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Digital transmission of television signals – Part 3

Advanced digital downstream transmission systems for television, sound and data services for cable distribution

Recommendation ITU-T J.382

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Advanced digital downstream transmission systems for television, sound and data services for cable distribution

Summary

Recommendation ITU-T J.382 provides specifications that should be considered for advanced digital cable downstream transmission technologies to provide high spectral efficiency schemes saving transmission resources for downstream in hybrid fibre coax (HFC) based networks.

This Recommendation covers the common definition of framing structure, channel coding and modulation for television, sound and data services including high quality broadcast and multicast services distributed through HFC based networks.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T J.382	2014-01-13	9	11.1002/1000/12104
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Keywords

Advanced transmission systems, cable distribution, DVB-C2, HFC, OFDM.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

As the demand for high quality broadcast and multicast services from the consumers' side is increasing, cable operators are diligently researching more efficient ways to transmit those services through hybrid fibre coax (HFC) based networks.

Modulation and coding schemes for global use in cable industry are based on [b-ITU-T J.83], which was developed and deployed in the 1990s. These technologies, specified in [b-ITU-T J.83], can support up to 38 Mbit/s per 6 MHz channel when using a 256 quadrature amplitude modulation (QAM) modulation scheme and thus do not serve demands for advanced digital downstream transmission systems.

In the near future, advanced digital transmission systems including enhanced coding and modulation, can replace digital cable transmission systems defined in [b-ITU-T J.83].

Recommendation ITU-T J.382

Advanced digital downstream transmission systems for television, sound and data services for cable distribution

1 Scope

The scope of this Recommendation is to define a globally common specification for framing structure, channel coding and modulation schemes for television, sound and data services including high quality broadcast and multicast services for downstream transmission distributed through hybrid fibre coax (HFC) based networks to provide high spectral efficiency. This Recommendation will contribute to the development of common products for cable broadcast and telecommunication downstream physical layer (PHY).

The specifications included in this Recommendation are based on the requirements defined in [ITU-T J.381].

2 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 J.381] Recommendation ITU-T J.381 (2012), *Requirements for advanced digital transmission technologies*.

[ETSI EN 302 769] ETSI EN 302 769 V1.3.1 (2015), *Digital Video Broadcasting (DVB) – Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2)*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 HFC-based networks [ITU-T J.381]: HFC-based networks include legacy cable networks such as hybrid fibre coax; recent technology deployments such as radio frequency over glass (RFoG) and cable network technologies that may be deployed in the near future.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

16-QAM 16-ary Quadrature Amplitude Modulation

64-QAM 64-ary Quadrature Amplitude Modulation

256-QAM 256-ary Quadrature Amplitude Modulation

1024-QAM	1024-ary Quadrature Amplitude Modulation
4096-QAM	4096-ary Quadrature Amplitude Modulation
ACM	Adaptive Coding and Modulation
ADC	Analogue-to-Digital Converter
AWGN	Additive White Gaussian Noise
BB	Baseband
BCH	Bose-Chaudhuri-Hocquenghem multiple error correction binary block code
CCM	Constant Coding and Modulation
CNR	Carrier-to-Noise Ratio
CRC	Cyclic Redundancy Check
dB	decibel
DEMUX	De-Multiplexer
DS	Data Slice
DVB	Digital Video Broadcasting
DVB-C	DVB system for cable transmission
DVB-C2	DVB system for second generation cable transmission
FEC	Forward Error Correction
FFT	Fast Fourier Transform
GI	Guard Interval
GSE	Generic Stream Encapsulation
HFC	Hybrid Fibre Coax
IFFT	Inverse Fast Fourier Transform
IP	Internet Protocol
LDPC	Low Density Parity Check (codes)
MATV	Master Antenna Television
Mbit	2^{20} = 1,048,576 bits
Mbit/s	Mbit per second
MHz	10^6 Hertz
MPEG	Moving Pictures Experts Group
OFDM	Orthogonal Frequency Division Multiplex
PAPR	Peak to Average Power Ratio
PHY	Physical Layer
PLP	Physical Layer Pipe
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RFoG	Radio Frequency over Glass
SMATV	Satellite Master Antenna Television

SNR	Signal-to-Noise Ratio
TDM	Time Division Multiplex
TI	Time Interleaver
TS	Transport Stream
VCM	Variable Coding and Modulation

5 Conventions

None.

6 Advanced digital downstream transmission systems for cable distribution

6.1 System concept

A downstream framer, capable of receiving multiple formats of streams, such as MPEG-2 transport streams and Ethernet packet streams, has the function of framing these streams for efficient transmission. A downstream forward error correction (FEC) encoder, followed by a downstream framer, adds an encoding function to protect information data from channel noise through HFC based networks. The downstream modulator covers functions for mapping the high order quadrature amplitude modulation (QAM) constellation in order to improve spectral efficiency, as well as interleaving mechanisms for the protection of information data from burst noise in the time and frequency domain.

The basic block diagram of advanced digital transmission processing is shown in Figure 1.

Input stream does not only represent a single stream, but instead can consist of multiple independent data streams, containing signals and components of advanced digital downstream transmission systems for television, sound and data services for cable distribution.

The channel model of HFC-based networks is primarily a bandwidth-limited linear channel, with a balanced combination of white noise, interference and multi-path distortion. The orthogonal frequency division multiplex (OFDM) technique with channel coding can have advantages to minimize the loss due to typical channel distortions in HFC-based networks.

The advanced digital downstream transmission system shall be fully transparent with respect to the different transmitter inputs and related receiver output signals.

Upstream advanced digital transmission technologies are not covered by this Recommendation.

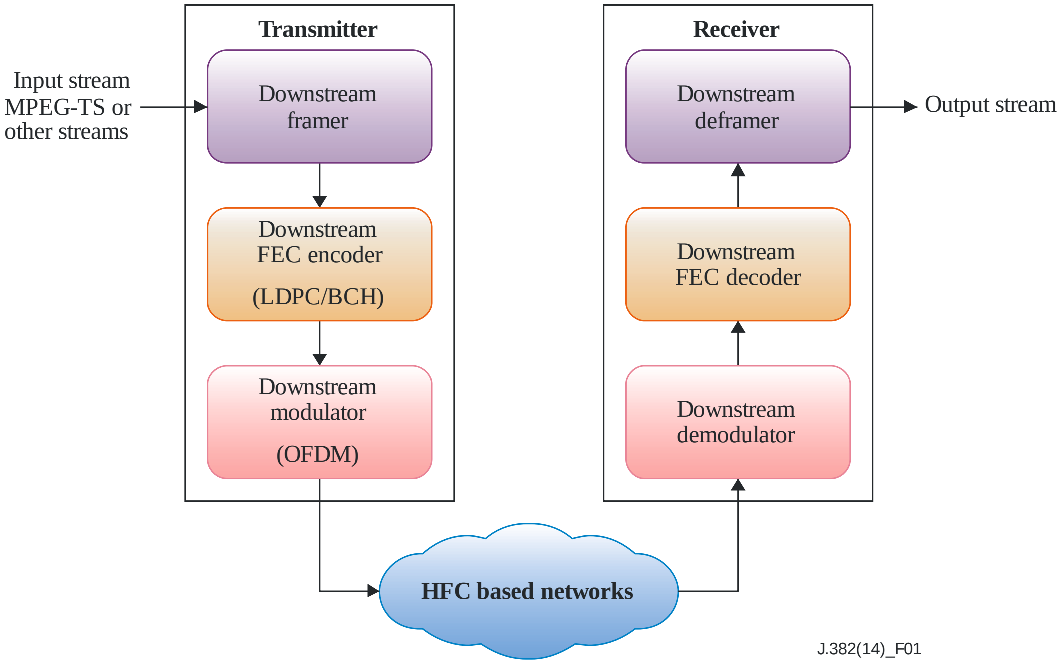

Figure 1 – System concept for advanced digital downstream transmission system

6.2 Specifications of advanced digital downstream transmission systems

Advanced digital downstream transmission systems are required to support the following technical specifications regarding framing, channel coding and modulation. The fundamental framework is described in Table 1 and extended parameters are defined in Table 2.

Table 1 – PHY downstream specifications in summary form indicating fundamental framework

Item	Specification
Input signals	MPEG-TS, any packetized or continuous stream
Framing structure	Two dimensional time division multiplex (TDM) structure: physical layer pipes (PLPs) and data slice (DS)
Signalling method	Embedded in the TDM framing structure
Modulation scheme	OFDM
FFT size	4096 for 8 MHz channel (2.232 kHz carrier spacing) or 4096 for 6 MHz channel (1.674 kHz carrier spacing)
Number of payload carriers	3408 for a 8 MHz channel
Channel coding	
Randomization	FEC frame scrambling (1 + X14 + X15)
FEC	LDPC/BCH
Interleaving	Bit-, time and frequency interleaving
Modulation	
Bandwidth	6 or 8 MHz basis, flexibility for wider bandwidth (up to 450 MHz)
Constellation	16/64/256/1024/4096 – QAM
Pilots	Scattered, continual and edge-pilots
Guard interval (GI)	1/64 or 1/128

Table 2 – Extended parameters

Item		Specification
Channel coding	Bit-Interleaving	Parity- and column twist Interleaving
	Time-Interleaving	At data slice (DS) level: Block interleaving with 0, 4, 8,16 symbols interleaving depth
	Frequency-Interleaving	At DS level
	Service-related robustness	Robustness parameters (modulation scheme and FEC parameters) can be chosen per PLP
	Variable coding and modulation (VCM)	Modulation parameters may be changed each DVB-C2 Frame
	Adaptive coding and modulation (ACM)	Possible
	Two layer multiplexing structure	Physical layer pipe (PLP): individual modulation parameters data slice (DS): Group of PLPs with individual time-/frequency interleaving settings
Modulation	Byte to symbol mapping	Depending on modulation scheme and FEC code rate
	Roll-off factor	Not defined
	Baseband filter characteristics	Not defined
	Pilots	Pilot density depending on guard interval (GI) choice
	Peak-to-average-power-ratio (PAPR)	Reduction of PAPR is possible by reserved tones
	Hooks for extensions	Available

The frequency allocation is not specified in this Recommendation, however the system is recommended to allow flexibility in order to reflect each country's usage of the frequency space.

The text of [ETSI EN 302 769] is applied with the modifications as given below:

Un-numbered clauses "Intellectual Property Rights" and "Foreword"

The introductory clauses labelled "Intellectual Property Rights" and "Foreword" do not apply in the context of this Recommendation.

Appendix I

A digital video broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2)

(This appendix does not form an integral part of this Recommendation.)

I.1 Introduction

This appendix derives from work done by the Digital Video Broadcasting (DVB) Project. The specification of the second generation DVB cable transmission system (i.e., DVB-C2) has been adopted by the Joint Technical Committee (JTC) of the European Broadcasting Union (EBU), the Comité Européen de Normalization Electrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI) as European Norm [ETSI EN 302 769].

DVB-C2 specifies the framing structure, channel coding and modulation for a second generation digital multi-programme television distribution by cable.

Although the MPEG transport stream (TS) is still the favoured protocol used in digital broadcasting, DVB-C2 supports TS, any packetized and continuous input formats as well as the so called generic stream encapsulation (GSE). All input streams are multiplexed into a baseband (BB) frame format. The forward error correction (FEC) scheme is applied to these BB frames. In line with the other DVB-X2 systems, DVB-C2 uses a combination of low density parity check (LDPC) and BCH codes, which is a very powerful FEC method providing about a 6 dB improvement of signal-to-noise ratio (SNR) with reference to DVB-C. Appropriate bit-interleaving schemes optimise the overall robustness of the FEC system. Extended by a header, those frames are called physical layer pipes (PLPs). One or several of such PLPs are multiplexed into a data slice (DS). A two-dimensional interleaving (in time and frequency domain) is applied to each slice enabling the receiver to eliminate impacts of burst impairments and frequency selective interference such as single frequency ingress. One or several data slices (DSs) compose the payload of a C2-frame. The frame building process includes, inter alia, the insertion of continual and scattered pilots. The first symbol of a DVB-C2 frame, the so-called "Preamble", carries the signalling data. A DVB-C2 receiver will find all relevant configuration data about the structure and the technical parameters of the DVB-C2 signal in the signalling data block in the preamble as well as in the headers of the PLPs. In the following step the OFDM symbols are generated by means of an inverse fast Fourier transform (IFFT). A 4K-IFFT algorithm is applied generating a total of 4096 sub-carriers, 3409 of which are actively used for the transmission of data and pilots within a frequency band of 8 MHz. The guard interval (GI), used between the OFDM symbols, has a relative length of either 1/128 or 1/64 in reference to the symbol length (448 μs).

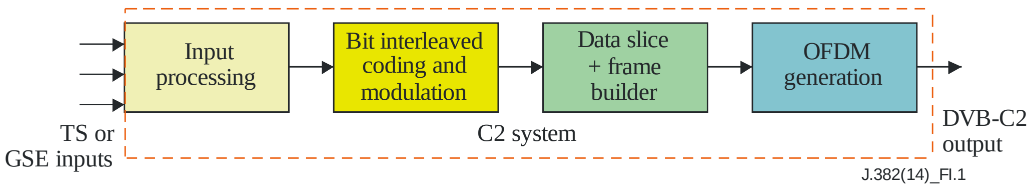

Figure I.1 – High level block diagram of a DVB-C2 modulator

Figure I.1 shows the block diagram of a DVB-C2 modulator. The input processing block is able to process a traditional MPEG transport stream or any packetized or continuous input stream. The second block (identified as: Bit interleaved coding as modulation) adds the FEC information and maps the data into cells. The third block (identified as: Data slice + frame builder) covers the multiplexing of the different input components to the framing structure, whereas in the last block the final OFDM modulation and frequency up-conversion is performed.

I.2 Main building blocks of a DVB-C2 modulator

The following clauses give a short overview of the functionalities available in the four building blocks identified in Figure I.1.

I.2.1 DVB-C2 modulator input processing

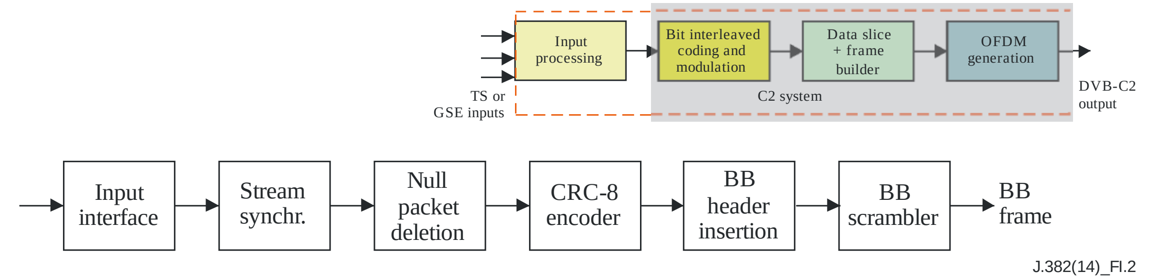

Figure I.2 – Building blocks of the input processing part

Figure I.2 shows the main building blocks of the input processing part for one input signal of a DVB-C2 modulator. Different types of input formats are possible: MPEG transport stream, GSE signals or any continuous or packetized signal format. The signal is synchronized and mapped into a baseband (BB) framing structure. Null packets are deleted in case of MPEG transport streams, a baseband frame header and a cyclic redundancy check (CRC) code are added and the frames are spectrum formed by a scrambler. A baseband (BB) frame is the payload of a physical layer pipe (PLP).

I.2.2 Bit interleaved FEC processing and mapping

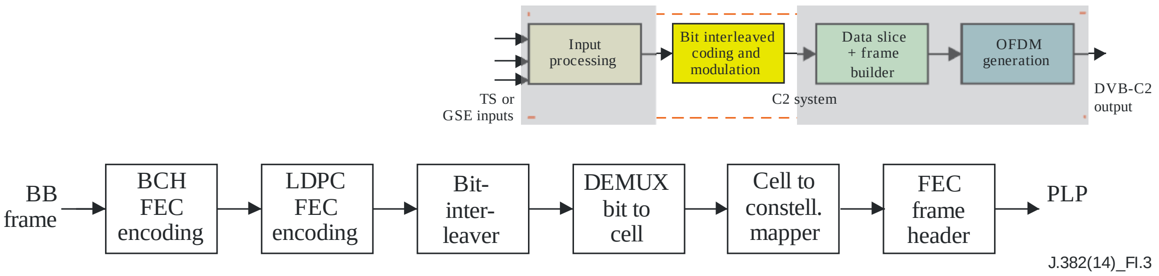

Figure I.3 – Building blocks of the FEC processing part

Figure I.3 shows the main building blocks of the FEC processing part of a DVB-C2 modulator. Baseband frames are extended by both BCH and LDPC FEC data. The bit stream is de-multiplexed and mapped to QAM cells. A FEC-frame header is added. The output signal of this processing part is called a PLP. A DVB-C2 modulator is able to process multiple PLPs.

I.2.3 Data slice and frame builder

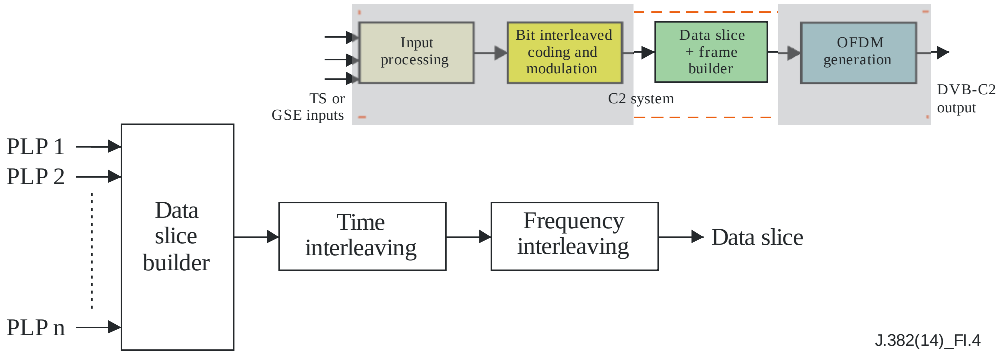

Figure I.4 – Building blocks of the data slice building part

Figure I.4 shows the data slice builder, which multiplexes different PLPs to one data slice. Per data slice (DS), time- and frequency interleaving is applied. A DVB-C2 modulator is able to process multiple data slices, as shown in Figure I.5. The frame builder multiplexes the different data slices (DSs) into a DVB-C2 frame. Furthermore, the frame builder adds pilot signals components and the preamble, which carries the DVB-C2 signalling data, the DVB-C2 frame.

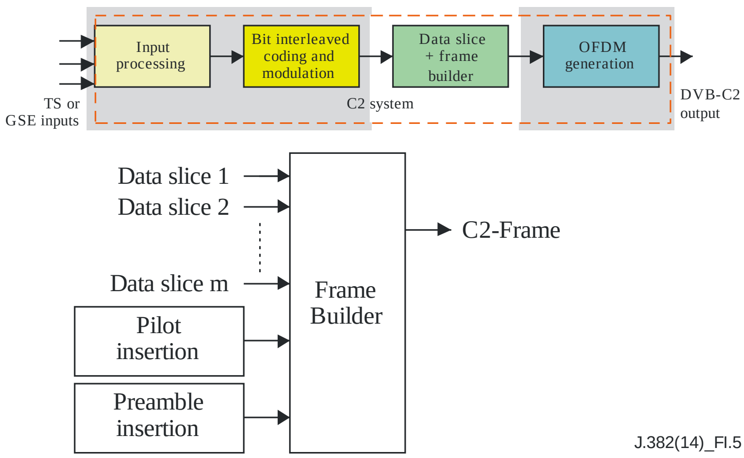

Figure I.5 – Building blocks of the frame building part

I.2.4 OFDM generation

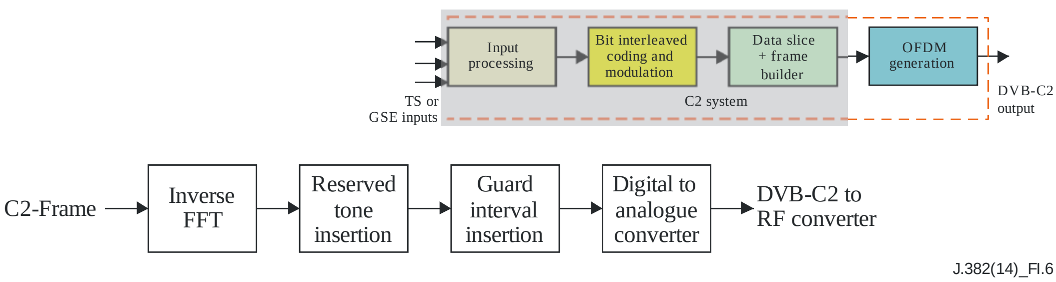

Figure I.6 – Building blocks of the OFDM generation part

Figure I.6 shows the main building blocks of the OFDM generation unit of a DVB-C2 modulator. After the inverse fast Fourier transform (IFFT) processing, the guard interval is added and an analogue-to-digital conversion is carried out. In the unlikely event of high peak-to-average power ratio (PAPR), reserved tone symbols can be inserted.

I.3 Summary of the key DVB-C2 features

I.3.1 Single pipe versus multiple pipes and formats

The first generation transmission systems were designed to carry one MPEG transport stream. One key requirement for DVB-C2 was to implement significantly more flexibility in terms of supporting multiple input signals and in terms of supporting more packetized and even continuous input formats, including IP. The flexibility allows the integration of different input signals in physical layer pipes (PLPs) and to bundle PLPs in data slices (DSs). DVB-C2 provides a very flexible multiplexing scheme, capable of supporting future complex services.

I.3.2 Orthogonal frequency division multiplexing (OFDM) modulation

Although single carrier QAM-modulation was successful for many years in digital cable transmission systems, DVB has taken the decision to choose orthogonal frequency division multiplex (OFDM) because of its excellent spectrum efficiency and superb flexibility.

I.3.3 Low density parity check (LDPC) code for FEC

The chosen forward error correction (FEC) scheme is a combination of low density parity check (LDPC) code as the inner code and Bose Chaudhuri Hoquenghem (BCH) code as the outer code. The combination is both very powerful and efficient in relation to typical and relevant interference scenarios in cable networks. The excellent performance of the chosen FEC-scheme is the major reason for the significantly higher spectrum efficiency of DVB-C2. Those state of the art FEC codes are very complex. The LDPC-FEC processing part will require about half of the chip size of a DVB-C2 demodulator.

I.3.4 From 16-QAM to 4096-QAM constellations

The requirement and performance figures of cable networks cover a wide range from low cost master antenna TV (MATV) solutions to high quality professional HFC networks. DVB-C2 therefore offers a fine granularity of solutions from very robust modes up to the highest spectrum efficiency that is mainly limited by cost constraints of receiver analogue-to-digital converters (ADCs). Different FEC code rates and QAM-schemes allow the granularity of about 2 dB over the whole range from 15 to 35 dB carrier-to-noise ratio (CNR). Furthermore, higher modulation constellations may be introduced in the future in a backwards compatible way. Hooks are already available for future extensions of DVB-C2.

I.3.5 Fixed 8 MHz versus flexible bandwidth

Although DVB-C2 is perfectly in line with the European 8 MHz channel raster (and the 6 MHz United States raster) implemented in cable, one of the outstanding features of DVB-C2 is its flexibility in terms of bandwidth allocation. DVB-C2 allows increased spectrum efficiency and broader transmission signals entailing a higher gain for statistical multiplexing while maintaining the support for simple receivers with a fixed 8 MHz (6 MHz in the United States) receiving window for Europe. For the implementation of future broadband tuner concepts, DVB-C2 opens more options for all kinds of broadband applications.

I.3.6 Constant coding and modulation (CCM) versus variable and adaptive coding and modulation (VCM and ACM)

DVB-C2 offers another dimension of flexibility. Up to now the coding schemes for cable transmission systems were fixed. With DVB-C2 the modulation parameters may vary over time and this variation may even be related to individual services within a transmitted DVB-C2 signal. The first option is to vary the robustness over time. This may be required for different quality of service (QoS) levels. However, it is also possible to adapt the performance of a DVB-C2 transmission to individual requirements of a customer by means of adaptive coding and modulation. The receiving conditions of an individual customer may be used to adjust the robustness parameters of the DVB-C2 transmission.

I.3.7 Physical layer pipes (PLP), data slices and frames

In terms of broadband access and in the terms of video quality the end customer demand is permanently growing. From a cable network operator's point of view, bigger pipes are required to transmit the requested services over networks in an efficient way. The big differences between narrowband and broadband services require flexible multiplexing schemes. DVB-C2 therefore offers a two stage multiplexing scheme. Different input signals, converted to so called physical layer pipes (PLPs) are multiplexed to a data slice (DS) and different DSs are combined to a "DVB-C2 frame" in the second stage. So, in simple broadcasting applications a DVB-C2 transmission signal will consist of one PLP and one data slice (DS), in case a single MPEG transport stream has to be transmitted. However, in more complex services configurations DVB-C2 will allow the offering to be structured in PLPs and DSs and would even be able to provide service related robustness and allow that the payload capacity of those PLPs or DSs vary slightly over time.

I.3.8 Two dimensional interleaving in time and frequency domain

DVB-C2 offers both time and frequency interleaving, which are powerful tools to cope with critical interference scenarios in cable networks.

I.3.9 Signalling issues

The flexibility of DVB-C2 requires an appropriate signalling scheme, allowing a receiver a fast synchronisation and an easy access to all relevant parameters required to configure the demodulation and decoding of the requested service. All relevant signalling information is transported in the preamble, which is repeated for every DVB-C2 frame.

I.3.10 Backward compatibility

DVB-C2 is not backward compatible with the System B of [b-ITU-T J.83] (DVB-C) which had also been developed by the DVB consortium. However, it is assumed that all implementations of the second generation cable transmission system will support DVB-C2 and the first generation solutions in parallel. Such an approach would provide backward compatibility during the transition period to the second generation systems.

I.4 Cable system concept

The DVB-C2 system provides a wide range of solutions for all kind of cable networks deployed worldwide. With 16-QAM modulation, very robust modulation schemes for very simple networks (e.g., satellite master antenna television (SMATV) networks) are available, whereas the 4096-QAM modulation scheme can be considered as headroom for future enhanced HFC infrastructures. The granularity of solutions of DVB-C2 is about 2 dB in the range from 12 dB SNR to 35 dB SNR.

With the growing demand of cable customers for more bandwidth, cable operators are forced to upgrade their cable infrastructures. Fibre-based backbone systems are used for the core network. More and more network segments based on coaxial cable are replaced by fibre and so generally fibre gets closer and closer to the customers and coaxial cable is in many cases only used for the so called last mile. Those necessary network upgrades provide not only more available bandwidth per customer due to optimizations of the network topology, but also higher signal quality, which allows the cable operator to deploy a higher order of modulation for their digital services.

The first generation digital cable transmission systems provided neither solutions with state of the art spectrum efficiency nor the flexibility and higher order modulation needed to optimize the throughput of digital data in those upgraded networks.

DVB-C2 provides a fine granularity of solutions very close to the theoretical "Shannon Limit" for all kinds of cable networks, see Figure I.7.

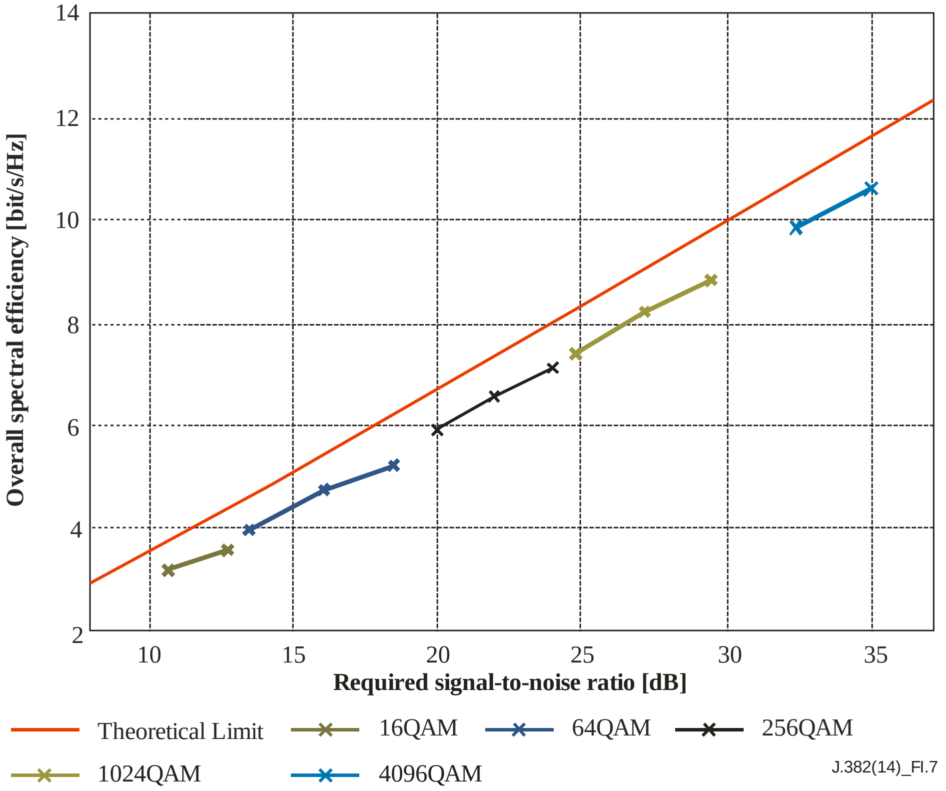

Figure I.7 – DVB-C2 performance in an AWGN channel

In summary, the key technical features of DVB-C2 are the combination of flexibility and efficiency. It is expected that the deployment of DVB-C2 will on one hand increase the downstream capacity of cable networks by 30% and for optimized networks up to 60%. On the other hand, DVB-C2 will allow network operators to utilize the available frequency resources in a more flexible way and allow the introduction of both enhanced services and bigger pipes, for all kinds of service containers, including the support of IP-based transport mechanisms.

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