参考資料３

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

STUDY GROUP 9

TD 576 Rev.1 (GEN/9)

English only

Original: English

Question(s): 1/9 Geneva, 8-12 September 2014

TD

Source: Rapporteur for Q1/9

Title: Output – Draft revised Recommendation J.183 " Time-division multiplexing of multiple MPEG-2 transport streams over cable television systems " for progressing

Based on the COM9-C59 discussion, Q1/9 provides TD AAA, the draft revision of J.183 for progressing. Revision marks indicated in this document are developed in this meeting.

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[DRAFT REVISED] ITU-T RECOMMENDATION J.183

ITU-T Recommendation J.183

Time-division multiplexing of multiple MPEG-2 transport streams over cable television systems

1 Scope

The scope of this Recommendation is the definition of a time-division multiplexing frame format to adapt the multiple MPEG-2 transport streams, some of which exceeds the transmission rate per a single channel, into the existing physical layer interface specified in Annex C/J.83. This format may be applicable to other transmission systems.

The frame aims to multiplex transport streams without change except that some of the service information (SI) related to the network are replaced. By using this frame structure as an option to the conventional digital transmission equipment, multiple transport streams can be multiplexed as they are. The functionality of multiplexing transport streams into a single transport stream is not needed. Also, the expansion of the frame format, being compliant with the first version of J.183 (2001-03-09), can provide the additional functionality for high speed transmission scheme by channel bonding technology.

Implementation of ~~this~~ the first version of the frame format enables the cable television operator to pack multiple transport streams in a single channel. And the second version of this frame format can be additionally applied to high speed transport streams, such as UHDTV signals, to be multiplexed into multiple channels as well. In other words, the second version of J.183 maintains backward compatibility with the first one. {Editor's note: appropriate expression for "first/second version" should be considered.}

書式変更: 蛍光ペン

~~Also, t~~The flexibility on operation of cable distribution network would be obtained if the integration of services could be achieved by the transport stream basis.

This Recommendation provides the information needed by the designers and manufacturers of equipment (including receivers) for digital multi-programme signals distributed by cable networks.

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.

– ITU-T H.222.0 (2000) | ISO/IEC 13818-1:2000, *Information technology – Generic coding of moving pictures and associated audio information: systems*.

– ITU-T J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution*.

– ITU-T J.84 (1997), *Distribution of digital multi-programme signals for television, sound and data services thorough SMATV networks*.

– ITU-T J.94 (1998), *Service information for digital broadcasting in cable television systems*.

2.2 Informative references

– JCTEA STD-002-2.0, Multiplexing System for Digital Cable Television.

– JCTEA STD-007-1.0, BS digital compliant Digital Cable Television Receiver.

3 Terms and definitions

This Recommendation defines the following terms:

3.1 MPEG-2: Refers to ISO/IEC 13818 (All parts). Systems coding is defined in ITU-T H.222.0 | ISO/IEC 13818-1. Video coding is defined in ITU-T H.262 | ISO/IEC 13818-2. Audio coding is defined in ISO/IEC 13818-3 and in ISO/IEC 13818-7.

3.2 network: A collection of MPEG-2 transport stream multiplexes transmitted on a single delivery system, e.g., all digital channels on a specific cable system.

3.3 original_network_id: A label identifying the network_id of the originating delivery system.

3.4 programme: A concatenation of one or more events under the control of a broadcaster, e.g., news show, entertainment show.

3.5 physical interface: The interface on a physical layer equipment for transmission.

3.6 reserved_for_future_use: The term "reserved_for_future_use", when used in the clause defining the coded bitstream, indicates that the value may be used in the future defined extensions. All "reserved_for_future_use" bits shall be set to "1".

3.7 set-top box: A hardware box that contains digital signal demodulator, de-multiplexer, MPEG-2 decoder, other functionalities and interfaces related to digital signal reception and presentation of the distributed programme at the subscriber's site.

3.8 transport stream (TS): A TS is a data structure defined in ITU-T H.222.0 | ISO/IEC 13818-1.

3.9 transport_stream_id (TS_id): A unique identifier of a TS within an original network.

4 Abbreviations

This Recommendation uses the following abbreviations:

bslbf	bit string, left bit first
CRC	Cyclic Redundancy Check
rpchof	remainder polynomial coefficients, highest order first
TS	Transport Stream
TSMF	Transport Streams Multiplexing Frame
uimsbf	unsigned integer, most significant bit first

5 Multiple-TS transmission system

The proposed framing structure for a multiple-TS transmission system meets the following requirements:

a) Multiple MPEG-2 transport streams should be transmitted over a digital carrier in compliance with existing cable TV systems.

b) All packets of all MPEG-2 transport streams should be transmitted without any packet loss.

c) All transport streams received are in compliance with the specification of MPEG-2 systems.

d) The system should make effective use of cable TV channel capacity.

e) Delay time resulting from optional use of signal processing should not affect digital broadcasting services.

f) The added cost of introduction of the optional facilities in a cable TV headend and the receiver should be low.

g) The system should support interoperability with conventional single transport stream transmission systems for cable distribution.

5.1 Framing structure for multiple-TS transmission

The multiple-TS transmission system uses the frame structure shown in Table 1 to multiplex MPEG-2 transport streams (TSs). The frame is called the transport streams multiplexing frame (TSMF). The TS packets shall be assigned to slots in the TSMF. A slot is constituted from 188 bytes of the same size as a TS packet, and the TSMF consists of N slots. The TSMF has a TSMF_header in the first slot. In the TSMF_header, information about multiplexing and de-multiplexing is contained. By outputting this frame repeatedly, multiple TSs are transmitted.

Table 1/J.183 – TSMF structure

Syntax	No. of bytes	Description
TSMF () {		
TSMF_header()	188	
for (i = 1; i < N; i++){		
TS_packet[i]	188	
}		
}		

5.2 Physical interface and channel coding of the multiple-TS transmission system

Except for the framing block, channel coding is identical to that of the single-TS transmission system (Figure 1) because the multiplexed signal by using the TSMF is a stream of TS packets. The technology and standards specified for the physical interface of a single-TS transmission system, for example, ITU-T J.83, can be applied.

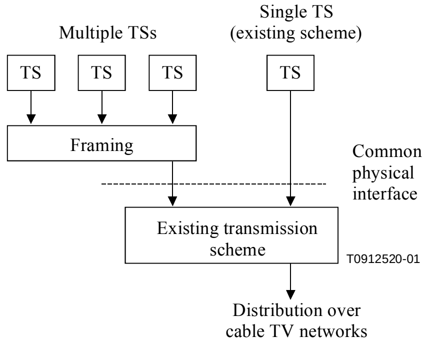

Figure 1/J.183 – System configuration for single TS and multiple TSs transmission

5.3 TSMF header structure

The TSMF_header should be comprised of 188-byte data. The first byte of 0x47 is for packet synchronization purpose, followed by 187 bytes of the following information:

– frame synchronization;

– MPEG-2 TS identification for each slot; and

– others (e.g. version number, flag bit for emergency alert broadcasting).

Each of the MPEG-2 TSs, multiplexed in the TSMF, is uniquely distinguished by the TS identification (TS_id) and original network identification (original_network_id). Instead of directly using the corresponding information between a slot number and TS_id/original_network_id, the relative TS number (relative_TS_number) is employed. The TS_id/original_network_id of a TS, which a TS_packet in a slot belongs to, is resolved in two stages: the first is translation of slot number to relative_TS_number, and the next is translation of relative_TS_number to TS_id/original_network_id. This method reduces the number of bits for the TS identification in the TSMF_header. The content of the TSMF_header is specified in Table 2 and below:

Table 2/J.183 – TSMF_header

Syntax	No. of bits	Description
TSMF_header() {		
packet_header()	32	
TSMF_sync	16	bslbf
version_number	V	
slot_information()	S	
identifiers_information()	32 * M	M = 2^m – 1
control_information()	C	bslbf
relative_TS_information()	m * (N – 1)	
private_data	1424 – V – S – 32 * M – C – m * (N – 1)	
CRC	32	rpchof
}		

NOTE 1 – The semantic definition of the fields in the TSMF header is as follows:

TSMF_sync: This is a 16-bit field. Its value shall be determined by the system.

version_number: This V-bit field is the version number that indicates renewal of the area from the slot_information to the control_information in the TSMF_header. It shall be incremented by 1 when a change occurs. When it reaches maximum value, it wraps around to 0.

private_data: This is a field whose syntax and semantics shall be defined by the system.

CRC: CRC (cyclic redundancy check) is added to detect any errors. As defined in ITU-T H.222.0, the value of CRC has zero register output when 184 bytes of a TSMF_header, excluding the first 4 bytes, are input into the register of a decoder.

NOTE 2 – $V + S = 8 * I_1$, where V is the number of bits for version_number, S is the number of bits for slot_information, and I_1 is an integer.

NOTE 3 – $C = 8 * I_2$, where C is the number of bits for control_information, and I_2 is an integer.

NOTE 4 – N is the number of slots in the TSMF, or the total length of the frame.

NOTE 5 – M is the maximum number of transport streams multiplexed in the TSMF.

5.3.1 Packet_header

The first 4 bytes of the TSMF_ header have a structure similar to the MPEG-2 TS packet header, as shown in Table 3.

Table 3/J.183 – Packet_header

Syntax	No. of bits	Description
packet_header() {		
sync_byte	8	bslbf
'000'	3	bslbf
TSMF_header_PID	13	uimsbf
'0001'	4	bslbf
continuity_counter	4	uimsbf
}		

NOTE – The semantic definition of the fields in packet header is as follows:

sync_byte: This is a fixed 8-bit field whose value is '0100 0111' (0x47).

TSMF_header_PID: This is a 13-bit field whose value is set to a unique value other than the PIDs of TS packets. The TSMF_header can be identified from other TS packets, as the value of TSMF_header_PID is unique.

continuity_counter: The continuity_counter is a 4-bit field incrementing with each TSMF_header. When the value reaches '1111' (0x0f), it wraps around to 0.

5.3.2 TSMF_sync

The TSMF_sync is used for frame synchronization. Using the TSMF_sync and the TSMF_header_PID together, frame synchronization is ensured. The value shall be defined by the system.

5.3.3 Version_number

The version_number indicates renewal of the TSMF_header information. It shall be incremented each time the TSMF header is renewed. The receiver may decode the TSMF header information only when a change of information occurs. The use of version number and the area where information renewal is examined are optionally defined by the system.

5.3.4 Slot_information

The slot_information (see Table 4) shall include the TSMF_format, and the indicator of the availability of each relative_TS_number, and so on. The TSMF_format may indicate the maximum number of TSs transmitted simultaneously and the number of slots in the TSMF. Each of the availability_for_relative_TS_number shall be transmitted sequentially in order of the relative_TS_number from 1 to M.

Table 4/J.183 – Slot_information

Syntax	No. of bits	Description
slot_information() {		
TSMF_format	F	bslbf
for (i = 1; i <= M; i++) {		M = 2^m – 1
availability_for_relative_TS_number[i]	1	bslbf
}		

reserved_for_future_use }	S-F-M	

NOTE 1 – F is the number of bits of TSMF_format.

NOTE 2 – M is the maximum number of transport streams multiplexed in the TSMF.

NOTE 3 – S is the number of bits of slot_information.

NOTE 4 – Semantic definition of the fields in the slot information is as follows:

TSMF_format: This is a V-bit field which indicates N and M. The value of N and M should be the same as defined in Annex C/J.94.

availability_for_relative_TS_number[i]: This is a 1-bit field that represents availability of the TS labelled by relative_TS_number i.

5.3.5 Identifiers_information

Table 5 shows the algorithm relating relative_TS_number and TS_id/original_network_id. TS_id/original_network_id shall be composed of 32-bit numbers and shall be arranged in order of the relative_TS_number from 1 to M.

Table 5/J.183 – Identifiers_information

Syntax	No. of bits	Description
identifiers_information(){		
for (i = 1; i <= M; i++) {		M = 2^m – 1
TS_id[i]	16	uimsbf
original_network_id[i]	16	uimsbf
}		
}		

NOTE 1 – The maximum number of TSs transmitted simultaneously, M, shall be indicated by the 'TSMF_format' as shown in Table 4.

NOTE 2 – The semantic definition of the fields in the identifiers information is as follows:

TS_id[i]: This is a 16-bit field that represents TS_id of the TS labelled as relative_TS_number i.

original_network_id[i]: This is a 16-bit field that represents original_network_id of the TS labelled as relative_TS_number i.

5.3.6 Control information

The control information may be used to control set-top boxes, e.g. a flag for emergency alert broadcasting. The encoding format shall be defined by the system. The number of bits for the control information, "C", is defined in Table 2.

5.3.7 Relative TS number information

The relative_TS_number for each TS_packet shall be transmitted sequentially in order of slot from 1 to (N – 1) as shown in Table 6. The number of slots in TSMF, N, shall be defined by the system.

Table 6/J.183 – Relative TS_number_information

Syntax	No. of bits	Description
relative_TS_information(){		
for (i = 1; i < N; i++) {		
relative_TS_number[i]	m	uimsbf
}		
}		

NOTE 1 – M is 2^ m – 1.

NOTE 2 – Semantic definition of the fields in the relative TS number information is as follows:

relative_TS_number[i]: This is an m-bit field that represents the relative_TS_number of the i-th TS_packet.

Annex A for digital multi-programme System A

(For further study)

{Editor's note: provide definition of System A and System B.}

Annex B for digital multi-programme System B

(For further study)

Annex C Extended format of TSMF for System C of J.83

(This annex forms an integral part of this Recommendation)

C.1 Introduction

This annex describes the extension format of existing TSMF structure in order to adapt a large capacity of MPEG-2 transport streams, such as an UHDTV signals including a large capacity of transport stream, to be divided into the multiple channel physical layer interfaces specified in Annex C/J.83. The extendedExtended TSMF is designed for channel bonding technology. It is backward compatible with the first version of TSMF, J.183 (2001-03-09). This technology will support cable TV transmission system to distribute relatively large sized contents with multiple carriers while conventional system having HDTV channels in the same physical layer specification.

C.2 Concept

Figure C.1 overviews the channel bonding technology. The large capacity of MPEG-2 TS is divided at the cable TV headend and multiplexed into time division multiplexing (TDM) frames that are described as "Super Frames" in the following section. Each of the frames is transmitted by a 64 QAM or 256 QAM signal. Each of the QAM channels can be allocated to any frequency. The signal of each channel is separately demodulated and all of the demodulated signals are restored to the original MPEG-2 TS of UHDTV at a receiver.

The channels carrying UHDTV service and those for existing broadcasting services are confirmed not to disturb each other. As 256 QAM offers transmission capacity larger than 64 QAM, the former is preferable to transmit UHDTV signals. However, 256 QAM is less robust against any kind of noise and distortion than 64 QAM.

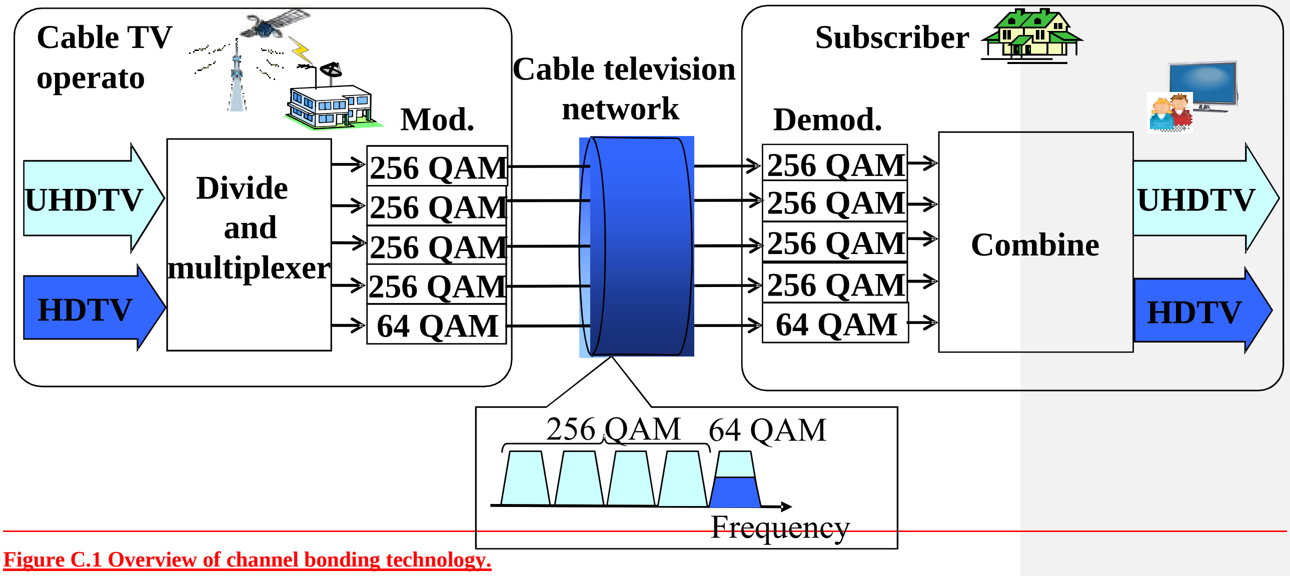

Figure C.1 Overview of channel bonding technology.

Figure C.2 shows an example of the combination of one 64 QAM and four 256 QAM channels used for a single UHDTV transmission. In this figure, a UHDTV signal occupies four 256 QAM channels and a part of 64 QAM channel. It is noted that another program such as a HDTV may be transmitted with the use of the remained capacity of the 64 QAM channel. Any combination of QAM scheme among the relevant multi carriers group should be allowed for cable TV operation. Since the bitrates transmitted by 64 and 256 QAMs are different, e-TSMF is required for bonding channels with different bitrates.

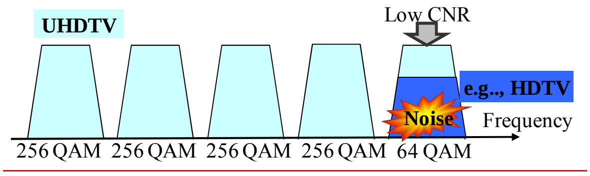

Figure C.2 Multiple channels used for UHDTV transmission.

Figure C.3 shows an example of a TS transmitted by one 64 QAM and two 256 QAM signals by using ~~extended~~Extended TSMF format. Channel coding is identical to that of the single-TS transmission system because the stream divided for multiple channels by using the Extended TSMF is a stream of TS packets.

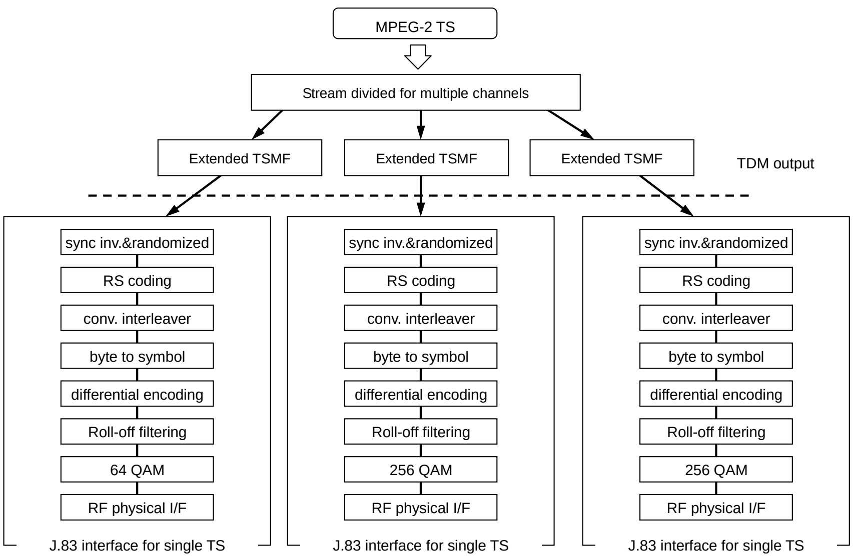

Figure C.3 Example of a TS carried by one 64 QAM and two 256 QAM signals by using ~~extended~~Extended TSMF format.

変更されたフィールド コード

C.3 Super frame

Figure C.4 outlines the structure of the super frame. The number of TSMFs in a super frame is determined to make the periods of super frames identical regardless of the modulation format.

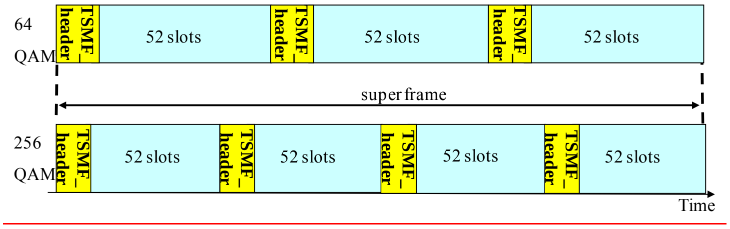

Figure C.4 Structure of super-frame for 64 QAM and 256 QAM.

A super frame for a 64 QAM has three TSMFs and that for a 256 QAM has four TSMFs according to the bit-rate ratio. The modulation scheme of either channel, 64 QAM or 256 QAM, is determined depending on the transmission characteristics of the channel.

At the receiver, the arrival time of transmitted signals may differ depending on the propagation delay in each channel. A receiver has to temporally align all relevant signals demodulated from received carriers. The TSMF_header of the first TSMF in every super frame is utilized as a marker to synchronize received signals.

In order to apply the TSMF structure for channel bonding technology, we define some of the additional parameters in the private data of TSMF_header in J.183.

C.4 Extended TSMF

In order to define the ~~extended~~Extended TSMF for channel bonding functionality, additional parameters are specified within the private data of TSMF_header as shown in Table C.1:

Table C.1 TSMF and ~~Extended~~Extended TSMF header

TSMF_header	Extended TSMF_header	No.of bits	Description
TSMF_header() {	Extended_TSMF_header() {		
packet_header()	the same as Table 3/J.183		
TSMF_sync	the same as Table 2/J.183		
version_number	the same as Table 2/J.183		
slot_information()	the same as Table 4/J.183		
identifiers_information()	the same as Table 5/J.183		
control_information()	the same as Table 2/J.183		
relative_TS_number_information()	the same as Table 6/J.183		
~~private_data~~	auxiliary code information	AC	bslbf
The field 'private data' is replaced by the field specified as shown in the right column as the second version.	group_id	8	uimsbf
	number_of_carriers	8	uimsbf
Before implementation, users should confirm that conventional receiver is not affected by the additional definition in this field.	carrier_sequence	8	uimsbf
	number_of_frames	4	uimsbf
	frame_position	4	uimsbf
It was defined as private data field in the first version(2001-03-09).	reserved_for_future_use	See NOTE2	
CRC	the same as Table 2/J.183		
}	}		

NOTE1 − The definition of specific fields in the Extended TSMF header is as follows:

auxiliary code information: This code information is used to provide auxiliary information for cable TV subscribers, such as, earthquake early warning message in the specific region. The number of bits for auxiliary code information, "AC", and its coding format shall be defined by the system.

group_id: This is a 8-bit field which represents a unique identifier of a group corresponding to bonding channels.

number_of_carriers: This is a 8-bit field which describes the number of carriers for channel bonding in the same group_id.

carrier_sequence: This is a 8-bit field which indicates the sequence number for channel bonding among carriers with the same group id.

number_of_frames: This is a 4-bit field which represents the number of Extended TSMF included in the super frame. (ex. 0x03 for 64 QAM, 0x04 for 256 QAM in J.83 Annex C)

frame_position: This is a 4-bit field which represents the sequence number of multiple Extended TSMFs in the super frame.

NOTE2 − The value is {(No. of bits in private_data in Table 2/J.183) −AC−32}

APPENDIX I

Table I.1 shows parameters for the TSMF employed with the physical layer interface specified in Annex C/J.83.

Table I.1/J.183 – System parameters

Parameter	Notation	Value	Remarks
The number of slots in the TSMF, or the total length of the frame	N	53	including TSMF_header
The maximum number of transport streams multiplexed in the TSMF	M	15	
TSMF_sync			reserved 3 bits 0x1a86 13 bits
version_number			3 bits (V = 3)
slot_information			21 bits (S = 21)
TSMF_type			slot_allocation_type 1 bit frame_type[a)] 4 bits (F = 5)
control_information			receive_status 2 * M = 30 bits emergency_indicator 1 bit
private_data			85 bytes
a) The "frame_type" in the TSMF_type should be included in the cable delivery system descriptor of network information table (NIT) for the reception. The set-top box could identify whether each channel on cable network is with the TSMF or not. The values of N and M are identical to the definition in Annex C/J.94.			

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INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

COM 9 – C 59 – E

August 2014

English only

Original: English

Question(s): 1/9

STUDY GROUP 9 − CONTRIBUTION 59

Source: Nippon Hoso Kyokai (NHK) (Japan Broadcasting Corporation)

Title: Proposed new work item for high speed transmission scheme by channel bonding technology for UHDTV distribution on cable TV networks

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Introduction

Recently, development and standardization of the systems for UHDTV is accelerating. For example, in ITU-R Study Group 4, transmission systems for UHDTV satellite broadcasting is under study as described in Annex 9 to Document 4B/162 "Working document towards a preliminary draft new Recommendation ITU-R BO.[UHDTV_Transmission] - Transmission system for UHDTV satellite broadcasting". And Japan has a plan for test broadcasting of UHDTV (the 7680 × 4320 system specified in Recommendation ITU-R BT. 2020) via satellite in 2016.

NHK has developed a cable transmission scheme for UHDTV distribution and proposed it to the Japan Cable Television Engineering Association (JCTEA) which is one of the recognized SDOs according to Recommendations ITU-T A.5. It allows a high speed downstream transmission which exceeds the physical bit rate capacity per cable TV channel by channel bonding technology. The channel bonding is achieved by extension of Time Division Multiplexing (TDM) frame format of MPEG-2 transport streams defined in Recommendation J.183 and physical layer specification for secondly distribution defined in Recommendation J.83, and thus the system maintains backward compatibility with Recommendation J.183 and can be commonly used in the transport layer regardless of the format of the physical layer.

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Considering its importance of the study in time on UHDTV distribution over cable networks in ITU-T, Study Group 9 should start to study a new work item for seeking high speed transmission scheme, which is easy to implement in operating cable TV facilities.

Two attachments are provided in this document for consideration to the initiation of the new work.

Attachment 1 contains working document with an overview of the system for seeking discussion towards revision of Recommendation or development of a draft new Recommendation. Attachment 2 describes the results of performance evaluation tests of our proposed cable TV transmission system for UHDTV distribution.

Related ITU-T Recommendations and documents/publications to the work described in Attachment 1 and 2 are listed below for information.

ITU-T Recommendations

[1] Recommendation ITU-T H.222.0 (06/2012) | ISO/IEC 13818-1:2000, Information technology − Generic coding of moving pictures and associated audio information: systems.

[2] Recommendation ITU-T J.83 (12/2007), Digital multi-programme systems for television, sound and data services for cable distribution.

[3] Recommendation ITU-T J.94 (11/2008), Service information for digital broadcasting in cable television systems

[4] Recommendation ITU-T J.183 (03/2001), Time-division multiplexing of multiple MPEG-2 transport streams over cable television systems

Other documents and publications

[5] "Proposed working document towards a preliminary draft new recommendation" ITU-R BO.[UHDTV_TRANSMISSION], Document 4B/153, (Jun. 2014)

[6] "An UHDTV Cable Television Distribution in Combinations of Multiple 64 and 256 QAM Channels," IEEE ICCE2013 vol.2, pp.488-489, (Jan. 2013)

[7] "UHDTV (8K) Distribution Technology and Field Trial on Cable Television Networks", ITE Trans. on MTA, 2, 1, pp.2-7, (Jan. 2014)

[8] "Action for installation of UHDTV in Japan," ITU-R WP6C workshop, (Mar. 2014), http://www.itu.int/oth/R0A07000035

[9] "8K Super Hi-vision distribution technology for cable TV networks"(May, 2014) http://www.nhk.or.jp/strl/open2014/tenji/tenji05/index_e.html

ATTACHMENT 1

WORKING DOCUMENT TOWARDS revision of existing recommendation or development of a preliminary draft new Recommendation

1 Background

As shown in the document (4B/153) of ITU-R SG4, The UHDTV satellite broadcasting system, which has been developed in Japan, provides transmission capacity about 100 Mbps through a 34.5 MHz satellite transponder using 16 APSK with an inner coding rate 7/9 and achieves a 99.5% service availability.

Our proposal is based on research activity considering that a cable TV channel is having difficulty of carrying an UHDTV broadcasting signal which is planned to be distributed via satellite in 2016.

2 Scope

The scope of Attachment 1 is an introduction of an extended format of J.183 time-division multiplexing frame (TSMF[1]) to adapt a large capacity of MPEG-2 transport stream, such as an UHDTV, to be divided into the multiple channel physical layer interfaces specified in Annex C/J.83. This format may be applicable to other transmission systems.

3 Overview of UHDTV distribution by using multiple channels

Figure 1 overviews our developed channel bonding technology. The large capacity of MPEG-2 TS is divided at the cable TV headend and multiplexed into time division multiplexing (TDM) frames that are described as "Super Frames" in the following Section.

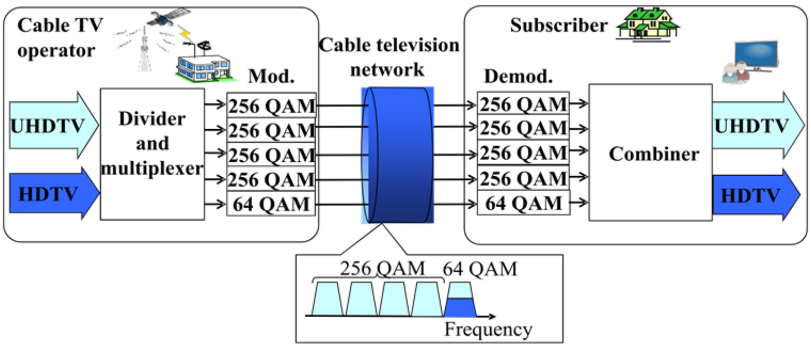

Fig. 1 Overview of channel bonding technology.

[1] TSMF (Transport Stream Multiplexing Frame) is defined in recommendation J.183.

Each of the frames is transmitted by a 64 QAM or 256 QAM signal. Each of the QAM channels can be allocated to any frequency. The signal of each channel is separately demodulated and all of the demodulated signals are restored to the original MPEG-2 TS of UHDTV at a receiver. UHDTV distribution has to coexist with conventional FDM based digital broadcasting distribution on cable television networks. The modulation schemes, 64 and 256 QAM, that the proposed method utilizes, are already standardized for cable transmission. Then channels carrying UHDTV service and those for existing broadcasting services are confirmed not to disturb each other. As 256 QAM offers transmission capacity larger than 64 QAM, the former is preferable to transmit UHDTV signals. However, 256 QAM is less robust against any kind of noise and distortion than 64 QAM. In most cable facilities, transmission characteristics on channels are different and some channels may have a low carrier-to-noise ratio (CNR). They can carry 64 QAM signals, but cannot carry 256 QAM signals. Since the proposed method utilizes both of 64 and 256 QAMs, it makes efficient use of cable channels.

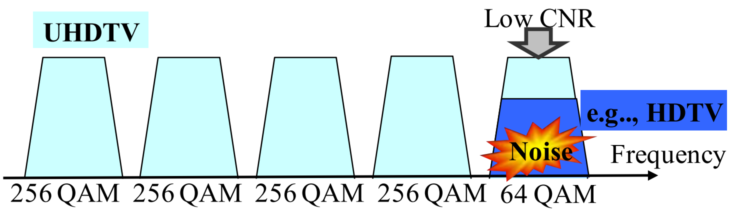

Fig. 2 Multiple channels used for UHDTV transmission.

Fig. 2 shows an example of the combination of one 64 QAM and four 256 QAM channels used for a single UHDTV transmission. In this figure, a UHDTV signal occupies four 256 QAM channels and a part of 64 QAM channel. It is noted that another program such as a HDTV may be transmitted with the use of the remained capacity of the 64 QAM channel. The bitrates transmitted by 64 and 256 QAMs are different. This causes a problem how the bonding channels of different bitrates. To restore the UHDTV signal from data streams of different bitrates, we introduce the Super Frame, which is an large frame containing multiple TSMFs, described in the following section.

Fig.3 shows an example of a TS transmitted by one 64 QAM and two 256 QAM signals

by using extended TSMF format. Channel coding is identical to that of the single-TS transmission system because the stream divided for multiple channels by using the Extended TSMF is a stream of TS packets. The specification for the physical interface of a single-TS transmission system, for example, ITU-T J.83, can be applied as J.183(TSMF). The syntax of Extended TSMF is also described in the following section.

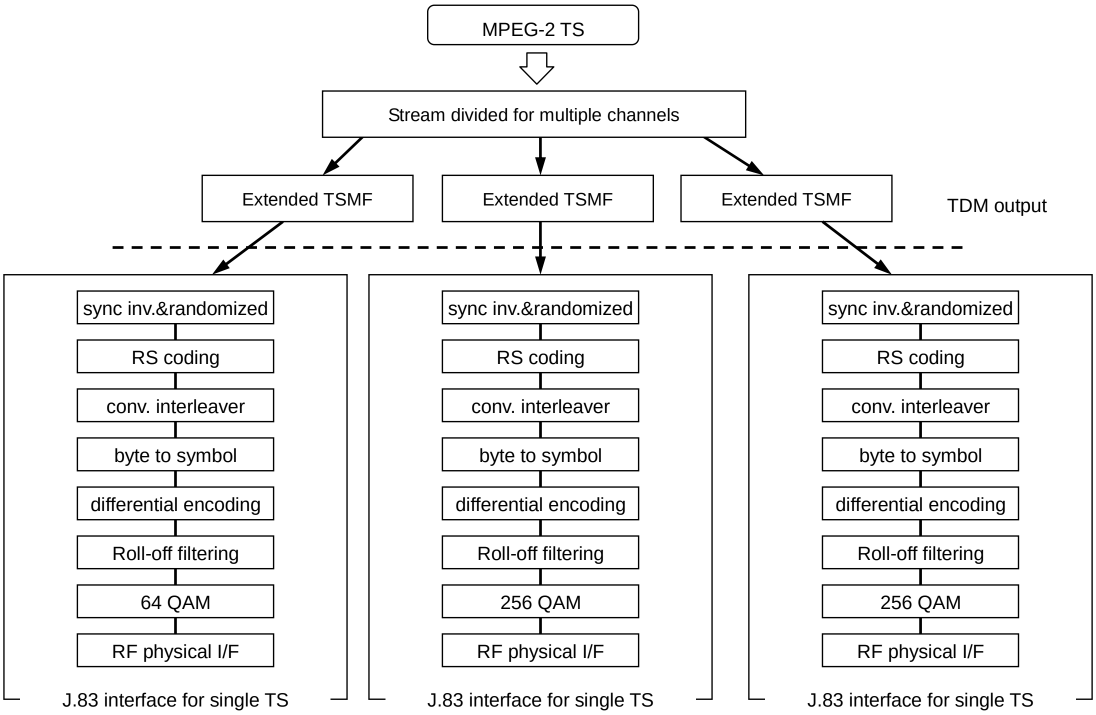

Fig. 3 Example of a TS carried by one 64 QAM and two 256 QAM signals
by using extended TSMF format.

4 Proposal for Super Frames

At the cable TV headend, the implementation of framing structure of the transport streams multiplexing frames (TSMF) of ITU-T J.183 enables cable TV operators to encapsulate multiple MPEG-2 TSs into a single stream independently. TSMF adapts the stream into the physical layer interface of existing cable TV modulator.

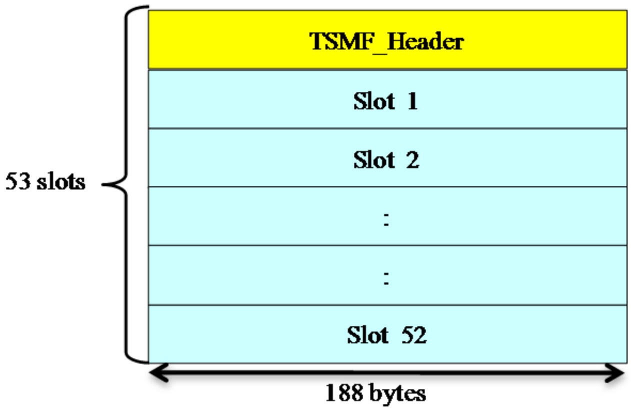

Fig. 4 Framing structure of TSMF.

One of the examples of TSMF (see Appendix I of J.183) is composed of the 53 slots shown in Fig. 4. Each slot is 188 bytes long, which is the same length as a MPEG-2 TS packet. The information identifying bundled MPEG-2 TS streams and other additional information are stored in the TSMF_header located in the first slot of TSMF. The maximum number of MPEG-2 TSs multiplexed in the TSMF is 15.

Since the bitrate for 64 QAM is different from that for 256 QAM, the period to transmit a TSMF frame differs for 64 QAM and 256 QAM, which is 2.73 msec for the former and 2.05 msec for the latter since the symbol rate is 5.274 Mbaud when applied in J.83 Annex C. Therefore, it is necessary to synchronize frames between demodulated signals at the receiver in combinations of multiple 64 and 256 QAM channels. We propose a novel super frame consisting of multiple TSMFs to use channel bonding technology in combinations of multiple 64 and 256 QAM channels.

Fig. 5 outlines the structure of the super frame. The number of TSMFs in a super frame is determined to make the periods of super frames identical regardless of the modulation format.

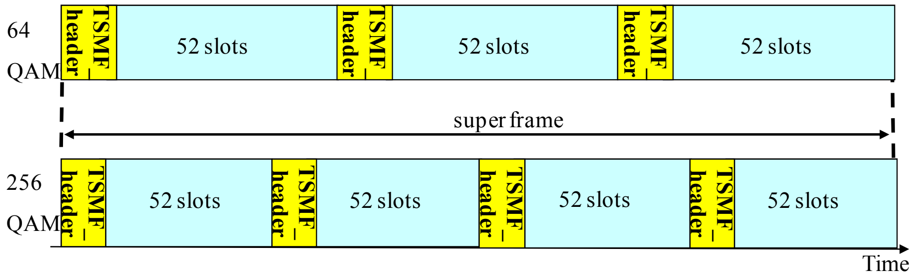

Fig. 5 Structure of super-frame for 64 QAM and 256 QAM.

A super frame for a 64 QAM has three TSMFs and that for a 256 QAM has four TSMFs according to the bit-rate ratio. The modulation scheme of either channel, 64 QAM or 256 QAM, is determined depending on the transmission characteristics of the channel. At the receiver, the arrival time of transmitted signals may differ depending on the propagation delay in each channel. A receiver has to temporally align all relevant signals demodulated from received carriers. The TSMF_header of the first TSMF in every super frame is utilized as a marker to synchronize received signals. The maximum acceptable delay difference between channels is designed so that it is equal to the minimum period of super frames, 8.2 msec, which corresponds to the duration of three TSMF frames for 64 QAM and that of four TSMF frames for 256 QAM. After all signals have been aligned, the receiver restores the split signals to the original MPEG-2 TS of UHDTV.

In order to apply the TSMF structure for channel bonding technology, we define some of the additional parameters in the private_data of TSMF_header in J.183.

For channel bonding functionality, the following parameters (T.B.D.) should be newly defined to have an extension of existing TSMF_header as shown in Table 1:

Table 1 comparison of frame header between J.183 and the extension

TSMF_header (J.183)	Extended TSMF_header (T.B.D.)
TSMF_header() {	* the same as on the left
packet_header()	*
TSMF_sync	*
version_number	*
slot_information()	*
identifiers_information()	*
control_information()	*
relative_TS_information()	*
private_data	group_id
	number_of_carriers
	carrier_sequence
	number_of_frames
	frame_position
CRC	*
}	

group_id: a unique identifier of a group corresponding to bonding channels.

number_of_carriers: the number of carriers for channel bonding in the same group_id.

carrier_sequence: the sequence number of carriers which contain Extended TSMF for channel bonding to restore original TSs

number_of_frames: the number of Extended TSMF in which the super frame contains in the carrier. (ex. 0x03 for 64 QAM, 0x04 for 256 QAM in J.83 Annex C)

frame_position: the sequence number of Extended TSMF in the super frame

5 Channel bonding cable delivery system descriptor

Additional descriptor, which will be located in NIT (Network Information Table), should be defined for receivers to identify the physical layer specification of channel bonding in cable TV network. Table 2 is a proposal of channel bonding cable delivery system descriptor.

Table 2 -channel bonding cable delivery system descriptor (T.B.D.)

Syntax	No. of bits	Identifier
channel_bonding_cable_delivery_system_descriptor(){		
descriptor_tag	8	uimsbf
descriptor_length	8	uimsbf
for(i=0;i<N;i++){		
frequency	32	bslbf
reserved_for_future_use	8	
frame_type	4	uimsbf
FEC_outer	4	bslbf
modulation	8	bslbf
symbol_rate	28	bslbf
FEC_inner	4	bslbf
group_id	8	bslbf
}		
}		

Semantics for channel bonding cable delivery system descriptor

Below are the semantics extracted from Cable delivery system descriptor in J.94 Annex C.

The frame type is to be revised for use in channel bonding cable TV descriptor.

Table C.9/J.94 – Frame type (To be revised)

frame_type bit 3210	Description
0000	Reserved for future use
0001	(N, M) = (53, 15)[a)]
0010	The waveform is limited for channel bonding use.
0011 ~~0010~~ to 1110	Reserved for future use
1111	None – indicates that the waveform does not use TSMF
a) The frame type (N, M) is (53,15) for Annex C. It might be determined for other transmission systems.	

FEC_outer: The FEC_outer is a 4-bit field specifying the outer Forward Error Correction (FEC) scheme used according to Table C.10.

Table C.10/J.94 – Outer FEC scheme

FEC_outer bit 3210	Description
0000	Not defined
0001	No outer FEC coding
0010	RS(204/188)
0011 to 1111	Reserved for future use

modulation: This is an 8-bit field. It specifies the modulation scheme used on a cable delivery system according to Table C.11.

Table C.11/J.94 – Modulation scheme for cable

Modulation (hex)	Description
0x00	Not defined
0x01	16-QAM
0x02	32-QAM
0x03	64-QAM
0x04	128-QAM
0x05	256-QAM
0x06 to 0xFF	Reserved for future use

symbol_rate: The symbol_rate is a 28-bit field giving the 4-bit BCD values specifying 7 characters of the symbol_rate in Msymbol/s where the decimal point occurs after the third character (e.g. 005.2740).

FEC_inner: The FEC_inner is a 4-bit field specifying the inner FEC scheme used according to Table C.12.

Table C.12/J.94 – Inner FEC scheme

FEC_inner bit 3210	Description
0000	Not defined
0001	1/2 conv. code rate
0010	2/3 conv. code rate
0011	3/4 conv. code rate
0100	5/6 conv. code rate
0101	7/8 conv. code rate
1111	No conv. Coding
0110 to 1110	Reserved for future use

ATTACHMENT 2

Performance Evaluation of the proposed channel bonding transmission system for UHDTV distribution

1 Experimental setup

In order to find out how well our proposed method of transmission works, we evaluated the bit error rate (BER) and the functionality of multiple-channel bonding with our prototype. As shown in Fig. 6, a 181.2 Mbps MPEG-2 TS is transmitted with five channels, consisting of a 64 QAM and four 256 QAMs.

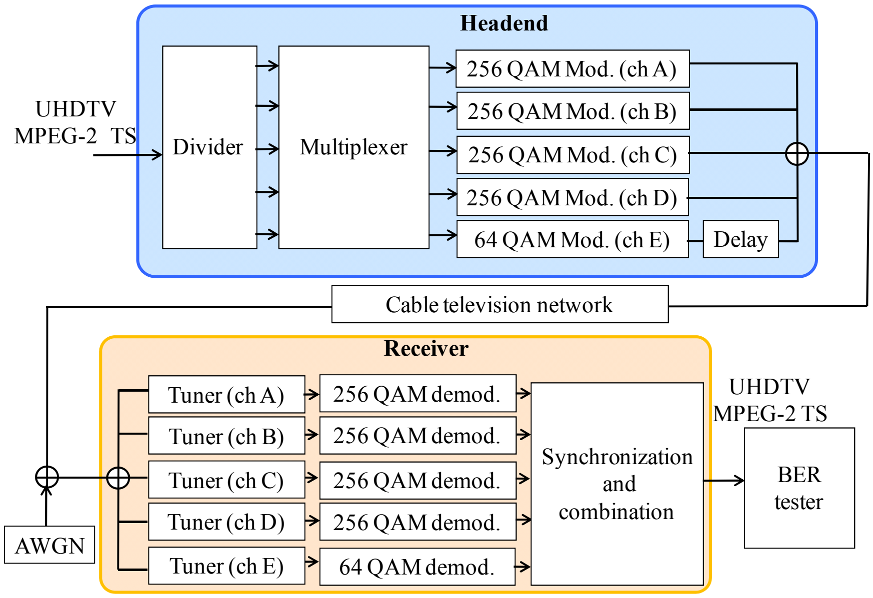

Fig. 6 Experimental setup(indoor test).

Table 3 summarizes the parameters of the transmitted signals. The input power at each tuner of the prototype receiver is – 43.7 dBm. Additive white Gaussian noise (AWGN) was added to all the channels. Fig. 7 is a photograph of the experimental setup for UHDTV transmission.

Table 3 Parameters of Transmitted Signals.

MPEG-2 TS rate	181.2 Mbps
Video coding for UHDTV(8K)	MPEG-4 AVC / H.264
Audio coding	MPEG-2 AAC
Bandwidth per channel	6 MHz
Symbol rate	5.274 Mbaud
Bit rate per channel w/o parity bits for FEC	256 QAM : 38.149 Mbps 64 QAM : 28.611 Mbps
No. of channels	Four channels with 256 QAM and a channel with 64 QAM
Center frequencies (MHz)	256 QAM: 267 MHz, 273 MHz 279 MHz and 285 MHz, 64 QAM: 291 MHz

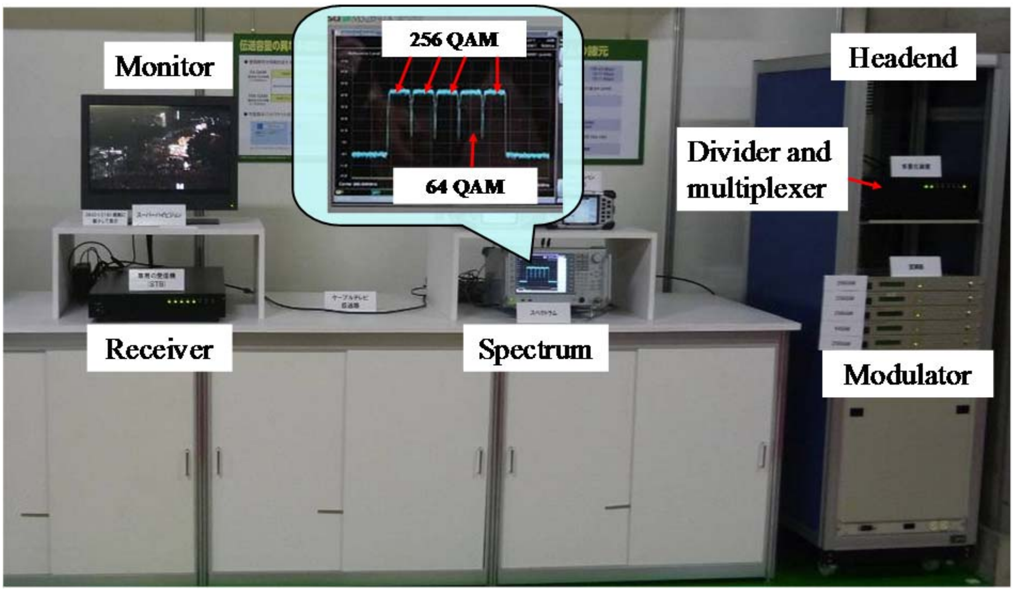

Fig. 7 Setup for UHDTV transmission.

2 BER performance

The theoretical BER of 2^n– QAM with rotational symmetry and gray coding is calculated as:

$$BER = \frac{\sqrt{2^n} + \left(n/2\right) - 1}{\sqrt{2^n} \cdot \left(n/2\right)} \cdot erfc\left(\frac{\delta}{\sqrt{2}\,\sigma}\right), \tag{1}$$

where n is the number of bits per symbol, δ is half the minimum distance between coded symbols, and σ 2 is the variance in AWGN. The BER_{UHDTV}, which is the BER of

a restored MPEG-2 TS at a receiver, is derived as:

$$BER_{UHDTV} = \frac{1}{N_{64QAM} + M_{256QAM}} \left\{ \frac{10}{24} \sum_{i=1}^{N_{64QAM}} erfc\left(\frac{CNR_{64QAM,i}}{42}\right)^{1/2} + \frac{19}{64} \sum_{i=1}^{M_{256QAM}} erfc\left(\frac{CNR_{256QAM,i}}{170}\right)^{1/2} \right\}, \tag{2}$$

where N_{64QAM} and M_{256QAM} are the number of 64 QAM carriers and 256 QAM carriers, respectively. CNR_{64QAM}, i and CNR_{256QAM}, i are the carrier to noise ratios (CNRs) of the i-th channel of 64 QAM and 256 QAM, respectively.

Considering that the 256 QAM channel is less robust than 64 QAM, and the BER of each 256 QAM is dominant degradation factor for the BER_{UHDTV} at higher CNR, Eq. (2) is applied as the theoretical BER_{UHDTV} at a CNR of 28 dB or higher. Fig. 8 plots the measured BER of a large capacity MPEG-2 signal for UHDTV. The transmitter and receiver were located with a back-to-back connection. The required CNR is theoretically 30 dB for the BER of

2×10^{-4} before forward error correction (FEC) to achieve quasi-error free performance using Reed Solomon (204,188) coding. The results demonstrate that the BER of 2×10^{-4} without FEC at the CNR of 30.9 dB is measured and original MPEG-2 TS signal could be restored error free at the CNR or higher at the receiver.

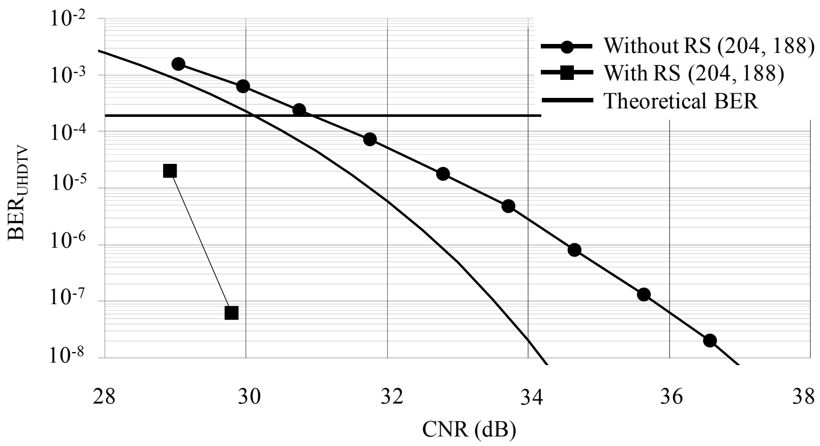

Fig. 8 BER of UHDTV.

3 Time Alignment between Channels

The functionality of adjusting delays between multiple channels was evaluated. An optical fiber was applied to a 64 QAM channel transmission as a delay line at the headend as shown in Fig.6. The delay time varies corresponding to the length of the fiber. For example,

the length of a 500-km long optical fiber caused a delay of 2.5 msec. The received CNR of the signals was adjusted to a constant value of 31.5 dB, independently of the length of the fiber. Fig. 9 plots the BER of signals versus the delay time of a 64 QAM. The experimental

results indicated that the measured BER_{UHDTV} was almost constant and our prototype receiver could successfully compensate for delays and synchronize the super frames of multiple QAM carriers.

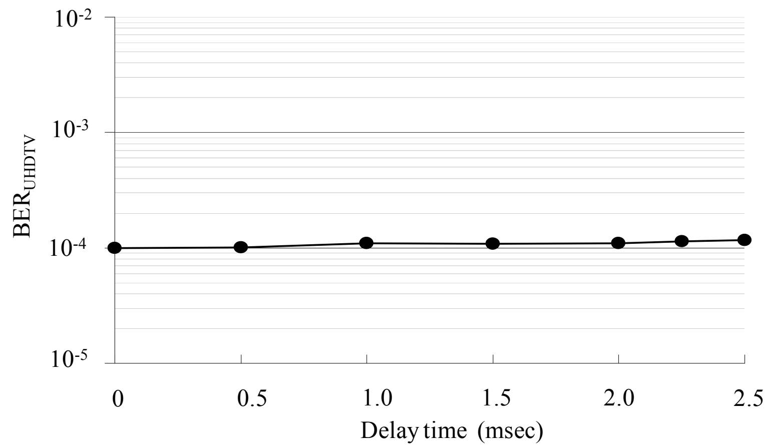

Fig. 9 BER of MPEG-2 TS versus delay time of 64 QAM.

4 Field Trial for UHDTV Cable Television Distribution (February 2012)

This section describes our first field trial for UHDTV distribution with the schemes that were developed through existing cable television distribution networks in Yamanashi prefecture, Japan. The experiments were conducted in the hybrid fiber and coaxial (HFC) and the fiber to the home (FTTH) networks as shown in Fig. 10. The specifications for the cable television facilities used in the experiments are summarized in Table 4.

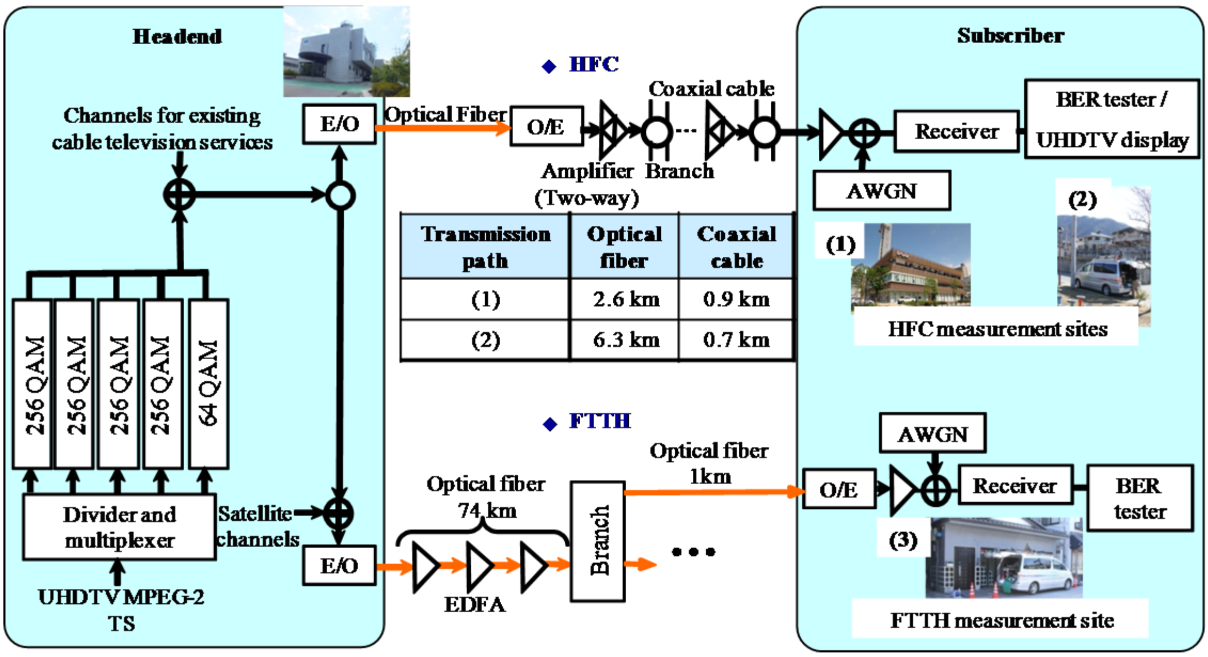

Fig. 10 Experimental setup (Nihon Network Service co., ltd. ,Yamanashi prefecture, Japan).

Table 4 Specifications for Cable Television Facilities of NNS.

Transmission band	HFC : 90 MHz-770 MHz FTTH : 90 MHz-2.6 GHz
Location for experiment	Yamanashi prefecture, Japan

The cable television operator's facilities have 53 channels and the occupied bandwidth is 6 MHz per channel in the HFC network. The frequencies on the HFC network ranged from 90 MHz to 770 MHz and that of the FTTH network is from 90 MHz to 2.6 GHz. Eleven

satellite reception channels were added to the upper band of the UHF cable channels in the FTTH distribution network to operate digital cable television services plus additional satellite master television services. Table 5 lists the parameters applied to the transmitted signal in a field trial. We carried out a 181.2 Mbps MPEG-2 TS transmission with five channels on

the HFC and FTTH networks. Five QAM carriers to transmit UHDTV were mixed at the cable television headend. The signals were transmitted on the HFC and FTTH networks.

Fig. 11 shows the frequency spectrum for the transmission signals at the cable television headend. The transmitted power of each QAM carrier for UHDTV transmission was the same as that of existing cable television operator's channels.

Table 5 Parameters for Transmitted Signal in Field Trial.

MPEG-2 TS rate	181.2 Mbps
Video coding for UHDTV(8K)	MPEG-4 AVC / H.264
Audio coding	MPEG-2 AAC
Bandwidth per channel	6 MHz
Symbol rate	5.274 Mbaud
Bit rate per channel w/o parity bits for FEC	256 QAM : 38.149 Mbps 64 QAM : 28.611 Mbps
No. of channels	Four channels with 256 QAM and one channel with 64 QAM
Freq. of multiple QAM channels (center frequency(MHz))	256 QAM : 695 MHz, 701 MHz, 707 MHz, 713 MHz, 64 QAM : 719 MHz

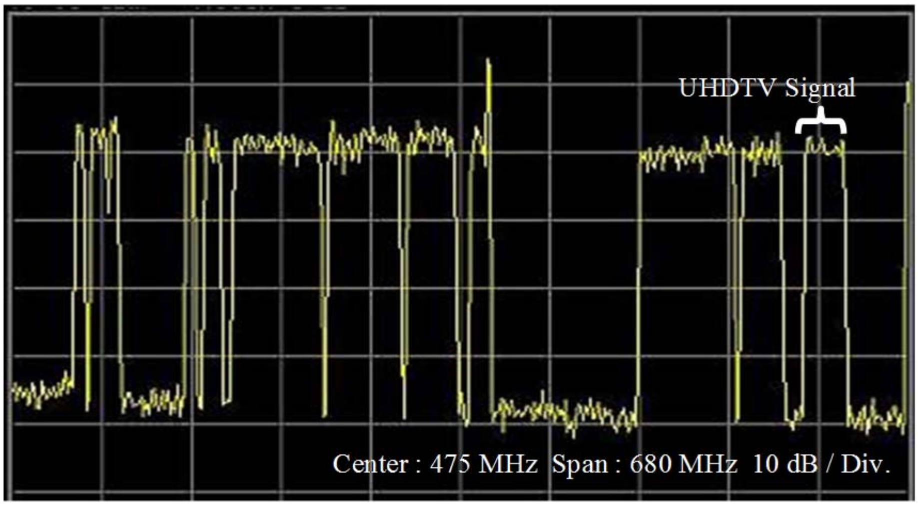

Fig. 11 FDM signals at headend of NNS.

4.1 BER performance

We evaluated the BER of the UHDTV signal transmitted with our prototype to confirm whether the proposed method of transmission worked well in existing cable television networks. As AWGN was added to all the channels at the front-end of the prototype receiver,

the quality of operational cable television signals for subscribers did not degrade during this experiment. We measured the BER at three measurement sites. Two of them were located in the HFC network and one site was chosen from the FTTH network.

Fig. 12 plots the BER without Reed Solomon (204,188) coding at the three measurement sites on the HFC and FTTH networks. The average received CNRs of multiple QAM carriers, without any additional AWGN, was more than 37 dB at each measurement site. The difference between the required CNR for quasi-error-free performance and the average measured CNRs without AWGN was 6 dB or higher. The results revealed that at least 6 dB was permissible for the CNR of the QAM signals to degrade due to further cable distributions at the subscriber's premises. The experimental results revealed that UHDTV distribution with our developed scheme could be achieved on all existing cable television networks having some noise and distortion on the transmission path.

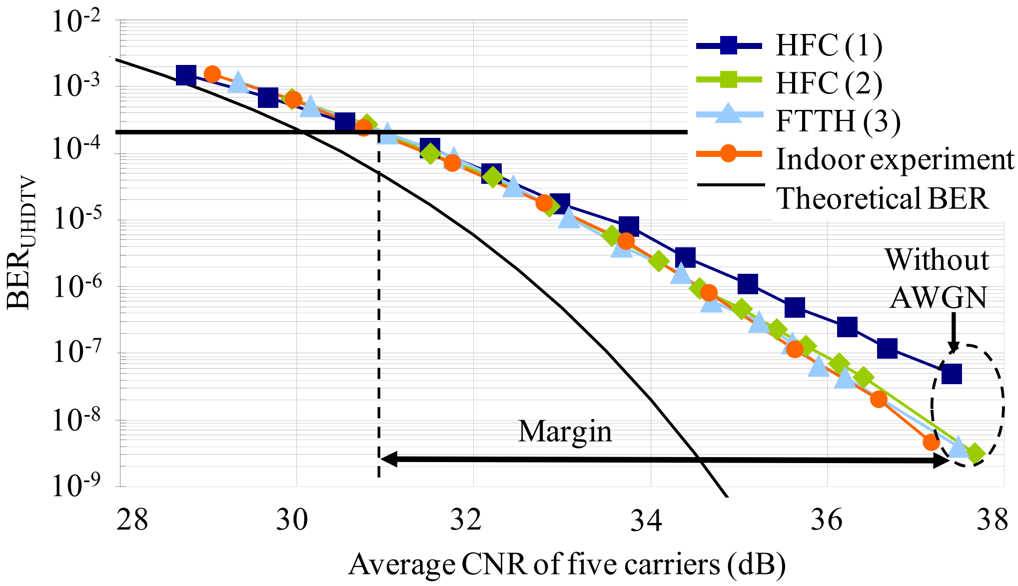

Fig. 12 BER in cable television networks.

4.2 Functionality of Multiple Channel Bonding

We also measured the BERs of five QAM channels separately to clarify that the functionality of channel bonding did not degrade performance at the receiver. The average of five QAM channels' BERs and measured BER with channel bonding are plotted in Fig. 13. The BER with the five channels bonding was used to compare the average of the five QAM channels' BERs. The average of five QAM channels' BERs was in good agreement with the measured BER with channel bonding at the measurement site of HFC (1). This clearly indicates that the receiver could successfully compensate for delays between multiple channels and synchronize the super frames of multiple QAM carriers. And there is almost no loss in implementation caused by our channel bonding scheme at CNRs of 28 dB or higher.

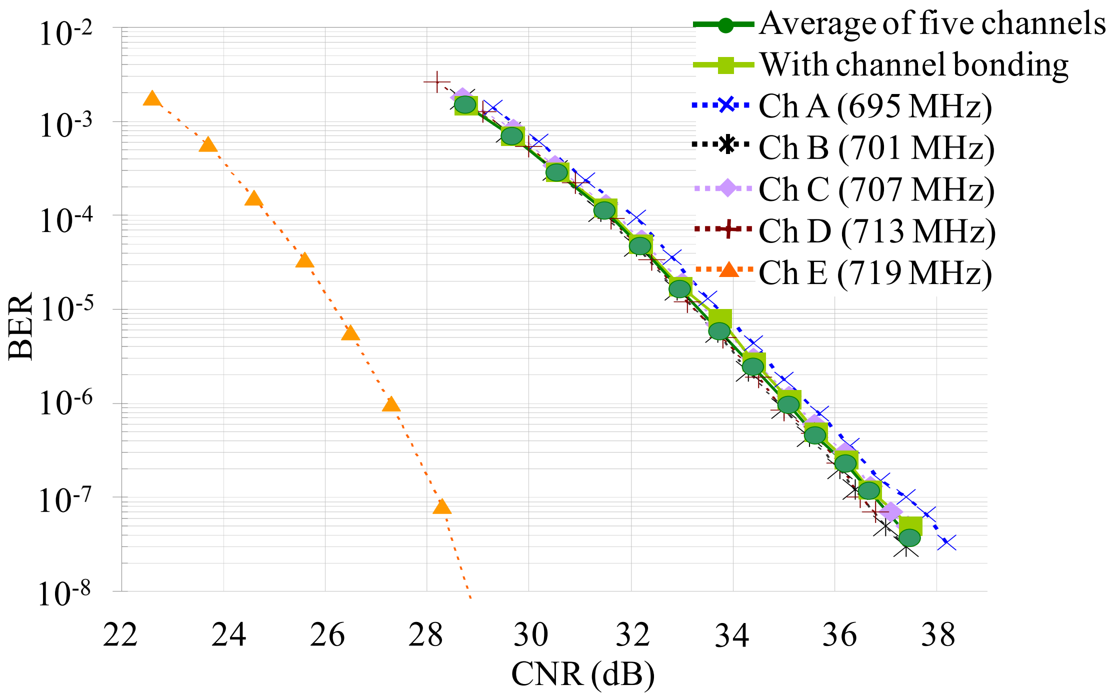

Fig. 13 BER vs. CNR.

4.3 UHDTV (8K) Distribution in NNS network

We also transmitted MPEG-2 TS carrying UHDTV that was divided into a 64 QAM channel and four 256 QAM channels on an HFC network. We demonstrated UHDTV cable television distribution that was stably played on the 85 inch LCD display with 22.2-multichannel sound at one of the HFC reception sites (Fig. 14).

Fig. 14 Demonstration of Received UHDTV.

5 Field Trial for UHDTV Cable Television Distribution (May 2014)

At an open house event of NHK Science and Technology Research Laboratories held in May 2014, we demonstrated UHDTV cable television distribution that was stably played on the 145-inch 8K PDP display through a commercial large-scale cable network in Tokyo.

The trial was conducted in the hybrid fiber and coaxial (HFC) network as shown in Fig. 15. Table 6 lists the parameters applied to the transmitted signal of UHDTV. In total, one hundred four channels ,including three channels carrying an UHDTV signal, were frequency division multiplexed and transmitted from the headend.

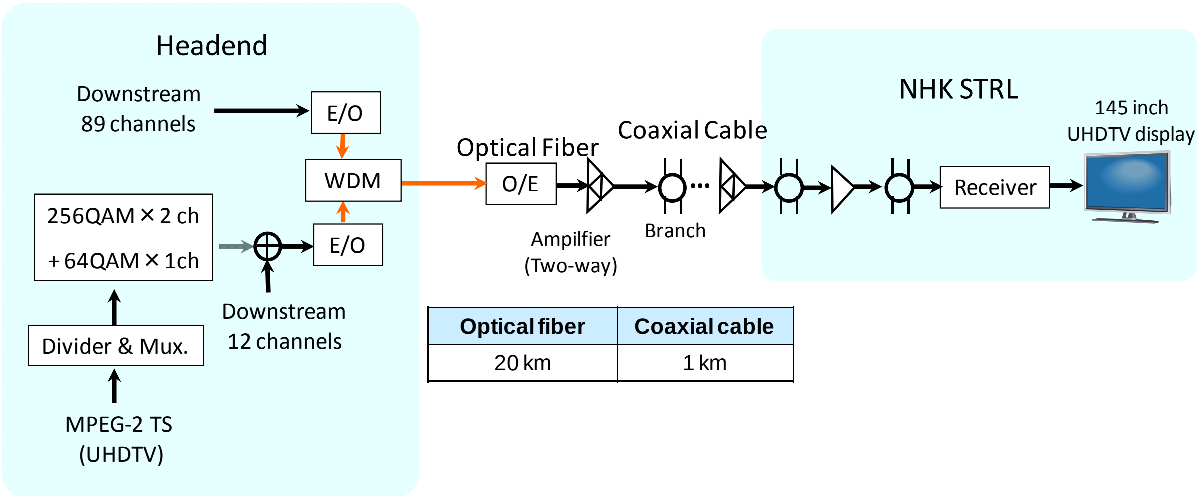

Fig. 15 Experimental setup (Jupiter Telecommunications Co., Ltd.,Tokyo , Japan).

Table 6 Parameters for Transmitted Signal.

MPEG-2 TS rate	100 Mbps
Video coding for UHDTV(8K)	MPEG-4 AVC / H.264
Audio coding	MPEG-2 AAC
Bandwidth per channel	6 MHz
Symbol rate	5.274 Mbaud
Bit rate per channel w/o parity bits for FEC	256 QAM : 38.149 Mbps 64 QAM : 28.611 Mbps
No. of channels	Two channels with 256 QAM and one channel with 64 QAM
Freq. of multiple QAM channels (center frequency(MHz))	256 QAM : 273 MHz, 447 MHz 64 QAM : 635 MHz

5.1 Measurement results

Figure 16 shows the spectrum of FDM signals measured at reception site. Table 7 listed the CNR and BER of three signals carrying UHDTV in this trial. Because the required CNR is 25 dB for 64 QAM and 31.5 dB for 256 QAM before error correction (BER is around 10^{-4}) in our prototype receiver. The received signals had enough margin of CNR to distribute more at subscribers site. As shown in Fig.17, we successfully achieved UHDTV transmission in large scale cable TV network in Tokyo.

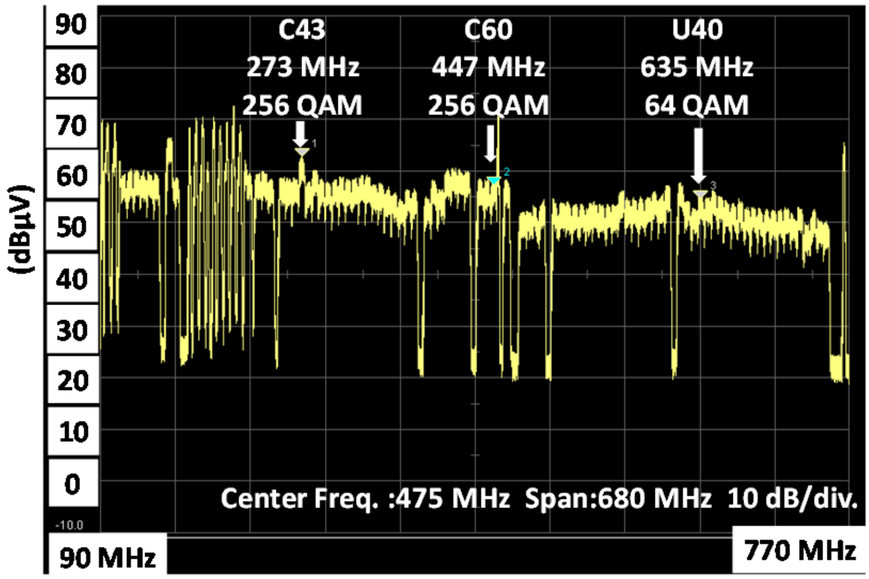

Fig. 16 FDM signals at reception site (NHK STRL).

Table 7 BER performance of three carriers before channel bonding.

Center Freq. [MHz]	Modulation	CNR [dB]	BER w/o FEC
273	256 QAM	37.0 dB	4×10^{-7}
447	256 QAM	36.0 dB	2×10^{-6}
635	64 QAM	33.4 dB	Below 10^{-8}

Fig. 17 Received UHDTV signal on 145 inch 8K PDP display

Acknowledgment

NHK would like to thank Nihon Network Service co., ltd.(NNS) and

Jupiter Telecommunications Co., Ltd. (J:COM) for providing their cable television network facilities for field trial of the UHDTV cable distribution.