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Telecommunications
Engineers***

**ENGINEERING COMMITTEE
Data Standards Subcommittee**

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**Downstream RF Interface for Cable Modem
Termination System**

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1 SCOPE AND PURPOSE

1.1 Scope

NOTE: This document is identical to SCTE 133 2010 except for informative components which may have been updated such as the title page, NOTICE text, headers and footers. No normative changes have been made to this document.

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

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

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

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

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

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

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 multiple system operators (MSOs) around the world.

1.3 Organization of Document

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

1.4 Requirements

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

“MUST”	This word or the adjective “REQUIRED” means that the item is an absolute requirement of this specification.
“MUST 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.

2 REFERENCES

2.1 Normative References

In order to claim compliance with this standard, 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] ANSI/SCTE 79-1 2009, DOCSIS 2.0 Part 1: Radio Frequency Interface.
- [CEA-542-B] CEA-542-B: "CEA Standard: Cable Television Channel Identification Plan," July 2003.
- [ANSI/SCTE 02] ANSI/SCTE 02 2006, "Specification for F Port, Female, Indoor."
- [ITU-T J.83-B] Annex B to ITU-T Recommendation J.83 (12/07), "Digital multi-programme systems for television sound and data services for cable distribution."
- [ISO 13818] ISO/IEC 13818-1, "Information Technology – Generic Coding of Moving Pictures and Associated Audio: Systems / ITU-T Recommendation H.222.0," 2007.

2.2 Informative References

This standard uses the following informative references.

- [NSI] CMTS Network Side Interface, SP-CMTS-NSI-I01-960702, July 2, 1996, Cable Television Laboratories, Inc.
- [M-OSSI] ANSI/SCTE 137-3 2010, Modular Head End Architecture Part 3: M-CMTS Operations Support System Interface.
- [CMCI] Cable Modem CPE Interface, CM-SP-CMCI-C01-081104, November 4, 2008, Cable Television Laboratories, Inc.
- [DEPI] SCTE 137-2 2010, Modular Head End Architecture Part 2: M-CMTS Downstream External PHY Interface.
- [DTI] ANSI/SCTE 137-1 2010, Modular Head End Architecture Part 1: DOCSIS Timing Interface.
- [ERMI] ANSI/SCTE 137-4 2010, Modular Head End Architecture Part 4: Edge Resource Manager Interface.

2.3 Reference Acquisition

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

3 TERMS AND DEFINITIONS

This standard uses the following terms:

Ceiling (ceil)	Returns the first integer that is greater than or equal to a given value.
CM	Cable Modem. A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.
CPE	Customer Premises Equipment. Equipment at the end user's premises; may be provided by the service provider.
Carrier-to-Noise Ratio (C/N or CNR)	Carrier-to-Noise Ratio. The ratio of signal power to noise power in a defined measurement bandwidth. For digital modulation, $CNR = E_s/N_o$, the energy-per symbol to noise-density ratio; the signal power is measured in the occupied bandwidth, and the noise power is normalized to the modulation-rate bandwidth. For analog NTSC video modulation, the noise measurement bandwidth is 4 MHz.
Decibels (dB)	Ratio of two power levels expressed mathematically as $dB = 10\log_{10}(P_{OUT}/P_{IN})$.
Decibel-Millivolt (dBmV)	Unit of RF power expressed in decibels relative to 1 millivolt over 75 ohms, where $dBmV = 20\log_{10}(\text{value in mV}/1 \text{ mV})$.
Encompassed Spectrum	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.
Electronic Industries Alliance (EIA)	A voluntary body of manufacturers which, among other activities, prepares and publishes standards.
EQAM	EdgeQAM modulator. A head end or hub device that receives packets of digital video or data. It re-packetizes the video or data into an MPEG transport stream and digitally modulates the digital transport stream onto a downstream RF carrier using quadrature amplitude modulation (QAM).
FEC	Forward Error Correction. A class of methods for controlling errors in a communication system. FEC sends parity information with the data which can be used by the receiver to check and correct the data.
Gap Channel	A channel within the encompassed spectrum which is not active; this occurs with non-contiguous channel frequency assignments on an RF output port.
Gigahertz (GHz)	A unit of frequency; 1,000,000,000 or 10^9 Hz.
Hertz (Hz)	A unit of frequency; formerly cycles per second.
HRC	Harmonic Related Carriers. A method of spacing channels on a cable television system with all carriers related to a common reference.
HFC	Hybrid Fiber/Coax System. A broadband bidirectional shared-media transmission system using optical fiber trunks between the head-end and the fiber nodes, and coaxial cable distribution from the fiber nodes to the customer locations.
IRC	Incremental Related Carriers. A method of spacing NTSC television channels on a cable television system in which all channels are offset up 12.5 kHz with respect to the [CEA-542-B] standard channel plan except for channels 5 and 6.
kilohertz (kHz)	Unit of frequency; 1,000 or 10^3 Hz; formerly kilocycles per second.
Media Access Control (MAC)	Used to refer to the layer 2 element of the system which would include DOCSIS framing and signaling.
Megahertz (MHz)	A unit of frequency; 1,000,000 or 10^6 Hz; formerly megacycles per second.

MER	Modulation Error Ratio. The ratio of the average symbol power to average error power.
M/N	Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate.
Multiple System Operator (MSO)	A corporate entity that owns and/or operates more than one cable system.
Non-contiguous Channel Assignment	The encompassed spectrum on an RF output port contains gap channels (inactive channels).
NTSC	National Television Systems Committee. Committee which defined the analog, color television, broadcast standards in North America. The standards television 525-line video format for North American television transmission is named after this committee.
NGNA LLC	Company formed by cable operators to define a next-generation network architecture for future cable industry market and business requirements.
Physical Media Dependent Sublayer (PMD)	A sublayer of the Physical layer which is concerned with transmitting bits or groups of bits over particular types of transmission link between open systems and which entails electrical, mechanical and handshaking procedures.
QAM channel (QAM ch)	Analog RF channel that uses quadrature amplitude modulation (QAM) to convey information.
Quadrature Amplitude Modulation (QAM)	A modulation technique in which an analog signal's amplitude and phase vary to convey information, such as digital data.
Radio Frequency (RF)	A portion of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light.
Radio Frequency Interface (RFI)	Term encompassing the downstream and the upstream radio frequency interfaces.
Root Mean Square (RMS)	Square root of the mean value squared a function.
Self-Aggregation	Method used to compute the headend noise floor by summing measured noise from a single device over a specified output frequency range.
Standard Channel Plan (STD)	Method of spacing NTSC television channels on a cable television system defined in [ANSI/SCTE 02].
Upstream Channel Descriptor (UCD)	The MAC Management Message used to communicate the characteristics of the upstream physical layer to the cable modems.
Video on Demand (VoD)	System that enables individuals to select and watch video content over a network through an interactive television system.

4 ACRONYMS AND ABBREVIATIONS

This standard uses the following terms:

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

5 FUNCTIONAL ASSUMPTIONS

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

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

5.1 Broadband Access Network

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

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

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

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

5.2 Equipment Assumptions

5.2.1 Frequency Plan

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

5.2.2 Compatibility with Other Services

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

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

5.2.3 Fault Isolation Impact on Other Users

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

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

5.3 Downstream Plant Assumptions

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

5.3.1 Transmission Levels

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

5.3.2 Frequency Inversion

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

5.3.3 Analog and Digital Channel Line-up

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

5.3.4 Analog Protection Goal

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

The specification assumes that the transmitted power level of the digital channels will be 6 dB below the peak envelope power of the visual signal of analog channels, which is the typical condition for 256-QAM transmission. It is further assumed that the channel lineup will place analog channels at lower frequencies versus digital channels, 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.

6 PHYSICAL MEDIA DEPENDENT SUBLAYER SPECIFICATION

6.1 Scope

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

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

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

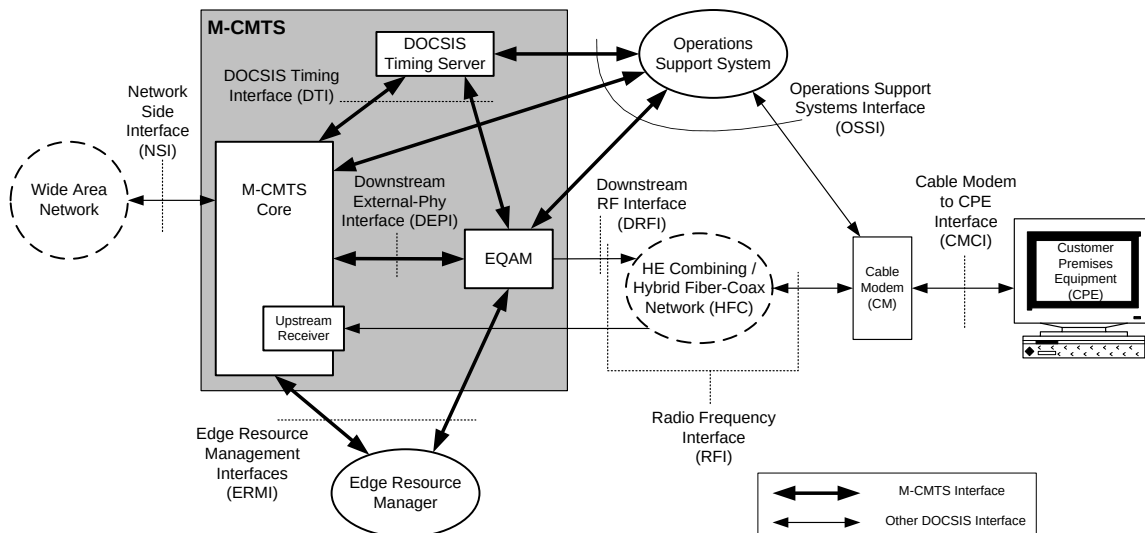


Figure 6–1 - Logical View of Modular CMTS and Interfaces

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

6.2 EdgeQAM (EQAM) differences from CMTS

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

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

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

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

6.3 Downstream

6.3.1 Downstream Protocol

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

6.3.2 Spectrum Format

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

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

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

A CMTS or EQAM MUST support the set of interleaver depths described in Table 6–1 and Table 6–2. 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
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	
			Burst Protection	Latency	Burst Protection	Latency
Four Bits	I	J				
0000	128	1	95 uSec	4.0 mSec	66 uSec	2.8 mSec
0010	128	2	190 uSec	8.0 mSec	132 uSec	5.6 mSec
0100	128	3	285 uSec	12 mSec	198 uSec	8.4 mSec
0110	128	4	380 uSec	16 mSec	264 uSec	11 mSec
1000	128	5	475 uSec	20 mSec	330 uSec	14 mSec
1010	128	6	570 uSec	24 mSec	396 uSec	17 mSec
1100	128	7	664 uSec	28 mSec	462 uSec	20 mSec
1110	128	8	759 uSec	32 mSec	528 uSec	22 mSec

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

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

6.3.4 Downstream Frequency Plan

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

6.3.5 DRFI Output Electrical

EQAMs and 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.
- 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

A CMTS or EQAM **MUST** output an RF modulated signal with the characteristics defined in Table 6–3, Table 6–4, 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

Parameter	Value
Center Frequency (fc) of any RF channel of a CMTS or EQAM	MAY be 57 MHz to 999 MHz ± 30 kHz (Note 1) MUST be at least 91 MHz to 867 MHz ± 30 kHz
Level	Adjustable. See Table 6–4.
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	<= -48dBc; where channel spurious and noise includes all discrete spurious, noise, carrier leakage, clock lines, synthesizer products, and other undesired transmitter products. Spurious and noise within ± 50 kHz of the carrier is excluded. When $N > 1$, noise outside the Nyquist bandwidth is excluded.
Out of Band Spurious and Noise	
	See Table 6–5.