eight or fewer channels; even so, it is still defined as a greater-than-eight multiple channel device.

An  $N$ -channel per RF port device capable of generating no more than eight channels per port **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  $N' = 1$ . An  $N$ -channel per RF port device capable of generating more than eight channels per port **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 values of  $N'$  less than  $N$ .

For an  $N$ -channel per RF port device with  $N \geq 9$  and  $N' < N/4$ , the applicable maximum power per channel and spurious emissions requirements are defined using a value of  $N'' = \text{minimum}(4N', \text{ceiling}[N/4])$ .

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<sup>8</sup>

A CMTS or EQAM **MUST** output an RF modulated signal with the characteristics defined in the requirements lists following Table 6–3, and Table 6–4, and the characteristics defined in Table 6–5, Table 6–6 and Table 6–7. The condition for these requirements is all  $N'$  combined channels, commanded to the same average power, except for the Single Channel Active Phase Noise, Diagnostic Carrier Suppression, and power difference (Table 6–4) requirements, and except as described for Out-of-Band Noise and Spurious Requirements (Table 6–5).

**Table 6–3 - RF Output Electrical Requirements<sup>9</sup>**

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)  required to be at least 91 MHz to 867 MHz $\pm 30$ kHz (See item #1 in the requirements list immediately following this table for further details)
Level	Adjustable. See Table 6–4.
Modulation Type	64-QAM, 256-QAM (See item #2 in requirements listed immediately following this table)
Symbol Rate (nominal) 64-QAM 256-QAM	5.056941 Msym/sec 5.360537 Msym/sec (See item #3 in requirements list immediately following this table)
Nominal Channel Spacing	6 MHz (See item #4 in requirements list immediately following this table)
Frequency response 64-QAM 256-QAM	~ 0.18 Square Root Raised Cosine Shaping ~ 0.12 Square Root Raised Cosine Shaping (See item #5 in the requirements list immediately following this table)

<sup>8</sup> Revised per DRFI-N-10.0891-2, per DRFI-N-09.0892-2 on 6/2/10, and per DRFI-N-10.0927-3 on 6/9/10 by JB. Revised per DRFI-N-16.1658-3 on 12/22/16 by JB.

<sup>9</sup> Table modified per 07.0576-2 on 1/16/08 by KN, per DRFI-N-09.0869-2 on 12/7/09 and per DRFI-N-09.0891-2 on 6/1/10 by JB.

Parameter	Value
Inband Spurious, Distortion, and Noise	Unequalized MER > 35 dB Equalized MER > 43 dB
Inband Spurious and Noise	$\leq -48\text{dBc}$ ; 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 $\pm 50\text{ kHz}$ of the carrier is excluded. When $N > 1$ , noise outside the Nyquist bandwidth is excluded. (See item #6 in the requirements list immediately following this table)
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, item 6) 64-QAM and 256-QAM	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, item 7) 64-QAM and 256-QAM	1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power (See item #7 in the requirements list immediately following this table)
Output Impedance	75 ohms (See item #8 in the requirements list immediately following this table)
Output Return Loss (See Table Note 3)	> 14 dB within an active output channel from 88 MHz to 750 MHz (See Table Note 4) > 13 dB within an active output channel from 750 MHz to 870 MHz > 12 dB within an active output channel from 870 MHz to 1002 MHz > 12 dB in every inactive channel from 54 MHz to 870 MHz > 10 dB in every inactive channel from 870 MHz to 1002 MHz (See item #9 in the requirements list immediately following this table)
Connector	F connector per [ANSI/SCTE 02]
<b>Table Notes:</b> 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 $\pm 50\text{ kHz}$ 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 row 1 in table above), then the EQAM or CMTS is to provide a return loss of > 14 dB within an active output channel, from 54 MHz to 750 MHz ( $f_{\text{edge}}$ ). See item #10 in the requirements list below.	

The following is a list of RF Output Electrical Requirements based on Table 6–3 above.

- The Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM
  - MAY be 57 MHz to 999 MHz  $\pm 30\text{ kHz}$  (Note 1)
  - MUST be at least 91 MHz to 867 MHz  $\pm 30\text{ kHz}$
- A CMTS or EQAM MUST support Modulation Types of:
  - 64-QAM,

- 256-QAM
3. A CMTS or EQAM MUST have a Symbol Rate (nominal) as follows:
    - 5.056941 Msym/sec for 64-QAM
    - 5.360537 Msym/sec for 256-QAM
  4. The Nominal Channel Spacing of a CMTS or EQAM output MUST be 6 MHz
  5. The Frequency response of a CMTS or EQAM MUST be:
    - ~ 0.18 Square Root Raised Cosine Shaping for 64-QAM
    - ~ 0.12 Square Root Raised Cosine Shaping for 256-QAM
  6. To verify Inband Spurious, Distortion, and Noise performance CMTS or EQAM MUST meet the following MER performance criteria:
    - Unequalized MER (Note 2) > 35 dB (see Table Note 2 above)
    - Equalized MER > 43 dB
  7. The Inband Spurious and Noise of a CMTS or EQAM MUST be  $\leq -48\text{dBc}$ ; 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  $\pm 50\text{ kHz}$  of the carrier is excluded. When  $N > 1$ , noise outside the Nyquist bandwidth is excluded.
  8. The Phase Noise of a CMTS or EQAM MUST meet the following performance criteria:
    - For a Single Channel Active,  $N - 1$  Channels Suppressed (see Section 6.3.5.1.2, item 6) for 64-QAM and 256-QAM:
      - Double sided noise power 1 kHz - 10 kHz:  $-33\text{dBc}$ ;
      - Double sided noise power 10 kHz - 50 kHz:  $-51\text{dBc}$ ;
      - Double sided noise power 50 kHz - 3 MHz:  $-51\text{dBc}$ .
    - All  $N$  Channels Active, (see Section 6.3.5.1.2, item 7) for 64-QAM and 256-QAM:
      - Double sided noise power 1 kHz - 10 kHz:  $-33\text{dBc}$
      - Double sided noise power 10 kHz - 50 kHz:  $-51\text{dBc}$
  9. The Output Impedance of a CMTS or EQAM RF Electrical Output MUST be 75 ohms.
  10. The Output Return Loss of a CMTS or EQAM RF Electrical Output MUST be as follows:
    - > 14 dB within an active output channel from 88 MHz to 750 MHz.
    - (Note 4) If the EQAM or CMTS provides service to a center frequency of 57 MHz (see row 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 (fedge).
    - > 13 dB within an active output channel from 750 MHz to 870 MHz.
    - > 12 dB in every inactive channel from 54 MHz to 870 MHz.
    - > 10 dB in every inactive channel from 870 MHz to 1002 MHz.
    - > 12 dB within an active output channel from 870 MHz to 1002 MHz.

### 6.3.5.1.1 Power per Channel CMTS or EQAM<sup>10</sup>

An EQAM or CMTS are required to generate an RF output with power capabilities as defined in the requirements lists immediately following Table 6–4. Channel RF power may be adjustable on a per channel basis with each channel independently meeting the power capabilities defined in the requirement lists following Table 6–4. Channel RF power is required to be adjustable on a per channel basis as stated in the lists following Table 6–4. If the EQAM or CMTS has independent modulation capability on a per channel basis, then the channel RF power is required to be adjustable on a per channel basis, with each channel independently meeting the power capabilities defined in the list following Table 6–4.

**Table 6–4 - DRFI Device Output Power<sup>11</sup>**

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 (See item #1 in the requirements list immediately following this table)
Range of commanded power per channel; adjusted on a per channel basis	0 dBc to -2 dBc relative to highest commanded transmit power per channel, up to 8 dB below required power level (for modulators capable of generating 9 or more channels per single RF output port.) <i>Required power (in table below) to required power - 8 dB, independently on each channel.</i> (See item #2 in the requirements list immediately following this table)
Commanded power per channel step size	=< 0.2 dB Strictly monotonic (See item #3 in the requirements list immediately following this table)
Power difference between any two adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)	=< 0.5 dB (See item #4 in the requirements list immediately following this table)
Power difference between any two non-adjacent channels in a 48 MHz contiguous bandwidth block (with commanded power difference removed if channel power is independently adjustable)	=< 1 dB (See item #5 in the requirements list immediately following this table)
Power difference between any two non-adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)	=< 2 dB (See item #6 in the requirements list immediately following this table)
Power per channel absolute accuracy	±2 dB (See item #7 in the requirements list immediately following this table)

<sup>10</sup> Revised per DRFI-N-16.1658-3 on 12/22/16 by JB.

<sup>11</sup> Revised this table per DRFI-N-05.0248-1 on 10/28/05, per DRFI-N-09.0889-4 on 6/1/10 and per DRFI-N-09.0891-2 and per DRFI-N-10.0917-1 on 6/2/10 by JB.



Parameter	Value
Diagnostic carrier suppression (3 modes) Mode 1: One channel suppressed	$\geq 50$ dB carrier suppression within the Nyquist bandwidth in any one 6 MHz active channel without service impacting discontinuity or detriment to the unsuppressed channels.
Mode 2: All channels suppressed except one	50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz active channel except one without service-impacting discontinuity or detriment to the remaining channel for modulators with $N \leq 8$ , where N equals the maximum number of channels per port. For modulators with $N \geq 9$ the suppression is not required to be glitchless, and the remaining unsuppressed active channel is allowed to operate with increased power such as the total power of the $N'$ active channels combined.
Mode 3: All channels suppressed	50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz active channel. The power allowed in the 6 MHz suppressed channel(s) by this carrier suppression requirement is combined with the spurious emissions requirements of the remaining (not suppressed) active channels to produce the ultimate test limit for power in the 6 MHz suppressed channel(s).  In all three modes the output return loss of the suppressed channel(s) is to comply with the Output Return Loss requirements for active channels given in Table 6–3 - RF Output Electrical Requirements. (See item #8 in the requirements list immediately following this table.)
RF output port muting	$\geq 73$ dB below the unmuted aggregate power of the RF modulated signal, in every 6 MHz channel from 54 MHz to 1002 MHz.  The specified limit applies with all active channels commanded to the same transmit power level. Commanding a reduction in the transmit level of any, or all but one, of the active channels does not change the specified limit for measured muted power in 6 MHz.  (See item #9 in the requirements list immediately following this table)
Required power per channel for $N$ channels combined onto a single RF port. for $N \leq 8$ , where $N \equiv$ maximum number of combined channels per port and $N' \equiv$ number of active combined channels per port ( $N' \leq N$ ):  $N' = 1$ $N' = 2$ $N' = 3$ $N' = 3$ $4 < N' \leq 8$	Required power in dBmV per channel:  60 dBmV 56 dBmV 54 dBmV 52 dBmV $60 - \text{ceil}[3.6 \cdot \log_2(N')]$ dBmV (See item #10 in the requirements list imme
Required power per channel for $N'$ channels combined onto a single RF port for $N' \geq N/4$ and $N \geq 9$ :	Required power in dBmV per channel
$N' \geq N/4$	$60 - \text{ceil}[3.6 \cdot \log_2(N')]$ dBmV (See item #11 in the requirements list immediately following this table)

Parameter	Value
Required power per channel for $N$ channels combined onto a single RF port for $N' < N/4$ and $N \geq 9$ :	Required power in dBmV per channel, where $N'' = \min [4N', \text{ceil}[N/4]]$
$1 \leq N' < N/4$	$60 - \text{ceil}[3.6 \cdot \log_2(N'')] \text{ dBmV}$ (See item #12 in the requirements list immediately following this table)

The following is a list of DRFI Device Output Power Requirements based on Table 6–4 above.

- In a CMTS or EQAM, the range of commanded transmit power per channel MUST be  $\geq 8$  dB below required power level specified below maintaining full fidelity over the 8 dB range.
- In a CMTS or EQAM, the range of commanded power per channel; adjusted on a per channel basis is as follows:
  - MUST be 0 dBc to -2 dBc relative to highest commanded transmit power per channel, up to 8 dB below required power level (for modulators capable of generating 9 or more channels per single RF output port.)
  - MAY be *required power* (in table above) to *required power* - 8 dB, independently on each channel.
- In a CMTS or EQAM, the commanded power per channel step size MUST be  $\leq 0.2$  dB strictly monotonic.
- In a CMTS or EQAM, the power difference between any two adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable) MUST be  $\leq 0.5$  Db.
- In a CMTS or EQAM, the power difference between any two non-adjacent channels in a 48 MHz contiguous bandwidth block (with commanded power difference removed if channel power is independently adjustable) MUST be  $\leq 1$  dB.
- In a CMTS or EQAM, the power difference between any two non-adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable) MUST be  $\leq 2$  dB.
- In a CMTS or EQAM, the power per channel absolute accuracy MUST be  $\pm 2$  dB.
- A CMTS or EQAM MUST support the following 3 modes of diagnostic carrier suppression.
  - Mode 1: One channel suppressed. For this mode, the CMTS or EQAM MUST support  $\geq 50$  dB carrier suppression within the Nyquist bandwidth in any one 6 MHz active channel, without service impacting discontinuity or detriment to the unsuppressed channels.
  - Mode 2: All channels suppressed except one. For this mode, the CMTS or EQAM MUST support 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz active channel except one, without service-impacting discontinuity or detriment to the remaining channel for modulators with  $N \leq 8$ , where  $N$  equals the maximum number of channels per port.
  - Mode 3: All channels suppressed. For this mode, the CMTS or EQAM MUST support 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz active channel.

In all three modes the output return loss of the suppressed channel(s) on a CMTS or EQAM MUST comply with the Output Return Loss requirements for active channels given in Table 6–3 - RF Output Electrical Requirements.
- In a CMTS or EQAM, the RF output port power, when muting, MUST be  $\geq 73$  dB below the unmuted aggregate power of the RF modulated signal, in every 6 MHz channel from 54 MHz to 1002 MHz.
 

In a CMTS or EQAM, the output return loss of the output port MUST comply with the Output Return Loss requirements for inactive channels given in Table 6–3 - RF Output Electrical Requirements.

10. For a CMTS or EQAM, the required power per channel for  $N$  channels combined onto a single RF port for  $N < 8$ , where  $N \equiv$  maximum number of combined channels per port and  $N' \equiv$  number of active combined channels per port ( $N' \leq N$ ), MUST comply with the following:
  - $N' = 1$ , 60 dBmV per channel
  - $N' = 2$ , 56 dBmV per channel
  - $N' = 3$ , 54 dBmV per channel
  - $N' = 4$ , 52 dBmV per channel
  - $4 < N' \leq 8$ ,  $60 - \text{ceil}[3.6 * \log_2(N')]$  dBmV per channel
11. In a CMTS or EQAM, the required power per channel for  $N'$  channels combined onto a single RF port for  $N' \geq N/4$  and  $N \geq 9$  MUST be  $60 - \text{ceil}[3.6 * \log_2(N')]$  dBmV per channel.
12. In a CMTS or EQAM, the required power per channel for  $N'$  channels combined onto a single RF port for  $N' < N/4$  and  $N \geq 9$  and  $1 \leq N' < N/4$  MUST be  $60 - \text{ceil}[3.6 * \log_2(N'')]$  dBmV per channel, where  $N'' \equiv \min[4N', \text{ceil}[N/4]]$ .

#### 6.3.5.1.2 Independence of individual channel within the multiple channels on a single RF port<sup>12</sup>

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.<sup>13</sup>
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. A multiple-channel CMTS or EQAM capable of generating nine or more channels on a single RF output port MUST provide for independent selection of center frequency with the ratio of number of active channels to gap channels in the encompassed spectrum being at least 2:1, and with each channel independently meeting the requirements in Table 6-3 except for spurious emissions (including Table 6-5). A multiple-channel CMTS or EQAM capable of generating nine or more channels on a single RF output port MUST meet the requirements of Table 6-3 when the ratio of number of active channels to gap channels in the encompassed spectrum is at least 4:1. (A ratio of number of active channels to gap channels of at least 4:1 provides that at least 80% of the encompassed spectrum contains active channels, and the number of gap channels is at most 20% of the encompassed spectrum.)
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. 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

<sup>12</sup> Revised per DRFI-N-10-0913-3 on 6/2/10 by JB.

<sup>13</sup> Revised this statement per DRFI-N-05.0248-1 on 10/28/05.

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.
8. A CMTS or EQAM capable of generating more than eight channels per physical RF port **MUST** be capable of glitchless reconfiguration over a range of active channels from  $\text{ceiling}[7*N'_{\text{max}}/8]$  to  $N'_{\text{max}}$ . Channels which are undergoing configuration changes are referred to as the "changed channels." The channels which are active and are not being reconfigured are referred to as the "continuous channels." Each DRFI modulator capable of generating more than eight channels per physical RF port **MUST** accept a command setting  $N'_{\text{max}}$ . Glitchless reconfiguration consists of any of the following actions while introducing no discontinuity or detriment to the continuous channels, where the modulator is operating in a valid DRFI-required mode both before and after the reconfiguration with an active number of channels staying in the range  $\{\text{ceiling}[7*N'_{\text{max}}/8], N'_{\text{max}}\}$ : adding and/or deleting one or more channels, and/or moving some channels to new RF carrier frequencies, and/or changing the interleaver depth, modulation, power level, or frequency on one or more channels. Any change in the modulation characteristics (power level, modulation density, interleaver parameters, center frequency) of a channel excuses that channel from being required to operate in a glitchless manner. For example, changing the power per channel of a given channel means that channel is not considered a continuous channel for the purposes of the glitchless modulation requirements. Glitchless operation is not required when  $N'_{\text{max}}$  is changed, even if no reconfigurations accompany the change in  $N'_{\text{max}}$ .

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<sup>14</sup>

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, and in systems deploying modulators capable of generating nine or more digital channels on a single RF port analog channels will be placed at center frequencies below 600 MHz. An adjustment of  $10*\log_{10}(6\text{ MHz} / 4\text{ MHz})$  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, Table 6–6, and Table 6–7 list 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 among the active channels. When commanded to the same power level, "dBc" should be interpreted as the average channel

<sup>14</sup> Revised per DRFI-N-09.0891-2 on 6/2/10 and per DRFI-N-10.0927-3 on 6/9/10 by JB.

power, averaged over the active channels, to mitigate the variation in channel power across the active channels (see Table 6–4), which is allowed with all channels commanded to the same power.

Modulators capable of generating  $N \leq 8$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table 6–5 with a contiguous block of  $N'$  combined channels.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table 6–5 in channels below 600 MHz and outside the encompassed spectrum when the active channels are contiguous or when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table 6–5, with 1 dB relaxation, in gap channels below 600 MHz and within the encompassed spectrum when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table 6–5, with 3 dB relaxation, when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater, in channels with center frequency at or above 600 MHz, outside the encompassed spectrum or in gap channels within the encompassed spectrum.

In cases where  $N \geq 9$ , and the  $N'$  combined active channels are not contiguous, and the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater, the spurious emissions requirements are determined by summing the spurious emissions power allowed in a given measurement bandwidth by each of the contiguous sub-blocks among the active channels. In the gap channels within the encompassed spectrum and below 600 MHz there is a 1 dB relaxation in the spurious emissions requirements, so that within the encompassed spectrum the spurious emissions requirements (in absolute power) are 26% higher power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. In all channels above 600 MHz there is a 3 dB relaxation in the spurious emissions requirements, so that the spurious emissions requirements (in absolute power) are double the power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. The following three paragraphs provide the details of the spurious emissions requirements for non-contiguous channel operation outside the encompassed spectrum; within the encompassed spectrum the same details apply except there is an additional 1 dB allowance below 600 MHz; and 3 dB allowance is applied above 600 MHz for all channels.

The full set of  $N'$  channels is referred to throughout this specification as the modulated channels or the active channels. However, for purposes of determining the spurious emissions requirements for non-contiguous transmitted channels, each separate contiguous sub-block of channels within the active channels is identified, and the number of channels in each contiguous sub-block is denoted as  $N_i$ , for  $i = 1$  to  $K$ , where  $K$  is the number of contiguous sub-blocks. Therefore,  $N' = \sum_{i=1 \text{ to } K} N_i$ . Note that  $K = 1$  when and only when the entire set of active channels is contiguous. Also note that an isolated transmit channel, i.e., a transmit channel with empty adjacent channels, is described by  $N_i = 1$  and constitutes a sub-block of one contiguous channel. Any number of the "contiguous sub-blocks" may have such an isolated transmit channel; if each active channel was an isolated channel, then  $K = N'$ .

When  $N' \geq N/4$ , Table 6–6 is used for determining the noise and spurious power requirements for each contiguous sub-block, even if the sub-block contains fewer than  $N/4$  active channels. When  $N' < N/4$ , Table 6–7 is used for determining the noise and spurious power requirements for each contiguous sub-block. Thus, the noise and spurious power requirements for all contiguous sub-blocks of transmitted channels are determined entirely from Table 6–6 or entirely from Table 6–7, where the applicable table is determined by  $N'$  being greater than or equal to  $N/4$ , or not. The noise and spurious power requirements for the  $i$ th contiguous sub-block of transmitted channels is determined from Table 6–6 or Table 6–7 using the value  $N_i$  for the "number of active channels combined per RF port", and using "dBc" relative to the strongest carrier among all the active channels, and not just the strongest channel in the  $i$ th contiguous sub-block, in cases where the  $N'$  combined channels are not commanded to the same power. The noise and spurious emissions power in each measurement band, including harmonics, from all  $K$  contiguous sub-blocks, is summed (absolute power, NOT in dB) to determine the composite noise floor for the non-contiguous channel transmission condition.

For the measurement channels adjacent to a contiguous sub-block of channels, the spurious emissions requirements from the non-adjacent sub-blocks are divided on an equal "per Hz" basis for the narrow and wide adjacent measurement bands. For a measurement channel wedged between two contiguous sub-blocks, adjacent to each, the

measurement channel is divided into three measurement bands, one wideband in the middle and two narrowbands each abutting one of the adjacent transmit channels. The wideband spurious and noise requirement is split into two parts, on an equal "per Hz" basis, to generate the allowed contribution of power to the middle band and to the farthest narrowband. The ceiling function is applied to the resulting sum of noise and spurious emissions, per Table Note 1 of Table 6-5, Table 6-6 and Table 6-7 to produce a requirement of ½ dB resolution.

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 2<sup>nd</sup> and 3<sup>rd</sup> harmonics of the commanded channel, are fully identified in the table.

Item 6 lists the requirements on the 2N' 2<sup>nd</sup> harmonic channels and the 3N' 3<sup>rd</sup> harmonic channels.

**Table 6-5 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements for  $N \leq 8$** <sup>15</sup>

<b>for <math>N \leq 8</math> Maximum Number of Combined Channels per RF Port</b> <b><math>N \equiv</math> Maximum Number of Combined Channels per RF Port</b> <b><math>N' \equiv</math> Number of Active Channels Combined per RF Port</b>						
Item	Band	N'				
		1	2	3	4	N' > 4
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<-58 dBc	<-58 dBc	$<10 \cdot \log_{10} [10^{-58/10} + (0.75/6) \cdot (10^{-65/10} + (N'-2) \cdot 10^{-73/10})]$
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 $N'=7$ : -64 dBc; For $N' \geq 8$ : $<-73 + 10 \cdot \log_{10}(N')$
5	Noise in other channels (47 MHz to 1002 MHz) Measured in each 6 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)	<-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 2nd harmonic and with 3rd harmonic components respectively (up to 1002 MHz)	$<-73 + 10 \cdot \log_{10}(N')$ , or -63 dBc, whichever is greater				

<sup>15</sup> Added footnote to Table 6-5 per DRFI-N-06.0285-2 by GO on 10/9/06. Revised table per DRFI-N-09.0890-4 on 2/9/2010, per DRFI-N-09.0891-2 on 6/2/10, and per DRFI-N-10.0927-3 on 6/9/10 by JB.

for $N \leq 8$ Maximum Number of Combined Channels per RF Port $N \equiv$ Maximum Number of Combined Channels per RF Port $N' \equiv$ Number of Active Channels Combined per RF Port						
Item	Band	$N'$				
		1	2	3	4	$N' > 4$
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	$< -50 + 10 \cdot \log_{10}(N')$				
8	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	$< -55 + 10 \cdot \log_{10}(N')$				
<b>Table Notes:</b> 1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc. 2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency 600 MHz and above. For example -73 dBc becomes -70 dBc. 3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -73 dBc becomes -72 dBc.						

**Table 6-6 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements  $N \geq 9$  and  $N' \geq N/4$ <sup>16</sup>**

<b>for <math>N \geq 9</math> Maximum Number of Combined Channels per RF Port</b> <b><math>N' \geq N/4</math> Number of Active Channels Combined per RF Port</b>					
Item	Band	N'			
		2	3	4	N' >4
1	Adjacent channel up to 750 kHz from channel block edge	$< -58$ dBc	$< -58$ dBc	$< -58$ dBc	$< 10 \log_{10} [10^{-58/10} + (0.75/6) * (10^{-65/10} + (N'-2) * 10^{-73/10})]$
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	$< -60$ dBc	$< -60$ dBc	$< -60$ dBc	$< 10 \log_{10} [10^{-62/10} + (5.25/6) * (10^{-65/10} + (N'-2) * 10^{-73/10})]$
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	$< -64$ dBc	$< -63.5$ dBc	$< -63$ dBc	$< 10 \log_{10} [10^{-65/10} + (N'-1) * 10^{-73/10}]$
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge).	$< -70$ dBc	$< -67$ dBc	$< -65$ dBc	For $N'=5$ : -64.5 dBc; For $N'=6$ : -64 dBc; For $N'=7$ : -64 dBc; For $N' \geq 8$ : $< -73 + 10 \log_{10}(N')$
5	Noise in other channels (47 MHz to 1002 MHz) Measured in each 6 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)	$< -70$ dBc	$< -68$ dBc	$< -67$ dBc	$< -73 + 10 \log_{10}(N')$

<sup>16</sup> Added footnote to Table 6-5 per DRFI-N-06.0285-2 by GO on 10/9/06. Revised per DRFI-N-09.0890-4 on 2/9/2010 and per DRFI-N-09.0891-2 on 6/2/10 by JB.

for $N \geq 9$ Maximum Number of Combined Channels per RF Port $N' \geq N/4$ Number of Active Channels Combined per RF Port				
Item	Band	N'		
		2	3	4
6	In each of $2N'$ contiguous 6 MHz channels or in each of $3N'$ contiguous 6 MHz channels coinciding with 2nd harmonic and with 3rd harmonic components respectively (up to 1002 MHz)	< $-73 + 10 \cdot \log_{10}(N')$ , or -63 dBc, whichever is greater		
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	< $-50 + 10 \cdot \log_{10}(N')$		
8	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	< $-55 + 10 \cdot \log_{10}(N')$ for $N' \leq 8$ < $-60 + 10 \cdot \log_{10}(N')$ for $N' > 8$		
Table Notes:				
1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling( $2 \cdot$ Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.				
2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency 600 MHz and above. For example -73 dBc becomes -70 dBc.				
3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -73 dBc becomes -72 dBc.				

**Table 6-7 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements  $N \geq 9$  and  $N' < N/4$ <sup>17</sup>**

for $N \geq 9$ Maximum Number of Combined Channels per RF Port $N' < N/4$ Number of Active Channels Combined per RF Port $N'' \equiv$ Effective Number of Active Channels for Spurious Emissions Requirements = minimum[ $4N'$ , ceil( $N/4$ ) ]				
Item	Band	$N''$		
		3	4	$N'' > 4$
1	Adjacent channel up to 750 kHz from channel block edge	$< -58$ dBc	$< -58$ dBc	$< 10 \log_{10} [10^{-58/10} + (0.75/6) * (10^{-65/10} + (N''-2) * 10^{-73/10})]$
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	$< -60$ dBc	$< -60$ dBc	$< 10 \log_{10} [10^{-62/10} + (5.25/6) * (10^{-65/10} + (N''-2) * 10^{-73/10})]$
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	$< -63.5$ dBc	$< -63$ dBc	$< 10 \log_{10} [10^{-65/10} + (N''-1) * 10^{-73/10}]$
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge).	$< -67$ dBc	$< -65$ dBc	For $N''=5$ : -64.5 dBc; For $N''=6$ : -64 dBc; For $N''=7$ : -64 dBc; For $N'' \geq 8$ : $< -73 + 10 \log_{10}(N'')$
5	Noise in other channels (47 MHz to 1002 MHz) Measured in each 6 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)	$< -68$ dBc	$< -67$ dBc	$< -73 + 10 \log_{10}(N'')$

<sup>17</sup> Added footnote to Table 6-5 per DRFI-N-06.0285-2 by GO on 10/9/06. Revised per DRFI-N-09.0890-4 on 2/9/2010 and per DRFI-N-09.0891-2 on 6/2/10 by JB. Revised per DRFI-N-11.1011-2 on 11/4/11 by JB.



for $N \geq 9$ Maximum Number of Combined Channels per RF Port $N' < N/4$ Number of Active Channels Combined per RF Port $N'' \equiv$ Effective Number of Active Channels for Spurious Emissions Requirements= minimum[ $4N'$ , ceil( $N/4$ ) ]				
Item	Band	$N''$		
		3	4	$N'' > 4$
6	In each of $2N'$ contiguous 6 MHz channels or in each of $3N'$ contiguous 6 MHz channels coinciding with 2 <sup>nd</sup> harmonic and with 3 <sup>rd</sup> harmonic components respectively (up to 1002 MHz)	< $-73 + 10 \cdot \log_{10}(N'')$ , or -63 dBc, whichever is greater		
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	< $-50 + 10 \cdot \log_{10}(N'')$		
8	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	< $-55 + 10 \cdot \log_{10}(N'')$ for $N'' \leq 8$ < $-60 + 10 \cdot \log_{10}(N'')$ for $N'' > 8$		
<b>Table Notes:</b>				
1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling( $2 \cdot$ Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.				
2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency 600 MHz and above. For example -73 dBc becomes -70 dBc.				
3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -73 dBc becomes -72 dBc.				

### 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  $\leq 10$  nSec peak-to-peak ( $\pm 5$  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  $\pm 20$  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.<sup>18</sup>

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,  $\leq 21$  nSec; 1,024,000 length segments separated by one 10,240,000-cycle segment,  $\leq 30$  nSec; adjacent 102,400,000 segments,  $\leq 120$  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

<sup>18</sup> Revised per DRFI-N-06.0285-2 by GO on 10/9/06.

- $< [-50 + 20 \cdot \log(f_{MC}/10.24)]$  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<sup>19</sup>

This section contains the EQAM and CMTS requirements for locking the Downstream Symbol Clock to the Master Clock.

#### 6.3.6.1 CMTS Clock Generation<sup>20</sup>

The CMTS MUST lock the Downstream Symbol Clock to the CMTS Master Clock using the M/N divisors provided in Table 6–8.

#### 6.3.6.2 EQAM Clock Generation

An EQAM operates with an active DTI interface which provides a 10.24 MHz Master Clock. An EQAM MUST lock the Downstream Symbol Clock to the Master Clock using the M/N divisors provided in Table 6–8.

#### 6.3.6.3 Downstream Symbol Rate<sup>21</sup>

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 6–8 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  $\pm 1$  ppm from its specified nominal value.

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

Table 6–8 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.

<sup>19</sup> Revised per DRFI-N-09.0832-2 on 8/3/09 by JB.

<sup>20</sup> Revised per DRFI-N-09.0832-2 on 8/3/09 by JB; Heading 4 number applied to section on 6/13/13 by CP.

<sup>21</sup> Revised this section per DRFI-N-05.0249-1 on 10/28/05 and per DRFI-N-09.0832-2 on 8/3/09 by JB.

**Table 6–8 - 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, 64-QAM	5.056941	401/812	10.239990..	5.056945..	0.95 ppm
Annex B, 256-QAM	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 Jitter<sup>22</sup>

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:

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

<sup>22</sup> Added this section per 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.

MPEG Header (4 bytes)	pointer_field (1 byte)	DOCSIS Payload (183 or 184 bytes)
--------------------------	---------------------------	--------------------------------------

**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 Specification<sup>23</sup>

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 References<sup>24</sup>

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-C02-090422, April 22, 2009, 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 Recommendation 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.

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<sup>23</sup> Added Annex A per DRFI-N-05.0263-3 by GO on 1/3/06.

<sup>24</sup> 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 256-QAM 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, and that in systems deploying modulators capable of generating nine or more channels on a single RF output port analog channels will be placed at center frequencies below 600 MHz. 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,  $\omega$  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 Scalable 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	64-QAM 6.952 Msym/sec 6 bits per symbol		256-QAM 6.952 Msym/sec 8 bits per symbol	
		Burst Protection	Latency	Burst Protection	Latency
12	17	18 $\mu$ s	0.43 ms	14 $\mu$ 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<sup>25</sup>**

A CMTS or EQAM MUST output an RF-modulated signal with the characteristics defined in Table A–2, Table A–3, Table A–4, Table A–5, and Table A–6. The condition for these requirements is that all N' channels delivered to a single RF output 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), Diagnostic Carrier Suppression and Power Difference (Table A–3), and except as described for Out-of-Band Noise and Spurious Requirements (Table A–4, Table A–5, and Table A–6).

**A.6.3.5.1.1 Output Electrical per RF Port<sup>26</sup>**

Table A–2 shows the electrical output requirements per RF port.

**Table A–2 - Output Electrical Requirements per RF Port<sup>27</sup>**

Parameter	Value
Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM	SHOULD be 90 MHz to 1002 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	64-QAM, 256-QAM
Symbol Rate (nominal) 64-QAM 256-QAM	6.952 Msym/sec 6.952 Msym/sec
Nominal Channel Spacing	8 MHz
Frequency response 64-QAM 256-QAM	~ 0.15 Square Root Raised Cosine Shaping ~ 0.15 Square Root Raised Cosine Shaping
Inband Spurious, Distortion, and Noise	Unequalized MER (Note 1) > 35 dB Equalized MER > 43 dB
Inband Spurious and Noise ( $f_c \pm 4$ MHz)	$\leq -46.7$ 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 $\pm 50$ kHz of the carrier is excluded. When $N > 1$ , noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	See Table A–4.
Phase Noise Single Channel Active, $N - 1$ Channels Suppressed (see Section 6.3.5.1.2, item 5) 64-QAM and 256-QAM	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 6.3.5.1.2, item 6) 64-QAM and 256-QAM	1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power
Output Impedance	75 ohms

<sup>25</sup> Revised per DRFI-N-10-0927-3 on 6/9/10 by JB.

<sup>26</sup> Revised per DRFI-N-09.0891-2 on 6/2/10 by JB.

<sup>27</sup> Table modified per 07.0576-2 on 1/16/08 by KN. Revised per DRFI-N-11.1012-2 on 11/4/11 by JB.

Parameter	Value
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 86 MHz to 862 MHz > 10 dB in every inactive channel from 862 MHz to 1006 MHz
Connector	F connector per [IEC-61169-24]
<b>Table Notes:</b> 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 $\pm 50$ 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. 2. If the EQAM or CMTS provides service to a center frequency of 90 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 86 MHz to 108 MHz. If the EQAM or CMTS provides service to a center frequency of 1002 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 1006 MHz.	

#### 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<sup>28</sup>**

Parameter	Value
Range of commanded transmit power per channel	$\geq 8$ dB below required power level specified below maintaining full fidelity over the 8 dB range.
Range of commanded power per channel; adjusted on a per channel basis	MUST: 0 dBc to -2 dBc relative to highest commanded transmit power per channel, up to 8 dB below required power level (for modulators capable of generating 9 or more channels per single RF output port) MAY: required power (as defined in Table A–3) relative to required power - 8 dB, independently on each channel.
Commanded power per channel step size	$\leq 0.2$ dB strictly monotonic
Power difference between any two adjacent channels in a block (with commanded power difference removed if channel power is independently adjustable)	$\leq 0.5$ dB
Power difference between any two non-adjacent channels in a 64 MHz contiguous bandwidth block (with commanded power difference removed if channel power is independently adjustable)	$\leq 1$ dB
Power difference between any two non-adjacent channels in the 86-1006 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)	$\leq 2$ dB
Power per channel absolute accuracy	$\pm 2$ dB

<sup>28</sup> Revised per DRFI-N-09.0889-4 on 6/1/10 and per DRFI-N-09.0891-2 on 6/2/10 by JB. Revised per DRFI-N-11.1012-2 on 11/4/11 by JB.

Parameter	Value
Diagnostic carrier suppression (3 modes) Mode 1: One channel suppressed  Mode 2: All channels suppressed except one  Mode 3: All channels suppressed	<p>1) <math>\geq 50</math> dB carrier suppression within the Nyquist bandwidth in any one 8 MHz active channel. This MUST be accomplished without service-impacting discontinuity or detriment to the unsuppressed channels.</p> <p>2) <math>\geq 50</math> dB carrier suppression within the Nyquist bandwidth in every 8 MHz active channel except one. This MUST be accomplished without service-impacting discontinuity or detriment to the remaining channel for modulators with <math>N \leq 8</math>, where N equals the maximum number of channels per port. For modulators with <math>N \geq 9</math> the suppression is not required to be glitchless, and the remaining unsuppressed active channel is allowed to operate with increased power such as the total power of the N' active channels combined.</p> <p>3) <math>\geq 50</math> dB carrier suppression within the Nyquist bandwidth in every 8 MHz active channel.</p> <p>The power allowed in the 8 MHz suppressed channel(s) by this carrier suppression requirement is combined with the spurious emissions requirements of the remaining (not suppressed) active channels to produce the ultimate test limit for power in the 8 MHz suppressed channel(s).</p> <p>In all three modes the output return loss of the suppressed channel(s) MUST comply with the Output Return Loss requirements for active channels given in Table A-2 - Output Electrical Requirements per RF Port.</p>
RF output port muting	<p><math>\geq 71.5</math> dB below the unmuted aggregate power of the RF modulated signal, in every 8 MHz channel from 86 MHz to 1006 MHz.</p> <p>The specified limit applies with all active channels commanded to the same transmit power level. Commanding a reduction in the transmit level of any, or all but one, of the active channels does not change the specified limit for measured muted power in 8 MHz.</p> <p>The output return loss of the output port of the muted device MUST comply with the Output Return Loss requirements for inactive channels given in Table A-2 - Output Electrical Requirements per RF Port.</p>
Required power per channel for N channels combined onto a single RF port with $N < 8$ , where N $\equiv$ maximum number of combined channels per port and N' $\equiv$ number of active combined channels per port ( $N' \leq N$ ):  N' = 1 N' = 2 N' = 3 N' = 4 4 < N' < 8	<p>Required power in dBmV per channel</p> <p>60 dBmV 56 dBmV 54 dBmV 52 dBmV <math>60 - \text{ceil}[3.6 \cdot \log_2(N)]</math> dBmV</p>
Required power per channel for N' channels combined onto a single RF port with $N' \geq N/4$ and $N' > 9$ :  N' > N/4	<p>Required power in dBmV per channel</p> <p><math>60 - \text{ceil}[3.6 \cdot \log_2(N')]</math> dBmV</p>
Required power per channel for N' channels combined onto a single RF port with $N' < N/4$ and $N > 9$ :  1 < N' < N/4	<p>Required power in dBmV per channel, where <math>N'' = \min[4 \cdot N', \text{ceil}(N/4)]</math></p> <p><math>60 - \text{ceil}[3.6 \cdot \log_2(N'')]</math> dBmV</p>

### A.6.3.5.1.3 Independence of individual channel within the multiple channels on a single RF port <sup>29</sup>

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-2 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. A multiple-channel CMTS or EQAM capable of generating nine or more channels on a single RF output port **MUST** provide for independent selection of center frequency with the ratio of number of active channels to gap channels in the encompassed spectrum being at least 2:1, and with each channel independently meeting the requirements in Table A-3 except for spurious emissions (including Table A-4). A multiple-channel CMTS or EQAM capable of generating nine or more channels on a single RF output port **MUST** meet the requirements of Table A-3 when the ratio of number of active channels to gap channels in the encompassed spectrum is at least 4:1. (A ratio of number of active channels to gap channels of at least 4:1 provides that at least 80% of the encompassed spectrum contains active channels, and the number of gap channels is at most 20% of the encompassed spectrum.)
4. 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 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.
7. A CMTS or EQAM capable of generating more than eight channels per physical RF port **MUST** be capable of glitchless reconfiguration over a range of active channels from  $\text{ceiling}[7*N'_{\text{max}}/8]$  to  $N'_{\text{max}}$ . Channels which are undergoing configuration changes are referred to as the "changed channels". The channels which are active and are not being reconfigured are referred to as the "continuous channels". Each DRFI modulator capable of generating more than eight channels per physical RF port **MUST** accept a command setting  $N'_{\text{max}}$ . Glitchless reconfiguration consists of any of the following actions while introducing no discontinuity or detriment to the continuous channels, where the modulator is operating in a valid DRFI-required mode both before and after the reconfiguration with an active number of channels staying in the range  $\{\text{ceiling}[7*N'_{\text{max}}/8], N'_{\text{max}}\}$ : adding and/or deleting one or more channels, and/or moving some channels to new RF carrier frequencies, and/or

<sup>29</sup> Revised per DRFI-N-09.0892-2 and DRFI-N-10-0913-3 on 6/2/10 by JB.

changing the modulation, power level, or frequency on one or more channels. Any change in the modulation characteristics (power level, modulation density, center frequency) of a channel excuses that channel from being required to operate in a glitchless manner. For example, changing the power per channel of a given channel means that channel is not considered a continuous channel for the purposes of the glitchless modulation requirements. Glitchless operation is not required when  $N'_{\text{max}}$  is changed, even if no reconfigurations accompany the change in  $N'_{\text{max}}$ .

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 <sup>30</sup>

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 256-QAM transmission. It is further assumed, for the purpose of calculation, that the channel lineup will place analog channels at lower frequencies than digital channels, and that in systems deploying modulators capable of generating nine or more channels on a single RF output port analog channels will be placed at center frequencies below 600 MHz. 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.

Table A-4, Table A-5, and Table A-6 list 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 among the active channels. When commanded to the same power level, "dBc" should be interpreted as the average channel power, averaged over the active channels, to mitigate the variation (see Table A-3) in channel power across the active channels, which is allowed with all channels commanded to the same power.

Modulators capable of generating  $N \leq 8$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table A-4 with a contiguous block of  $N'$  combined channels.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table A-4 in channels with center frequencies below 600 MHz and outside the encompassed spectrum when the active channels are contiguous or when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table A-4, with 1 dB relaxation, in gap channels within the encompassed spectrum when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater and when the center frequency of the channel is below 600 MHz.

Modulators capable of generating  $N \geq 9$  channels on a single RF output port MUST satisfy the out-of-band spurious emissions requirements of Table A-4, with 3 dB relaxation, in gap channels within the encompassed spectrum and in channels outside the encompassed spectrum when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater and when the center frequency of the channel is at or above 600 MHz.

In cases where  $N \geq 9$ , and the  $N'$  combined active channels are not contiguous, and the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater, the spurious emissions requirements are determined by summing the spurious emissions power allowed in a given measurement bandwidth by each of the contiguous sub-blocks among the active channels. In the gap channels within the encompassed spectrum and with center frequency below 600 MHz there is a 1 dB relaxation in the spurious emissions requirements, so that within the

<sup>30</sup> Revised per DRFI-N-09.0891-2 on 6/2/10 by JB. Revised per DRFI-N-11.1012-2 on 11/4/11 by JB.



encompassed spectrum the spurious emissions requirements (in absolute power) are 26% higher power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. In all channels with center frequencies at or above 600 MHz there is a 3 dB relaxation in the spurious emissions requirements, so that the spurious emissions requirements (in absolute power) are double the power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. The following three paragraphs provide the details of the spurious emissions requirements for non-contiguous channel operation outside the encompassed spectrum; within the encompassed spectrum the same details apply except there is an additional 1 dB allowance in channels with center frequencies below 600 MHz; 3 dB allowance is applied to all channels with center frequencies above 600 MHz.

The full set of  $N'$  channels is referred to throughout this specification as the modulated channels or the active channels. However, for purposes of determining the spurious emissions requirements for non-contiguous transmitted channels, each separate contiguous sub-block of channels within the active channels is identified, and the number of channels in each contiguous sub-block is denoted as  $N_i$ , for  $i = 1$  to  $K$ , where  $K$  is the number of contiguous sub-blocks. Therefore,  $N' = \sum_{i=1 \text{ to } K} N_i$ . Note that  $K = 1$  when and only when the entire set of active channels is contiguous. Also note that an isolated transmit channel, i.e., a transmit channel with empty adjacent channels, is described by  $N_i = 1$  and constitutes a sub-block of one contiguous channel. Any number of the "contiguous sub-blocks" may have such an isolated transmit channel; if each active channel was an isolated channel, then  $K = N'$ .

When  $N' \geq N/4$ , Table A-5 is used for determining the noise and spurious power requirements for each contiguous sub-block, even if the sub-block contains fewer than  $N/4$  active channels. When  $N' < N/4$ , Table A-6 is used for determining the noise and spurious power requirements for each contiguous sub-block. Thus, the noise and spurious power requirements for all contiguous sub-blocks of transmitted channels are determined entirely from Table A-5 or entirely from Table A-6, where the applicable table is determined by  $N'$  being greater than or equal to  $N/4$ , or not. The noise and spurious power requirements for the  $i$ th contiguous sub-block of transmitted channels is determined from Table A-5 or Table A-6 using the value  $N_i$  for the "number of active channels combined per RF port", and using "dBc" relative to the strongest carrier among all the active channels, and not just the strongest channel in the  $i$ th contiguous sub-block, in cases where the  $N'$  combined channels are not commanded to the same power. The noise and spurious emissions power in each measurement band, including harmonics, from all  $K$  contiguous sub-blocks, is summed (absolute power, NOT in dB) to determine the composite noise floor for the non-contiguous channel transmission condition.

For the measurement channels adjacent to a contiguous sub-block of channels, the spurious emissions requirements from the non-adjacent sub-blocks are divided on an equal "per Hz" basis for the narrow and wide adjacent measurement bands. For a measurement channel wedged between two contiguous sub-blocks, adjacent to each, the measurement channel is divided into three measurement bands, one wideband in the middle and two narrowbands each abutting one of the adjacent transmit channels. The wideband spurious and noise requirement is split into two parts, on an equal "per Hz" basis, to generate the allowed contribution of power to the middle band and to the farthest narrowband. The ceiling function is applied to the resulting sum of noise and spurious emissions, per Table Note 1 of Table A-4, Table A-5 and Table A-6 to produce a requirement of  $\frac{1}{2}$  dB resolution.

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 2<sup>nd</sup> and 3<sup>rd</sup> harmonics of the commanded channel, are fully identified in the table.

Item 6 lists the requirements on the  $2N'$  2<sup>nd</sup> harmonic channels and the  $3N'$  3<sup>rd</sup> harmonic channels.

**Table A-4 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements for  $N \leq 8$  with  $N \equiv$  Maximum Number of Combined Channels per RF Port and  $N' \equiv$  Number of Active Channels Combined per RF Port<sup>31</sup>**

Item	Band	N' (for N ≤ 8)				
		1	2	3	4	N' > 4
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<-58 dBc	<-58 dBc	$<10 \cdot \log_{10} [10^{-58/10} + (0.75/8) \cdot (10^{-63.5/10} + (N-2) \cdot 10^{-71.5/10})]$
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	$<10 \cdot \log_{10} [10^{-60.5/10} + (7.25/8) \cdot (10^{-63.5/10} + (N-2) \cdot 10^{-71.5/10})]$
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: <-62.5 dBc; For N≥8: <-71.5 + 10*log <sub>10</sub> (N)
5	Noise in other channels (80 MHz to 1006 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 <sub>10</sub> (N)
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 1006 MHz)	< -71.5 + 10*log <sub>10</sub> (N), or -63 dBc, whichever is greater				
7	Lower out-of-band noise in the band of 5 MHz to 65 MHz Measured in 8 MHz channel bandwidth	< -50 + 10*log <sub>10</sub> (N)				
8	Higher out-of-band noise in the band of 1006 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	< -55 + 10*log <sub>10</sub> (N)				

**Table Notes:**

- All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2\*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.
- Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency at 600 MHz and above. For example -71.5 dBc becomes -68.5 dBc.
- Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -71.5 dBc becomes -70.5 dBc.

<sup>31</sup> Added footnote to Table A-4; editorial corrections, per DRFI-N-06.0285-2 by GO on 10/9/06, per DRFI-N-09.0890-4 on 6/2/10 and per DRFI-N-10.0927-3 on 6/9/10 by JB. Revised per DRFI-N-11.1011-2 on 11/4/11 by JB.

**Table A-5 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements for  $N \geq 9$  and  $N' \geq N/4$  with  $N \equiv$  Maximum Number of Combined Channels per RF Port and  $N' \equiv$  Number of Active Channels Combined per RF Port<sup>32</sup>**

Item	Band	N' (for $N \geq 9$ and $N' \geq N/4$ )			
		2	3	4	N' > 4
1	Adjacent channel up to 750 kHz from channel block edge	<-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)	<-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 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).	<-68.5 dBc	<-65.5 dBc	<-64 dBc	For $N'=5$ : <-63 dBc; For $N'=6$ : <-62.5 dBc; For $N'=7$ : <-62.5 dBc; For $N' \geq 8$ : $<-71.5 + 10 \cdot \log_{10} (N')$
5	Noise in other channels (80 MHz to 1006 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)	<-68.5 dBc	<-66.5 dBc	<-65.5 dBc	$<-71.5 + 10 \cdot \log_{10} (N')$
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 1006 MHz)	$<-71.5 + 10 \cdot \log_{10} (N')$ , or -63 dBc, whichever is greater			
7	Lower out of band noise in the band of 5 MHz to 65 MHz Measured in 8 MHz channel bandwidth	$<-50 + 10 \cdot \log_{10} (N')$			
8	Higher out of band noise in the band of 1006 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	$<-55 + 10 \cdot \log_{10} (N')$ for $N' \leq 8$ $<-60 + 10 \cdot \log_{10} (N')$ for $N' > 8$			

**Table Notes:**

- All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2\*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.
- Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency at 600 MHz and above. For example -71.5 dBc becomes -68.5 dBc.
- Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -71.5 dBc becomes -70.5 dBc.

<sup>32</sup> Added per DRFI-N-09.0890-4 on 6/2/10 and per DRFI-N-10.0927-3 on 6/9/10 by JB. Revised per DRFI-N-11.1012-2 on 11/4/11 by JB.

**Table A-6 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements for  $N \geq 9$  and  $N' < N/4$  with  $N \equiv$  Maximum Number of Combined Channels per RF Port and  $N' \equiv$  Number of Active Channels Combined per RF Port and  $N'' \equiv$  Effective Number of Active Channels for Spurious Emissions Requirements<sup>33</sup>**

Item	Band	$N'' = \text{minimum}[4*N', \text{ceiling}(N/4)]$ (for $N \geq 9$ and $N' < N/4$ )		
		3	4	$N'' > 4$
1	Adjacent channel up to 750 kHz from channel block edge	<-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)	<-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)	<-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).	<-65.5 dBc	<-64 dBc	For $N''=5$ : <-63 dBc; For $N''=6$ : <-62.5 dBc; For $N''=7$ : <-62.5 dBc; For $N'' \geq 8$ : $<-71.5 + 10 \cdot \log_{10} (N'')$
5	Noise in other channels (80 MHz to 1006 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)	<-66.5 dBc	<-65.5 dBc	$<-71.5 + 10 \cdot \log_{10} (N'')$
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 1006 MHz)	$<-71.5 + 10 \cdot \log_{10} (N'')$ , or -63 dBc, whichever is greater		
7	Lower out of band noise in the band of 5 MHz to 65 MHz Measured in 8 MHz channel bandwidth	$<-50 + 10 \cdot \log_{10} (N'')$		
8	Higher out of band noise in the band of 1006 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	$<-55 + 10 \cdot \log_{10} (N'')$ for $N'' \leq 8$ $<-60 + 10 \cdot \log_{10} (N'')$ for $N'' > 8$		

**Table Notes:**

- All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling( $2 \cdot \text{Power}$ ) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.
- Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency at 600 MHz and above. For example -71.5 dBc becomes -68.5 dBc.
- Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -71.5 dBc becomes -70.5 dBc

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

See Section 6.3.5.2.

<sup>33</sup> Added per DRFI-N-09.0890-4 on 6/2/10 and per DRFI-N-10.0927-3 on 6/9/10 by JB. Revised per DRFI-N-11.1011-2 on 11/4/11 by JB.

**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-7.

**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-7.

**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-7.

**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-7 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  $\pm 1$  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-7 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-7 - 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], 64-QAM	6.952	869/1280	10.240..	6.952	0 ppm
[EN 300 429], 256-QAM	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

- $< [-53 + 20 \cdot \log(f_{DS}/6.952)]$  dBc (i.e.,  $< 0.07$  ns RMS) 100 Hz to 1 kHz
- $< [-53 + 20 \cdot \log(f_{DS}/6.952)]$  dBc (i.e.,  $< 0.07$  ns RMS) 1 kHz to 10 kHz
- $< [-36 + 20 \cdot \log(f_{DS}/6.952)]$  dBc (i.e.,  $< 0.5$  ns RMS) 10 kHz to 100 kHz
- $< [-30 + 20 \cdot \log(f_{DS}/6.952)]$  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<sup>34</sup>**

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].

<sup>34</sup> Added this Annex per DRFI-N-06.0333-1 by GO on 1/16/07.

## **Annex B DOCS-DRF-MIB (normative)<sup>35</sup>**

The full normative text of [DOCS-DRF-MIB] is available at <http://mibs.cablelabs.com/MIBs/DOCSIS>.

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<sup>35</sup> Annex added per DRFI-N-08.0697-2 on 12/08/08 by JS. Revised per DRFI-N-16.1615-2 on 12/6/16 by JB.

## Annex C Additions and Modifications for Chinese Specification<sup>36</sup>

This annex applies to the third 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 C-DOCSIS CMTS. 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.

### C.1 Scope and purpose

See Section 1.

### C.2 References

#### C.2.1 Normative References

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.

- |                     |  |
|---------------------|--|
| [GB 8898-2001]      | GB 8898-2001 Audio, video and similar electronic apparatus–Safety requirements   |
| [GB/T 11318.1-1996] | Television and Voice Cable Distribution System Equipment and Components, Part 1: General Specification   |
| [DOCSIS2]           | Data-Over-Cable Service Interface Specifications, Radio Frequency Interface Specification v2.0, CM-SP-RFIV2.0-C02-090422, April 22, 2009, 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 Recommendation 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.  |

### C.3 Terms and Definitions

See Section 3.

### C.4 Acronyms and Abbreviations

See Section 4.

### C.5 Functional Assumptions

See Section A.5, where all text and requirements apply except those that are EQAM-specific.

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<sup>36</sup> Annex added per DRFI-N-13.1112-4 on 8/1/13 by PO.



## C.6 Physical Media Dependent Sublayer Specification

### C.6.1 Scope

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

For the remainder of this section see Section 6.1.

### C.6.2 EdgeQAM (EQAM) differences from CMTS

EQAM will not be discussed further in this annex, as it does not apply to the Chinese Specification.

### C.6.3 Downstream

#### C.6.3.1 Downstream Protocol

For 64-QAM and 256-QAM constellations, the downstream PMD sublayer MUST conform to [EN 300 429]. If the 1024-QAM constellation is supported, the downstream PMD sublayer MUST conform to [EN 300 429], except as denoted differently in Sections C.6.3.2 to C.6.3.9, and as defined in C.6.3.10.

#### C.6.3.2 Spectrum Format

The downstream modulator for each QAM channel of the 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,  $\omega$  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].

#### C.6.3.3 Scalable Interleaving to Support Video and High-Speed Data Services

The CMTS downstream PMD sublayer MUST support an interleaver with the characteristics defined in Table C–1. This interleaver mode fully complies with [EN 300 429].

**Table C–1 - Interleaver Characteristics**

Interleaver Taps	Interleaver Increment	64-QAM 6.952 Msym/sec 6 bits per symbol		256-QAM 6.952 Msym/sec 8 bits per symbol		1024-QAM 6.952 Msym/sec 10 bits per symbol	
		Burst Protection	Latency	Burst Protection	Latency	Burst Protection	Latency
1	J						
12	17	18 $\mu$ s	0.43 ms	14 $\mu$ s	0.32 ms	11 $\mu$ s	0.26 ms

#### C.6.3.4 Downstream Frequency Plan

Center frequencies of channels are limited to increments of 250 kHz, with up to  $\pm 30$  kHz offset, starting from 87 MHz (as shown in Table C–2).

#### C.6.3.5 DRFI Output Electrical

A CMTS MUST be capable of generating 16 RF channels on its physical RF port. A CMTS MUST be capable of operating with  $N'$  channels on the RF port for all values of  $N'$  up to 16. A CMTS MAY support more than 16 RF channels on its physical RF port, but the output electrical requirements of such a device are not specified here.

##### C.6.3.5.1 CMC/CMTS Output Electrical

A CMTS MUST output an RF-modulated signal with the characteristics defined in Table C–2, Table C–3, and Table C–4. The condition for these requirements is that all  $N'$  channels delivered to a single RF output port are commanded to the same average power: 1) except as noted for the Single Channel Active Phase Noise (Table C–2)

and Diagnostic Carrier Suppression and Power Difference (Table C–3), and 2) except as described for Out-of-Band Noise and Spurious Requirements (Table C–4).

#### C.6.3.5.1.1 Output Electrical per RF Port

Table C–2 shows the electrical output requirements per RF port.

**Table C–2 - Output Electrical Requirements per RF Port**

Parameter	Value
Center Frequency ( $f_c$ ) of any RF channel of a CMTS (Note 1)	MUST be 115 MHz to 858 MHz $\pm 30$ kHz at 250 kHz increments SHOULD be 87 MHz to 1002 MHz $\pm 30$ kHz at 250 kHz increments
Level	Adjustable. See Table C–3.
Modulation Type	64-QAM, 256-QAM, 1024-QAM
Symbol Rate (nominal) 64-QAM 256-QAM 1024-QAM	6.952 Msym/sec 6.952 Msym/sec 6.952 Msym/sec
Nominal Channel Spacing	8 MHz
Frequency response 64-QAM 256-QAM 1024-QAM	~ 0.15 Square Root Raised Cosine Shaping ~ 0.15 Square Root Raised Cosine Shaping ~ 0.15 Square Root Raised Cosine Shaping
Inband Spurious ( $f_c \pm 4$ MHz), Distortion, and Noise	Unequalized MER (Note 2) > 35 dB Equalized MER > 43 dB
Inband Spurious and Noise (Note 3)	$\leq -46.7$ dBc
Out of Band Spurious and Noise	See Table C-3.
Phase Noise Single Channel Active, $N - 1$ Channels Suppressed 64-QAM and 256-QAM and 1024-QAM	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 64-QAM and 256-QAM and 1024-QAM	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 4)	> 12 dB (111MHz to 862MHz active output channels)
Connector	F connector per (see ANSI/SCTE 406-1998)
<b>Table Notes:</b> <ol style="list-style-type: none"> <li>30 kHz includes an allowance of 25 kHz for the largest frequency offset normally built into upconverters.</li> <li>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 <math>\pm 50</math> 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.</li> <li>Channel spurious and noise include all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, and other undesired transmitter products. Spurious and noise within <math>\pm 50</math> kHz of the carrier is excluded. When <math>N &gt; 1</math>, noise outside the Nyquist bandwidth is excluded.</li> <li>Frequency ranges are edge-to-edge.</li> </ol>	

## C.6.3.5.1.2 Power per Channel CMTS

The channel RF power **MUST** be adjustable on a per channel basis, with each channel independently meeting the power capabilities defined in Table C–3.

**Table C–3 - DRFI Device Output Power**

Parameter		Value
Range of commanded transmit power per channel		$\geq 8$ dB below required power level specified below maintaining full fidelity over the 8 dB range
Range of commanded power per channel; adjusted on a per channel basis		8dB, independently on each channel
Commanded power per channel step size (strictly monotonic)		$\leq 0.2$ dB
Power difference between any two non-adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)		$\leq 2$ dB
Power per channel absolute accuracy		$\pm 2$ dB
Diagnostic carrier suppression (Note 1)	Mode 1: One channel suppressed	$\geq 50$ dB carrier suppression within the Nyquist bandwidth in any one active channel.
	Mode 2: All channels suppressed except one	50 dB carrier suppression within the Nyquist bandwidth in every active channel except one. (Note 2)
	Mode 3: All channels suppressed	50 dB carrier suppression within the Nyquist bandwidth in every active channel. (Note 3)
RF output port muting		$\geq 63$ dB below the unmuted aggregate power of the RF modulated signal, in every channel from 54 MHz to 1002 MHz. The specified limit applies with all active channels commanded to the same transmit power level. Commanding a reduction in the transmit level of any, or all but one, of the active channels does not change the specified limit for measured muted power. The output return loss of the output port of the muted device <b>MUST</b> comply with the Output Return Loss requirements for inactive channels given in Table C–2.
Required power per channel for N' channels combined onto a single RF port		Required power in dBmV per channel 52dBmV (N' = 4) 49dBmV (N' = 8) 45dBmV (N' = 16)
<b>Table Notes:</b> <ol style="list-style-type: none"> <li>In all three modes the output return loss of the suppressed channel(s) <b>MUST</b> comply with the Output Return Loss requirements for active channels given in Table C-2.</li> <li>The suppression is not required to be glitchless, and the remaining unsuppressed active channel is allowed to operate with increased power such as the total power of the Ne active channels does not The power allowed in the suppressed channel(s) by this carrier suppression requirement is combined with the spurious emissions requirements of the remaining (not suppressed) active channels to produce the ultimate test limit for power in the suppressed channel(s).</li> </ol>		

## C.6.3.5.1.3 Independence of individual channel within the multiple channels on a single RF output port

The CMTS **MUST** provide the ability to set RF power, center frequency, and modulation type on a per-channel basis.

- The CMTS **MUST** be configurable with the interleaver depth defined in Section C.6.3.3 for each channel.<sup>37</sup>

<sup>37</sup> Updated per DRFI-N-13.1122-1 on 11/5/13 by PO.

- The CMTS MUST provide for 3 modes of carrier suppression of RF power for diagnostic and test purposes. See Table C–3 Item 6 for mode description and carrier RF power suppression level.
- The CMTS MUST provide for independent adjustment of RF power in a per channel basis with each RF carrier independently meeting the requirements defined in Table C–3.
- The CMTS MUST provide for independent selection of modulation (ETSI EN 300 429 64-QAM, or 256-QAM, or 1024-QAM if supported), on a per channel basis, with each channel independently meeting the requirements in Table C–3. In order to complete the phase noise testing, the CMTS MUST provide two test modes. One test mode is 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; the CW output frequency MUST be within the frequency range specified in Table C–3. The second mode requires  $N'$  active channels; the selected channel generates one-CW-per-channel at the center frequency, with all other  $N' - 1$  of the combined channels active and containing valid data modulation at operational power levels; the CW output frequency MUST be within the frequency range specified in Table C–3.

#### C.6.3.5.1.4 Out-of-Band Noise and Spurious Requirements for CMTS

Modulators MUST satisfy the out-of-band spurious emissions requirements of Table C–4 outside the encompassed spectrum when the active channels are contiguous.

Modulators MUST satisfy the out-of-band spurious emissions requirements of Table C–4, with 2 dB relaxation, outside the encompassed spectrum when the active channels are not contiguous and the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

Table C–4: Items 1 and 2 list the requirements in channels adjacent to the commanded channels.

Table C–4: Items 3, 4 and 5 list the requirements in all other channels further from the commanded channels.

**Table C–4 - CMTS Output Out-of-Band Noise and Spurious Emissions Requirements**

<b><math>N' \equiv</math> Number of Active Channels Combined per RF Port</b>				
<b>Item</b>	<b>Band</b>	<b><math>N'</math></b>		
		<b>4</b>	<b>8</b>	<b>16</b>
1	Adjacent channel up to 750 kHz from channel block edge	≤57 dBc	≤57 dBc	≤57 dBc
2	Adjacent channel (750 kHz from channel block edge to 8 MHz from channel block edge)	≤53.5 dBc	≤52.5 dBc	≤51.5 dBc
3	Noise in other channels (47 MHz to 1002 MHz) Measured in each 8 MHz channel excluding the following: a) Desired channel(s) b) 1st adjacent channels (see Items 1 and 2 in this table)	≤55.5 dBc	≤54.5 dBc	≤51.5 dBc
4	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 8 MHz channel bandwidth	≤50 dBc	≤50 dBc	≤50 dBc
5	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	≤50 dBc	≤50 dBc	≤50 dBc
<b>Table Notes:</b> 1. Add 2 dB relaxations to the values specified above for noise and spurious emissions requirements in gap channels when the ratio of active channels to gap channels is 4:1 or greater. For example -53.5 dBc becomes -51.5 dBc.				

#### C.6.3.5.2 CMTS Master Clock Jitter for Asynchronous Operation

See Section 6.3.5.3, where all text and requirements apply except those that are EQAM-specific.

#### C.6.3.5.3 CMTS Master Clock Jitter for Synchronous Operation

See Section 6.3.5.3, where all text and requirements apply except those that are EQAM-specific.

#### C.6.3.5.4 CMTS Master Clock Frequency Drift for Synchronous Operation

See Section 6.3.5.4, where all text and requirements apply except those that are EQAM-specific.

### C.6.3.6 CMTS 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 C–5.

#### C.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 C–5.

#### C.6.3.6.2 RF Interface Module Clock Generation

The CMTS contains a 10.24 MHz Master Clock which is the timing source for upstream burst reception as specified in C.6.3.6 above.

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.

#### C.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  $f_m$  represent the nominal Master Clock rate (10.24 MHz). The standard deviation of the timing error of the CMTS RF symbol clock, referenced to the Master Clock, **MUST** be less than 1.5 ns measured over 100 seconds. Let  $f_b$  represent the nominal specified downstream symbol rate.

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:

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

In the above expressions, M and N are unsigned integer values, each representable in 16 bits.

Table C-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. A value of  $f_b'$  or  $f_m'$  **MUST** be no more than  $\pm 1$  ppm from its specified nominal value.

**Table C–5 - Downstream symbol rates & parameters for synchronization with Master Clock**

Downstream Mode	Modulation	fb (MHz)	M/N	fm' (MHz)	fb' (MHz)	Offset from Nominal
8MHzChannel	64-QAM	6.952	869/1280	10.240	6.952	0 ppm
	256-QAM	6.952	869/1280	10.240	6.952	0 ppm
	1024-QAM	6.952	869/1280	10.240	6.952	0 ppm

### C.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:

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

for [EN 300 429] 64-QAM, 256-QAM and 1024-QAM, DENOMINATOR = 6.952.  $f_{DS}$  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. For another example, an  $f_{DS} = 27.808$  MHz clock may be measured if there is no explicit 6.952 MHz clock available.

The CMTS MUST provide test points for direct access to the master clock and the downstream symbol clock. Alternatively, the CMC 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.

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

### C.6.3.8 Downstream Symbol Clock Drift for Synchronous Operation

See Section 6.3.8.

### C.6.3.9 Timestamp Jitter

The 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:

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

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.  $f_{\text{CMTS}}$  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.

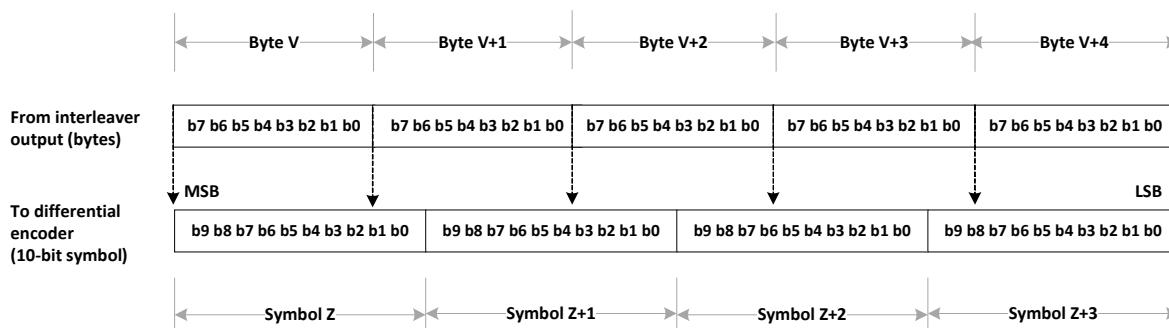
### C.6.3.10 1024-QAM Specifications

#### C.6.3.10.1 Modulation Method

For modulator requirements independent of constellation density, the downstream PMD sublayer for 1024-QAM modulation **MUST** conform to the requirements in Section C.6.3.1 to Section C.6.3.9. Modulator requirements dependent on constellation density are provided in C.6.3.10.2 and C.6.3.10.3.

#### C.6.3.10.2 Rotationally Invariant Pre-Coding

64-QAM and 256-QAM byte to symbol mapping is provided in [EN 300 429] Section 8. For 2<sup>m</sup> QAM, the process involves mapping  $k$  bytes into  $n$  symbols in order to meet the relationship  $8k = n \times m$ . For 1024-QAM,  $m = 10$ ,  $k = 5$  and  $n = 4$ , and the mapping process is shown in Figure C–1.

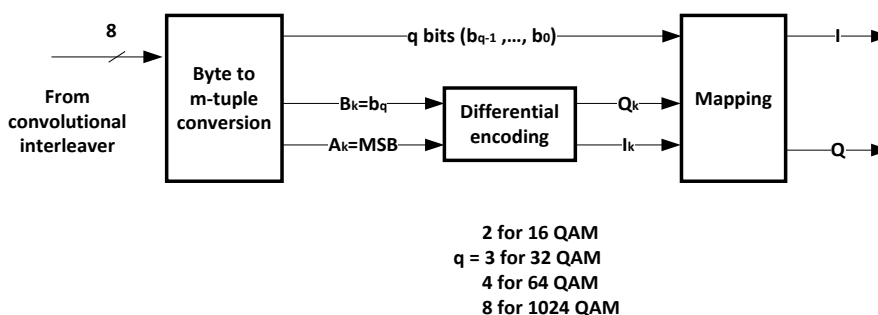


**Note 1:** b0 shall be understood as being the Least Significant Bit (LSB) of each byte or m-tuple.

**Note 2:** In this conversion, each byte results in more than one m-tuple, labelled Z, Z+1, etc. with Z being transmitted before Z+1.

**Figure C–1 - Byte to m-Tuple Conversion for 1024-QAM**

With the addition of 1024-QAM, the process of the byte-to-m-tuple conversion and the differential encoding of the two most significant bits is shown in Figure C–2.



**Figure C–2 - Example implementation of the byte to m-tuple conversion and the differential encoding of the two MSBs**

#### C.6.3.10.3 Constellation Mapping

64-QAM and 256-QAM constellation mapping is provided in [EN 300 429] Section 9.

The constellation diagram for 1024-QAM is shown in Figure C–3.

The 10-tuple of the  $k^{\text{th}}$  symbol generated by the differential encoding, denoted as  $(I_k, Q_k, b7, b6, b5, b4, b3, b2, b1, b0)$ , maps into the constellation point location shown in the figures with the corresponding bits:

$[I_k \ Q_k \ b7 \ b6 \ b5$   
 $b4 \ b3 \ b2 \ b1 \ b0]$ .

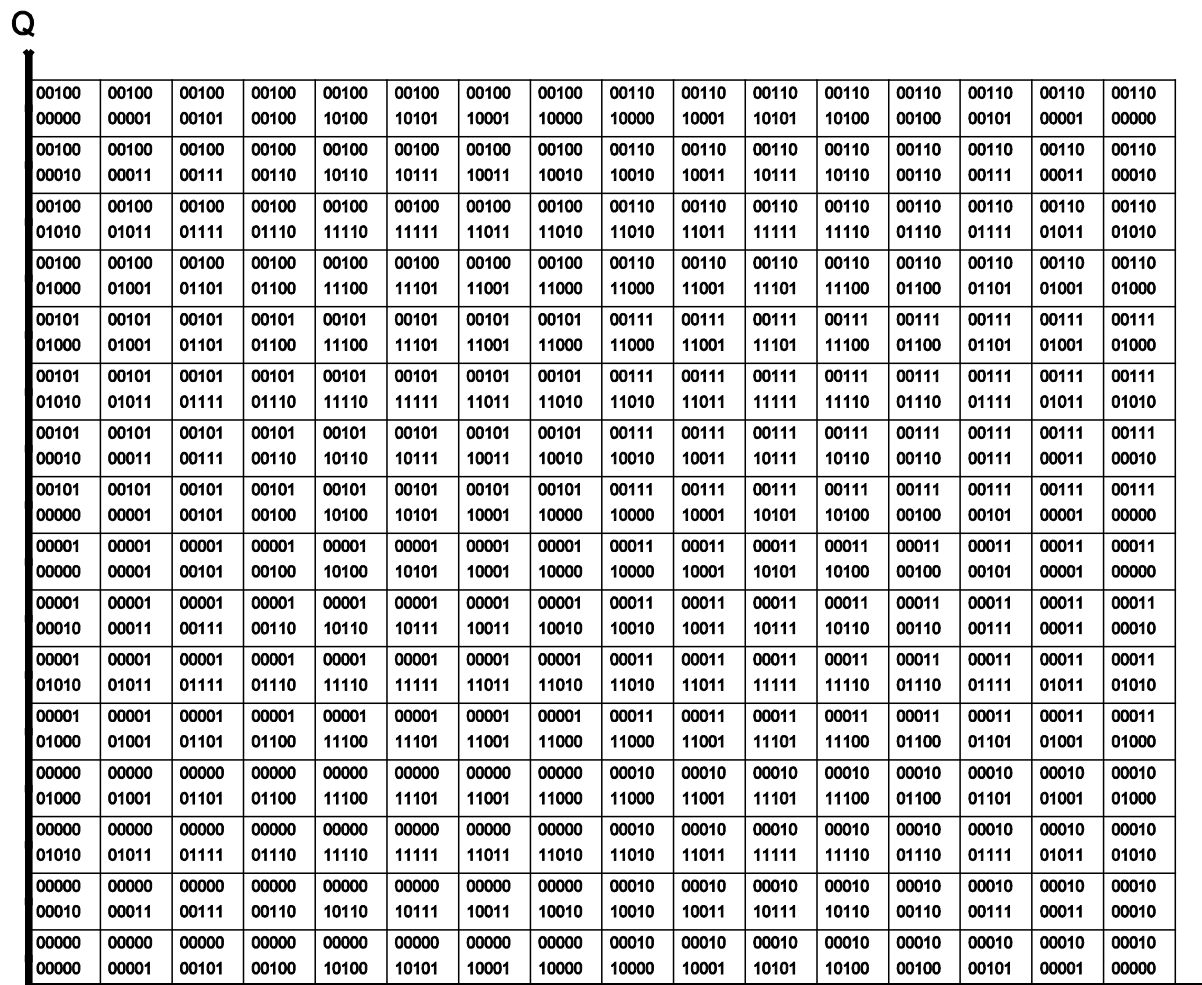
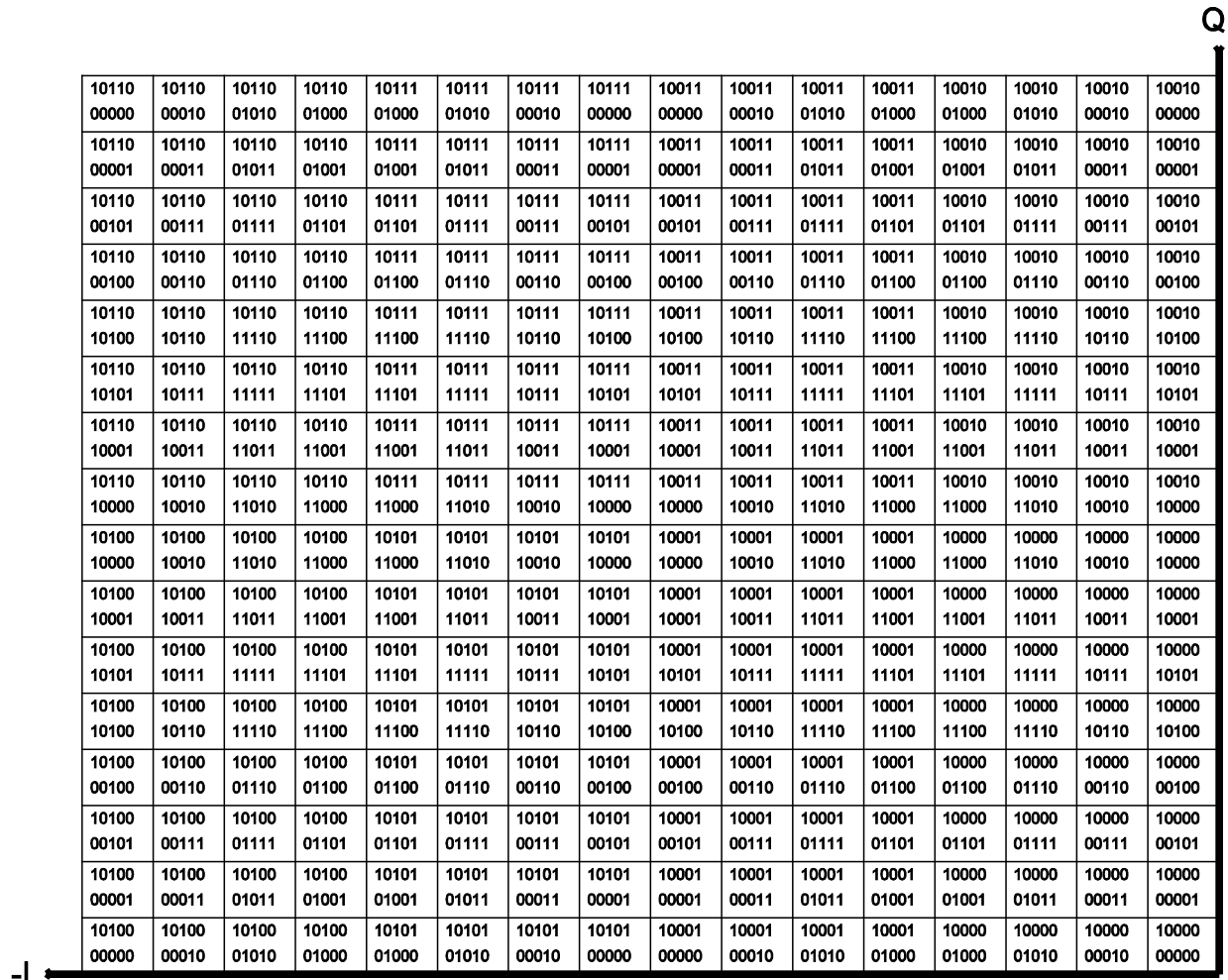
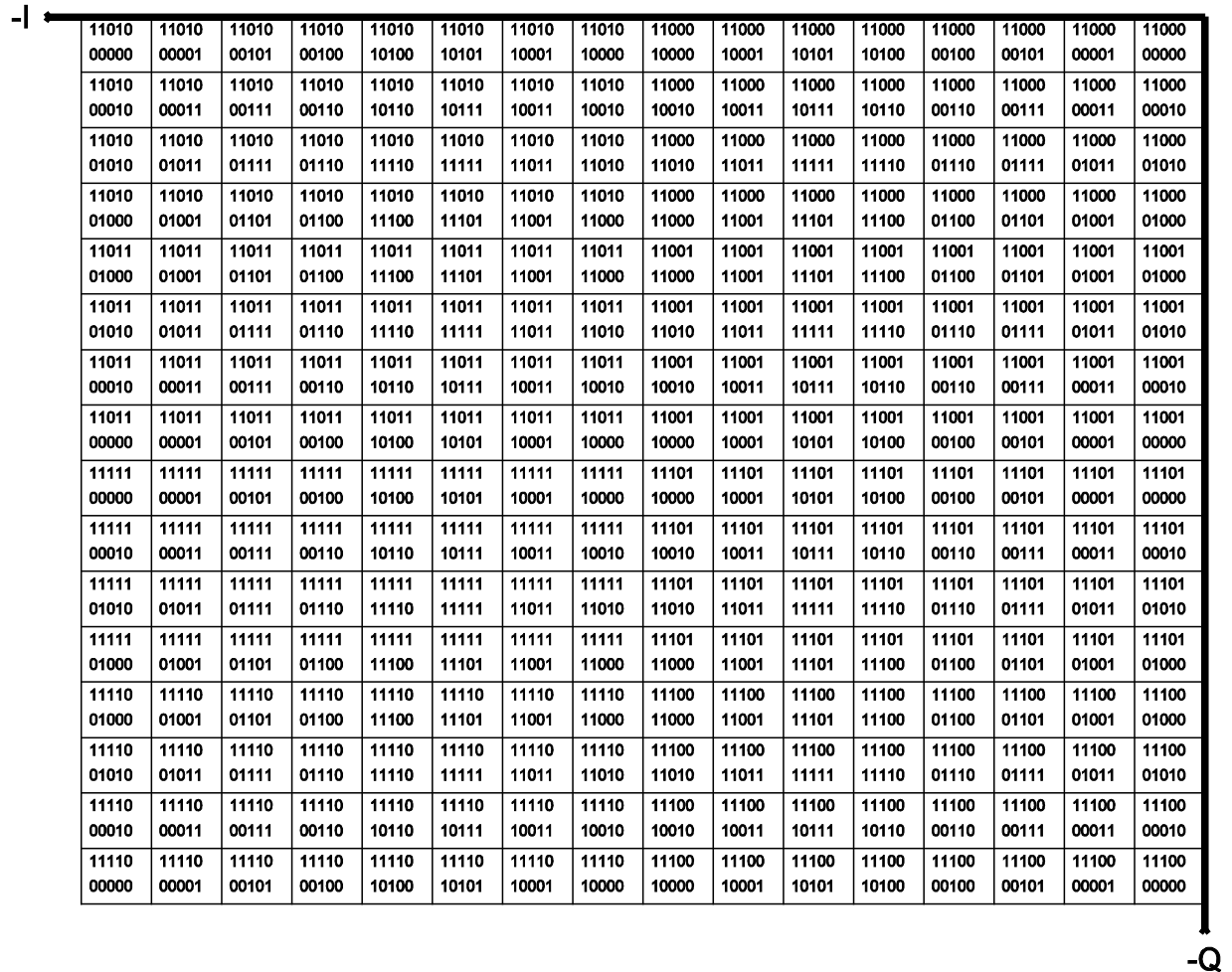
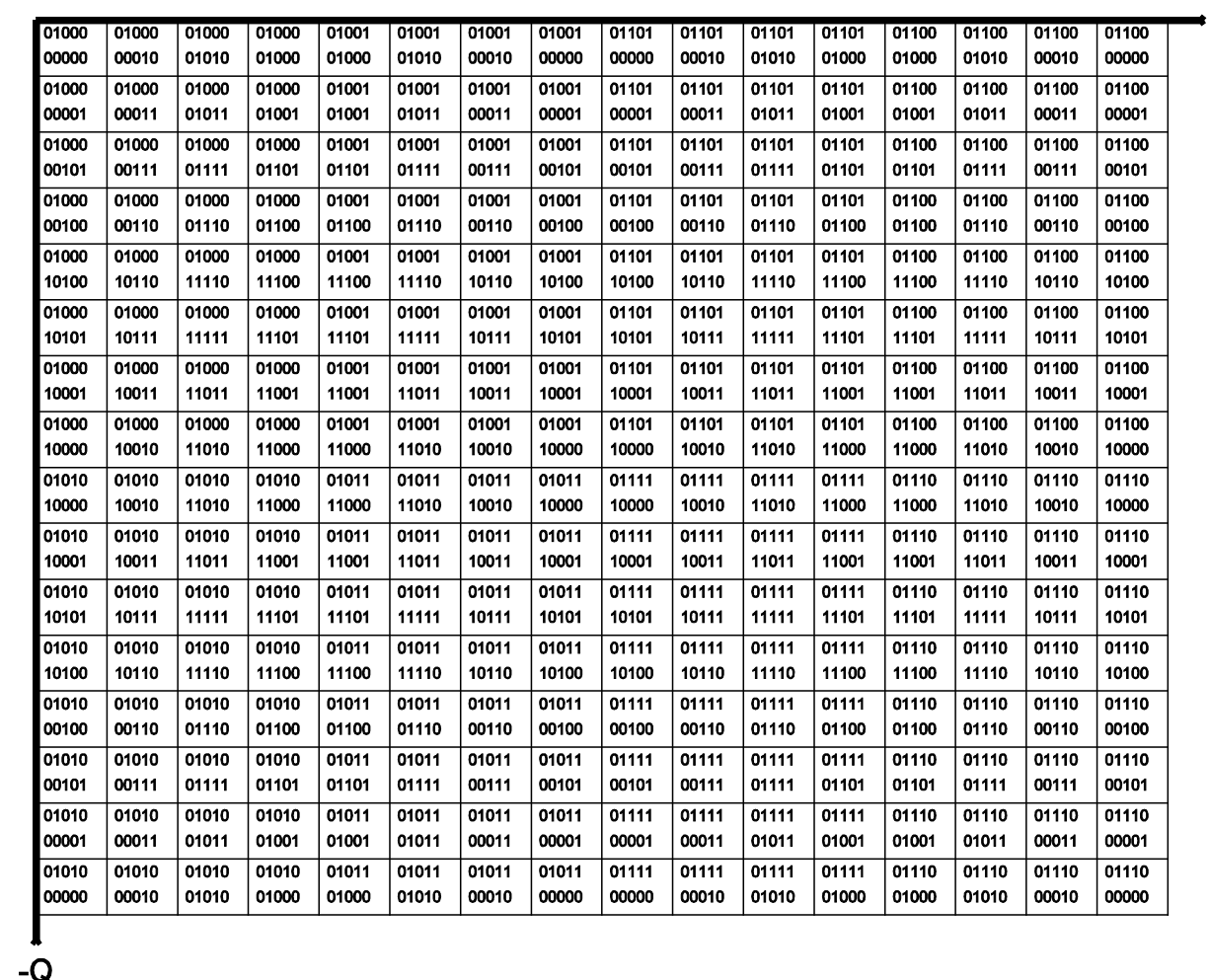


Figure C-3 - 1024-QAM Constellation (1<sup>st</sup> quadrant)



Figure C-4 - 1024-QAM Constellation (2<sup>nd</sup> quadrant)

Figure C-5 - 1024-QAM Constellation (3<sup>rd</sup> quadrant)

Figure C-6 - 1024-QAM Constellation (4<sup>th</sup> quadrant)

#### C.6.3.10.4 QAM Characteristics

The QAM characteristics should meet the relevant requirements of Section 6.3.

## C.7 Downstream Transmission Convergence Sublayer

### C.7.1 Introduction

See Section 7.1.

### C.7.2 MPEG Packet Format

See Section 7.2.

### C.7.3 MPEG Header for DOCSIS Data-Over-Cable

See Section 7.3.

### C.7.4 MPEG Payload for DOCSIS Data-Over-Cable

See Section 7.4.

**C.7.5 Interaction with the MAC Sublayer**

See Section 7.5.

**C.7.6 Interaction with the Physical Layer**

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

## Annex D Additions and Modifications for Remote PHY Device for DOCSIS and EuroDOCSIS<sup>38</sup>

This annex applies to the fourth technology mentioned in Section 1.1. The first technology option is specified in Sections 5, 6, and 7.

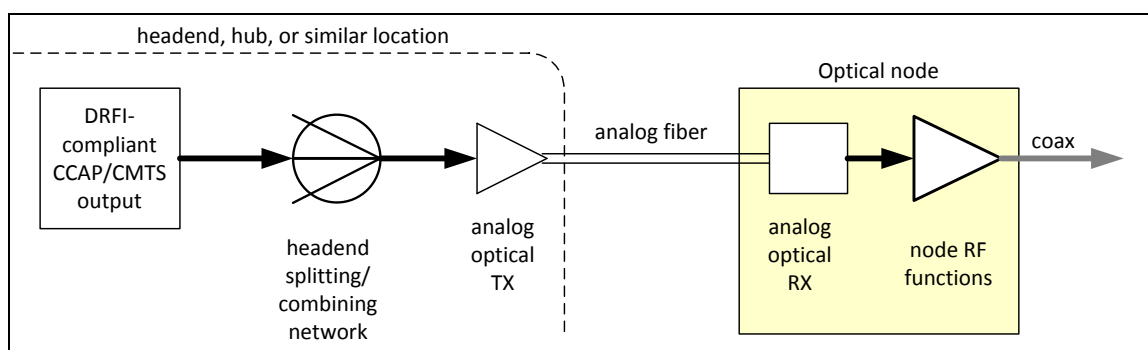
This annex describes the physical layer specifications required for the location and operation of a downstream modulator in an optical node in a cable television plant, in North America (DOCSIS) and in Europe (EuroDOCSIS), serving as additions and modifications to the DRFI main body for DOCSIS and to DRFI Annex A for EuroDOCSIS. The downstream modulator, or PHY Device, is part of an RPD module contained within an optical node, instead of being located at a head-end or hub site,. The architecture and requirements for an RPD and surrounding system are further described by the DCA-MHAv2 family of specifications. This annex in no way affects certification of equipment not covered by the DCA-MHAv2 specifications.

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.

### D.1 Problem Definition, Scope, and Purpose

#### D.1.1 Problem Definition

In today's DOCSIS downstream the signal path is approximately as follows:

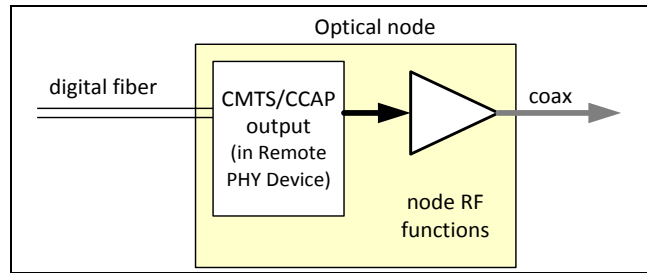


**Figure D-1 - DOCSIS Downstream Signal Path**

In this case, the DRFI requirements are dictated not only by the desired performance on the coax but also by the need to pass through a headend combining network and drive an analog laser at its optimum input power level. The combining operations and the analog optical links introduce various distortions and degradations which ultimately reduce signal quality on the coax.

A major objective of placing the PHY in the node is to improve signal quality on the coax by removing the analog optics. When the CMTS/CCAP output is located in the node, the signal path looks more like Figure D-2 below:

<sup>38</sup> This Annex added per DRFI-N-16.1478-2 on 5/10/16 by JB. Full Annex revised per DRFI-N-16.1614-3 on 12/5/16 by JB.



**Figure D–2 - RPD Downstream Signal Path**

If a Remote PHY Device in a node can achieve DRFI-like signal quality, the cleaner signal path results in improved signal quality on the coax, which helps to enable the use of the higher modulation orders provided by DOCSIS 3.1 technology.

Thus, the goal is to require DRFI-like signal quality in an RPD (Remote PHY Device).

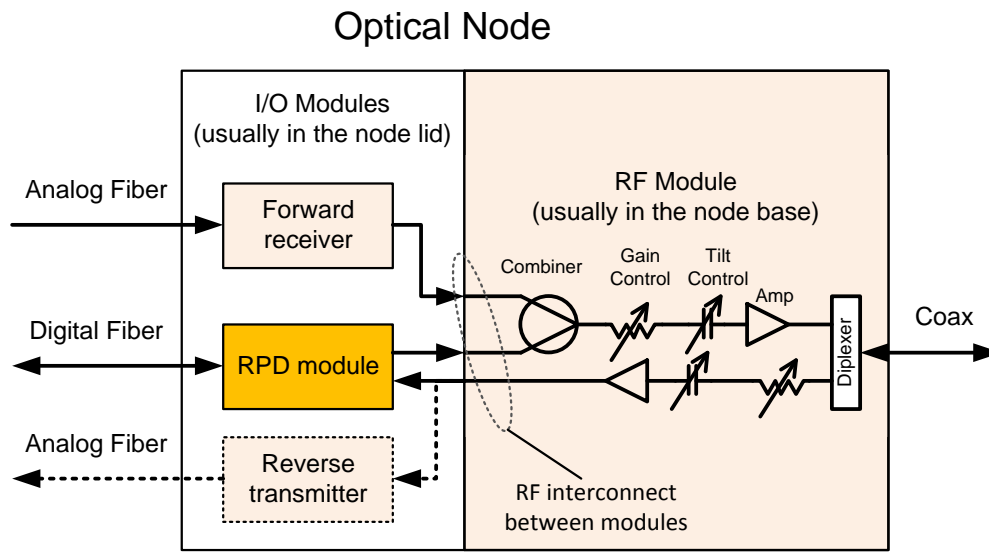
The main reason DRFI cannot be mandated directly when the RPD is located in a node is because DRFI was designed to drive a combining network and analog laser as mentioned above. The power levels and range of overall power adjustability (not per-channel adjustability) needed to achieve optimum laser input power are not necessarily the same as those needed at the input of the RF functions of a fiber node.

This annex documents the variances from the DRFI which are allowed/required when the CMTS/CCA output is located in an RPD within a fiber node (this annex does not apply to an RPD in a headend or hub location).

For this effort, the RPD is modelled as a module within a fiber node. DRFI plus “RPHY/DRFI Annex” functionality is considered to be part of the RPD module, while node functionality not currently in scope for DRFI is considered to be outside of the RPD module. There is no intention to expand the scope of DRFI as a part of this effort.

The objective of the Annex is to maintain DRFI performance levels at the RPD module output while allowing for variances that better match the RPD module output to the node RF input.

The diagram below shows the model partitioning in more detail. This is intended as an example to illustrate the demarcation of the RPD module.

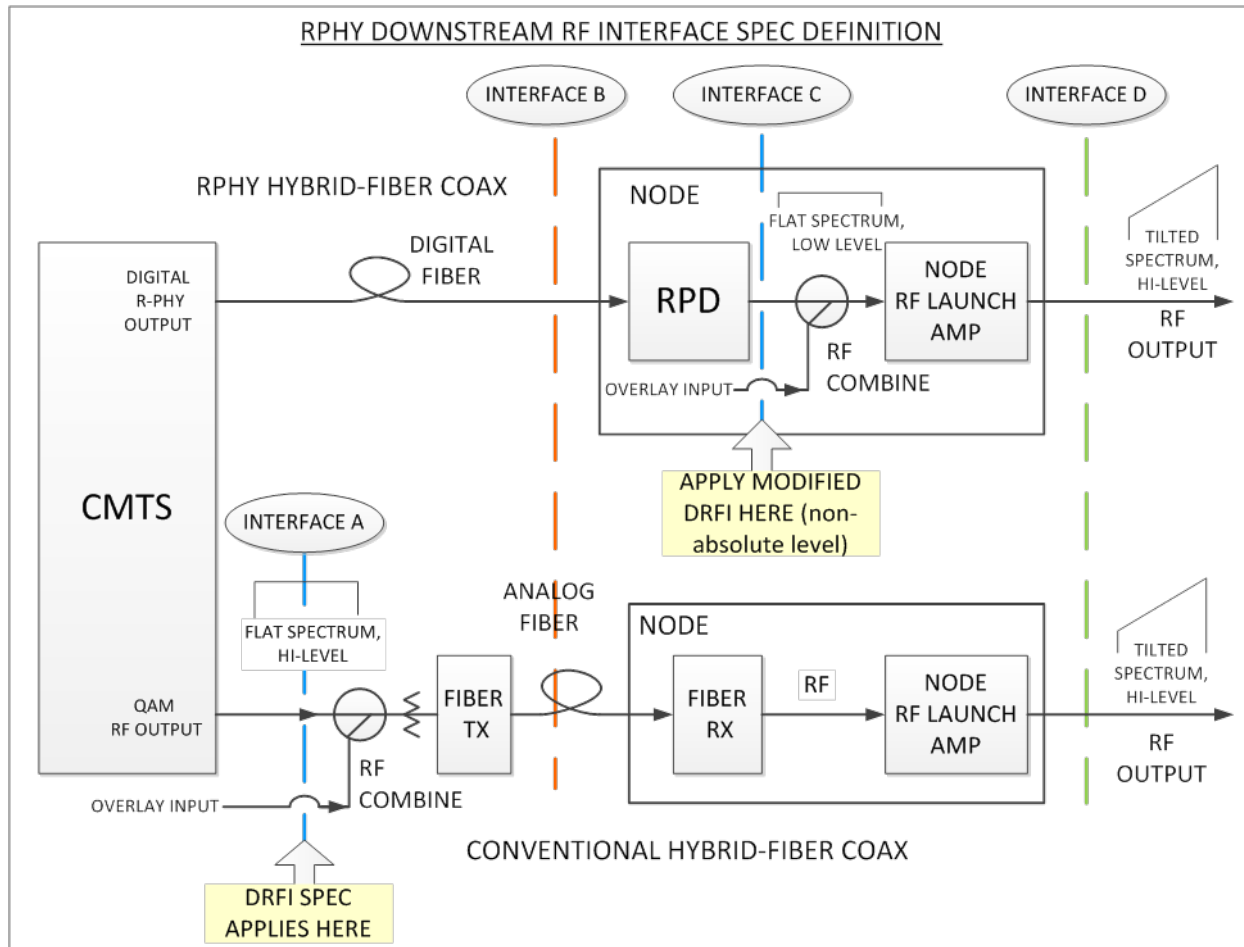


**Figure D–3 - Logical View of RPD and Interfaces**

From the node perspective, the RPD module looks like a forward optical receiver plus reverse optical transmitter, with an RF interface between the module and the rest of the node. This receiver/transmitter could be in addition to receivers/transmitters already present for other purposes (e.g., analog video, telemetry) as shown in the diagram, or it could be the only receiver/transmitter in the node. Various physical form factors and combinations of functionality outside of the RPD module can be supported without impacting the requirements of the RPD module itself.

It is recognized that a physical implementation of an RPD and fiber node may not exactly conform to the model described. In this case, for purposes of compliance testing the vendor would be responsible for providing a test point and system configuration at which the available signal meets RPHY/DRFI Annex requirements.

Another view of the system is given in the diagram below. The lower part of the diagram shows today's downstream signal path from an integrated CMTS, while the upper part shows a Remote PHY Device functioning as a module within a fiber node.



**Figure D-4 - RPHY Downstream RF Interface Definition**

The marked interfaces in Figure D-4 are as follows:

- Interface A is the location at which DRFI specs currently apply to an integrated CMTS or CCAP;
- Interface B is the test point for the DEPI and UEPI interfaces being defined by the Remote PHY working group;
- Interface C is the point in the Remote PHY signal path corresponding to Interface A in the integrated CCAP signal path, and hence the point at which RPHY/DRFI Annex specs would be applied to an RPD module in a fiber node;
- Interface D is the output of the node onto the coax. This interface is currently defined by operator-specific product requirements and will remain so in the Remote PHY standards.

### D.1.2 Scope

This Annex defines modifications to this Downstream Radio Frequency Interface specification which apply when the modulator, or PHY Device, is located in an optical node in a cable television plant.

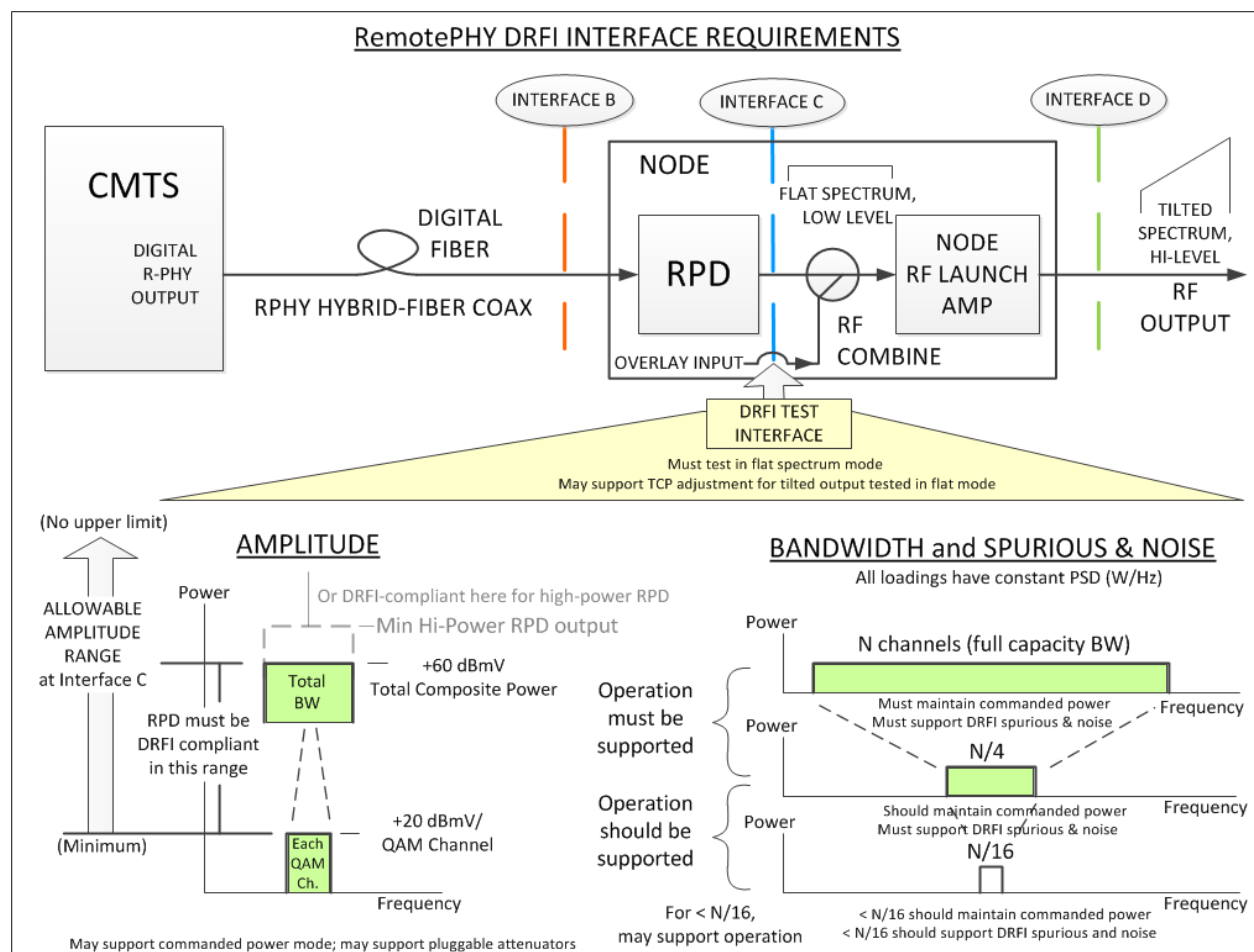
The main body of this document defines specifications for a CMTS or EQAM which is presumed to be located at a headend or hub site. However, the DCA-MHAv2 family of specifications describes an alternate system architecture in which the downstream modulator, or PHY Device, may instead be located within an optical node as part of an RPD (Remote PHY Device). Some, but not all, of the requirements for a PHY Device in a DCA-MHAv2 architecture are the same as those which apply to a CMTS or EQAM.



For sections containing requirements which are different for a PHY Device in a DCA-MHAv2 architecture, this Annex provides new text to replace the corresponding text in the main body of this document. Sections containing requirements which are unchanged for a PHY Device in a DCA-MHAv2 architecture provide only a cross-reference to the corresponding section in the main body of this document. For these sections, the text in the main body of this document should be read using the term “PHY Device” in place of “CMTS or EQAM” wherever the latter term occurs.

A device which complies with this Annex is expected to be capable of generating a large number of channels on a single RF port. It is not expected that such a device would be used in a mode where only a single channel or a small number of channels are being generated; the space and power constraints of an optical node dictate that the modulator density be quite high. Each QAM channel generated by this device could be used either as a downstream link for high-speed data services or for delivery of digital video services. These specifications are crafted to enable a PHY Device to be used to deliver both types of services simultaneously. “Simultaneous” generally means that some channel(s) may be delivering high-speed data while some other channel(s) may be delivering digital video. The most common deployment scenario expected for devices compliant with this Annex would involve a single PHY Device generating a complete lineup of digital services (high-speed data and digital video, plus other specialized services outside the scope of this specification) for a Service Group. A use case wherein a single QAM channel may share bandwidth between high-speed data and digital video in the same MPEG transport stream is not expected in the context of this Annex.

Figure D–5 below includes, but is not limited to, a visual representation of the scope for Annex D.



**Figure D–5 - Remote PHY DRFI Interface Requirements**

### **D.1.3 Purpose of Annex D**

The purpose of this Annex is to define the RF characteristics required in the QAM downstream transmitter(s) of a PHY Device located within an optical node, with sufficient specificity to enable vendors to build devices meeting the needs of cable operators around the world. This Annex can be used by CableLabs to develop a certification/qualification program for such devices.

### **D.1.4 Organization of Document**

See Section 1.3.

### **D.1.5 Requirements**

See Section 1.4.

## **D.2 References**

See Section 2 and Section A.2.1.

## **D.3 Terms and Definitions**

See Section 3.

## **D.4 Acronyms and Abbreviations**

See Section 4.

## **D.5 Functional Assumptions**

See Section A.5.

### **D.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.

### **D.5.2 Equipment Assumptions**

#### **D.5.2.1 *Frequency Plan***

See Section 5.2.1 for DOCSIS systems and see Section A.5.2.1 for EuroDOCSIS systems.

#### **D.5.2.2 *Compatibility with Other Services***

The RPHY MUST coexist with the other services on the cable network, for example:

- a. They MUST be interoperable in the cable spectrum assigned for RPHY 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 RPHY. 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).

#### **D.5.2.3      *Fault Isolation Impact on Other Users***

See Section 5.2.3.

### **D.5.3      Downstream Plant Assumptions**

See Section 5.3.

#### **D.5.3.1      *Transmission Levels***

The nominal average power level of the downstream RF signal(s) within a 6 MHz channel (DOCSIS) or 8 MHz channel (EuroDOCSIS) 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).

#### **D.5.3.2      *Frequency Inversion***

See Section 5.3.2.

#### **D.5.3.3      *Analog and Digital Channel Line-up***

See Section 5.3.3 and Section A.5.3.3.

#### **D.5.3.4      *Analog Protection Goal***

For DOCSIS, one of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 60 dB measured in a 4 MHz wide frequency band for systems deploying up to 119 DRFI-compliant QAM channels.

For purposes of calculation, it is assumed 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 within the range of typical conditions for 256-QAM 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, and that analog channels will be placed at center frequencies below 600 MHz. An adjustment of  $10 \cdot \log_{10} (6 \text{ MHz} / 4 \text{ MHz})$  is used to account for the difference in bandwidth used to define the noise requirements for DRFI-compliant digital QAM channels, versus analog NTSC channels. With the assumptions above, for a 119-QAM channel system, the specification in item 5 of Table D-6 – DOCSIS RPD Output Out-of-Band Noise and Spurious Emissions Requirements  $N' \geq N/4$  equates to an analog CNR protection of 60 dB.

For EuroDOCSIS, 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 256-QAM 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, and that in systems deploying modulators capable of generating nine or more channels on a single RF output port analog channels will be placed at center frequencies below 600 MHz. 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 D–7 - EuroDOCSIS RPD Output Out-of-Band Noise and Spurious Emissions Requirements for  $N' \geq N/4$  equates to an analog CNR protection of 59 dB.

## D.6 Physical Media Dependent Sublayer Specification

### D.6.1 Scope

This annex applies to a fourth technology, RPHY, mentioned in Section 1.1. In cases where the requirements for RPHY and the base DRFI technology options are identical, a reference is provided to the main text in a sub-section of Section 6; the referenced requirements in the main text which apply to a DRFI-compliant device are applied to the RPD.

For the remainder of this section, see Section 6.1.

### D.6.2 EdgeQAM (EQAM) differences from CMTS

See Section 6.2.

### D.6.3 Downstream

#### D.6.3.1 Downstream Protocol

See Section 6.3.1 for DOCSIS systems and see Section A.6.3.1 for EuroDOCSIS systems.

#### D.6.3.2 Spectrum Format

See Section 6.3.2 for DOCSIS systems and see Section A.6.3.2 for EuroDOCSIS systems.

#### D.6.3.3 Scalable Interleaving to Support Video and High-Speed Data Services

For DOCSIS systems, the RPD 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."

An RPD MUST support the set of interleaver depths described in Table D–1 and Table D–2. Further requirements for operational availability of interleaver depths are given in Section 6.3.5.1.2, numbered list item # 1.

**Table D–1 - Low Latency Interleaver Depths**

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

**Table D–2 - Long Duration Burst Noise Protection Interleaver Depths**

Control Word	Interleaver Taps	Interleaver Increment	64-QAM 5.056941 Msym/s 6 bits per symbol		256-QAM 5.360537 Msym/s 8 bits per symbol	
			Burst Protection	Latency	Burst Protection	Latency
Four Bits	I	J				

Control Word	Interleaver Taps	Interleaver Increment	64-QAM 5.056941 Msym/s 6 bits per symbol		256-QAM 5.360537 Msym/s 8 bits per symbol	
0000	128	1	95 $\mu$ s	4.0 ms	66 $\mu$ s	2.8 ms
0010	128	2	190 $\mu$ s	8.0 ms	132 $\mu$ s	5.6 ms
0100	128	3	285 $\mu$ s	12 ms	198 $\mu$ s	8.4 ms
0110	128	4	380 $\mu$ s	16 ms	264 $\mu$ s	11 ms

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.

For EuroDOCSIS systems, see Section A.6.3.3.

#### D.6.3.4 Downstream Frequency Plan

See Section 6.3.4 for DOCSIS systems and see Section A.6.3.4 for EuroDOCSIS systems.

#### D.6.3.5 DRFI Output Electrical

Remote PHY Devices (RPDs) perform the modulation of channels which are ordinarily generated by EQAMs and CMTSs at the headend, which are defined in the main section of this specification, in the category of multiple channel devices capable of generating more than eight channels simultaneously per physical RF port.

Control over an RPD's electrical output is required for many of the characteristics, such as RF channel power, number of RF channels, modulation characteristics of the channels, center frequency of channels, and so forth. Two distinct mechanisms of control can exist for an RPD. One mechanism of control is via commands carried in the downstream link into the RPD. A second mechanism of control is "local-only", separate from the downstream link into the RPD, such as an electrical interface operable at installation, or even pluggable components set at installation. In an RPD some adjustable characteristics can be controlled by one mechanism, and not the other, or by both; therefore, some "adjustable" characteristics can perhaps not be remotely changed. Local-only adjustments made at installation can be subsequently amended, but not remotely, and could incur service interruption.

An RPD is capable of generating some maximum number of channels onto the RF port,  $N$ , and is capable of generating a power per channel of at least 20 dBmV. The Channel Power Reference Setting (dBmV/6 MHz for DOCSIS systems or dBmV/8 MHz for EuroDOCSIS systems) of the RPD could possibly be adjustable remotely, but is also permitted to be adjustable only locally, or even fixed (not adjustable), and serves as the reference power (0 dBc) for independently controlled individual channel power adjustment, and for spurious emissions. The power per channel of the RPD has to be adjustable for each channel independently, via remote adjustment, over a range of 2 dB below the Channel Power Reference Setting. An RPD has to be adjustable to operate with fewer than  $N$ -channels on its RF port. An  $N$ -channel per RF port device has to comply with all requirements operating with all  $N$  channels on the RF port, and has to comply with all requirements for an  $N'$ -channel per RF port device operating with  $N'$  channels on the RF port for all values of  $N'$  less than  $N$  that it supports.

RPD is not expected to have  $N < 56$  channels.

For an  $N$ -channel per RF port device with  $N' < N/4$ , the applicable spurious emissions requirements are defined using a value of  $N'' = \text{minimum}(4N', \text{ceiling}[N/4])$ .

An  $N$ -channel per RF port RPD MUST support operation over  $N \geq N' \geq N/4$ . The RPD MUST maintain the commanded power when operating with any  $N'$  over this range. For DOCSIS systems the RPD MUST meet Table D-3, Table D-5 and Table D-6 when operating with any  $N'$  over this range. For EuroDOCSIS systems the RPD MUST meet Table D-4, Table D-5, and Table D-7 when operating with any  $N'$  over this range.

An  $N$ -channel per RF port RPD SHOULD support operation over  $N/4 > N' \geq N/16$ . The RPD SHOULD maintain the commanded power when operating with any  $N'$  over this range. For DOCSIS systems, the RPD MUST meet

Table D-3, Table D-5 and Table D-8 when operating with any  $N'$  over this range. For EuroDOCSIS systems, the RPD MUST meet Table D-4, Table D-5 and Table D-9 when operating with any  $N'$  over this range.

An  $N$ -channel per RF port RPD MAY support operation over  $N' < N/16$ . The RPD SHOULD maintain the commanded power when operating with any  $N'$  over this range. For DOCSIS systems, the RPD MUST meet Table D-3, Table D-5 and Table D-8 when operating with any  $N'$  over this range. For EuroDOCSIS systems, the RPD MUST meet Table D-4, Table D-5 and Table D-9 when operating with any  $N'$  over this range.

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

#### D.6.3.5.1 RPD Output Electrical

An RPD MUST output an RF modulated signal with the characteristics defined in Table D-3 or Table D-4, Table D-5, Table D-6 or Table D-7, and Table D-8 or Table D-9, depending on application to DOCSIS or EuroDOCSIS systems. The condition for these requirements is all  $N'$  combined channels, commanded to the same average power, except for the Single Channel Active Phase Noise, Diagnostic Carrier Suppression, and power difference (Table D-5) requirements, and except as described for Out-of-Band Noise and Spurious Requirements (Table D-6 or Table D-7 and Table D-8 or Table D-9).

**Table D-3 – DOCSIS RF Output Electrical Requirements**

Parameter	Value
Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM	57 MHz to 999 MHz $\pm 30$ kHz (Note 1) at least 91 MHz to 867 MHz $\pm 30$ kHz
Level	Adjustable. See Table D-5.
Modulation Type	64-QAM, 256-QAM
Symbol Rate (nominal) 64-QAM 256-QAM	5.056941 Msym/sec 5.360537 Msym/sec
Nominal Channel Spacing	6 MHz
Frequency response 64-QAM 256-QAM	~ 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	$\leq -48$ 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 $\pm 50$ kHz of the carrier is excluded. When $N > 1$ , noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	See Table D-6 and Table D-8
Phase Noise Single Channel Active, $N - 1$ Channels Suppressed (see Section D.6.3.5.1.2, item 6) 64-QAM and 256-QAM	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 D.6.3.5.1.2, item 7) 64-QAM and 256-QAM	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 > 12 dB within an active output channel from 870 MHz to 1002 MHz > 12 dB in every inactive channel from 54 MHz to 870 MHz > 10 dB in every inactive channel from 870 MHz to 1002 MHz

Parameter	Value
Connector	F connector per [ANSI/SCTE 02], OR 75 Ohm MCX [ANSI/SCTE 176] table_note_A, OR 75 Ohm SMB [MIL-STD-348] table_note_B  Table note_A. CCAP spec approved and commonly used in CMTS/EQAM. Table note_B. Commonly used in nodes.

**Table Notes:**

- Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM MAY be 57 MHz to 999 MHz  $\pm 30$  kHz. Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM MUST be at least 91 MHz to 867 MHz  $\pm 30$  kHz. 30 kHz includes an allowance of 25 kHz for the largest FCC frequency offset normally built into upconverters.
- 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  $\pm 50$  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.
- Frequency ranges are edge-to-edge.
- If the RPD provides service to a center frequency of 57 MHz (see row 1 in Table D-3), then the EQAM or CMTS MUST provide a return loss of  $> 14$  dB within an active output channel, from 54 MHz to 750 MHz ( $f_{edge}$ ).

**Table D-4 - EuroDOCSIS RF Output Electrical Requirements<sup>39</sup>**

Parameter	Value
Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM	90 MHz to 1002 MHz $\pm 30$ kHz at 250 kHz increments 112 MHz to 858 MHz $\pm 30$ kHz at 250 kHz increments (Note 1)
Level	Adjustable. See Table D-5
Modulation Type	64-QAM, 256-QAM
Symbol Rate (nominal) 64-QAM 256-QAM	6.952 Msym/sec 6.952 Msym/sec
Nominal Channel Spacing	8 MHz
Frequency response 64-QAM 256-QAM	$\sim 0.15$ Square Root Raised Cosine Shaping $\sim 0.15$ Square Root Raised Cosine Shaping
Inband Spurious, Distortion, and Noise	Unequalized MER (Note 2) $> 35$ dB Equalized MER $> 43$ dB
Inband Spurious and Noise ( $f_c \pm 4$ MHz)	$\leq -46.7$ 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 $\pm 50$ kHz of the carrier is excluded. When $N > 1$ , noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	See Table D-7 and Table D-9.
Phase Noise Single Channel Active, $N - 1$ Channels Suppressed (see Section 6.3.5.1.3, item 5) 64-QAM and 256-QAM  All $N$ Channels Active (see Section 6.3.5.1.3, item 6) 64-QAM and 256-QAM	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  1 kHz - 10 kHz: -33dBc double sided noise power 10 kHz - 50 kHz: -51dBc double sided noise power
Output Impedance	75 ohms

<sup>39</sup> Table modified per 07.0576-2 on 1/16/08 by KN. Revised per DRFI-N-11.1012-2 on 11/4/11 by JB.

Parameter	Value
Output Return Loss	> 14 dB within an active output channel in the frequency range from 108 MHz to 862 MHz (Note 3) > 12 dB in every inactive channel from 86 MHz to 862 MHz > 10 dB in every inactive channel from 862 MHz to 1006 MHz
Connector	F connector per [IEC-61169-24]

**Table Notes:**

- Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM SHOULD be 90 MHz to 1002 MHz  $\pm 30$  kHz at 250 kHz increments. Center Frequency ( $f_c$ ) of any RF channel of a CMTS or EQAM MUST be 112 MHz to 858 MHz  $\pm 30$  kHz at 250 kHz increments.
- 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  $\pm 50$  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.
- If the EQAM or CMTS provides service to a center frequency of 90 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 86 MHz to 108 MHz. If the EQAM or CMTS provides service to a center frequency of 1002 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 1006 MHz.

**D.6.3.5.1.1 Power Per Channel RPD**

An RPD MUST generate an RF output with power capabilities as defined in Table D-5. Channel RF power for an RPD is set relative to the Channel Power Reference Setting (dBmV/6 MHz) for DOCSIS systems or dBmV/8 MHz for EuroDOCSIS systems), which is associated with 0 dBc in the following requirements, and is independent of the number of active channels  $N'$  (does not change even if  $N'$  is changed). The Channel Power Reference Setting has to be at least 20 dBmV to guarantee sufficient SNR performance with the expected noise figure of the devices following the RPD. Channel Power Reference Setting MAY be adjustable. An RPD's power per channel has to be adjustable by at least 2 dB, over a range of 0 dBc to -2 dBc, by remote adjustment, as stated in Table D-5.

**Table D-5 - DRFI Device Output Power<sup>40</sup>**

Parameter	Value
Range of Channel Power Reference Setting (Table Note 1)	adjustable locally
Range of commanded power per channel; adjusted on a per channel basis (Table Note 2)	0 dBc to -2 dBc relative to Channel Power Reference Setting, via remote adjustment.  larger variations than 2 dB below Channel Power Reference Setting, via remote adjustment.
Commanded power per channel step size	$\leq 0.2$ dB Strictly monotonic
Power difference between any two adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)	$\leq 0.5$ dB
Power difference between any two non-adjacent channels in a 48 MHz contiguous bandwidth block (with commanded power difference removed if channel power is independently adjustable)	$\leq 1$ dB

<sup>40</sup> Revised per DRFI-N-16.164DRFI-N-16.1641-1 on 12/22/16 by JB.



Parameter	Value
Power difference between any two non-adjacent channels in the 54-1002 MHz downstream spectrum (with commanded power difference removed if channel power is independently adjustable)	$\leq 2$ dB
Power per channel absolute accuracy	$\pm 3$ dB Table footnote: Remote PHY System spec [R-PHY] contains stability requirement which is much tighter than $\pm 3$ dB.
Diagnostic carrier suppression (3 modes) (Table Note 3) Mode 1: One channel suppressed controlled remotely.  Mode 2: All channels suppressed except one controlled remotely.  Mode 3: All channels suppressed controlled remotely.	1) $\geq 50$ dB carrier suppression within the Nyquist bandwidth in any one 6 MHz active channel.  2) 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz or 8 MHz active channel except one. The suppression is not required to be glitchless, and the remaining unsuppressed active channel is allowed to operate with increased power such as the total power of the N' active channels combined.  3) 50 dB carrier suppression within the Nyquist bandwidth in every 6 MHz or 8 MHz active channel. The power allowed in the 6 MHz or 8 MHz suppressed channel(s) by this carrier suppression requirement is combined with the spurious emissions requirements of the remaining (not suppressed) active channels to produce the ultimate test limit for power in the 6 MHz or 8 MHz suppressed channel(s).
RF output port muting controlled remotely. (Table Note 4)	$\geq 73$ dB below the unmuted aggregate power of the RF modulated signal, in every 6 MHz or 8 MHz channel from 54 MHz to 1002 MHz.  The specified limit applies with all active channels commanded to the same transmit power level. Commanding a reduction in the transmit level of any, or all but one, of the active channels does not change the specified limit for measured muted power in 6 MHz or 8 MHz.
Channel Power Reference Setting (Maximum required power, i.e., 0 dBc, per channel for N' channels combined onto a single RF port for an N channel RPD): (Table Note 5)	Required power in dBmV per 6 MHz or 8 MHz channel  $\geq 20$ dBmV

**Table Notes:**

- The Range of Channel Power Reference Setting MAY be adjustable locally.  
An RPD with adjustable Channel Power Reference Setting MUST meet full fidelity (Table D-3, Table D-6 and Table D-8 for DOCSIS systems or Table D-4, Table D-7 and Table D-9 for EuroDOCSIS systems) whenever Channel Power Reference Setting is at or below:  $60 - \text{ceil}[3.6 \cdot \log_2(N)]$  dBmV.  
For RPD with Channel Power Reference Setting range which does not reach as low as  $60 - \text{ceil}[3.6 \cdot \log_2(N)]$  dBmV, the RPD MUST meet full fidelity with Channel Power Reference Setting at the lowest setting for the device.
- Range of commanded power per channel (adjusted on a per channel basis) MUST be 0 dBc to -2 dBc relative to Channel Power Reference Setting, via remote adjustment.  
Range of commanded power per channel (adjusted on a per channel basis) MAY be larger variations than 2 dB below Channel Power Reference Setting, via remote adjustment.
- In an RPD's diagnostic carrier suppression Mode 1, one channel suppressed MUST be controlled remotely. An RPD in Mode 1 with  $\geq 50$  dB carrier suppression within the Nyquist bandwidth in any one 6 MHz or 8 MHz active channel, the suppression MUST be accomplished without service impacting discontinuity or detriment to the unsuppressed channels.  
In an RPD's diagnostic carrier suppression Mode 2, all channels suppressed except one MUST be controlled remotely.  
In an RPD's diagnostic carrier suppression Mode 3, all channels suppressed MUST be controlled remotely.

In all three modes (Mode 1, Mode 2, Mode 3), the RPD's output return loss of the suppressed channel(s) MUST comply with the Output Return Loss requirements for active channels given in Table D-3 – DOCSIS RF Output Electrical Requirements or Table D-4 - EuroDOCSIS RF Output Electrical Requirements.

4. RF output port muting in an RPD MUST be controlled remotely.  
The RPD's output return loss of the output port of the muted device MUST comply with the Output Return Loss requirements for inactive channels given in Table D-3 Table D-3 – DOCSIS RF Output Electrical Requirements or Table D-4 - EuroDOCSIS RF Output Electrical Requirements.
5. An RPD's Channel Power Reference Setting's required power in dBmV per 6 MHz or 8 MHz channel MUST be  $\geq 20$  dBmV.  
An RPD which has fixed Channel Power Reference Setting MUST meet full fidelity (Table D-3, Table D-6 and Table D-8 or Table D-4, Table D-7, and Table D-9) at that setting.  
No upper limit to the Channel Power Reference Setting which an RPD can provide.  
No requirement for remote adjustability for Channel Power Reference Setting  
For RPD which has adjustable Channel Power Reference Setting, see Table Note 1.

#### D.6.3.5.1.2 Independence of Individual Channel within the Multiple Channels on a Single RF Port

A potential use of an RPD 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 an RPD MUST be configurable with at least two different interleaver depths, using any of the interleaver depths shown in Table D-1 and Table D-2 for DOCSIS systems or Table A-1 for EuroDOCSIS systems. Although not as critical as per-channel interleaver depth control, there are strong benefits for the operator if the RPD is provided with the ability to set RF power, center frequency, and modulation type on a per-channel basis.

1. An RPD 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 D-1 and Table D-2 for information on interleaver depths for DOCSIS systems or Table A-1 for information on interleaver depths for EuroDOCSIS systems.
2. An RPD MUST provide for 3 modes of carrier suppression of RF power for diagnostic and test purposes, see Table D-5, Item 6 for mode descriptions and carrier RF power suppression level.
3. An RPD is required to provide for independent adjustment of RF power in a per channel basis with each RF carrier independently meeting the requirements defined in Table D-5.
4. An RPD MUST provide for independent selection of center frequency with the ratio of number of active channels to gap channels in the encompassed spectrum being at least 2:1, and with each channel independently meeting the requirements in Table D-3 or Table D-4 except for spurious emissions (including Table D-6 and Table D-8 or Table D-7 and Table D-9). An RPD MUST meet the requirements of Table D-3 or Table D-4 when the ratio of number of active channels to gap channels in the encompassed spectrum is at least 4:1. (A ratio of number of active channels to gap channels of at least 4:1 provides that at least 80% of the encompassed spectrum contains active channels, and the number of gap channels is at most 20% of the encompassed spectrum.)
5. An RPD 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 D-3 or Table D-4.
6. An RPD 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 D-3 or Table D-4. 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 D-3 or Table D-4.
7. An RPD 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 D-3 or Table D-4. 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 D-3 or Table D-4.

8. An RPD MUST be capable of glitchless reconfiguration over a range of active channels from  $\text{ceiling}[7*N'_{\text{max}}/8]$  to  $N'_{\text{max}}$ . Channels which are undergoing configuration changes are referred to as the "changed channels." The channels which are active and are not being reconfigured are referred to as the "continuous channels". Each DRFI modulator MUST accept a command setting  $N'_{\text{max}}$ . Glitchless reconfiguration consists of any of the following actions while introducing no discontinuity or detriment to the continuous channels, where the modulator is operating in a valid DRFI-required mode both before and after the reconfiguration with an active number of channels staying in the range  $\{\text{ceiling}[7*N'_{\text{max}}/8], N'_{\text{max}}\}$ : adding and/or deleting one or more channels, and/or moving some channels to new RF carrier frequencies, and/or changing the interleaver depth, modulation, power level, or frequency on one or more channels. Any change in the modulation characteristics (power level, modulation density, interleaver parameters, center frequency) of a channel excuses that channel from being required to operate in a glitchless manner. For example, changing the power per channel of a given channel means that channel is not considered a continuous channel for the purposes of the glitchless modulation requirements. Glitchless operation is not required when  $N'_{\text{max}}$  is changed, even if no reconfigurations accompany the change in  $N'_{\text{max}}$ .

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

For DOCSIS systems, 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. One of the deployment configurations for the RPD has a similar goal, where the RPD output is combined with a legacy or traditional HFC downstream carrying many channels, without the benefit of bandpass filtering in the combiner.

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, and analog channels will be placed at center frequencies below 600 MHz, although accommodation of RPD modulated channels below 600 MHz is required in at least one deployment configuration. An adjustment of  $10*\log_{10}(6\text{ MHz} / 4\text{ MHz})$  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 D-6 equates to an analog CNR protection of 60dB.

For EuroDOCSIS, 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 256-QAM 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, and that in systems deploying modulators capable of generating nine or more channels on a single RF output port analog channels will be placed at center frequencies below 600 MHz. An adjustment of  $10*\log_{10}(8\text{ MHz} / 5.08\text{ MHz})$  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 D-7 equates to an analog CNR protection of 59 dB.

Table D-6, Table D-7, Table D-8, and Table D-9 list 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 among the active channels. When commanded to the same power level, "dBc" should be interpreted as the average channel power, averaged over the active channels, to mitigate the variation in channel power across the active channels (see Table D-5), which is allowed with all channels commanded to the same power.

RPD MUST satisfy the out-of-band spurious emissions requirements of Table D-6 or Table D-7, and Table D-8 or Table D-9 in channels below 600 MHz and outside the encompassed spectrum when the active channels are contiguous or when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

RPD MUST satisfy the out-of-band spurious emissions requirements of Table D-6 or Table D-7, and Table D-8 or Table D-9, with 1 dB relaxation, in gap channels below 600 MHz and within the encompassed spectrum when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater.

RPD MUST satisfy the out-of-band spurious emissions requirements of Table D-6 or Table D-7 and Table D-8 or Table D-9, with 3 dB relaxation, when the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater, in channels with center frequency at or above 600 MHz, outside the encompassed spectrum or in gap channels within the encompassed spectrum.

In cases where the  $N'$  combined active channels are not contiguous, and the ratio of active channels to gap channels within the encompassed spectrum is 4:1 or greater, the spurious emissions requirements are determined by summing the spurious emissions power allowed in a given measurement bandwidth by each of the contiguous sub-blocks among the active channels. In the gap channels within the encompassed spectrum and below 600 MHz there is a 1 dB relaxation in the spurious emissions requirements, so that within the encompassed spectrum the spurious emissions requirements (in absolute power) are 26% higher power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. In all channels above 600 MHz there is a 3 dB relaxation in the spurious emissions requirements, so that the spurious emissions requirements (in absolute power) are double the power in the measurement band determined by the summing of the contiguous sub-blocks' spurious emissions requirements. The following three paragraphs provide the details of the spurious emissions requirements for non-contiguous channel operation outside the encompassed spectrum; within the encompassed spectrum the same details apply except there is an additional 1 dB allowance below 600 MHz; and 3 dB allowance is applied above 600 MHz for all channels.

The full set of  $N'$  channels is referred to throughout this specification as the modulated channels or the active channels. However, for purposes of determining the spurious emissions requirements for non-contiguous transmitted channels, each separate contiguous sub-block of channels within the active channels is identified, and the number of channels in each contiguous sub-block is denoted as  $N_i$ , for  $i = 1$  to  $K$ , where  $K$  is the number of contiguous sub-blocks. Therefore,  $N' = \sum_{i=1}^K N_i$ . Note that  $K = 1$  when and only when the entire set of active channels is contiguous. Also note that an isolated transmit channel, i.e., a transmit channel with empty adjacent channels, is described by  $N_i = 1$  and constitutes a sub-block of one contiguous channel. Any number of the "contiguous sub-blocks" may have such an isolated transmit channel; if each active channel was an isolated channel, then  $K = N'$ .

When  $N' \geq N/4$ , Table D-6 or Table D-7 is used for determining the noise and spurious power requirements for each contiguous sub-block, even if the sub-block contains fewer than  $N/4$  active channels. When  $N' < N/4$ , Table D-8 or Table D-9 is used for determining the noise and spurious power requirements for each contiguous sub-block. Thus, the noise and spurious power requirements for all contiguous sub-blocks of transmitted channels are determined entirely from Table D-6 or Table D-7 or entirely from Table D-8 or Table D-9, where the applicable table is determined by  $N'$  being greater than or equal to  $N/4$ , or not. The noise and spurious power requirements for the  $i$ th contiguous sub-block of transmitted channels is determined from Table D-6 or Table D-7 or Table D-8 or Table D-9 using the value  $N_i$  for the "number of active channels combined per RF port", and using "dBc" relative to the strongest carrier among all the active channels, and not just the strongest channel in the  $i$ th contiguous sub-block, in cases where the  $N'$  combined channels are not commanded to the same power. The noise and spurious emissions power in each measurement band, including harmonics, from all  $K$  contiguous sub-blocks, is summed (absolute power, NOT in dB) to determine the composite noise floor for the non-contiguous channel transmission condition.

For the measurement channels adjacent to a contiguous sub-block of channels, the spurious emissions requirements from the non-adjacent sub-blocks are divided on an equal "per Hz" basis for the narrow and wide adjacent measurement bands. For a measurement channel wedged between two contiguous sub-blocks, adjacent to each, the measurement channel is divided into three measurement bands, one wideband in the middle and two narrowbands each abutting one of the adjacent transmit channels. The wideband spurious and noise requirement is split into two parts, on an equal "per Hz" basis, to generate the allowed contribution of power to the middle band and to the farthest narrowband. The ceiling function is applied to the resulting sum of noise and spurious emissions, per Table Note 1 of Table D-6 or Table D-7 and Table D-8 or Table D-9 to produce a requirement of  $\frac{1}{2}$  dB resolution.

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 2<sup>nd</sup> and 3<sup>rd</sup> 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 D-6 – DOCSIS RPD Output Out-of-Band Noise and Spurious Emissions Requirements  $N' \geq N/4$**

for $N' \geq N/4$ Number of Active Channels Combined per RF Port					
Item	Band	$N'$			
		2	3	4	$N' > 4$
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<-58 dBc	$<10^{\frac{65}{10}} \log_{10} [10^{-\frac{58}{10}} + (0.75/6) * (10^{\frac{65}{10}} + (N'-2) * 10^{-\frac{73}{10}})]$
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	<-60 dBc	<-60 dBc	<-60 dBc	$<10^{\frac{65}{10}} \log_{10} [10^{-\frac{62}{10}} + (5.25/6) * (10^{\frac{65}{10}} + (N'-2) * 10^{-\frac{73}{10}})]$
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	<-64 dBc	<-63.5 dBc	<-63 dBc	$<10^{\frac{65}{10}} \log_{10} [10^{-\frac{65}{10}} + (N'-1) * 10^{-\frac{73}{10}}]$
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge).	<-70 dBc	<-67 dBc	<-65 dBc	For $N'=5$ : -64.5 dBc; For $N'=6$ : -64 dBc; For $N'=7$ : -64 dBc; For $N' \geq 8$ : $<-73 + 10^{\frac{65}{10}} \log_{10}(N')$
5	Noise in other channels (47 MHz to 1002 MHz) Measured in each 6 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)	<-70 dBc	<-68 dBc	<-67 dBc	$<-73 + 10^{\frac{65}{10}} \log_{10}(N')$
6	In each of 2N' contiguous 6 MHz channels or in each of 3N' contiguous 6 MHz channels coinciding with 2nd harmonic and with 3rd harmonic components respectively (up to 1002 MHz)	$<-73 + 10^{\frac{65}{10}} \log_{10}(N')$ , or -63 dBc, whichever is greater			
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	$<-50 + 10^{\frac{65}{10}} \log_{10}(N')$			
8	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	$<-55 + 10^{\frac{65}{10}} \log_{10}(N')$ for $N' \leq 8$ $<-60 + 10^{\frac{65}{10}} \log_{10}(N')$ for $N' > 8$			

**Table Notes:**

1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2\*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.
2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency 600 MHz and above. For example -73 dBc becomes -70 dBc.
3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -73 dBc becomes -72 dBc.

**Table D-7 - EuroDOCSIS RPD Output Out-of-Band Noise and Spurious Emissions Requirements for  $N' \geq N/4$** 

for N' >= N/4 Number of Active Channels Combined per RF Port					
Item	Band	N'			
		2	3	4	N' > 4
1	Adjacent channel up to 750 kHz from channel block edge	<-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)	<-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 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).	<-68.5 dBc	<-65.5 dBc	<-64 dBc	For N'=5: <-63 dBc; For N'=6: <-62.5 dBc; For N'=7: <-62.5 dBc; For N'>=8: <-71.5 + 10*log <sub>10</sub> (N')
5	Noise in other channels (80 MHz to 1006 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)	<-68.5 dBc	<-66.5 dBc	<-65.5 dBc	<-71.5 + 10*log <sub>10</sub> (N')
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 1006 MHz)	< -71.5 + 10*log <sub>10</sub> (N'), or -63 dBc, whichever is greater			
7	Lower out of band noise in the band of 5 MHz to 65 MHz Measured in 8 MHz channel bandwidth	< -50 + 10*log <sub>10</sub> (N')			
8	Higher out of band noise in the band of 1006 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	< -55 + 10*log <sub>10</sub> (N') for N' <= 8 < -60 + 10*log <sub>10</sub> (N') for N' > 8			
Table Notes:					
1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.					
2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency at 600 MHz and above. For example -71.5 dBc becomes -68.5 dBc.					
3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -71.5 dBc becomes -70.5 dBc.					

**Table D-8 – DOCSIS RPD Output Out-of-Band Noise and Spurious Emissions Requirements  $N' < N/4$** 

for N' < N/4 Number of Active Channels Combined per RF Port N'' ≡ Effective Number of Active Channels for Spurious Emissions Requirements= minimum[ 4N', ceil(N/4) ]				
Item	Band	N''		
		3	4	N'' > 4
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	<10*log <sub>10</sub> [10 <sup>-58/10</sup> +(0.75/6)*(10 <sup>-65/10</sup> + (N''-2)*10 <sup>-73/10</sup> )]
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	<-60 dBc	<-60 dBc	<10*log <sub>10</sub> [10 <sup>-62/10</sup> +(5.25/6)*(10 <sup>-65/10</sup> + (N''-2)*10 <sup>-73/10</sup> )]
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	<-63.5 dBc	<-63 dBc	<10*log <sub>10</sub> [10 <sup>-65/10</sup> + ( N''-1)*10 <sup>-73/10</sup> ]
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge).	<-67 dBc	<-65 dBc	For N''=5: -64.5 dBc; For N''=6: -64 dBc; For N''=7: -64 dBc; For N''>=8: <-73 + 10*log <sub>10</sub> (N'')
5	Noise in other channels (47 MHz to 1002 MHz) Measured in each 6 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 2 <sup>nd</sup> and 3 <sup>rd</sup> harmonics (see Item 6 in this table)	<-68 dBc	<-67 dBc	<-73 + 10*log <sub>10</sub> (N'')
6	In each of 2N' contiguous 6 MHz channels or in each of 3N' contiguous 6 MHz channels coinciding with 2 <sup>nd</sup> harmonic and with 3 <sup>rd</sup> harmonic components respectively (up to 1002 MHz)	< -73 + 10*log <sub>10</sub> (N''), or -63 dBc, whichever is greater		
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	<-50 + 10*log <sub>10</sub> (N'')		
8	Higher out of band noise in the band of 1002 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	<-55 + 10*log <sub>10</sub> (N'') for N'' =< 8 <-60 + 10*log <sub>10</sub> (N'') for N'' > 8		
Table Notes:				
1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc.				
2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency 600 MHz and above. For example -73 dBc becomes -70 dBc.				
3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -73 dBc becomes -72 dBc.				

**Table D-9 - EuroDOCSIS Output Out-of-Band Noise and Spurious Emissions Requirements for  $N' < N/4$** 

for $N' < N/4$ Number of Active Channels Combined per RF Port $N'' \equiv$ Effective Number of Active Channels for Spurious Emissions Requirements= minimum[ $4N'$ , ceil( $N/4$ ) ]				
Item	Band	$N''$		
		3	4	$N'' > 4$
1	Adjacent channel up to 750 kHz from channel block edge	<-58 dBc	<-58 dBc	$<10 \cdot \log_{10} [10^{-58/10} + (0.75/8) \cdot (10^{-63.5/10} + (N''-2) \cdot 10^{-71.5/10})]$
2	Adjacent channel (750 kHz from channel block edge to 8 MHz from channel block edge)	<-58.5 dBc	<-58.5 dBc	$<10 \cdot \log_{10} [10^{-60.5/10} + (7.25/8) \cdot (10^{-63.5/10} + (N''-2) \cdot 10^{-71.5/10})]$

for N' < N/4 Number of Active Channels Combined per RF Port N'' ≡ Effective Number of Active Channels for Spurious Emissions Requirements= minimum[ 4N', ceil(N/4) ]				
Item	Band	N''		
		3	4	N''>4
3	Next-adjacent channel (8 MHz from channel block edge to 16 MHz from channel block edge)	<-62.5 dBc	<-62 dBc	$<10*\log_{10} [10^{-63.5/10} + (N''-1)*10^{-71.5/10}]$
4	Third-adjacent channel (16 MHz from channel block edge to 24 MHz from channel block edge).	<-65.5 dBc	<-64 dBc	For N'' =5: <-63 dBc; For N'' =6: <-62.5 dBc; For N'' =7: <-62.5 dBc; For N'' >=8: <-71.5 + 10*log <sub>10</sub> (N'')
5	Noise in other channels (80 MHz to 1006 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)	<-66.5 dBc	<-65.5 dBc	<-71.5 + 10*log <sub>10</sub> (N'')
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 1006 MHz)	< -71.5 + 10*log <sub>10</sub> (N''), or -63 dBc, whichever is greater		
7	Lower out of band noise in the band of 5 MHz to 65 MHz Measured in 8 MHz channel bandwidth	< -50 + 10*log <sub>10</sub> (N'')		
8	Higher out of band noise in the band of 1006 MHz to 3000 MHz Measured in 8 MHz channel bandwidth	< -55 + 10*log <sub>10</sub> (N'') for N'' =< 8 < -60 + 10*log <sub>10</sub> (N'') for N'' > 8		
<b>Table Notes:</b> 1. All equations are Ceiling(Power, 0.5) dBc. Use "Ceiling(2*Power) / 2" to get 0.5 steps from ceiling functions that return only integer values. For example Ceiling(-63.9, 0.5) = -63.5 dBc. 2. Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with center frequency at 600 MHz and above. For example -71.5 dBc becomes -68.5 dBc. 3. Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example -71.5 dBc becomes -70.5 dBc				

#### D.6.3.5.2 RPD Master Clock Requirements for Timing Master Operation

An RPD operating as an R-DTI Timing Master distributes phase and frequency information to the other Remote-PHY devices located in the same timing domain as per the [R-DTI] specification. In the Timing Master mode, the RPD provides the DOCSIS Master Clock. An RPD operating as an R-DTI Timing Master MUST include a Master Clock with specifications as follows:

The 10.24 MHz Master Clock MUST have:

A frequency accuracy of  $\leq \pm 5$  ppm, and

An edge jitter of  $\leq 10$  ns peak-to-peak ( $\pm 5$  ns). The drift rate and jitter requirements on the RPD Master Clock implies that the duration of two adjacent segments of 10,240,000 cycles will be within 30 ns, due to 10 ns jitter on each segments' duration, and 10 ns due to frequency drift. Durations of other counter lengths also may be deduced: adjacent 1,024,000 segments,  $\leq 21$  ns; 1,024,000 length segments separated by one 10,240,000-cycle segment,  $\leq 30$  ns; adjacent 102,400,000 segments,  $\leq 120$  ns. The RPD Master Clock MUST meet such test limits in 99% or more measurements.

In addition, the RPD Master Clock MUST meet the requirements in Section D.6.3.5.3.



#### D.6.3.5.3 RPD Master Clock Jitter Requirements

An RPD operating as an R-DTI Timing Slave derives both phase and frequency information from the Timing Master located in the same timing domain as per the [R-DTI] specification. In this mode, the RPD locks both the phase and frequency of its 10.24 MHz Master Clock to the Timing Master. Regardless of the RPD's Timing Operation mode, the 10.24 MHz RPD Master Clock MUST meet the following double sideband phase noise requirements over the specified frequency ranges:

$$< [-50 + 20 \cdot \log(f_{MC}/10.24)] \text{ dBc (i.e., } < 0.05 \text{ ns RMS) } 10 \text{ Hz to } 100 \text{ Hz}$$

$$< [-58 + 20 \cdot \log(f_{MC}/10.24)] \text{ dBc (i.e., } < 0.02 \text{ ns RMS) } 100 \text{ Hz to } 1 \text{ kHz}$$

$$< [-50 + 20 \cdot \log(f_{MC}/10.24)] \text{ dBc (i.e., } < 0.05 \text{ ns RMS) } 1 \text{ kHz to } 10 \text{ kHz}$$

$$< [-50 + 20 \cdot \log(f_{MC}/10.24)] \text{ dBc (i.e., } < 0.05 \text{ ns RMS) } 10 \text{ kHz to } f_{MC}/2$$

$f_{MC}$  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.

In addition, regardless of the RPD's Timing Operation mode, the frequency of the RPD Master Clock MUST NOT drift more than 10-8 per second.

#### D.6.3.5.4 Section Intentionally Empty for Annex D

### D.6.3.6 RPHY Clock Generation

When the 10.24 MHz Master Clock is provided by the R-DTI interface, RPD MUST lock the Downstream Symbol Clock to the 10.24 MHz Master Clock using the M/N divisors provided in Table D-10.

#### D.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 D-10.

#### D.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 D-10.

#### D.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:

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

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 D-10 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  $\pm 1$  ppm from its specified nominal value.

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

Table D-10 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 D–10 - Downstream Symbol Rates and Parameters for Synchronization with the Master Clock**

<b>Downstream mode</b>	<b>Nominal Specified Symbol Rate, <math>f_b</math> (MHz)</b>	<b>M/N</b>	<b>Master Clock Rate, <math>f_m'</math> (MHz)</b>	<b>Downstream Symbol Rate, <math>f_b'</math> (MHz)</b>	<b>Offset from Nominal</b>
Annex B, 64-QAM	5.056941	401/812	10.239990..	5.056945..	0.95 ppm
Annex B, 256-QAM	5.360537	78/149	10.240000..	5.360536..	0.02 ppm
[EN 300 429], 64-QAM	6.952	869/1280	10.240..	6.952	0 ppm
[EN 300 429], 256-QAM	6.952	869/1280	10.240..	6.952	0 ppm

**D.6.3.7 Downstream Symbol Clock Jitter for Synchronous Operation**

See Section 6.3.7 for DOCSIS systems and see Section A.6.3.7 for EuroDOCSIS systems.

**D.6.3.8 Downstream Symbol Clock Drift for Synchronous Operation**

See Section 6.3.8

**D.6.3.9 Timestamp Jitter**

See Section 6.3.9.

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

See Section 7.1

**D.7.2 MPEG Packet Format**

See Section 7.2

**D.7.3 MPEG Header for DOCSIS Data-Over-Cable**

See Section 7.3

**D.7.4 MPEG Payload for DOCSIS Data-Over-Cable**

See Section 7.4

**D.7.5 Interaction with the MAC Sublayer**

See Section 7.5

**D.7.6 Interaction with the Physical Layer**

See Section 7.6 for DOCSIS systems and see Section A.7.6 for EuroDOCSIS systems.

## Appendix I Acknowledgements (Informative)

### I.1 Specification Development Contributors

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.

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.

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### I.2 Specification Update Contributors

In addition CableLabs would like to thank the following individuals for their contributions to the specification update under the specification relaxation effort conducted from June 2009 to June 2010.

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 Videotron

## 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.

## II.7 Engineering Change for CM-SP-DRFI-I08-091002

The following Engineering Change was incorporated into CM-SP-DRFI-I08-091002:

ECN	ECN Date	Summary
DRFI-N-09.0832-2	7/22/09	Clarification of symbol clock locking requirement

## II.8 Engineering Change for CM-SP-DRFI-I09-100115

The following Engineering Change was incorporated into CM-SP-DRFI-I09-100115:

ECN	ECN Date	Summary
DRFI-N-09.0869-2	12/2/09	Return loss editorial change

## II.9 Engineering Changes for CM-SP-DRFI-I10-100611

The following Engineering Changes were incorporated into CM-SP-DRFI-I10-100611:

ECN	ECN Date	Summary
DRFI-N-09.0889-4	4/7/10	Muting and Suppression
DRFI-N-09.0890-4	2/3/10	Out of Band Spurious Emissions Requirements
DRFI-N-09.0891-2	2/24/10	Spec Relaxation for Dense Modulators with Few Active Channels per Port
DRFI-N-09.0892-2	2/24/10	Glitchless Channel Add and Delete
DRFI-N-10.0910-1	4/7/10	Analog CNR Protection with more than 119-QAM channels
DRFI-N-10.0911-1	4/7/10	Max Interleaver Depth for At Least 32 Channels
DRFI-N-10.0913-3	6/2/10	Spectrum Coverage Flexibility and Gaps
DRFI-N-10.0917-1	5/5/10	Output Power Flatness
DRFI-N-10.0927-3	6/9/10	Noncontiguous Channel Spurious Emissions

## II.10 Engineering Change for CM-SP-DRFI-I11-110210

The following Engineering Change was incorporated into CM-SP-DRFI-I11-110210:

ECN	ECN Date	Summary
DRFI-N-10.0969-1	1/5/11	CEA Reference Update

## II.11 Engineering Changes for CM-SP-DRFI-I12-111117

The following Engineering Changes were incorporated into CM-SP-DRFI-I12-111117:

ECN	ECN Date	Summary
DRFI-R-11.1011-1	9/21/11	Incorrect Formula used for Noise Calculation of European Specification
DRFI-R-11.1012-1	9/21/11	Align DS frequency range across European technology options in DOCSIS

## II.12 Engineering Change for CM-SP-DRFI-I13-130808

The following Engineering Change was incorporated into CM-SP-DRFI-I13-130808:

ECN	ECN Date	Summary	Author
DRFI-N-13.1112-4	7/10/2013	Additions and modifications to DRFI for the Chinese DOCSIS Architectures.	Padden

## II.13 Engineering Change for CM-SP-DRFI-I14-131120

The following Engineering Change was incorporated into CM-SP-DRFI-I14-131120:

ECN	ECN Date	Summary	Author
DRFI-N-13.1122-1	9/25/13	Downstream Interleaver Clarification in China DOCSIS Annex	Padden

## II.14 Engineering Change for CM-SP-DRFI-I15-160602

The following Engineering Change was incorporated into CM-SP-DRFI-I15-160602

ECN	ECN Date	Summary	Author
DRFI-N-16.1478-2	5/26/16	New DRFI Annex for RemotePHY Devices	Kolze

## II.15 Engineering Changes for CM-SP-DRFI-I16-170111

The following Engineering Changes were incorporated into CM-SP-DRFI-I16-170111

ECN	ECN Date	Summary	Author
DRFI-N-16.1614-3	11/3/2016	DRFI Annex D Updates and EuroDOCSIS Additions	Kolze
DRFI-N-16.1615-2	10/20/2016	DRFI Editorial Omnibus	Schnoor
DRFI-N-16.1641-1	11/17/2016	Editorial Change to Table D-2 to remove note that was not intended for publication	Huang
DRFI-N-16.1658-2	12/15/2016	DRFI - move technical requirements out of table cells with minor modifications	Webster