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

Digital transmission of television signals

Requirements for advanced digital cable transmission technologies

Recommendation ITU-T J.381

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Requirements for advanced digital cable transmission technologies

Summary

Recommendation ITU-T J.381 specifies the requirements that should be considered for advanced digital cable transmission technologies (ACTTs) to provide high spectral efficiency schemes designed to save transmission resource in hybrid fibre/coax (HFC)-based networks.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T J.381	2012-09-22	9

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Introduction

As the demand from consumers for high-quality broadcast and multicast services increases, cable system operators are seeking more efficient ways to transmit those services through hybrid fibre/coax (HFC)-based networks. Representative examples of high-quality broadcast services could be 3DTV and ultra high definition TV (UHDTV), and those of multicast services could be Data over Cable Service Interface Specification (DOCSIS) 3.0, standard definition/high definition (SD/HD), video on demand (VoD), switched digital video (SDV) and Internet protocol TV (IPTV).

There are several solutions that have been developed to solve the issues described above. First, some approaches are focusing on efficient compression of audio/video data so that more contents can be transmitted using the same channel bandwidth. Examples of this approach are Recommendation ITU-T H.264 and high efficiency video coding (HEVC). Second, some technologies aim to extend the usable frequency spectrum in HFC-based networks. In most cases, multiple system operators (MSOs) are using the frequency bandwidth up to 860 MHz, optionally up to 1 GHz, for their broadcasting and data services. These kinds of technologies can provide more transmission resources by increasing the usable frequency spectrum. The third approach focuses on improvement of spectral efficiency per hertz (i.e., bits per second per hertz).

In order to improve spectral efficiency, these kinds of technologies usually support higher order modulation, stronger FEC schemes, more efficient framing structures and so on. Regarding the modulation and coding scheme, the current transmission technology, which is widely used in the cable industry, is Recommendation ITU-T J.83. This Recommendation was developed and deployed in the 1990s and can support up to 39 Mbit/s per 6 MHz channel when using a 256-QAM modulation scheme.

Recommendation ITU-T J.381

Requirements for advanced digital cable transmission technologies

1 Scope

Among the three options described in the introduction, this Recommendation limits the scope to the employed technologies to improve spectral efficiency for downstream and upstream over hybrid fibre/coax (HFC)-based networks. The requirements stated herein are intended to be technology neutral.

Furthermore, this Recommendation defines the requirements for advanced digital cable transmission technologies on the physical layer, which includes modulation, channel coding, transmission schemes and frame structure for providing higher spectral efficiency.

1.1 Reference architecture

Figure 1 shows a reference architecture of advanced digital cable transmission technologies.

The headend part is composed of downstream Tx PHY and upstream Rx PHY. Furthermore, the user terminal is composed of the downstream Rx PHY and the upstream Tx PHY.

As Figure 1 shows, the downstream Tx PHY includes a downstream framer, a downstream FEC encoder and a downstream modulator. The downstream framer that receives multiple stream formats, such as MPEG-2 transport streams and Ethernet packet streams, will have a function of framing these kinds of streams. The downstream framer is followed by the downstream FEC encoder, which will have the function of encoding to protect information data from channel noise through the HFC networks. The downstream modulator will have multiple functions, including mapping for improving spectral efficiency, interleaving for protecting information data from burst noise in both time and frequency domains, and so on.

The downstream Rx PHY includes a downstream demodulator, a downstream FEC decoder, and a downstream deframer. The downstream demodulator will have the functions of timing offset recovery, frequency offset recovery, phase offset recovery, a demapper to retrieve transmission information, de-interleaver (the counterpart of the interleaver), and so on. The downstream demodulator is followed by the downstream FEC decoder, which will have the function of error correction from channel noise in the HFC network. The downstream deframer will rebuild multiple format streams, such as MPEG-2 transport and Ethernet packet streams from the frame structure for transmitting signals through HFC-based networks.

The upstream Tx PHY, which includes an upstream framer, an upstream FEC encoder and an upstream modulator, will have a function similar to the downstream Tx PHY. Furthermore, the upstream Rx PHY, which has an upstream demodulator, an upstream FEC decoder and an upstream deframer, will have a similar function of the downstream Rx PHY.

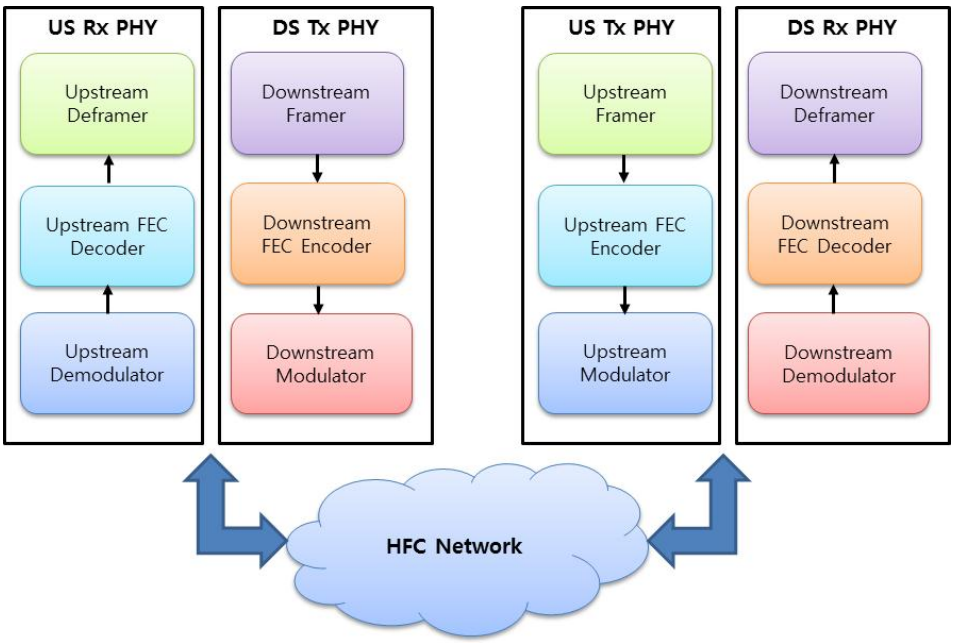

Figure 1 – A reference architecture of advanced digital cable transmission technologies

1.2 Considerations

Advanced digital cable transmission technologies should take into account the following considerations.

- Cable operators are seeking advanced technologies for highly efficient frequency spectrum utilization over their HFC-based networks.
- An improvement figure of 30% or greater is deemed to be the minimal impetus for cable operators to deploy advanced technologies into their networks.
- Since many countries consider HFC-based networks as one of the primary means for delivering broadcasting contents to their citizens, retransmission of terrestrial and satellite broadcasting over HFC will be necessary.
- There are various packet formats used in delivering broadcasting and multicasting services in other networks, so the advanced digital cable transmission technologies need to accommodate these input formats.
- A channel-bonding scheme is very useful for delivering high-volume content over HFC-based networks along with utilization of the available frequency spectrum.
- Interactive services such as gaming or IPTV are very sensitive to time latency.
- From the user experience viewpoint, acceptable delay for video channel switching and delivery of a visually stable image to the display device is deemed to be approximately 300 ms.
- Currently, cable operators use DOCSIS for providing interactive data services, so the advanced digital cable transmission technologies need to harmonize with DOCSIS transport systems.
- For developing practical transmission technologies, it is necessary to take into account HFC-based networks which are characterized and modelled on a global (e.g., North America, Asia and Europe) level (including customer premises networks) and realistic cable channel models, which include:
  - deployment of analogue PAL/SECAM/NTSC television channels;
  - deployment of different digital signals (such as [ITU-T J.83], DOCSIS, DAVIC) and the associated signal back-off ratios to analogue signals;

- different noise types (e.g., white, burst, impulse), non-linearities, and other impairments present in current and future networks.

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.83] Recommendation ITU-T J.83 (2007), *Digital multi-programme systems for television, sound and data services for cable distribution*.

[ITU-T J.222.1] Recommendation ITU-T J.222.1 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: Physical layer specification*.

[ITU-T Resolution 73] ITU-T Resolution 73 (2008), *Information and communication technologies and climate change*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 DOCSIS [ITU-T J.222.1]: Data Over Cable Service Interface Specifications.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 advanced digital cable transmission technology (ACTT): Advanced digital cable transmission technology on the physical layer, which includes modulation, channel coding, transmission schemes and frame structure to provide higher spectral efficiency.

3.2.2 HFC-based networks: 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.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3DTV Three Dimensional Television

ACM Adaptive Coding and Modulation

ACTT Advanced digital Cable Transmission Technology

CMTS Cable Modem Termination System

DOCSIS Data Over Cable Service Interface Specification

FEC Forward Error Correction

HD High Definition

HDTV High Definition Television

HEVC	High Efficiency Video Coding
HFC	Hybrid Fibre/Coax
IPTV	IP Packet Television
MSO	Multiple System Operators
PHY	Physical Layer
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RFoG	Radio Frequency over Glass
Rx	Receiver
SD	Standard Definition
SDTV	Standard Definition Television
SDV	Switched Digital Video
Tx	Transmitter
UHD	Ultra High Definition
UHDTV	Ultra High Definition Television
VoD	Video on Demand

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "**is prohibited from**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**can optionally**" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

In the body of this Recommendation, the words *shall*, *shall not*, *should*, and *may* sometimes appear, in which case they are to be interpreted, respectively, as *is required to*, *is prohibited from*, *is recommended*, and *can optionally*. The appearance of such phrases or keywords in an appendix or in material explicitly marked as *informative* is to be interpreted as having no normative intent.

6 General requirements

[ACTT-GER-001] ACTT is required to be applied to HFC-based networks.

[ACTT-GER-002] ACTT is required to be applied to two-way data transmission technologies such as high-speed Internet and VoD as well as digital television broadcasting services such as SD/HD TV, 3DTV and UHDTV.

[ACTT-GER-003] ACTT is required not to affect the existing services and deployments such as analogue broadcasting and digital broadcasting based on [ITU-T J.83].

[ACTT-GER-004] ACTT is required not to be affected by the existing services such as analogue broadcasting and digital broadcasting based on [ITU-T J.83].

[ACTT-GER-005] ACTT is required to support forward transmission from terrestrial broadcasting and satellite broadcasting to HFC-based networks without alteration.

[ACTT-GER-006] ACTT is recommended to support the scheme to provide immunity against noise in HFC-based networks.

[ACTT-GER-007] ACTT can optionally support flexible bandwidth and flexible, even non-contiguous, spectrum assignment so that cable operators can provide versatile services in their own HFC-based networks.

[ACTT-GER-008] ACTT is recommended to support a multiplicity of modulation and FEC (such as ACM) schemes to provide seamless transmission without service interruption.

[ACTT-GER-009] ACTT is recommended to exploit the technologies aiming to optimize the use of cable channels in HFC-based networks and not required to take backward compatibility into consideration. This includes enhanced flexibility and robustness, as well as maximized spectrum efficiency.

[ACTT-GER-010] ACTT is required to be applicable in bidirectional HFC-based networks. However, ACTT downstream PHY is required to not depend on the availability of a return channel.

[ACTT-GER-011] ACTT is required to provide a wide range of solutions in order to meet the requirement of different services and HFC-based networks characteristics.

[ACTT-GER-012] ACTT is required to allow service providers employing HFC-based networks to have physical layer robustness and latency service targets for individual services. Each individual physical channel is required to support only one service target, and optionally support more than one service target per individual physical channel.

[ACTT-GER-013] ACTT is recommended to utilize already existing appropriate techniques wherever applicable.

[ACTT-GER-014] ACTT technical specifications are recommended not only to address transmit-end functions, but also to take into account cost implications for different devices, such as receivers or headend equipment.

[ACTT-GER-015] ACTT is required to be generally applicable to all frequency bands available on HFC-based networks.

7 Performance and efficiency requirements

[ACTT-PER-001] ACTT is required to improve, by at least 30%, downstream throughput in HFC-based networks as compared to requirements of [ITU-T J.83] (e.g., 256-QAM as defined in [ITU-T J.83]).

[ACTT-PER-002] ACTT is required to improve, by at least 30%, upstream throughput in HFC-based networks as compared to that of DOCSIS (e.g., 64-QAM as defined in DOCSIS).

[ACTT-PER-003] ACTT is recommended to be able to efficiently support the migration from a mixed analogue/digital to full digital network to improve spectrum efficiency.

[ACTT-PER-004] ACTT is required to support a low latency mode.

[ACTT-PER-005] The ACTT transmission system is recommended to be able to support low power modes to maximally reduce power consumption in receivers according to [ITU-T Resolution 73].

[ACTT-PER-006] ACTT is required to provide a fully transparent retransmission link for MPEG transport streams, IP packets and other relevant protocols between the input of the modulator and the output of the demodulator with the goal of increasing spectral efficiency.

[ACTT-PER-007] ACTT is recommended to support the implementation of a receiver meeting the customer expectation of tuner/demodulator synchronization time. For a consumer initiated switch in the selected RF channel, it is recommended that the ACTT input user terminal delivers a stable signal to the TV receiver within 300 ms.

[ACTT-PER-008] In order to allow for consumer self-install, ACTT is recommended to be as immune to interference and harmful electrical characteristics as possible from customer premises networks.

8 Requirements of downstream PHY

[ACTT-DPR-001] ACTT downstream PHY is required to deliver continuous or burst streams over HFC-based networks.

[ACTT-DPR-002] ACTT downstream PHY is required to encode FEC for channel error correction over HFC-based networks.

[ACTT-DPR-003] ACTT downstream PHY is required to support flexible FEC and interleaving in accordance with services.

[ACTT-DPR-004] ACTT downstream PHY is recommended to support a flexible FEC coding rate in accordance with channel conditions in HFC-based networks.

[ACTT-DPR-005] ACTT downstream PHY is recommended to support the function for reducing the adjacent channel interference in HFC-based networks.

[ACTT-DPR-006] ACTT downstream PHY is recommended to support a time or frequency interleaving for robust data transmission through HFC-based networks.

[ACTT-DPR-007] ACTT downstream PHY is recommended to insert signals, if necessary, for synchronization, channel estimation and equalization at the receiver in HFC-based networks.

9 Requirements of upstream PHY

[ACTT-UPR-001] ACTT upstream PHY is required to deliver burst stream over HFC-based networks.

[ACTT-UPR-002] ACTT upstream PHY is recommended to support appropriate schemes for sharing the frequency and time resources.

[ACTT-UPR-003] The CMTS and user terminal have different clocks. Therefore, ACTT upstream PHY is required to support the scheme of compensating time differences between the local clock of the user terminal and the global clock of CMTS.

[ACTT-UPR-004] ACTT upstream PHY is required to support the most efficient coding schemes for channel error correction over HFC-based networks.

[ACTT-UPR-005] ACTT upstream PHY is required to support flexible FEC schemes in accordance with services.

[ACTT-UPR-006] User terminals located in HFC-based networks will have different channel conditions (e.g., different carrier-to-noise ratio and different impairments). Therefore, ACTT upstream PHY is required to support flexible FEC in accordance with channel conditions in HFC-based networks.

[ACTT-UPR-007] ACTT upstream PHY is recommended to support the function for reducing the adjacent channel interference in HFC-based networks.

[ACTT-UPR-008] ACTT upstream PHY is recommended to support a function of reducing packet losses due to typical interference scenarios in the upstream frequency range such as burst and narrow-band ingress noise for data transmission through HFC-based networks.

[ACTT-UPR-009] ACTT upstream PHY is recommended to insert signals, if necessary, for synchronization, channel estimation and equalization at the receiver in HFC-based networks.

Appendix I

Examples of transmission regarding downstream throughput improvement of ACTT compared to Annex B of ITU-T J.83

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

Table I.1 compares the improvement of throughput of Annex B of [ITU-T J.83] and ACTT with only payload data.

Table I.1 – Throughput for Annex B of [ITU-T J.83] and ACTT in accordance with improvement rate

	Bits/Hz	**Mbits/(6 MHz)**
ITU-T J.83B	6.47	38.80
ACTT (10%)	7.11	42.68
ACTT (20%)	7.76	46.56
ACTT (30%)	8.41	50.44

In this appendix, it is assumed that the capacity of HD content encoded by MPEG-4 AVC encoder would be 9~10 Mbit/s and frame rate is 30 Hz. The capacity of 4k UHD is four times larger than that of HD, and the capacity of 8k UHD is 16 times larger than that of HD.

Table I.2 shows the required capacity of HD, 4k UHD and 8k UHD, respectively. Furthermore, the required number of channels that transmit HD, 4k UHD and 8k UHD by transmission technologies are shown in Table I.2.

Table I.2 – The required number of channels that transmit HD, 4k UHD and 8k UHD

		Annex B of [ITU-T J.83]	**ACTT (10%)**	**ACTT (20%)**	**ACTT (30%)**
	Mbit/s	**Channel #**	**Channel #**	**Channel #**	**Channel #**
HD	10	0.26	0.23	0.21	0.20
UHD (4k)	40	1.03	0.94	0.86	0.79
UHD (8k)	160	4.12	3.75	3.44	3.17

For providing 8k UHD service, the required channel number value of Annex B of [ITU-T J.83] and ACTT are carried over 4 and 3, respectively. Furthermore, ACTT as well as Annex B of [ITU-T J.83] will take into account channel bonding schemes.

Bibliography

[b-ITU-T J.222.0] Recommendation ITU-T J.222.0 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: Overview*.

[b-ITU-T J.222.2] Recommendation ITU-T J.222.2 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: MAC and Upper Layer protocols*.

[b-ITU-T J.222.3] Recommendation ITU-T J.222.3 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: Security services*.

[b-ETSI EN 302 769] ETSI EN 302 769 V1.2.1 (2011), *Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2)*.

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