

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

J.210

(11/2006)

SERIES J: CABLE NETWORKS AND TRANSMISSION
OF TELEVISION, SOUND PROGRAMME AND OTHER
MULTIMEDIA SIGNALS

Interactive systems for digital television distribution

Downstream RF interface for cable modem termination systems

ITU-T Recommendation J.210



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ITU-T Recommendation J.210

Downstream RF interface for cable modem termination systems

Summary

This Recommendation 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.

Source

ITU-T Recommendation J.210 was approved on 29 November 2006 by ITU-T Study Group 9 (2005-2008) under the ITU-T Recommendation A.8 procedure.

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Downstream RF interface for cable modem termination systems

1 Scope

1.1 Scope

The DOCSIS Rec. J.112 and [ITU-T J.122] define the requirements for the two fundamental components that comprise a high-speed data-over-cable system: the cable modem (CM) and the cable modem termination system (CMTS). This Recommendation provides physical layer requirements for CMTS transmitters in the DOCSIS architecture. It applies to head-end components built according to the M-CMTS architecture ([ITU-T J.212] and [ITU-T J.211]) as well as integrated CMTS systems.

This Recommendation 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.

1.2 World wide use

There are differences in the cable spectrum planning practices adopted for different networks in the world. Therefore three 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 the Americas using 6 MHz channels. The second technology option is based on the corresponding European multi-program television distribution using 8 MHz channels. The third technology option is based on the corresponding Japanese multi-program television distribution using 6 MHz channels. All options have the same status, notwithstanding that the document structure does not reflect this equal priority. The first of these options is defined in clauses 5, 6, 7, whereas the second and the third are defined by replacing the content of those clauses with the content of Annexes A and B respectively. Correspondingly, [ITU-T J.83-B] and [CEA-542-B] apply only to the first option, [ETSI EN 300 429] applies only to the second, and [ITU-T J.83-C] applies only to the third option. Compliance with this Recommendation requires compliance with at least one of these implementations, not necessarily with more than one. It is not required that equipment built to one option shall interoperate with equipment built to the others.

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-B] for cable networks in the Americas, [ETSI EN 300 429] for cable networks deployed in Europe and [ITU-T J.83-C] for cable networks in Japan. 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 clauses 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 retransmission of the missing data. For video, the sequence of frames in the program is both time sensitive and order sensitive and cannot be retransmitted. 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.

2 References

2.1 Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T H.222.0] ITU-T Recommendation H.222.0 (2006) | ISO/IEC 13818-1:2006, *Information technology – Generic coding of moving pictures and associated audio information: Systems.*
- [ITU-T J.83-B] ITU-T Recommendation J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution. Annex B: Digital multi-programme System B.*
- [ITU-T J.83-C] ITU-T Recommendation J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution. Annex C: Digital multi-programme System C.*
- [ITU-T J.122] ITU-T Recommendation J.122 (2002), *Second-generation transmission systems for interactive cable television services – IP cable modems.*
- [ITU-T J.211] ITU-T Recommendation J.211 (2006), *Timing interface for cable modem termination systems.*
- [ETSI EN 300 429] ETSI EN 300 429 V1.2.1 (1998), *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems.*
- [IEC 60169-24] IEC 60169-24 (1991), *Radio-frequency connectors – Part 24: Radio-frequency coaxial connectors with screw coupling, typically for use in 75 ohm cable distribution systems (Type F).*

2.2 Informative References

- [ITU-T J.212] ITU-T Recommendation J.212 (2006), *Downstream external physical layer interface for modular cable modem termination systems*.
- [NSI] *Cable Modem Termination System Network Side Interface*, SP-CMTS-NSI-I01-960702, 2 July 1996, Cable Television Laboratories, Inc.
- [M-OSSI] *Modular CMTS Operations Support System Interface*, CM-SP-M-OSSI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.
- [CEA-542-B] CEA-542-B: *CEA Standard: Cable Television Channel Identification Plan*, July 2003.
- [CMCI] *Cable Modem to Customer Premises Equipment Interface*, CM-SP-CMCI-I10-050408, 8 April 2005, Cable Television Laboratories, Inc.
- [ERMI] *Edge Resource Manager Interface*, CM-SP-ERMI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.
- [Article 23-(1)] *Regulations for Enforcement of the Cable Television Article 23-(1)*, Ministry of Internal Affairs and Communications (MIC), Japan.

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>
- MIC: Ministry of Internal Affairs and Communications (MIC), http://www.soumu.go.jp/joho_tsusin/eng/index.html

3 Terms and definitions

This Recommendation defines the following terms:

3.1 ceiling (ceil): The ceiling function rounds a number up to the nearest integer or nearest multiple of significance. Use: Ceiling (number, significance).

3.2 cable modem (CM): A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.

3.3 customer premises equipment (CPE): Equipment at the end user's premises; may be provided by the service provider.

3.4 carrier-to-noise ratio (C/N or CNR): The ratio of signal power to noise power in a defined measurement bandwidth. For digital modulation, $CNR = E_s/N_0$, 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.

3.5 decibels (dB): Ratio of two power levels expressed mathematically as $dB = 10 \log_{10}(P_{OUT}/P_{IN})$.

- 3.6 decibel-millivolt (dBmV):** Unit of RF power expressed in decibels relative to 1 millivolt over 75 ohms, where $\text{dBmV} = 20\log_{10}(\text{value in mV}/1 \text{ mV})$.
- 3.7 decibel-microvolt (dBμV):** Unit of RF power expressed in decibels relative to 1 microvolt over 75 ohms, where $\text{dBμV} = 20\log_{10}(\text{value in μV}/1 \text{ μV})$.
- 3.8 Electronic Industries Alliance (EIA):** A voluntary body of manufacturers which, among other activities, prepares and publishes standards.
- 3.9 edgeQAM modulator (EQAM):** 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).
- 3.10 forward error correction (FEC):** 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.
- 3.11 harmonic related carriers (HRC):** A method of spacing channels on a cable television system with all carriers related to a common reference.
- 3.12 hybrid fibre/coax system (HFC):** A broadband bidirectional shared-media transmission system using optical fibre trunks between the head-end and the fibre nodes, and coaxial cable distribution from the fibre nodes to the customer locations.
- 3.13 incremental related carriers (IRC):** 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.
- 3.14 media access control (MAC):** Used to refer to the layer 2 element of the system which would include DOCSIS framing and signalling.
- 3.15 modulation error ratio (MER):** The ratio of the average symbol power to average error power.
- 3.16 M/N:** Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate.
- 3.17 multiple system operator (MSO):** A corporate entity that owns and/or operates more than one cable system.
- 3.18 national television systems committee (NTSC):** Committee which defined the analog, colour television, broadcast standards in North America. The standards television 525-line video format for North American television transmission is named after this committee.
- 3.19 NGNA LLC:** Company formed by cable operators to define a next-generation network architecture for future cable industry market and business requirements.
- 3.20 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.
- 3.21 QAM channel (QAM ch):** Analog RF channel that uses quadrature amplitude modulation (QAM) to convey information.
- 3.22 quadrature amplitude modulation (QAM):** A modulation technique in which an analog signal's amplitude and phase vary to convey information, such as digital data.
- 3.23 radio frequency (RF):** A portion of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light.

- 3.24 radio frequency interface (RFI):** Term encompassing the downstream and the upstream radio frequency interfaces.
- 3.25 root mean square (RMS):** Square root of the mean value squared a function.
- 3.26 self-aggregation:** Method used to compute the headend noise floor by summing measured noise from a single device over a specified output frequency range.
- 3.27 standard channel plan (STD):** Method of spacing NTSC television channels on a cable television system defined in [CEA-542-B].
- 3.28 upstream channel descriptor (UCD):** The MAC management message used to communicate the characteristics of the upstream physical layer to the cable modems.
- 3.29 video-on-demand (VoD):** System that enables individuals to select and watch video content over a network through an interactive television system.

4 Acronyms, abbreviations and conventions

4.1 Acronyms and abbreviations

This Recommendation uses the following abbreviations and acronyms:

CMCI	Cable Modem to 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 Specification
DRFI	Downstream Radio Frequency Interface
DTI	DOCSIS Timing Interface
ERMI	Edge Resource Manager Interface
M-CMTS	Modular Cable Modem Termination System
MPEG	Moving Picture Experts Group
NGNA	Next Generation Network Architecture, see <i>NGNA LLC</i>
OSSI	Operations Support System Interface
PHY	Physical Layer
ppm	parts per million
Q	Quadrature modulation component
S-CDMA	Synchronous Code Division Multiple Access

4.2 Conventions

Throughout this Recommendation, 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 Recommendation.
"MUST NOT" or "SHALL NOT"	This phrase means that the item is an absolute prohibition of this Recommendation.

"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 behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour 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.

5 Functional assumptions

This clause 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 clause.

Whenever there is a reference in this clause 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 6 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 fibre/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 Recommendation 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 fibre of approximately 1.5 ft/ns, 100 miles of fibre in each direction results in a round-trip delay of approximately 1.6 ms. For further information, see Appendix VIII of [ITU-T J.122].

5.2 Equipment assumptions

5.2.1 Frequency plan

In the downstream direction, the cable system is assumed to have a passband 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 passband, NTSC analog television signals in 6-MHz channels

are assumed present on the Standard (STD), HRC or IRC frequency plans, as well as other narrow-band 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:

- 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:
 - 1) No measurable degradation (highest level of compatibility);
 - 2) No degradation below the perceptible level of impairments for all services (standard or medium level of compatibility); or
 - 3) No degradation below the minimal standards accepted by the industry (for example, FCC for analog video services) or other service providers (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 clause 5.2.2 above.

5.3 Downstream plant assumptions

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

5.3.1 Transmission levels

The nominal power level of the downstream RF signal(s) within a 6-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 Recommendation, 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 Recommendation is to provide the minimum intended analog channel CNR protection of 60 dB for systems deploying up to 119 DRFI-compliant QAM channels.

This Recommendation assumes that the transmitted power level of the digital channels will be 6 dB below the peak envelope power of the visual signal of analog channels, which is the typical

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

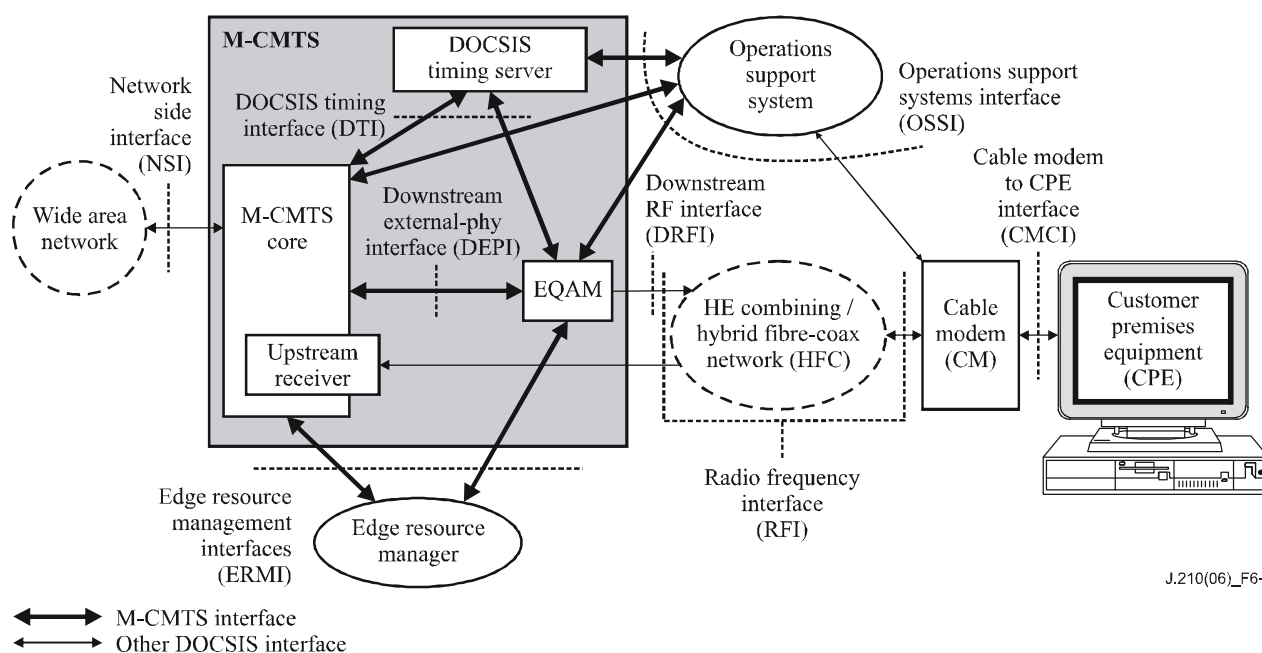
6 Physical media dependent sublayer specification

6.1 Scope

This clause applies to the first technology option referred to in clause 1. For the second option, refer to Annex A.

This Recommendation 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 Recommendation 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 Recommendation to imply any specific implementation. Figure 6-1 shows the M-CMTS structure and interfaces.

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



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Figure 6-1 – Logical view of modular CMTS and interfaces

The CMTS network side interface (NSI), Modular CMTS operations support system interface (M-OSSI), radio frequency interface (RFI), and the cable modem to CPE interface (CMCI) are documented in existing DOCSIS Recommendations (see clause 2.2). The DOCSIS timing interface (DTI), downstream external-PHY interface [ITU-T J.212], downstream radio frequency interface (this Recommendation), 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 [ITU-T J.212], 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 Recommendation.

Several new features are supported in this Recommendation. The DOCSIS 1.x and 2.0 Recommendations do not reflect the ability of vendors to support multiple RF channels per physical RF port. This Recommendation 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 [ITU-T J.211].

6.3 Downstream

6.3.1 Downstream protocol

The downstream PMD sublayer MUST conform to [ITU-T J.83-B], except for clause B.6.2. Interleaver depths are defined in clause 6.3.3. 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 Recommendation.

6.3.2 Spectrum format

The downstream modulator for each QAM channel of the EQAM, or CMTS, MUST provide operation with the RF signal format of $S(t) = I(t) \cdot \cos(\omega t) + Q(t) \cdot \sin(\omega t)$, where t denotes time, ω denotes RF angular frequency, and where $I(t)$ and $Q(t)$ are the respective Root-Nyquist filtered baseband quadrature components of the constellation, as specified in [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 Tables 6-1 and 6-2. Requirements for operational availability of interleaver depths are given in clause 6.3.5.1.2, item 1.