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ENGLISH TRANSLATION

TRANSMISSION SYSTEM FOR ADVANCED WIDE BAND DIGITAL SATELLITE BROADCASTING

ARIB STANDARD

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Association of Radio Industries and Businesses

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Foreword

The Association of Radio Industries and Businesses (ARIB) investigates and summarizes the basic technical requirements for various radio systems in the form of “ARIB Standards”. These standards are developed with the participation of and through discussions amongst radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

ARIB Standards include “government technical regulations” (mandatory standard) that are set for the purpose of encouraging effective use of frequency and preventing interference with other spectrum users, and “private technical standards” (voluntary standards) that are defined in order to ensure compatibility and adequate quality of radio equipment and broadcasting equipment as well as to offer greater convenience to radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

This ARIB Standard is developed for “TRANSMISSION SYSTEM FOR ADVANCED WIDE BAND DIGITAL SATELLITE BROADCASTING”. In order to ensure fairness and transparency in the defining stage, the standard was set by consensus at the ARIB Standard Assembly with the participation of both domestic and foreign interested parties from radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

ARIB sincerely hopes that this ARIB Standard will be widely used by radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

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Although this ARIB Standard contains no specific reference to any Essential Industrial Property Rights relating thereto, the holders of such Essential Industrial Property Rights state to the effect that the rights listed in the Attachment 1 and 2, which are the Industrial Property Rights relating to this standard, are held by the parties also listed therein, and that to the users of this standard, in the case of Attachment 1, such holders shall not assert any rights and shall unconditionally grant a license to practice such Industrial Property Rights contained therein, and in the case of Attachment 2, the holders shall grant, under reasonable terms and conditions, a non-exclusive and non-discriminatory license to practice the Industrial Property Rights contained therein. However, this does not apply to anyone who uses this ARIB Standard and also owns and lays claim to any other Essential Industrial Property Rights of which is covered in whole or part in the contents of the provisions of this ARIB Standard.

Attachment 1 (Selection of Option 1)
(N/A)

Attachment 2 (Selection of Option 2)

Patent Applicant/ Holder	Name of Patent	Registration No./ Application No.	Remarks
Japan Broadcasting Corporation (NHK)	デジタルデータの受信装置*1	特許第 2912323 号	Japan
	ディジタル伝送方法および送信、受信装置*1	特許第 3253524 号	Japan
	データ伝送装置およびデータ処理装置*1	特許第 3352940 号	Japan
	ＡＦＣ回路、キャリア再生回路および受信装置*1	特許第 3504470 号	Japan
	送信装置及び受信装置*1	特許第 3816397 号	Japan
	Submitted comprehensive confirmation of patents for ARIB STD-B44 Ver2.0*2		
Sony Corporation	Submitted comprehensive confirmation of patents for ARIB STD-B44 Ver2.0*2		
Panasonic Corporation	Submitted comprehensive confirmation of patents for ARIB STD-B44 Ver2.0*2		

*1：Valid for ARIB STD-B44 Ver1.0 (received on July 17, 2009)
*2：Valid for the revised parts of ARIB STD-B44 Ver2.0 (received on July 24, 2014)

TOTAL CONTENTS

TRANSMISSION SYSTEM
FOR ADVANCED WIDE BAND DIGITAL
SATELLITE BROADCASTING

Transmission system for advanced wide band digital satellite broadcasting

Contents

Chapter 1: General

1.1 Purpose

The purpose of this standard is to specify the transmission system for advanced wide band digital satellite broadcasting.

1.2 Scope

This standard applies to digital broadcasting using the transmission system for advanced wide band digital satellite broadcasting.

1.3 References

1.3.1 Normative References

The followings are those documents that a part of the items, provided in the following documents, is quoted in this standard.

- "Rules on Radio Equipment (The rule of Radio Management Commission No.18, 1950)" (Last Revision: July 3, 2014. Hereinafter referred to as "Rules on Radio Equipment.")
- "Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance of the Ministry of Internal Affairs and Communications No.87, 2011)" (Revision: Dec. 10, 2013, Revision: July 3, 2014. Hereinafter referred to as "Ordinance.")
- "On specifying the structure of TMCC information (Notice of the Ministry of Internal Affairs and Communications No. 304, 2011)" (Revision: Dec. 10, 2013, Revision: July 3, 2014. Hereinafter referred to as "Notice.")

In this standard, the items provided in the normative references are shown in boxes, in order to refer to them easily. Also, a description in the box does not completely agree with the statement in the normative references, because of supplemental explanations for technical contents and so on.

The modulation scheme of the advanced wide band digital satellite broadcasting specified in the Ordinance and the Notice is shown in Annex A. The requirement of frequency utilization for advanced BS digital broadcasting and advanced wide band CS digital broadcasting is shown in Annex B.

1.3.2 Informative References

The following are other standards relating to this standard.

- ARIB STD-B10 "Service Information for Digital Broadcasting System"
- ARIB STD-B32 "Video Coding, Audio Coding and Multiplexing Specifications for Digital Broadcasting"
- ARIB STD-B60 "MMT-Based Media Transport Scheme in Digital Broadcasting Systems"

1.4 Terminology

1.4.1 Definitions

Wide band transmission system: Wide band transmission system which is provided in Chapter 5, Clause 2 or Chapter 6, Clause 3 in the Standard system of

	transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011)
Advanced wide band transmission system:	Advanced wide band transmission system which is provided in Chapter 5, Clause 3 or Chapter 6, Clause 5 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011)
BS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by wide band transmission system, using radio wave whose frequency is more than 11.7GHz and less than or equal to 12.2GHz which are provided in Chapter 5, Clause 2 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011) and ARIB STD-B20
Advanced BS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by advanced wide band transmission system, using radio wave whose frequency is more than 11.7GHz and less than or equal to 12.2GHz which are provided in Chapter 5, Clause 3 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011) and this standard
Wide band CS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by wide band transmission system, using radio wave whose frequency is more than 12.2GHz and less than or equal to 12.75GHz which are provided in Chapter 6, Clause 3 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011) and ARIB STD-B20
Advanced wide band CS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by advanced wide band transmission system, using radio wave whose frequency is more than 12.2GHz and less than or equal to 12.75GHz which are provided in Chapter 6, Clause 5 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011) and this standard
Narrow band CS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by wide band transmission system, using radio wave whose frequency is more than 12.2GHz and

	less than or equal to 12.75GHz which are provided in Chapter 6, Clause 2 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011)
Advanced narrow band CS digital broadcasting:	Standard television broadcast, High-definition television broadcast, Ultra high definition television broadcast, very high frequency broadcast and data broadcast, which the satellite broadcast station broadcasts by advanced wide band transmission system, using radio wave whose frequency is more than 12.2GHz and less than or equal to 12.75GHz which are provided in Chapter 6, Clause 4 in the Standard system of transmission on digital broadcasting among standard television broadcast and so on (Ordinance No.87, 2011)
main signal:	connected signal excluding one byte of the head in TS packet, or signal which connects TLV packet
slot header:	region of control information about main signal
stuffing bit:	bit sequence which is added in order to adjust bit number of main signal, and six bits of '1' (111111)
slot:	signal that error correcting outer-code and stuffing bit are added to main signal and slot header, and that is error correcting inner-coded against the signal to which energy dispersal signals are added
frame synchronization signal:	signal that is added to the head of odd slot in order to identify the head of the frame
slot synchronization signal:	signal that is added to the head of even slot in order to identify the head of the slot
main signal:	signal that is generated as a unit of slot
TMCC information:	control information about transmission and multiplex
TMCC data:	signal that outer-code is added to TMCC information
TMCC signal:	error correcting inner-coded signal that energy dispersal signal is added to TMCC data
Pilot data:	information about phase and amplitude of modulation signal on transmission
Pilot signal:	Signal that the information on Pilot data is mapped to signal points and energy dispersal signal is added to. This signal can be used as the pilot signal for restrain of deterioration of transmission characteristics in non-linear amplifying.

1.4.2 Abbreviations

8PSK	8 Phase Shift Keying
APSK	Amplitude and Phase Shift Keying
BPSK	Binary Phase Shift Keying
BCH Code	Bose-Chaudhuri-Hocquenghem Code
CAT	Conditional Access Table
IMUX	Input Multiplexer
LDPC Code	Low Density Parity Check Code
LNA	Low Noise Amplifier
LNB	Low Noise Block Converter
LNC	Low Noise Converter
MPEG	Moving Picture Experts Group
NIT	Network Information Table
ODU	Outdoor Unit
OMUX	Output Multiplexer
PAT	Program Association Table
PCR	Program Clock Reference
PMT	Program Map Table
PRBS	Pseudo Random Binary Sequence
PSI	Program Specific Information
QPSK	Quadrature Phase Shift Keying, Quadri Phase Shift Keying Quaternary Phase Shift Keying
SI	Service Information
TLV	Type Length Value
TMCC	Transmission & Multiplexing Configuration Control
TS	Transport Stream
TWTA	Traveling Wave Tube Amplifier

Chapter 2: System Overview

Summary of the adopted channel coding scheme is shown in Table 2-1. As for error correcting code, the LDPC code was adopted which has a strong ability of error correction. As for modulation scheme, π/2 shift BPSK (π/2 shift binary phase shift keying) which is so improved as to make bandwidth expansion by non-linear channel decrease, QPSK (quadruple phase shift keying) and 8PSK (eight phase shift keying) which are also adopted to the wide band transmission system, 16APSK (sixteen value amplitude and phase shift keying) and 32APSK (thirty two value amplitude and phase shift keying) which enables to transmit more data are adopted to be used. Especially about APSK, as the transmitted signal often deteriorates by non-linear characteristics of TWTA in the transponder, pilot signal was introduced which enables optimal LDPC decoding even in the environment of non-linear effect. As for roll-off rate, by adopting factor 0.03 of steep filter characteristics, high symbol rate can be operated. As for Transmission and Multiplexing Configuration Control signal (TMCC signal), other than the function of the TMCC signal in the wide band transmission system, the function of control to transmit variable length packet such as IP packet etc., was also added.

Table 2-1: Summary of Channel coding scheme

Item		Description
Modulation scheme		π/2 shift BPSK, QPSK, 8PSK, 16APSK, 32APSK*[1]
Forward error correction	Inner code	LDPC (code length: 44880)
	Coding rate (approximate value)	41/120 (1/3), 49/120 (2/5), 61/120 (1/2), 73/120 (3/5), 81/120 (2/3), 89/120 (3/4), 93/120 (7/9), 97/120 (4/5), 101/120 (5/6), 105/120 (7/8), 109/120 (9/10)
	Outer code	BCH (65535, 65343, t=12) shortened code
TMCC signal	Modulation scheme	π/2 shift BPSK
	Inner code	LDPC(31680, 9614): LDPC(44880, 22184) shortened code
	Outer code	BCH(9614, 9422): BCH(65535, 65343) shortened code
	Control unit	Transmission control in units of slots
	Control information	- control of modulation and coding rate (layered transmission is available by this function) - control of multiplex data format (MPEG-2 TS, variable length packet (TLV)) - control of starting up for emergency warning broadcast system - control of plural independent TS identifications - information of site diversity - information of set up working point for satellite transponder
Frame structure		- 120 slots / frame - slot length of integral number times of the length of MPEG-2 TS
Symbol rate		33.7561 Mbaud
Roll-off factor		0.03

Others	- By using the synchronization reinforced burst signal also as a modulation signal modulated by TMCC signal, the capacitance of TMCC is expanded from 384 bits of BS and wide band CS digital broadcast to 9422 bits. - By using pilot signal, the deterioration of receiving performance by the non-linear characteristics of the satellite is improved.

*1: In order to secure a proper service availability on the worst month with more expansion of transmission capacity, a receiving antenna with bigger aperture is needed.

Chapter 3: Channel coding

3.1 Basic structure of channel coding

Basic structure of channel coding is shown in fig. 3.1-1. MPEG-2 TS, TLV stream (TS1. TS2, …, TSn, TLV1, TLV2, …, TLVm) and transmission parameters (TMCC1, TMCC2, …, TMCCk) for each stream are inputted as signals to be transmitted, and TMCC information is generated by using these transmission parameters. Also, a frame based on TMCC information is formed, and main data and TMCC information are processed in frame units. After forming a frame, main data is outer coded, energy dispersed and inner coded. In the case that modulation scheme is 8PSK, 16APSK or 32APSK, bit interleaving is performed. TMCC information is also outer coded, energy dispersed and inner coded almost as the same. In addition of these signals, synchronization signal (frame synchronization signal, slot synchronization signal) and energy dispersed pilot signal are modulated by each assigned modulation scheme, and modulation signal is generated by time division multiplexing.

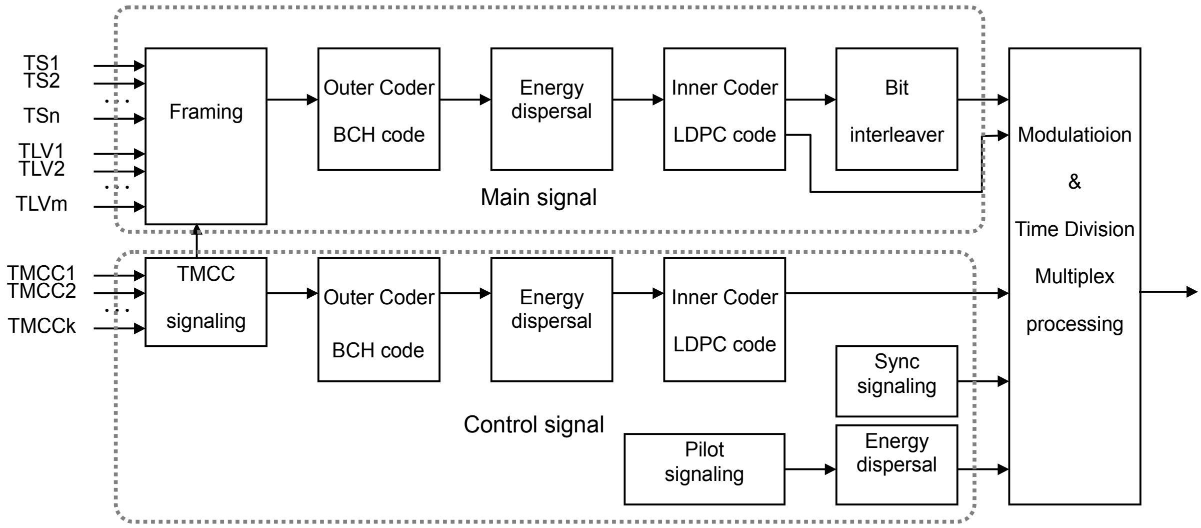


Fig. 3.1-1: Basic structure of channel coding (signal processing)

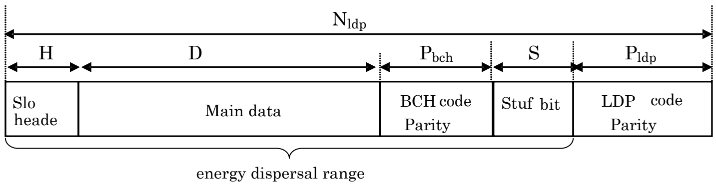
3.2 Frame structure of multiplex signal

(1) Frame structure of main signal

The procedure of structuring main signal is shown in Fig 3.2-1. The main signal before energy dispersal is those signal which is generated as a unit of slot by adding stuffing bit to main data and slot header. Here, main data is a connected signal except for head one byte of TS packet, or connected signal of TLV packet. Slot header is an area of control information on main data. Stuffing bit is an added bit sequence (6 bits '1' (111111)) in order to adjust bit number of error correcting outer-code and main signal. The main signal after energy dispersal is an error correcting inner-coded signal for the main signal to which energy dispersal signal is added. The bit structure of slot for coding rate of each inner code is shown in Table 3.2-1.

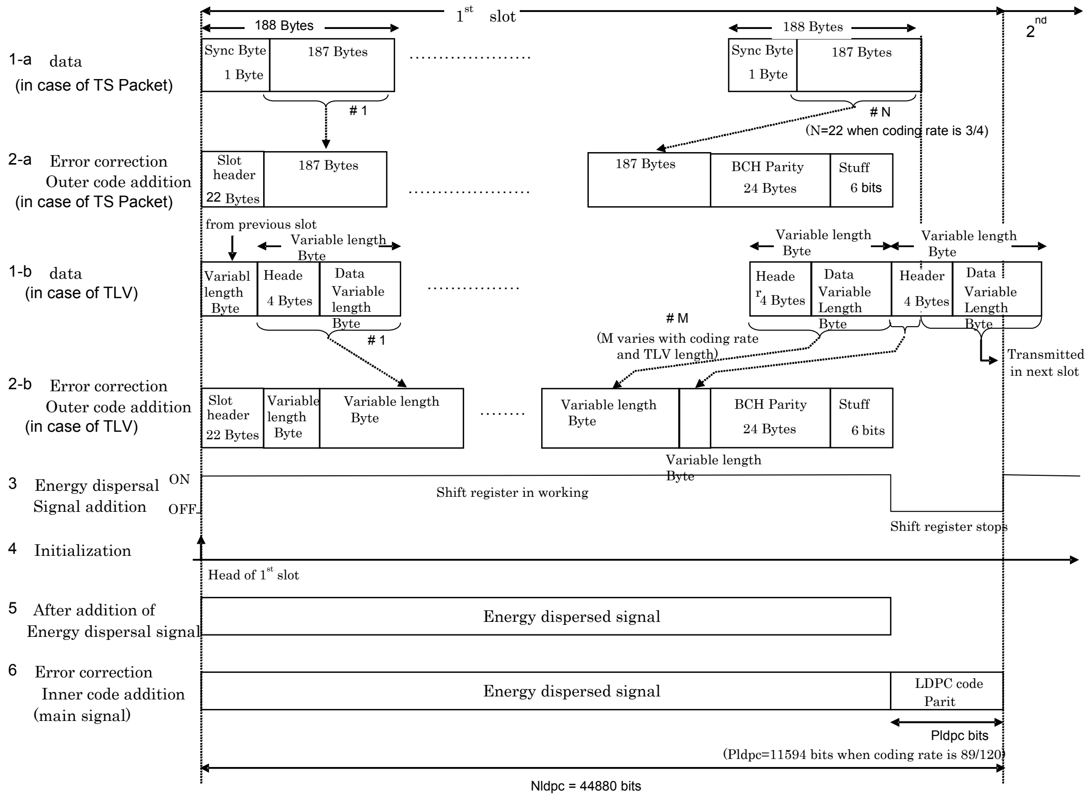
Setting transmission control by TMCC information is updated by each frame composed of 120 slots shown in Fig. 3.2-2, and transmission mode (modulation, coding rate of inner code, back off of satellite output), transmission stream ID etc., are designated by each slot position in a frame.

Table 3.2-1: Bit distribution of slot for each coding rate



Coding rate	Slot header [H] bits	Main data [D] bits	BCH parity [P_{bch}] bits	Stuff bit [S] bits	LDPC Parity [P_{ldpc}] bits	LDPC after coding [N_{ldpc}] bits
41/120	176	14960	192	6	29546	44880
49/120	176	17952	192	6	26554	44880
61/120	176	22440	192	6	22066	44880
73/120	176	26928	192	6	17578	44880
81/120	176	29920	192	6	14586	44880
89/120	176	32912	192	6	11594	44880
93/120	176	34408	192	6	10098	44880
97/120	176	35904	192	6	8602	44880
101/120	176	37400	192	6	7106	44880
105/120	176	38896	192	6	5610	44880
109/120	176	40392	192	6	4114	44880

(Article 60, paragraph 2 of Ordinance, Appended Table 66)



Note 1: In case that the slot is composed of TS packet, all bits of the slot are set to '1', and in case that the slot is composed of TLV packet, Appendix 1 is to be applied.

2: TLV packet may extend over plural slots.

Appendix 1: The structure of slot header in the slot composed of TLV packet

Head TLV indication	Undefined area
6	160

Transmission order →

Note 1: Head TLV indication indicates the head position of first TLV which is included in each slot immediately after the reservation of future, and the head byte position of first TLV in the slot is indicated as the number of byte from slot head except slot header. However, if the head byte does not exist, the value is set to 0xFFFF.

2: Undefined area is set to '1' of all bits.

(Article 60, paragraph 1 of Ordinance, Appended Table 65)

Fig. 3.2-1: Generation of main signal

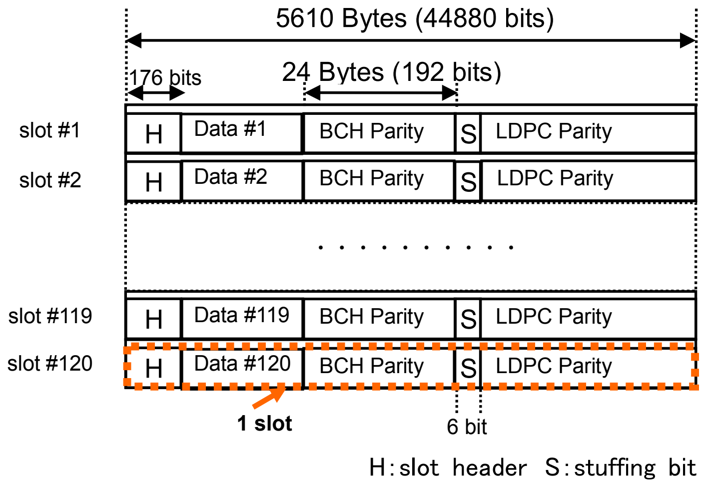


Fig. 3.2-2: Main signal

(2) Allocation rule of transmission mode for slot

Allocation rule of modulation scheme for slot is shown in Table 3.2-2 and Table 3.2-3. Modulation schemes for slot are allocated in a unit of five slots, and in case of transmission by combining multiple transmission modes, they are sequentially allocated to the slots beginning with slot #1 by ascending order, from

(a) higher modulation level for the modulation schemes, and
(b) higher inner coding rate for the same modulation scheme

by using TMCC information.

A maximum of eight combinations of modulation scheme and inner coding rate can be used together in one frame, as specified by the TMCC information. If the modulation scheme which requires null (dummy) slot is allocated, effective slots are to be placed at the head of that group of allocated 5 slots. Examples of slot allocations are shown in Fig. 3.2-3.

Table 3.2-2: Slot allocation rule (π/2 shift BPSK, QPSK, 8PSK, 16APSK)

Modulation	Slot unit	Valid slot number	Dummy slot number
16APSK	5	4	1
8PSK	5	3	2
4PSK	5	2	3
π/2 shift BPSK	5	1	4

(Article 59 of Ordinance, Appended Table 62, Appendix 2)

Table 3.2-3: Slot allocation rule (32APSK)

Modulation	Slot unit	Valid slot number	Dummy slot number
32APSK	5	5	0

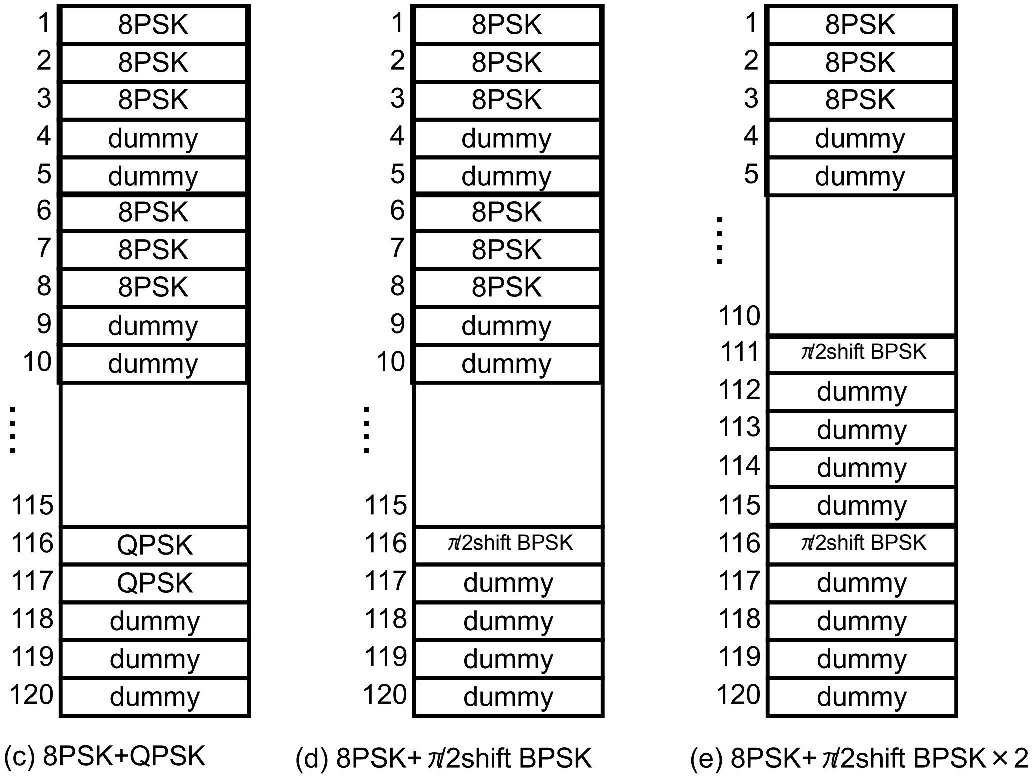


Fig. 3.2-3: Examples of slot allocation

(3) Synchronization signal, pilot data, and frame structure of TMCC signal

Frame structure of control signal is shown in Fig. 3.2-4. Multiplex frame of control signal is formed by 2880 bits of synchronization signals which are composed of frame synchronization signal and slot synchronization signal, 3840～19200 bits of pilot data, and 31680 bits of TMCC signals.

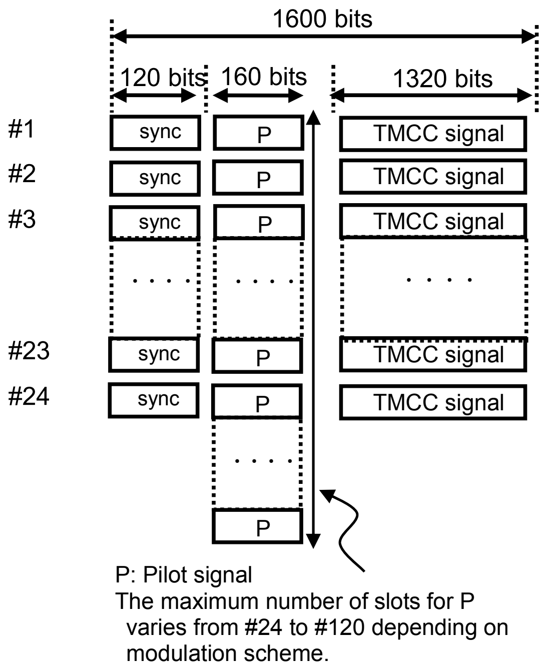
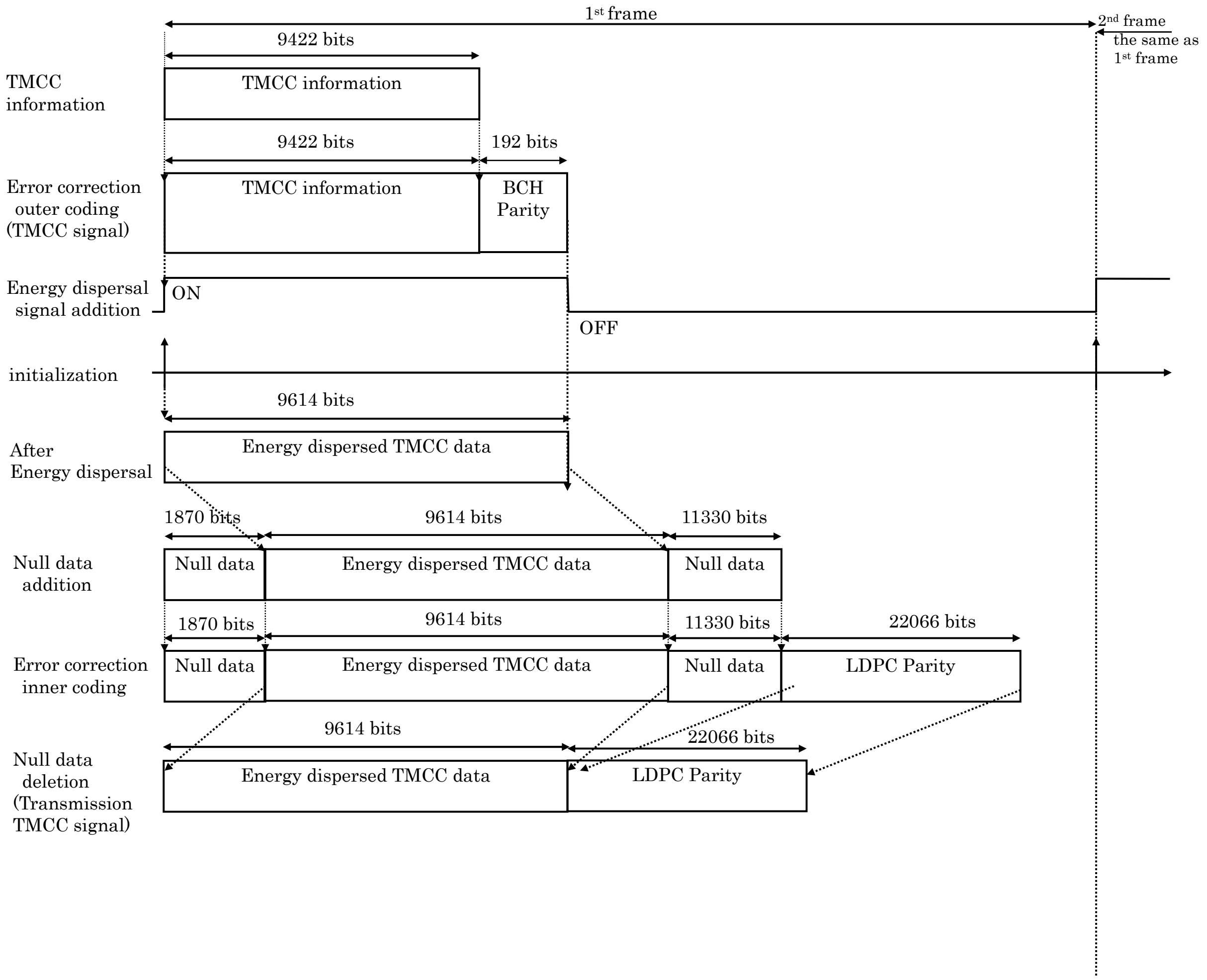


Fig. 3.2-4: Frame structure of sync signal, pilot data, and TMCC signal

A generation process of TMCC signal is shown in Fig. 3.2-5. TMCC signal is a signal of 31680 bits length that energy dispersal signal is added to TMCC data which is composed of 9422 bits of TMCC information and 192 bits of BCH parity, and 22066 bits of LDPC parity are added. An explanation on error correction coding is described in Clause 3.5.



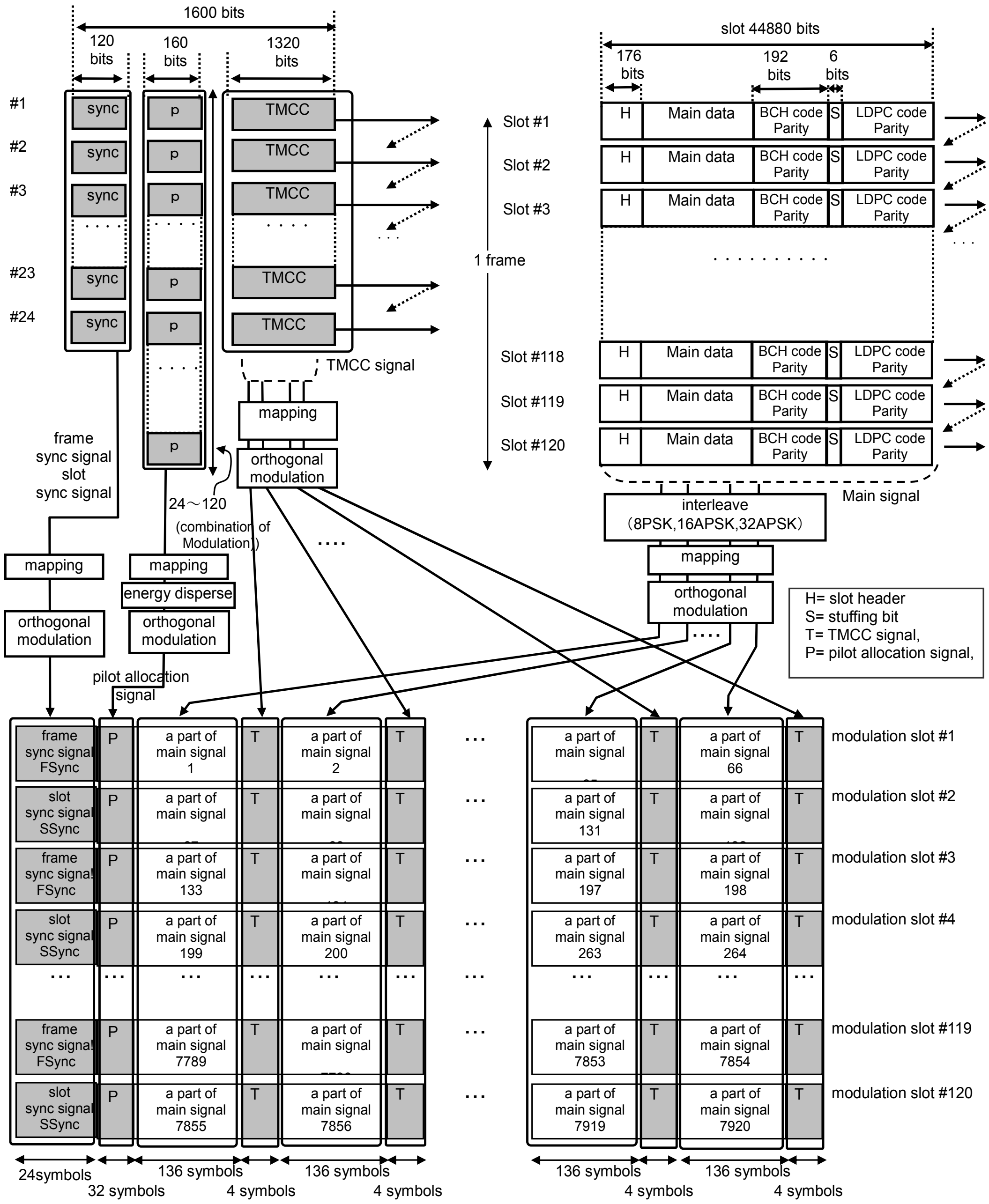
Note 1: the value of the null data are all set to '0'.

(Article 61, paragraph 1 of Ordinance, Appended Table 67)

Fig. 3.2-5: Generation process of TMCC signal

3.3 Frame structure of modulation signal

Block diagram for generating modulation signal from frame structured multiplex signal and frame structure of modulation signal are shown in Fig. 3.3-1.



Note: About frame synchronization signal FSync, !FSync and slot synchronization signal SSync, set FSync=52F866h, !FSync=AD0799h, SSync=36715Ah. ("h" means hexadecimal.)

Fig. 3.3-1: Generation of modulation signal and frame structure of modulation signal

Carrier is modulated by main signal, TMCC signal, synchronization signal which is composed of frame synchronization signal and slot synchronization signal, and pilot signal which is the pilot data that energy dispersal signal is added to.

As for carrier modulation scheme, π/2 shift BPSK, QPSK, 8PSK, 16APSK or 32APSK are applied to main signal and pilot signal. π/2 shift BPSK is applied to TMCC signal, frame synchronization signal and slot synchronization signal.

3.4 Error correction

(1) Outer code coding scheme

The method of outer coding is BCH(65535, 65343) shortened code with correcting ability t=12. The generator polynominal for BCH code before shortening is expressed as the product of all the polynominals listed in Table 3.4-1.

Table 3.4-1: Polynominal list of BCH code

$g_1(x)$	$1+x+x^3+x^{12}+x^{16}$
$g_2(x)$	$1+x^2+x^3+x^4+x^8+x^9+x^{11}+x^{12}+x^{16}$
$g_3(x)$	$1+x^2+x^3+x^7+x^9+x^{10}+x^{11}+x^{13}+x^{16}$
$g_4(x)$	$1+x+x^3+x^6+x^7+x^{11}+x^{12}+x^{13}+x^{16}$
$g_5(x)$	$1+x+x^2+x^3+x^5+x^7+x^8+x^9+x^{11}+x^{13}+x^{16}$
$g_6(x)$	$1+x+x^6+x^7+x^9+x^{10}+x^{12}+x^{13}+x^{16}$
$g_7(x)$	$1+x+x^2+x^6+x^9+x^{10}+x^{11}+x^{15}+x^{16}$
$g_8(x)$	$1+x+x^3+x^6+x^8+x^9+x^{12}+x^{15}+x^{16}$
$g_9(x)$	$1+x+x^4+x^6+x^8+x^{10}+x^{11}+x^{12}+x^{13}+x^{15}+x^{16}$
$g_{10}(x)$	$1+x+x^2+x^4+x^6+x^8+x^9+x^{10}+x^{11}+x^{15}+x^{16}$
$g_{11}(x)$	$1+x^6+x^8+x^9+x^{10}+x^{13}+x^{14}+x^{15}+x^{16}$
$g_{12}(x)$	$1+x+x^2+x^3+x^5+x^6+x^7+x^{10}+x^{11}+x^{15}+x^{16}$

(Article 60, Paragraph 2 of Ordinance, Appended Table 66)

The BCH coding for making code words $c=(m_{k_{bch}-1}, m_{k_{bch}-2}, \cdots, m_1, m_0, d_{n_{bch}-k_{bch}-2}, \cdots, d_1, d_0)$ of the information matrix $m=(m_{k_{bch}-1}, m_{k_{bch}-2}, \cdots m_1, m_0)$ is performed as follows:

- Multiply message polynomial $m(x)=m_{k_{bch}-1}x^{k_{bch}-1}+m_{k_{bch}-2}x^{k_{bch}-2}+\cdots+m_1x+m_0$ by $x^{n_{bch}-k_{bch}}$.
- Take $d(x)=d_{n_{bch}-k_{bch}-1}x^{n_{bch}-k_{bch}-1}+\cdots+d_1x+d_0$ to be the remainder of a division

with $x^{n_{bch}-k_{bch}}m(x)$ as dividend and generator polynomial $g(x)$ as divisor.

- Take $c(x)=x^{n_{bch}-k_{bch}}m(x)+d(x)$ to be the code word polynomial.

(2) Inner code coding scheme

The method of inner coding is LDPC with a code length of 44880 bits and coding rates are 11 as listed in Table 3.4-2.

Table 3.4-2: Coding rate of inner code

Coding rate	Approximate value
41/120	1/3
49/120	2/5
61/120	1/2
73/120	3/5
81/120	2/3
89/120	3/4
93/120	7/9
97/120	4/5
101/120	5/6
105/120	7/8
109/120	9/10

Here, the coding rates in the table are "true value", but approximate values are also written by a simple fraction.

The procedure of inner code coding is shown below. In the following explanation, n_{ldpc} denotes LDPC code length, and k_{ldpc} denotes the length after subtracting the number of parity length from the LDPC code length.

Let parity check bit be p_n $(n=0,1,........,n_{ldpc}-k_{ldpc}-1)$, and information bit be i_m $(m=0,1,........,k_{ldpc}-1)$. Then, LDPC code is calculated iteratively by every 374 bits on the information bit in the operations below.

Here, initial value of parity check bit is set to zero: $p_0=p_1=p_2=...=p_{n_{ldpc}-k_{ldpc}-1}=0$.

$p_x = p_x \oplus i_m$ (m=0, 374, 748, ...)

$p_y = p_y \oplus i_m$ (m=1, ...373, 375, ...747, 749, ...)

After operations on all information bits are finished, p_n is given by the following.

$p_0 = p_0 \oplus i_0$

$p_n = p_n \oplus p_{n-1}$ $(n=1,........,n_{ldpc}-k_{ldpc}-1)$

Note 1: ⊕ denotes the operator of exclusive-or.

2: x denotes the position of parity check bit specified by the (m/374+1)th row written in Appendix 1.

3: y denotes the position of parity check bit specified by

$$\{x+(m \bmod 374)\times q\} \bmod (n_{ldpc}-k_{ldpc}).$$

Here, x denotes the position of parity check bit specified by the ([m/374]+1)th row written in Appendix 1. ([ ] means integral part.)

Also, q denotes the constant specified depending on coding rate, and is shown in the following table.

Coding rate	q
41/120	79
49/120	71
61/120	59
73/120	47
81/120	39
89/120	31
93/120	27
97/120	23
101/120	19
105/120	15
109/120	11

Appendix 1 Bit position of parity check

In case of coding rate 41/120

625 1750 2125 3750 15250 18750 19250 27375 29000
4375 6750 7125 7500 13125 16250 19375 28875 29250
1500 6125 6533 13500 23500 25500 26000 27625 28750
6500 7625 9625 14875 16875 18000 18500 27500 27750
250 4204 6000 12500 17125 21204 21875 22079 23750
125 9125 11250 11875 12000 14000 14125 15875 24125
4875 9875 11000 11125 13000 16500 19000 25125 26375
2941 8500 12362 15125 16375 18250 20250 21375 24000
0 750 19875 21625 21750 22125 23250 27329 28375
875 2750 3125 8625 18875 20000 23375 26125 26829
500 5533 18375 18625 20125 20375 24625 25250 27875
1250 10000 10658 17000 17750 19500 19625 25875 29375
2250 3000 4000 5250 9375 11750 14750 24875 29500
5000 5750 12375 16625 17579 18125 21250 22625 26625
2500 3783 4625 9250 10875 15500 17625 22375 28500
1125 5500 9737 13329 13750 13875 16829 22750 24375
375 6875 10454 11375 12875 13375 14250 19750 23125
3375 4750 8375 10125 14500 17875 22500 24829 25829
1625 3500 5625 6783 8987 12250 21158 23625 24250
1000 12750 16204
3875 15000 16000
14625 15375 21500
7875 11625 24500

1875 2875 9000
8875 20500 28625
14375 17375 27125
8000 20875 26500
11500 20750 22329
4329 7250 12625
7750 13704 25000
3329 5875 23875
7000 17250 28250
5125 7375 22875
8125 26875 29125
25625 26250 28000
1375 15750 19125
4500 10625 15625
2079 9750 10250
2375 6250 28125
20625 23000 27000
8250 10750 25375

In case of coding rate 49/120

1165 4327 5257 6652 8977 14185 16417 17440 21346 22183 22741 25810
2002 2653 3769 7467 10930 19672 19951 23392 23671 24787 25159 26368
5908 7768 12489 13441 13999 15487 16324 16882 17161 17254 18370 18835
1072 1422 1723 3304 4513 5815 6187 8605 12024 13720 15673 19300
3025 4699 9349 9677 10279 12210 15766 17905 20974 21160 21532 22418
2910 6280 6931 8539 10186 10651 14907 18326 19021 22834 23485 25908
700 4048 5443 8047 12675 14721 17768 19858 22462 22648 24229 26160
4026 4792 6001 6838 9163 11023 13255 13534 18818 20695 24393 24601
235 2095 7210 15022 19486 20416 20952 21718 21953 23206 25903 26182
1515 2188 4141 5071 6537 11608 11674 11767 19464 19765 21067 25531
1909 5629 8233 10886 14535 16816 17347 18698 20509 22555 23113 26461
4420 9721 16975 20230
6094 12325 25717 26275
7024 9907 16789 22090
1537 3862 14092 24880
6559 7117 11116 24415
12303 18649 21625 24043
935 6373 9442 17068
886 8419 15930 17719
8884 14371 16138 18928
2445 8698 18277 22369
421 5421 15952 23857
3211 5793 7861 21253
7653 11581 12511 25066
328 8791 24136 24579
11209 14557 15301 20673
1258 3397 10465 24973
142 2932 5164 20044
6745 10093 16045 16231
3260 4234 14814 16510
7374 16696 19207 25252
10443 10837 21439 25438
1630 9699 11860 23950
2538 8512 17998 20859
2560 9327 9814 23578
12954 13047 18091 21997
10000 13233 20323 23020
14278 15208 15580 18742
12697 13069 19579 24694

607 3676 4978 17604
12046 12790 13813 22927
1050 2423 11302 15394
3583 7959 8211 9141
4606 11488 15115 23299
3490 7489 17812 19114
5536 13627 15000 25996
1887 2746 4885 21904
514 13419 13906 20279
8025 10558 23764 25700

In case of coding rate 61/120

935 1458 2280 7022 7261 10304 13046 14232 14442 19132
1219 2960 12710 16907 17635 18558 18607 20783 21275 21527
1713 3083 3992 8208 11182 14002 15040 19443 19860 21268
4595 8550 8796 9519 11520 15723 16495 17628 19287 20007
1324 5883 6312 6626 8651 11192 11796 12394 15476 16860
2150 3938 5484 5966 6871 10755 13112 15299 20144 21625
2503 3253 3414 4829 5574 6401 8181 10063 13159 17765
2408 4033 4160 5921 6539 7938 9001 15716 16189 16411
422 3861 7506 11878 11939 15138 15617 17293 18581 19050
4003 6185 7743 8979 11367 11605 14867 16383 18641 18700
8862 8986 12553 13230 13908 13986 16632 18386 20073 20655
325 2041 2891 5428 9469 9497 11906 16679 16693 20615
1483 2177 5196 7977 9040 9168 9712 9869 15086 18396
717 2863 2884 3614 6766 8413 12640 13271 14420 21818
1742 2267 5713 6214 16642 16847 18468 20656 21540 21830
2175 5642 6972 7614 9616 9955 10631 12293 12916 18984
12742 19462 20458
11100 11954 19267
1120 3218 7998
6212 15705 19295
8774 11612 12712
9661 17108 21492
6296 6815 8590
767 1804 3167
2793 10075 15390
4493 6855 21361
7432 7927 16108
879 9629 11718
12879 16882 19590
4982 19254 20006
7798 14941 15386
13088 14120 19159
5082 9270 12298
1372 8658 20254
4719 19278 21161
3106 3773 5181
3892 11004 19423
17566 18234 22002

10589 11280 18876
6845 9704 18378
17541 19105 19788
7463 17311 21787
11607 19830 21371
4359 12892 19222
2419 12692 14590
440 10303 14235
4683 7984 14856
3228 14298 15614
3549 16686 17386
1733 7291 20212
1502 12471 17171
10919 16678 18344
1559 19353 21032
15999 20879 21230
5138 16012 17488
507 18359 19398
2745 4062 11305
4976 4994 11744
3390 16158 20308
2524 9477 17992
3977 13357 16270

In case of coding rate 73/120

357 954 7119 7201 7951 8660 8833 10902 13537 15019 16162 17393 17414
415 1005 2768 4478 6376 6992 10421 11744 13008 13294 16054 16103 17398
33 1278 5158 7309 7692 7725 10635 12376 12386 14426 14624 15432 17361
1005 2169 2215 3348 3667 4112 6118 8391 9296 9353 14480 16954 17519
789 1675 1751 6153 6377 13166 13887 13905 14217 14507 14753 15707 15896
355 1880 2959 3279 3328 6405 7962 9391 11195 11415 13999 14370 17134
1487 2810 3059 3354 3515 4282 8082 14613 15099 15268 16682 17303 17559
1140 2561 2662 2668 3505 4851 5341 6138 10407 12194 13150 13223 13239
3068 3856 4550 8151 8244 9602 9752 11365 11636 11768 12134 13566 17105
1435 1664 2304 3212 4974 8135 11314 11588 11667 12195 15385 15715 16714
1741 1947 2773 4045 4340 8244 9170 9583 12382 13645 13768 14027 16709
4247 5364 12994
24 1585 9160
5678 9509 12795
1584 2932 7313
5311 6685 16318
1053 9398 14842
9448 12744 13810
3040 3679 7686
9816 11028 13609
352 3396 7645
293 6003 12642
6840 11000 13886

3030 6910 11489
4601 16312 16351
5633 5708 9483
6931 12266 15863
4080 11013 16587
6077 6901 8660
11160 12563 16833
12610 13589 17255
597 6780 12541
3572 5296 16178
2772 10557 16953
8315 9497 12811
9076 10590 17513
9464 11633 12939
117 11613 11782
4008 7056 12120
2156 6956 9614
11255 11681 14684
374 5204 5316
5750 10140 10754
3246 15326 16788
4839 13725 14859
3760 13834 16089
2988 3455 12733
5093 8924 16859
3592 3621 16569
6053 7951 8316
7331 13216 17181
8094 11141 16500
1956 3488 10371
2852 5454 8847
3016 3177 10250
2990 12736 13293
8599 10333 12826
11154 13241 16994
6472 14558 15541
309 3770 15650
3890 6732 12686
1791 5409 16925
10464 14384 14699
1282 10278 15135
5851 9569 10063
9527 13932 17090
4192 6788 17248
2322 2357 9161
1381 7313 16246
196 3561 7252

5881 10640 14399
1451 14495 17425
2911 8369 9439

In case of coding rate 81/120

4958 6639 6721 8238 9540 9550 10491 11742 11641 12092 13056 13460
1135 1453 1545 1594 2703 3390 4538 4466 6018 11272 11598 12726
4975 4835 7828 9796 9878 11211 11805 11887 12215 12732 13357 14181
477 1914 3849 5397 5569 7818 7910 10083 10247 11108 13025 13558
918 2825 3050 3130 3347 9325 11410 11549 12972 13560 14292 14183
1996 6166 6176 6922 7396 8318 8722 8976 9837 10272 11541 12611
899 1746 2968 3374 5260 5393 6379 7054 8048 9534 10696 14550
1166 4372 5364 5573 10123 10104 10586 10967 10971 10780 13320 14450
653 1703 1713 3800 4999 7275 7457 8366 8515 9175 9770 14341
897 1176 1100 1689 2011 1912 2195 3827 4942 5395 6179 8525
883 1697 2535 2785 7982 8505 8794 9803 10643 10411 12033 13592
4688 4907 6004 6338 6537 9299 11769 12841 13341 13843 13650 14362
5526 6516 10983
11959 13659 13523
2947 5532 8679
8687 12867 13486
5450 6719 10727
1432 3767 12129
735 4095 11557
9755 10288 13978
694 5899 6270
5696 6393 10124
4384 4710 7582
7500 11231 12010
5694 9259 11477
5983 6762 8156
2004 8197 11969
1881 4872 8853
7242 9017 9751
241 2168 8361
7254 7375 10401
3236 3726 5446
4979 5151 5778
4093 5858 6926
3714 13072 14265
2537 6752 9503
3599 10153 10534
2406 6141 14388
2334 12379 12664
2086 9319 14140
895 11639 13814
405 4456 13349
3601 8072 11104

7908 11344 12523
362 8113 10934
2330 3931 9632
1266 3150 3564
2494 4013 7900
1186 9395 9216
1553 7090 7377
4085 6389 8894
8730 9591 12502
6434 7131 13691
7172 7295 10575
1184 9936 14358
5284 8884 10438
407 5149 14548
5079 7049 13527
3685 7642 7992
2209 2453 3177
2978 4341 8029
846 3478 12943
2332 10276 13322
1871 8802 13277
2580 4292 10329
3277 7785 14210
6832 12949 13117
1994 4257 4425
2158 4782 13568
530 11096 11723
3183 12564 14152
403 6842 9509
9895 14161 14474
487 3318 11590
2517 6266 14306
3031 3769 11928
3029 3154 11846
6268 14052 14585
3933 5327 11826
6514 12785 13158
7888 11414 12662

In case of coding rate 89/120

1372 1492 2242 2362 3502 3622 6472 7912 8362 10252
3775 4732 6682 7942 9712 10162 10501 10343 10852 11184
1086 2482 2812 2932 5550 5602 6807 6862 8433 10042
1282 2844 5543 6147 7492 8122 8842 10282 10582 11573
682 986 2274 5780 5872 6595 7712 7674 7972 10828
1552 3000 5218 5182 5423 5635 7528 8756 9742 10553
473 2431 4224 4952 4762 6542 7413 8905 9446 11242
1262 1582 1793 3865 4590 4852 7854 8032 10137 11433

1109 1225 2302 3382 4232 6352 7312 8637 9757 10134
1922 4882 4972 5307 5610 7913 9204 10372 10860 11582
1111 2123 3833 4711 6238 6353 7102 8260 8872 11512
563 2003 3988 3748 3832 6515 7105 8550 10588 10617
689 1102 1735 2724 3023 4135 5309 7026 8334 9532
1384 1882 3594 4385 5784 9832 10752 11064 11274 11393
1316 1373 2040 4287 5483 6239 8878 9745 10855 11454
5243 7344 7493
1710 3597 11007
3472 6323 10974
1649 3082 5812
6444 9481 9809
1134 3352 9502
4553 8782 10972
4462 7073 8814
4781 10023 9989
2303 5754 6262
3055 5513 7162
3053 8337 9952
4012 4853 7015
3685 4583 10709
4588 5184 5242
3952 4288 7884
3112 5303 11152
803 5999 9144
688 1734 3202
2363 9412 9862
3052 7223 7794
8453 9954 11572
562 5093 9172
4709 5693 10095
5752 8573 11004
2244 4403 8452
4258 9442 9534
3263 5157 10919
7553 8932 11488
1402 3683 4644
3353 6684 8062
2093 8002 10164
2820 7432 7824
5363 6804 9232
3203 7734 10167
8518 9085 9052
2723 2995 9802
3328 9112 10614
3474 5046 8583
653 7137 7434

1294 6059 11484
1224 1343 1912
2184 4253 8512
1764 6474 8367
4915 6237 7914
1073 10494 11182
2453 2997 3292
4468 6954 10497
5964 6273 7252
3773 8572 8664
2008 2097 2064
4858 4942 8939
623 4764 8392
2760 6983 10192
982 2573 2694
1732 3743 9024
6712 9332 11223
1252 11363 11544
4312 6365 8662
3303 6925 11135
2753 6811 7225
4314 10823 11062
3448 3924 9562
5453 7704 9622
742 6628 7174
867 833 5632
6481 6717 11373
2452 7583 9324
2640 7222 8902
6173 9352 10889
1222 1522 7582
5758 6234 11452
2100 7020 10822
2633 4792 8214

In case of coding rate 93/120

521 781 2081 2419 3589 5877 6085 6267 6657
1769 2029 2315 5799 6215 7255 7281 7385 9361
547 651 1873 2159 2471 7671 8581 8659 8919
2107 3069 3953 4851 5851 8555 9113 8815 9049
131 4935 5038 5565 6406 7515 7593 8074 7905
495 1821 2705 3095 3485 7459 8452 8503 8841
638 880 2073 2426 5014 6475 7307 8968 9179
27 910 2731 3199 4915 7923 8061 9543 9595
869 3081 3396 4109 6137 6345 7320 7880 8619
2226 1979 2178 4701 5331 6423 9738 9224 9491
2353 2937 4337 3458 4496 4375 4889 9532 9725
9138 1381 1809 1449 1535 4655 8303 8113 8269

4855 7552 6470 8936 7994 7002 9233 9174 9647
1991 6823 3584 6083 6115 5899 7302 7463 8529
2777 2603 2707 3615 3823 5123 6995 9153
573 1941 7936 7524 7112 7047 9023 9673
1892 1847 2689 7176 7661 8559 7801 9465
7764 7894 7957
3756 5481 8893
3403 7657 8373
3572 4670 4343
8924 7853 8217
4000 6095 9101
1743 6759 7541
1249 7827 9439
3312 5833 7177
3017 5985 5773
497 5080 9231
1301 5407 4837
878 2598 2887
7100 5900 6605
2644 5537 8243
4601 5311 5253
6722 8930 9777
3332 4132 5227
8551 8991 9335
2419 2602 4421
5390 4626 8035
4110 5955 7879
2589 5643 6709
917 6697 8139
838 7638 9517
1230 2913 7619
2497 3519 5903
3307 4131 4577
5096 5435 7021
4121 7554 9621
6742 5965 8945
6140 6781 8321
2452 6557 7697
5034 4842 9205
4057 5398 9309
2445 3982 8191
3641 8639 7775
4946 7418 8737
1862 1613 3147
7115 2965 5201
1405 6891 8763
915 1431 8971

5167 4965 5721
1926 1888 5461
2686 2165 7099
2802 2055 5539
1329 4737 9413
1660 469 1951
5124 9257 9387
3015 5560 7983
4083 4239 4785
3348 6541 8165
6843 6820 9803
7736 5291 6371
1880 5079 9699
79 2033 6189
5874 5487 7762
6655 9299 9075
6139 5381 7567
1406 5583 6839
4609 3306 5513
319 3991 6917
5989 8846 9569
4735 4497 4447
2814 6943 8633
5453 5702 6059
3708 5981 9751
6368 5169 7333
3369 8002 9283
2628 2838 5383
7740 5424 7645
2130 1372 3121
1608 5747 8997
7097 7238 8399
2816 5125 5409
649 1657 2835

In case of coding rate 97/120

1215 1303 1606 1628 1804 2200 2244 5522 8475 8514
1364 2122 3569 4163 4554 4906 5418 4109 7150 8250
1043 1220 2916 4604 4827 6094 6492 6996 7527 8275
1134 2530 4052 3072 6060 5711 6170 6210 6938 8409
1321 1672 2073 2426 3481 4480 7678 7421 7835 8519
1598 1611 2200 2024 4938 5106 5216 6434 7750 8011
1932 1677 2800 3345 5811 6161 7132 7326 7713 7524
1855 1084 5315 5399 5846 6047 6497 7567 8414 7907
1262 3747 4097 5788 5733 6109 6832 6976 8437 8489
902 2082 1986 2479 2926 3666 4527 6857 8145 8522
1067 2848 4332 4822 4603 4759 5250 6182 6296 7900
2465 4449 4402

3939 5505 8147
4444 5346 7062
2046 3235 4116
2427 4335 5033
2118 4322 7480
819 1277 8343
3834 5128 6248
1877 2377 2513
2179 5632 8492
3332 7656 7925
930 2332 6424
804 6056 7350
2757 6645 7174
3547 5232 6940
2229 5493 7943
2008 2794 2884
2135 3158 3874
1149 2883 8010
4423 4445 8379
688 3036 4011
3272 3882 5414
890 1722 3239
4453 5638 7806
2730 4847 5588
1240 3058 7788
4533 6798 6954
3037 6715 7866
871 3640 6426
2797 8097 8421
1830 3549 3762
3786 3938 4229
3702 4752 7722
748 1023 7568
2150 2136 2913
3307 8301 8580
1543 5172 6956
684 6249 7876
6030 7041 7634
2048 2597 5109
2795 4555 6842
3306 4050 5214
3631 4957 8272
2514 4889 8541
2784 6759 8234
3940 5084 8382
6297 6634 6580
1129 8300 8470

2420 3349 7239
1480 6475 6804
841 2028 6436
3301 5766 6116
552 5045 7539
3279 4539 7422
2333 6820 8118
2268 6870 8316
4026 5921 8013
731 1212 6167
3438 5509 6688
1282 5594 8123
1903 3791 7551
893 1440 1501
1914 4340 6628
2647 2994 5018
2786 3245 8016
1614 3743 5258
1018 5065 6293
4291 6937 7640
3636 6077 7992
1265 1586 5765
3830 4599 6716
1122 7508 8213
1567 3213 6471
4978 5544 5874
2993 4405 5786
1826 4885 5681
4664 5907 6338
2621 3542 6491
2178 6143 6974
4105 7267 7282
1232 1431 5808
947 6103 7182
3752 5173 6060
2816 3635 6073
1343 4226 7744
3241 7047 7546

In case of coding rate 101/120

836 3140 3644 3968 4238 5858 5930 6470 6542 6866
1183 2385 3689 3248 3680 4112 4616 4868 5210 6344
494 1179 2908 3158 3715 5432 5426 5617 6998 6600
1325 2485 3466 5228 4605 5244 6102 6286 5107 6955
880 2704 3752 4204 4493 5403 6368 6308 5265 6950
538 1209 1201 1330 2205 2887 2931 3016 3613 6036
1699 2414 2441 1307 3886 4716 5761 6712 6817 5491
1299 1143 1974 2683 3880 4554 4851 5714 5811 6896

913 2626 4797 2922 3181 4324 5023 5936 6717 2455
2620 2983 3267 3036 4460 5026 5366 6428 6442 6644
2115 3862 3472 4369 4889 6431 6995 6743 7086 6093
3375 5631 7082
972 1348 5296
1001 1365 1684
1396 4861 4841
5103 5607 6092
1089 2876 5303
2731 4742 5733
1214 1594 5145
2046 4078 5566
3252 6375 6528
2138 2942 6892
983 3759 5216
1402 1888 4552
4033 6110 6794
2510 4725 6459
1188 3936 6868
430 900 3284
651 6083 6115
2973 4458 4475
2592 3141 5737
2194 5620 6060
3785 4332 4562
1652 4412 4736
778 2943 7104
695 2619 6133
2104 3650 6099
1680 6920 6970
1526 2109 3268
732 1075 3914
2958 3393 5055
1858 6297 6926
3673 3667 6852
3445 5500 6503
787 3071 6512
477 712 2852
914 2121 2898
2187 3251 3769
391 4383 6766
1338 1713 5858
1182 1905 2622
459 685 2150
2048 4077 4976
389 2360 2858
482 3852 5918

1666 4881 6507
1304 2709 5788
578 5561 6276
1938 2456 4323
929 1559 5859
1941 3070 3266
2710 3820 4452
4295 5300 5717
841 1845 4461
2087 3257 5057
3199 4322 4796
3992 4258 4639
3547 3786 5040
1099 3646 5320
1199 1593 2116
1835 6078 6693
1360 4214 5686
1655 2661 5662
3478 5227 5993
3201 4482 5066
659 1701 6062
4720 5070 6264
2408 4415 6264
2259 5124 7054
5558 5810 5863
3205 4959 6353
1305 3467 6132
639 4348 5894
567 3050 4065
1082 2497 4129
2006 5420 5247
1358 1600 3883
1060 1136 2716
1620 2407 6841
1899 6146 6386
1492 1792 4762
606 1648 4064
679 2534 7084
4403 6195 6601
3704 4840 5560
612 2406 2755
523 5545 6783
2296 3774 6996
1413 4713 7033
2386 3119 5283
3291 4930 6981

In case of coding rate 105/120

93 1986 2504 2631 2810 2877 3763 4354 4824

76 385 1193 1434 3481 3979 4379 4436 4587
160 350 911 964 1180 1428 2212 3465 4738
130 389 620 865 1966 1999 2315 3714 4392
139 2226 2900 2932 3167 3550 4630 5155 5271
163 519 902 1789 2809 3731 3759 5270 5287
390 2117 2436 2877 3378 3731 4882 5205 5463
2131 3304 3681 4382 4462 4594 4808 4929 4985
592 676 3162 3391 3817 4392 4847 5492 5513
640 1392 1583 1742 2649 3827 3918 4029 4319
479 669 1097 1380 2222 2538 2809 3727 3750
1214 1592 2559 3574 3966 4108 4284 4646 4930
205 641 1947 2048 2066 2589 3277 3999 4869
424 662 1243 1414 1873 1943 2212 3271 3493
993 1122 1453 2626 3469 3568 3981 4930 5392
892 928 3979
90 2273 4406
1890 2999 3206
2411 4980 5104
712 3958 4361
497 1159 3611
3145 4022 4896
1120 2568 3522
132 888 980
934 1275 2660
2797 3622 5588
2797 4621 5312
4070 4922 5171
851 2474 3190
57 2355 2527
3254 3519 5061
484 1948 4085
405 1895 5547
4288 4338 5337
1695 4773 5356
810 2881 5523
1077 2731 3000
796 3631 5170
1028 1679 3049
1138 3176 3866
2928 3499 4448
1079 1322 4875
1651 2305 3871
3223 3792 5541
833 2418 5504
1918 3292 5534
2953 4430 5553
1487 4715 4964

2396 2686 3438
4201 4519 5427
179 1193 3181
848 987 2822
1136 2399 4467
2909 3650 4553
129 1325 5190
3046 5252 5403
4120 4290 4687
150 3304 5605
16 4685 5478
2910 3667 4453
2471 2565 4228
1694 4247 4900
2116 4092 4412
3003 4733 5351
1377 1432 5404
1024 3100 3224
681 2154 5526
1844 1985 4974
330 2520 3746
2573 3454 5496
2088 4939 5384
1072 3111 3171
3672 3858 5543
2211 5080 5325
673 1822 2238
2003 2825 4007
2880 3302 4719
2080 2877 5362
402 756 2132
2318 2523 5597
241 1344 5488
3164 3215 5465
24 1943 2458
1704 5151 5608
1071 2514 3944
645 2392 3526
1484 1586 5052
3551 4029 5016
891 2493 5049
1686 3183 5438
3366 3538 3698
2033 3490 3792
1366 5137 5476
635 2040 5395
1678 1694 4675

268 849 1655
1400 2723 5093
363 1781 5053
1925 2804 2956
505 1267 2720
1880 2601 4547
2258 3386 5337
2094 5123 5159
1881 2988 3881
201 690 1016

In case of coding rate 109/120

220 484 3688 3808
880 1335 2704 4106
544 556 2092 2416
1504 1660 2152
1336 3700 3891
1564 2320 4024
1168 2644 4060
1958 2056 3712
938 2992 3004
3100 3459 4047
1045 1576 3050
278 1826 2235
1000 1984 3255
1178 3662 3724
172 2907 3532
160 2380 3064
628 1116 1790
579 2212 3328
302 435 1264
1479 1792 3796
1300 3591 3901
820 1143 3856
724 1093 2968
1106 3099 3604
255 2164 2656
951 1684 3472
592 2027 2308
2473 2487 3887
1024 1288 2269
736 1851 3172
1166 2436 2547
374 1312 2848
854 1924 3304
456 1108 1372
950 2091 2799
915 1708 1970

304 1059 3804
292 2030 2620
841 1240 1827
1492 2376 3160
546 976 1813
2127 2786 3972
604 2871 3652
471 2822 3040
290 640 3544
2282 2824 3784
1204 3500 4055
699 1743 3364
527 1599 2978
1250 3748 4074
316 373 2692
3220 3324 3490
925 3431 3736
1934 2007 3904
734 1971 2584
2055 3279 3964
1551 1672 4108
1596 2488 2560
1518 3614 3916
2607 3013 4012
663 2942 3940
1659 3267 3730
1740 2559 2752
496 1539 1800
2437 2798 4094
817 1420 3649
1480 1863 2200
2031 2187 2884
274 2716 3049
1491 2960 3232
1899 2523 3316
844 1655 2428
2339 2474 3919
388 2869 3952
999 2139 3508
1180 2115 2668
2379 3520 3589
564 2728 3903
616 1153 3196
697 759 3388
975 1864 3347
711 1418 2307
405 827 1712

1466 3107 3396
2691 3480 3992
952 2173 2605
519 543 1744
1146 1931 2812
1702 2919 3411
687 1593 1634
3384 3460 3528
856 2232 3170
195 411 1443
2522 3190 3988
1406 2377 2464
387 3202 3976
1320 2248 2795
243 2087 2367
448 1227 3698
1478 2999 3208
2546 2619 2632
196 1107 2272
2943 3178 3855
1252 1742 3551
364 591 3076
807 1404 1900
1192 3239 3579
890 2068 3650
793 1850 4048

(Article 60, Paragraph 2 of Ordinance, Appended Table 66)

An example of coding rate 81/120 is shown in the following.

- Set all parity bits to 0. $p_0 = p_1 = p_2 = ... = p_{n_{ldpc}-k_{ldpc}-1} = 0$
- Referring first row from the above table, which shows coding rate is 81/120, add it to first information bit i_0 .

$$p_{4958} = p_{4958} \oplus i_0$$
$$p_{6639} = p_{6639} \oplus i_0$$
$$p_{6721} = p_{6721} \oplus i_0$$
$$p_{8238} = p_{8238} \oplus i_0$$
$$p_{9540} = p_{9540} \oplus i_0$$
$$p_{9550} = p_{9550} \oplus i_0$$
$$p_{10491} = p_{10491} \oplus i_0$$
$$p_{11742} = p_{11742} \oplus i_0$$
$$p_{11641} = p_{11641} \oplus i_0$$
$$p_{12092} = p_{12092} \oplus i_0$$

$p_{13056} = p_{13056} \oplus i_0$

$p_{13460} = p_{13460} \oplus i_0$

- For information bit until 373 $i_m, m=1,2,\cdots,373$, add corresponding parity bit $\{x+(m \bmod 374)\times q\} \bmod (n_{ldpc}-k_{ldpc})$ to i_m . Here x is parity bit corresponding to i_0 , and q is a constant defined by coding rate written in the above table.

  In case of coding rate 81/120, q=39, so the following operations are performed for information bit i_1 .

$p_{4997} = p_{4997} \oplus i_1$

$p_{6678} = p_{6678} \oplus i_1$

$p_{6760} = p_{6760} \oplus i_1$

$p_{8277} = p_{8277} \oplus i_1$

$p_{9579} = p_{9579} \oplus i_1$

$p_{9589} = p_{9589} \oplus i_1$

$p_{10530} = p_{10530} \oplus i_1$

$p_{11781} = p_{11781} \oplus i_1$

$p_{11680} = p_{11680} \oplus i_1$

$p_{12131} = p_{12131} \oplus i_1$

$p_{13095} = p_{13095} \oplus i_1$

$p_{13499} = p_{13499} \oplus i_1$

- For information bit $i_{374} \sim i_{747}$ that comes after 375th information bit, second row in the table of coding rate 81/120 is used for summing parity bits.

- For new information bit after every other 374 bits, new row in the table is also used for summing parity bits.

After summing all information bits, last parity bit is calculated as the following.

- Starting from $i = 1$, the following operation is executed one after another.

$$p_i = p_i \oplus p_{i-1} \qquad i = 1,........, n_{ldpc} - k_{ldpc} - 1$$

- The final result p_i is equivalent to parity bit p_i . $i = 1,........, n_{ldpc} - k_{ldpc} - 1$

3.5 Error correction method for TMCC

As for outer code, the same coding method as the main data is used. As for inner code, a shortened version of the LDPC (1/2) for the main data is used (see Fig3.5-1). LDPC parity (22066 bits) of coding rate 1/2 is added to NULL data ('0' sequence of 1870 bits), TMCC data (9422 bits), BCH parity (192 bits) and NULL data ('0' sequence of 11330 bits) as the LDPC code data, and after deleting NULL data, the data is transmitted as TMCC signal. At the receiver, after inserting symbols in case of transmitting ideally 0's for NULL data section, LDPC code decoding is performed at coding rate 1/2.

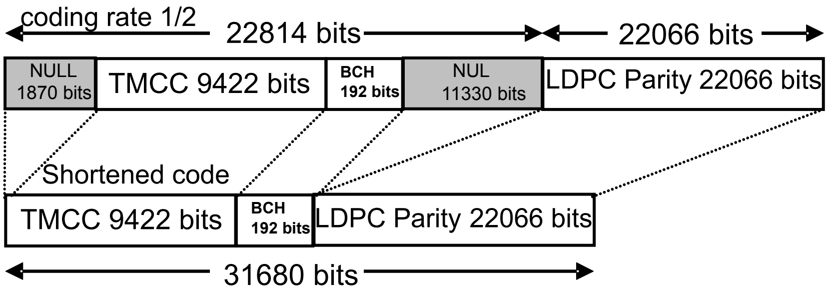
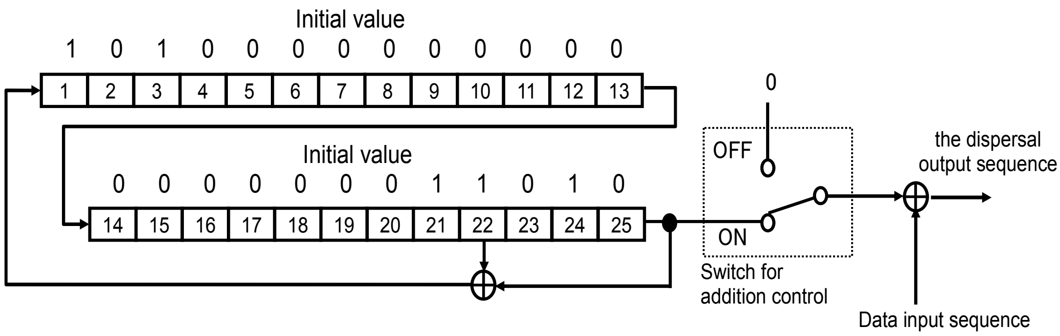


Fig. 3.5-1: Error correction coding for TMCC

3.6 Energy dispersal

(1) Energy dispersal for slot

The energy dispersal for slot is performed for the header, data, BCH parity and stuffing bit among slot elements, and is not performed for LDPC parity section and for dummy slot. The period of energy dispersal is one frame. Energy dispersal circuit operates exclusive-or of an output of 25th-order PRBS and the data input sequence as shown in Fig. 3.6-1. The shift register of energy dispersal circuit is halted for intervals in which no energy dispersal is performed.



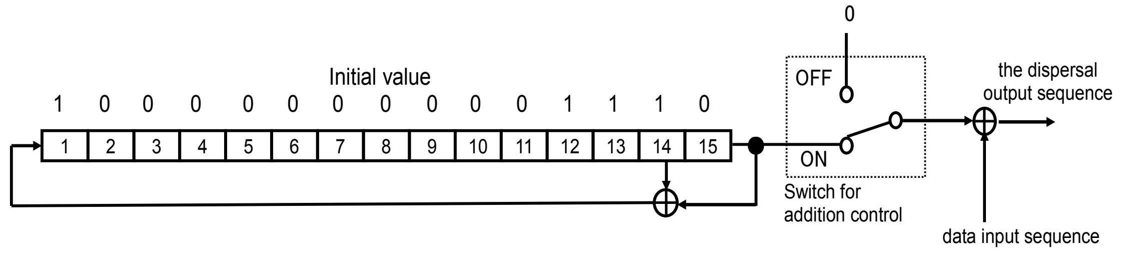
⊕: operational element of exclusive-or

(Article 60, Paragraph 1 of Ordinance, Appended Table 65, Appendix 2)

Fig. 3.6-1: Energy dispersal circuit (for slot data)

(2) Energy dispersal for TMCC data

Energy dispersal for TMCC data is performed by using a 15th order PRBS generator shown in Fig. 3.6-2. A period of energy dispersal is one frame. The energy dispersal circuit operates an exclusive-or of an output of 15th-order PRBS and the data input sequence. TMCC data and BCH parity section are dispersed, and the shift register is halted in the other interval.



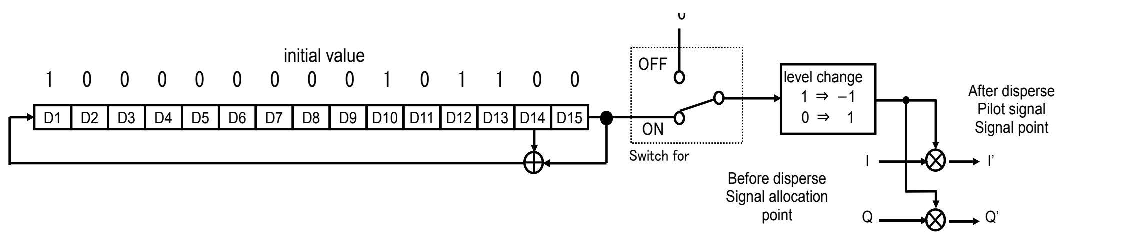
⊕: operational element of exclusive-or

(Article 61, Paragraph 1 of Ordinance, Appended Table 67, Appendix 1)

Fig. 3.6-2: Energy dispersal circuit (for TMCC)

(3) Energy dispersal for pilot signal

Energy dispersal for pilot signal is performed by using 15th order PRBS generator shown in Fig. 3.6-3. The period of energy dispersal is one frame. As shown in Fig. 3.6-3, energy dispersal is performed by rotating signal point coordinate on an I-Q orthogonal coordinate system by 0°/ 180° according to the bit 0/1 output of 15th PRBS. Energy dispersal is performed in the period of pilot signal, and the shift register of energy dispersal circuit is halted in the other interval.



⊕: operational element of exclusive-or

⊕: operational element of multiplication

(Article 59, Paragraph 1 of Ordinance, Appended Table 62, Appendix 3)

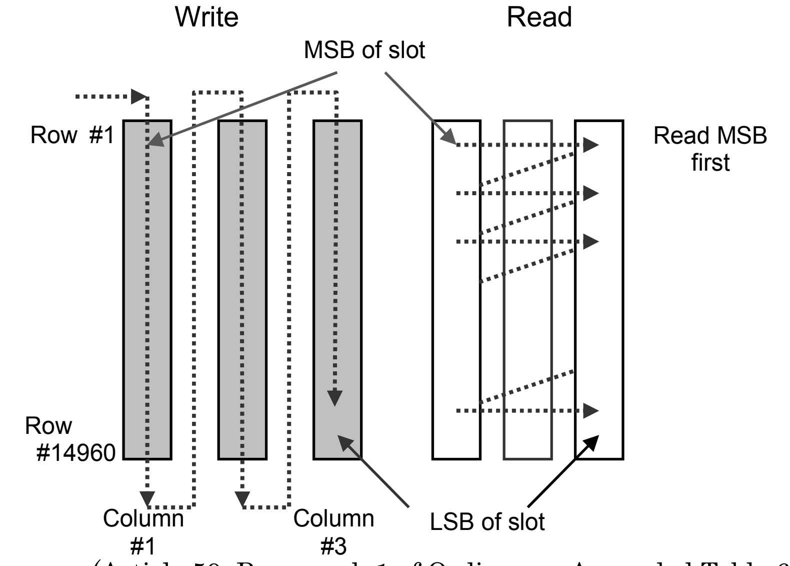
Fig. 3.6-3: Energy dispersal circuit (for pilot signal)

3.7 Interleaving

Interleaving is performed for the slot to which 8PSK, 16APSK or 32APSK are allocated, and is not performed for the slot to which π/2 shift BPSK or QPSK are allocated. When interleaving is performed, the output of LDPC coder is bit interleaved by the block interleaver. Table 3.7-1 shows the size of bit interleaving for each modulation, and the structures are shown in Fig. 3.7-1 to Fig. 3.7-6. The data is written column-by-column from top to bottom and is read out row-by-row in the forward direction from left (MSB) to right (LSB) or row-by-row in the backward direction from right (LSB) to left (MSB). It depends on inner coding rate as listed in Table 3.7-2 which direction to be used.

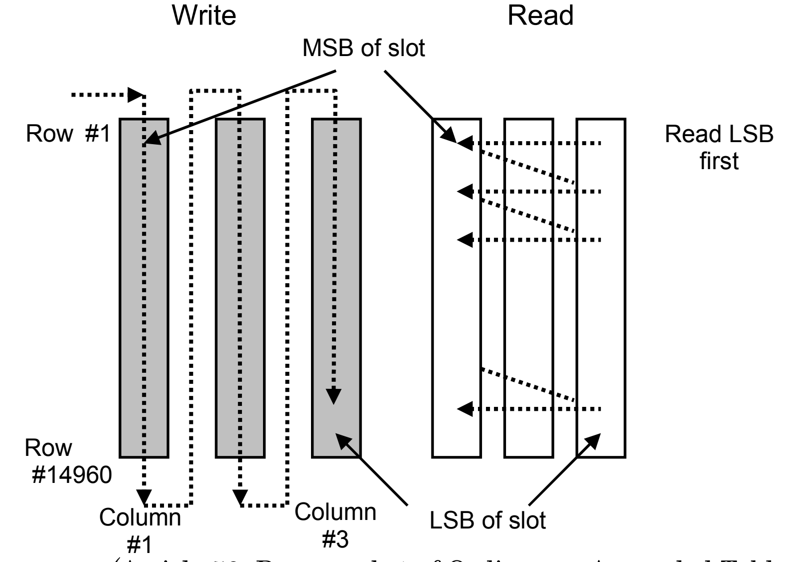
Table 3.7-1: Bit interleaving

Modulation	Row	Column
8PSK	14960	3
16APSK	11220	4
32APSK	9876	5



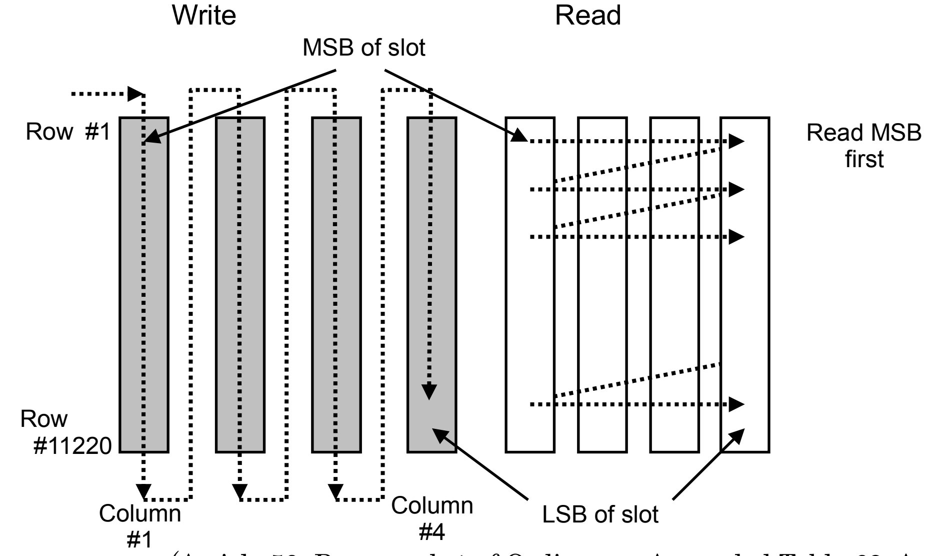
(Article 59, Paragraph 1 of Ordinance, Appended Table 62, Appendix 1)

Fig. 3.7-1: Bit interleaving 8PSK (forward direction read-out)



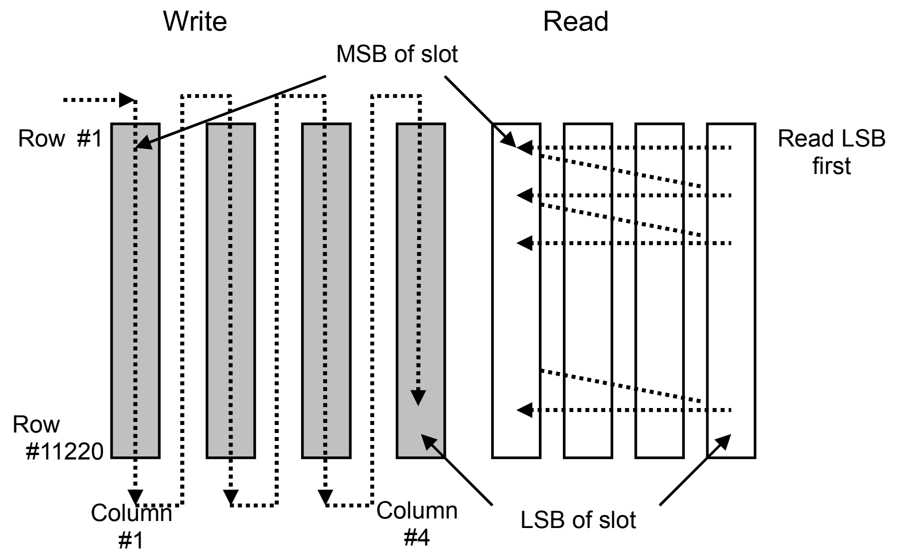
(Article 59, Paragraph 1 of Ordinance, Appended Table 62, Appendix 1)

Fig. 3.7-2: Bit interleaving 8PSK (backward direction read-out)



(Article 59, Paragraph 1 of Ordinance, Appended Table 62, Appendix 1)

Fig. 3.7-3: Bit interleaving 16APSK (forward direction read-out)



(Article 59, Paragraph 1 of Ordinance, Appended Table 62, Appendix 1)

Fig. 3.7-4: Bit interleaving 16APSK (backward direction read-out)

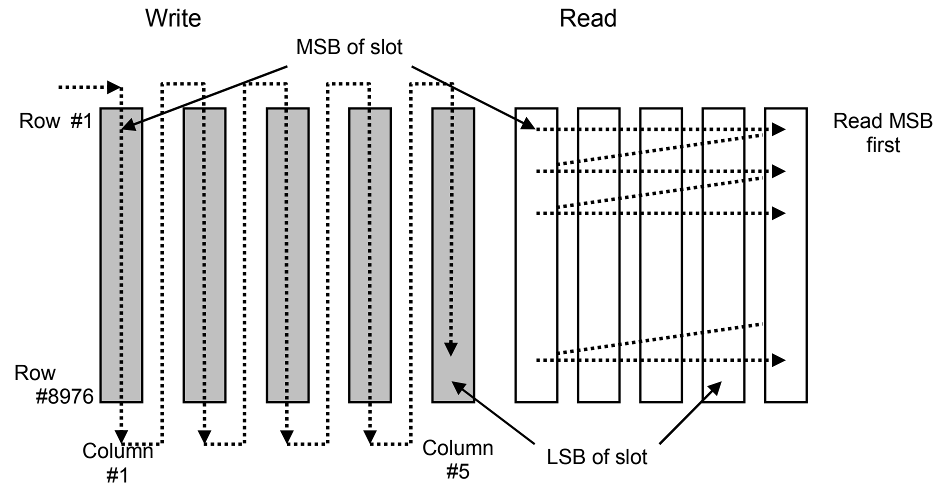


Fig. 3.7-5: Bit interleaving 32APSK (forward direction read-out)

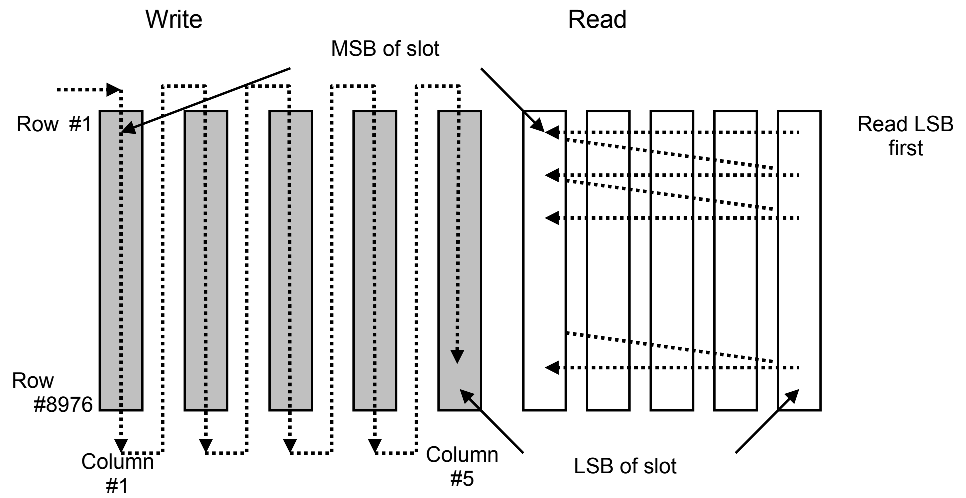


Fig. 3.7-6: Bit interleaving 32APSK (backward direction read-out)

Table 3.7-2: Interleaving read-out

modulation	Inner coding rate (approximate value)						
	below 2/5	1/2	3/5	2/3	3/4	7/9	over 4/5
8PSK	backward	forward	forward	forward	forward	forward	forward
16APSK	backward	forward	forward	forward	forward	forward	forward
32APSK	backward	forward	forward	forward	forward	backward	forward

3.8 Modulation schemes

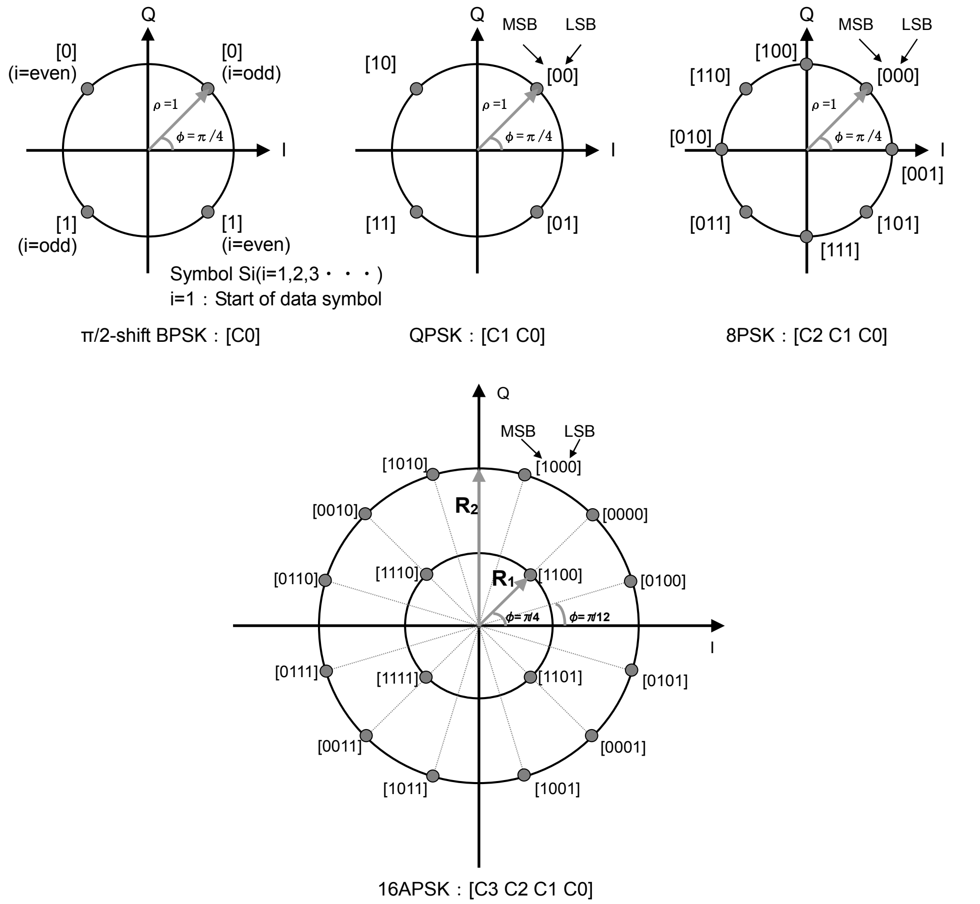
The applicable modulation schemes are listed in Table 3.8-1. And the constellation diagrams for each modulation scheme are depicted in Fig. 3.8-1.

Table 3.8-1: Modulation schemes

Modulation	Application
π/2 shift BPSK	Frame synchronization Slot synchronization TMCC signal Main signal (including pilot signal)
QPSK	Main signal (including pilot signal)
8PSK	Main signal (including pilot signal)
16APSK	Main signal (including pilot signal)
(32APSK)	Main signal (including pilot signal) (In order to secure a proper service availability on the worst month with more expansion of transmission capacity, a receiving antenna with bigger aperture is needed.)

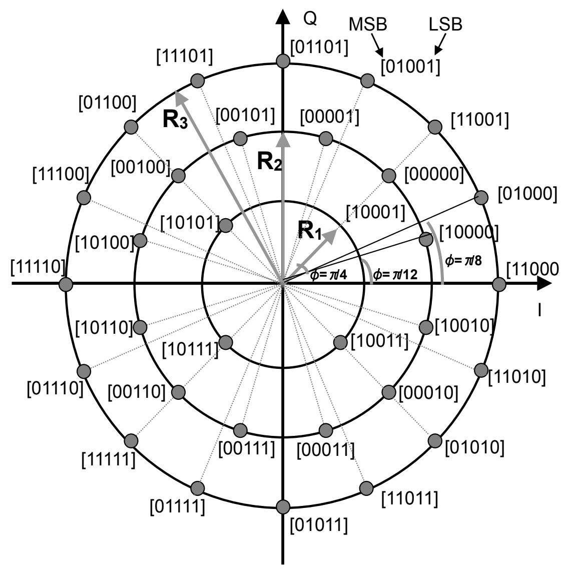
Here, modulation by π/2 shift BPSK uses the following constellation. For odd-numbered symbols including the 1st symbol at the front of the frame, symbol 0 and symbol 1 take on signal points in the 1st and 3rd quadrants, respectively, and for the second symbol and subsequent even-numbered symbols, the above points are rotated by 90° in the counter-clockwise direction.

For 16APSK and 32APSK, the radius ratio γ (=R2/R1) for 16APSK and those γ1 (=R2/R1) and γ2 (=R3/R1) for 32APSK listed in Table 3.8-2 and Table 3.8-3 according to the inner coding rate are taken in order to get optimal performance. Furthermore, while the radius is taken to be 1 and power is normalized to 1 in Fig. 3.8-1, we respectively use $4R_1^2+12R_2^2=16$ and $4R_1^2+12R_2^2+16R_3^2=32$ for 16APSK and 32APSK in Fig. 3.8-2, with power normalized to 1.



(Article 59, Paragraph 4 of Ordinance, Appended Table 53)

Fig. 3.8-1: Constellation diagrams for each modulation scheme (PSK, 16APSK)



32APSK：[C4 C3 C2 C1 C0]

Fig. 3.8-1: Constellation diagrams for each modulation scheme (32APSK)

Table 3.8-2: 16APSK radius ratio

Coding rate (approximation)	Radius ratio γ
41/120 (1/3)	3.09
49/120 (2/5)	2.97
61/120 (1/2)	3.93
73/120 (3/5)	2.87
81/120 (2/3)	2.92
89/120 (3/4)	2.97
93/120 (7/9)	2.87
97/120 (4/5)	2.73
101/120 (5/6)	2.67
105/120 (7/8)	2.76
109/120 (9/10)	2.69

(Article 59, Paragraph 4 of Ordinance, Appended Table 63)

Table 3.8-3: 32APSK radius ratio

Coding rate (approximation)	Radius ratio $\gamma 1$	Radius ratio $\gamma 2$
41/120 (1/3)	3.09	6.53
49/120 (2/5)	2.97	7.17
61/120 (1/2)	3.93	8.03
73/120 (3/5)	2.87	5.61
81/120 (2/3)	2.92	5.68
89/120 (3/4)	2.97	5.57
93/120 (7/9)	2.87	5.33
97/120 (4/5)	2.73	5.05
101/120 (5/6)	2.67	4.80
105/120 (7/8)	2.76	4.82
109/120 (9/10)	2.69	4.66

3.9 Pilot signal

The pilot signal sequentially transmits signal points for the modulation scheme specified for modulation slot by TMCC. For example, the pilot signal will transmit signal points 00000, 00001, 00010, 00011, …11111 in that order for 32APSK, signal points 0000, 0001, 0010, 0011, …1111 in that order twice for 16APSK, signal points 000, 001, 010, 011, …111 in that order four times for 8PSK, and signal points 00, 01, 10, and 11 in that order eight times for QPSK, and signal points 0 and 1 in that order 16 times for π/2 shift BPSK.

3.10 Band limitation of carrier wave (frequency characteristics of filter)

The frequency characteristics of filter which limits band of carrier wave is below.

$$\begin{cases} 1 & |F| \le F_n \times (1-\alpha) \\ \sqrt{\dfrac{1}{2} + \dfrac{1}{2}\sin\dfrac{\pi}{2F_n}\left[\dfrac{F_n - |F|}{\alpha}\right]} & F_n(1-\alpha) \le |F| \le F_n(1+\alpha) \\ 0 & |F| \ge F_n(1+\alpha) \end{cases}$$

Here, F is the center frequency of the carrier wave, Fn is the Nyquist frequency, α is the roll-off factor, and α=0.03.

3.11 TMCC information

The TMCC information is composed of information on transmission control such as the transmission stream allocation for each slot, the relationship between modulation schemes and each slot, and so on. The size of the area that can be used for transmitting TMCC information is 9422 bits per one frame. In case of changing transmission schemes, etc., the TMCC information transmits the switching information two frames prior to actual switching. The minimum update interval of the TMCC information is one frame.

The bit configuration of the control information in the TMCC information is shown in Fig. 3.11-1 (The numbers show the bit number. And so on to Fig. 3.11-9.).

Order of change	Transmission mode/ slot information	Stream type/ relative stream number information	Stream type/ relative stream number information	Packet format/ relative stream number information	Relative stream number/ slot information	Corresponding table between relative stream ID and transmission stream ID	Transmit/ receive control information	Extension information
8	192	128	896	3840	480	256	8	3614

(Notice, Appended Table 3)

Fig. 3.11-1: Bit configuration of TMCC information

(1) Order of change

The order of change is incremented by one every time contents in the TMCC information are changed. Its value is reset to "00000000" after "11111111." But, in case of changing only pointer/slot information, except for setting extended information separately, the order of change is not incremented.

(2) Transmission mode/slot information

The transmission mode/slot information indicates the modulation scheme used for the main signal, the inner coding rate of error correcting, the satellite output back off (OBO) value, and the number of allocated slots. The bit configuration of this information is shown in Fig. 3.11-2, and the field values are given in Tables 3.11-1～3.11-3.

Modulation scheme for transmission mode 1	Inner coding rate for transmission mode 1	Number of allocated slots for transmission mode 1	Satellite OBO for transmission mode 1	…	Modulation scheme for transmission mode 8	Inner coding rate for transmission mode 8	Number of allocated slots for transmission mode 8	Satellite OBO for transmission mode 8
4	4	8	8		4	4	8	8

(Notice, Appended Table 3, Appendix 1)

Fig. 3.11-2: Bit configuration of transmission mode/slot information

Table 3.11-1: Modulation scheme for transmission mode

Value	Allocation
0000	Reserved
0001	π/2-shift BPSK
0010	QPSK
0011	8PSK
0100	16APSK
0101	32APSK *
0110 ～ 1110	Reserved
1111	No scheme allocated

* Modulation scheme is not provided in the Notice. Also, '0101～1110' is defined as 'reserved' in the Notice.

Table 3.11-2: Inner coding rate for transmission mode

Value	Allocation
0000	Reserved
0001	41/120
0010	49/120
0011	61/120
0100	73/120
0101	81/120
0110	89/120
0111	93/120
1000	97/120
1001	101/120
1010	101/120
1011	109/120
1100 ～ 1110	Reserved
1111	No scheme allocated

(Notice, Appended Table 3, Appendix 1)

Table 3.11-3: Satellite Output Back-Off for transmission mode

Value	Allocation
00000000	0.0 dB
00000001	0.1 dB
00000010	0.2 dB
....	....
11111101	25.3 dB
11111110	25.4 dB
11111111	25.5 dB

(Notice, Appended Table 3, Appendix 1)

On allocating slot number for transmission mode, transmission modes 1–8 are allocated in the order of the modulation schemes having the most constellation points appear first, and in the case of identical modulation schemes, inner coding rates with higher code rates appear first.

The number of allocated slots for transmission mode indicates the number of slots, including dummy slots, and the number of slots allocated to each transmission mode must be a multiple of 5. And the total number of slots allocated to transmission modes must be equal to 120 (which is the number of slots for one transmission frame of main signal).

If the number of combination of modulation schemes to be used, inner coding rate of error correcting and satellite output back-off is less than 8, then, for any unused transmission mode, the value set for the modulation scheme is "1111", the code rate is "1111" and the value set for the number of allocated slots is "00000000", and satellite output back-off is "00000000."

The value to be written in the satellite output back-off is set to be the value that the ratio between modulated output power of satellite transponder for the transmission mode and output power in amplifying carrier to saturated level of the satellite transponder is taken, and the absolute value of the ratio indicated in dB is multiplied to 10, and indicated in binary.

(3) Stream type/relative stream number information

The stream type/relative stream number information indicates the area of the relationship between the relative stream numbers and the stream type, and the relative stream number allocated to each slot in the manner described in "(6) Relative stream/slot information" below shows the kind of packet stream.

The configuration of the stream type/relative stream information is shown in Fig. 3.11-3, and the correspondence between the values and the stream type is given in Table 3.11-4.

Stream type for relative stream #0	Stream type for relative stream #1	Stream type for relative stream #2	…	Stream type for relative stream #15
8	8	8		8

(Notice, Appended Table 3, Appendix 2)

Fig. 3.11-3: Bit configuration of stream type/relative stream information

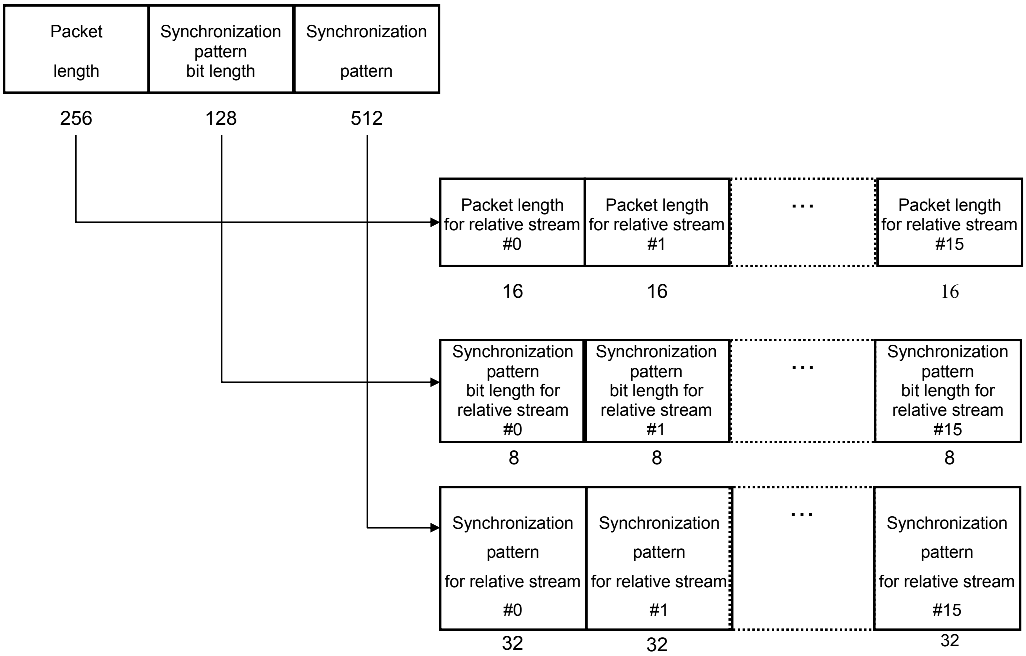
Table 3.11-4: Stream Type

Value	allocation
00000000	Reserved
00000001	MPEG-2 TS
00000010	TLV
00000011 ～ 11111110	Reserved
11111111	No type allocated

(Notice, Appended Table 3, Appendix 2)

(4) Packet format/relative stream information

The packet format/relative stream information shows the relationship between relative stream number and packet format, and indicates the packet format for each of the relative stream numbers allocated to the slots in the manner described in "(6) Relative stream/slot information" below. The configuration of packet format/relative stream information is shown in Fig. 3.11-4.



(Notice, Appended Table 3, Appendix 3)

Fig. 3.11-4: Bit configuration of packet format/relative stream number information

"Packet length" refers to the length of each packet in bytes, and the byte length of packet is indicated for each of relative streams from #0 to #15. In case that the stream type is MPEG-2 TS, it is 0x00BC, and in case that the stream type is TLV, it is 0x0000.

"Synchronization pattern bit length" refers to the length in bits of the synchronization pattern affixed to the front of the packet, and the bit length of synchronization pattern is indicated for each of the relative streams from #0 to #15. In case that the kind of stream is MPEG-2 TS, it is 0x08, and in case that the kind of stream is TLV, it is 0x00.

"Synchronization pattern" refers to the pattern affixed to the front of the packet, and the synchronization pattern affixed to the front of the packet is indicated for each of the relative streams from #0 to #15. If the synchronization pattern bit length happens to be less than 32 bits, the synchronization pattern for that transmission packet is to be written from the front of that field and surplus bits are to be filled with 0's. In case that stream type is MPEG-2 TS, it is 0x47000000, and in case that stream type is TLV, it is 0x00000000.

For the relative stream number which is not assigned to slot, all bits of "Packet length", "Synchronization pattern bit length" and "Synchronization pattern" are set to '0'.

(5) Pointer/slot information

The pointer/slot information indicates the very front (top pointer) of the first packet and the tail end (last pointer) of the final packet. The configuration of the pointer/slot information is shown in Fig. 3.11-5.

The top pointer indicates the position of the leading byte of the first packet within the slot in terms of the number of bytes from the front of the slot excluding the header. Here, the value 0xFFFF indicates that no leading byte exists.

The last pointer indicates the position of the final byte of the last packet plus 1 within the slot in terms of the number of bytes from the front of the slot excluding the header. Here, the value 0xFFFF indicates that no final byte exists.

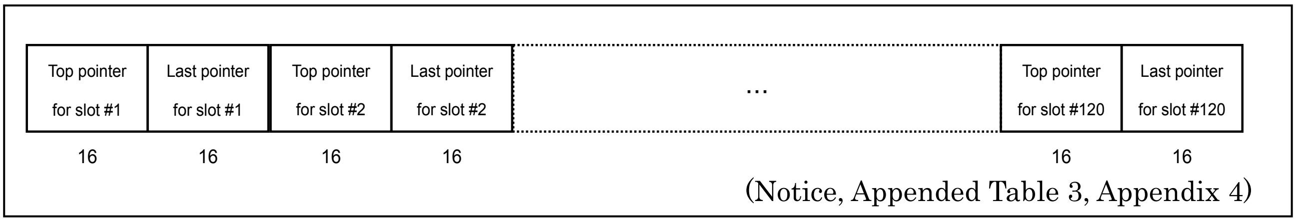


Fig. 3.11-5: Bit configuration of pointer/slot information

(6) Relative stream number/slot information

The relative stream number/slot information shows the relationship between slot and relative stream number, and indicates the number of relative streams to be transmitted in each slot in order from slot #1.

A maximum of 16 streams can be transmitted within one frame, which means that the relative stream number can be indicated with 4 bits. The same number is also allocated to dummy slots. The configuration of the relative stream number/slot information is shown in Fig. 3.11-6.

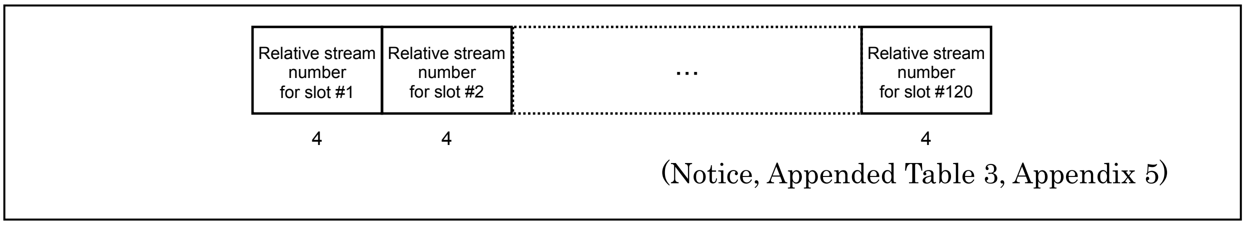


Fig. 3.11-6: Bit configuration of relative stream number/slot information

(7) Corresponding table between relative stream number and transmission stream ID

This table indicates the correspondence between the relative stream numbers used in "relative stream/slot information" and the transmission stream ID (which is the TS_ID of MPEG-2 systems in case of an MPEG-2 TS stream type and is the TLV stream ID in case of a TLV stream type). The configuration of the corresponding table between the relative stream number and transmission stream ID is shown in Fig. 3.11-7.

Transmission stream ID for relative stream number #0	Transmission stream ID for relative stream number #1	…	Transmission stream ID for relative stream number #15
16	16		16

(Notice, Appended Table 3, Appendix 6)

Fig. 3.11-7: Bit configuration of corresponding table between relative stream number and transmission stream ID

(8) Transmit/receive control information

The transmit/receive control information transmits control signals for the startup of the receiver for an emergency warning broadcasting system (EWS) and a control signal for switching the uplink station. The configuration of the transmit/receive control information is shown in Fig. 3.11-8.

Startup control signal	Up-link control information	Reserved
1	3	4

Note 1: The startup control signal transmits an emergency warning signal, and it is set to '1' for startup and control receiver, and set to '0' otherwise.
2: Uplink control information can be used to change and control earth stations.

(Notice, Appended Table 3, Appendix 7)

Fig. 3.11-8: Bit configuration of transmit/receive control information

(9) Extension information

Extension information is a field reserved for future extensions of the TMCC signal. The configuration of the extension information is shown in Fig. 3.11-9. When making an extension to the TMCC signal, the extension identification takes on a value other than the originally prescribed "0000000000000000", and that value indicates that the extension field is valid from thereon. In the case of an extension identification value of "0000000000000000," the extension field is stuffed with "1".

Extension identification	Extension field
16	3598

Note 1: In case that TMCC information is extended, extension identification value is set to anything but '0000000000000000'.
2: In case that extension identification value is '0000000000000000', 3598 bits in the extension field are set to all '1'.

(Notice, Appended Table 3, Appendix 8)

Fig. 3.11-9: Bit configuration of extension information

Annex A: Modulation scheme for the advanced wide band digital satellite broadcasting prescribed in Ministerial Ordinance and Notice

Table A-1 shows the relationship between transmission system for the advanced wide band digital satellite broadcasting provided in this standard and advanced wide band transmission system prescribed by Ministerial Ordinance and Notice. In this Table ○ shows modulation scheme provided in Ministerial Ordinance, Notice and this standard, and △ shows modulation scheme specified only by this standard. Modulation schemes for the advanced wide band transmission system prescribed by Ministerial Ordinance and Notice are restricted to π/2 shift BPSK, QPSK, 8PSK and 16APSK.

Table A-1 Corresponding modulation scheme

Modulation scheme	Compatibility
π/2 shift BPSK	Normative
QPSK	Normative
8PSK	Normative
16APSK	Normative
(32APSK)	Optional(Note)

(Note) In the Information and Communications Council's Report on "Technical requirements for the ultra-high definition broadcasting system" (March 25, 2014), a note of "Modulation scheme considered to be applicable in future taking into account spread state of corresponding equipment, because receiving antenna with large diameter is required to further expand transmission capacity and to properly ensure service availability in the worst month" is written.

Annex B: Frequency utilization requirements for the advanced BS digital broadcasting and the advanced wide band CS digital broadcasting

B.1 Frequency of the radio wave used by satellite broadcast stations

Frequency of the radio wave used by satellite broadcast stations is higher than 11.7 GHz to 12.2 GHz or higher than 12.2 GHz to 12.75 GHz.

B.2 Frequency bandwidth and frequency allocation of transmission carrier

Frequency bandwidth in use shall be 34.5 MHz.
Carrier wave frequency shall be allocated to the center frequency of frequency bandwidth.
(Ministerial Ordinance, Article 51)

B.3 Transmission rate

Transmission rate of the signal which modulates a carrier shall be 33.7561 Mbaud.
(Ministerial Ordinance, Article 59)

B.4 Tolerance deviation for transmission rate

(Tolerance deviation, etc.)
In the case of satellite broadcast station that performs broadcasting specified in the standard system for digital broadcasting (hereafter referred to as "advanced wide band satellite broadcast station"), the deviation of transmission rate for the signal which modulates a carrier wave shall not exceed ±20/1,000,000 from the value specified in the standard system for digital broadcasting.
(Ordinance Regulating Radio Equipment, Article 37-27-19)

The tolerance deviation for transmission symbol rate shall not exceed ±20ppm from 33.7561 Mbaud.

B.5 Band limitation of carrier wave

(Filter characteristics)

The following shows filter characteristics for limiting the band of carrier wave.

The filter characteristics for the advanced wide broadband transmission digital broadcasting:

$$\begin{cases} 1 & |F| \le F_n \times (1-\alpha) \\ \sqrt{\dfrac{1}{2} + \dfrac{1}{2}\sin\dfrac{\pi}{2F_n}\left[\dfrac{F_n - |F|}{\alpha}\right]} & F_n(1-\alpha) \le |F| \le F_n(1+\alpha) \\ 0 & |F| \ge F_n(1+\alpha) \end{cases}$$

Note: F is frequency, Fn is Nyquist frequency, and α is roll-off rate. The values of Fn and α are as follows:

Fn=16.87805(MHz)

α=0.03

(Ministerial Ordinance, Article 59-5, Appended Table 6)

EXPLANATION

Explanation

Contents

Explanation A: Improvement of receiving performance by using Pilot signal

A.1 Summary of synchronization process in a typical receiver

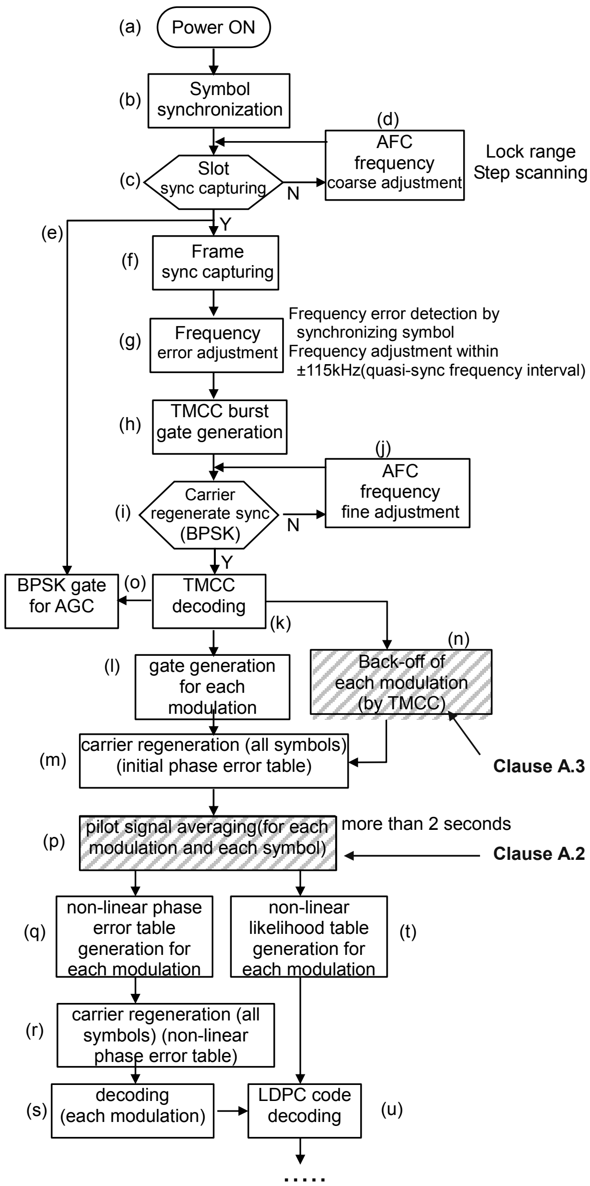


Fig. A-1: An assumed flowchart of a receiver

The working flow of the initial synchro-nization in a typical receiver is shown in Fig. A-1. After power is set ON (a) in the receiver, symbol synchronization is set (b) first. Then, capturing slot synchro-nization is tried (c). If slot synchro-nization cannot be captured, capture point is searched (d) by step scanning in the frequency range which is the design target of the receiver.

When slot synchronization is captured, as the multiplexed position of modulation symbol of slot sync or frame sync is found, the gate signal of these signal positions are given to AGC circuit (e), and the AGC circuit measures power of sync signal symbol and adjusts AGC gain. It is because AGC circuit of the receiver works wrong if modulation scheme for back-off operation is time division multiplexed.

After this, frame synchronization is captured (f). After capturing synchro-nization, frequency error of the oscillator for carrier regeneration is detected by receiving phase revolution of the signal position of sync symbol (g). Here, it is desirable frequency error is set within ±115kHz, because when the operation is switched to carrier regeneration using TMCC burst later, quasi-synchronization is generated at the interval of one by burst period (g).

Also, as the position of TMCC burst can be identified at this time, the gate signal which specifies π/2-shift BPSK symbol interval of synchronization and TMCC is generated (h), and carrier is regenerated by π/2-shift BPSK by gating only at the interval of π/2-shift BPSK (i). Then the regenerated carrier frequency is adjusted fine by detecting stable carrier regeneration (j).

After carrier regeneration is stable, TMCC signal is decoded (k). As TMCC signal involves information about modulation scheme of all modulated symbols and back-off amount, the gate signal for identifying each modulation interval is generated (l) by using this information, and carrier is regenerated by using not only synchronization and TMCC but also all symbols (m). At this time, the phase error table of initial operation is used for 16APSK and 32APSK, and it is generated by considering back-off information of APSK involved in TMCC (n). So it can be transferred to the carrier regeneration with little phase jitter. Also, if there is another modulation scheme amplifying to saturated level besides synchronization and TMCC, the gate signals involving these signals are generated, and by giving them to AGC circuit, the AGC level setting can be made to be more accurate (o).

As the receiving signal point of 16APSK and 32APSK is affected by the non-linearity of satellite transponder, outer circle point of the constellation involves distortion of amplitude and phase comparing inner circle point of the constellation, so these distortions cause cycle slip in carrier regeneration and deterioration of receiving performance. Therefore by averaging pilot signal for several seconds (p), and detecting signal point allocation after receiving affection of non-linear channel, and rewriting phase error table used for carrier regeneration dealing with the signal point allocation after affection of non-linearity (q), and regenerating carrier (r), and decoding (s). So cycle slip can be suppressed, and also, by rewriting likelihood table for LDPC code decoding alike (t), the deterioration of LDPC code decoding (u) can be suppressed.

In Clauses A2 and A3 below, details are explained on the part which needs supplemental explanations about the operation described above.

A.2 Pilot signal

A.2.1 Function of pilot signal

In the transmission system of advanced wide band satellite broadcasting, pilot signal is transmitted using 32 symbols per modulation slot of each frame as shown in Fig. A-2. For 32APSK, each symbol is transmitted once (see Fig. A-3). For other modulation schemes, 32 symbols are also used. Each symbol is transmitted twice for 16APSK, each symbol four times for 8PSK, each symbol 8 times for QPSK, and each symbol is transmitted 16 times for π/2-shifted BPSK. In the receiver, by averaging this pilot signal, the signal point allocation can be known after affected by non-linearity of transmission channel.

Fig. A-4 shows examples of (a) transmission signal point, (b) received signal point after passing non-linear channel, (c) signal point allocation after averaging pilot signal. In (b), on outer circle signal point is more suppressed to inside and phase is more rotated. Also in (c), signal point allocation acquired by averaging pilot signal is located almost center of received signal point can be confirmed. By updating likelihood table which is used for LDPC code decoding and phase error table for synchronization regeneration based on signal point which is acquired by averaging pilot signal, C/N-BER characteristics and cycle slip caused by non-linearity can be suppressed. Further, even if signal point allocation is changed, the change can be recognized in the receiver, and the receiver can deal with the changed signal point allocation.

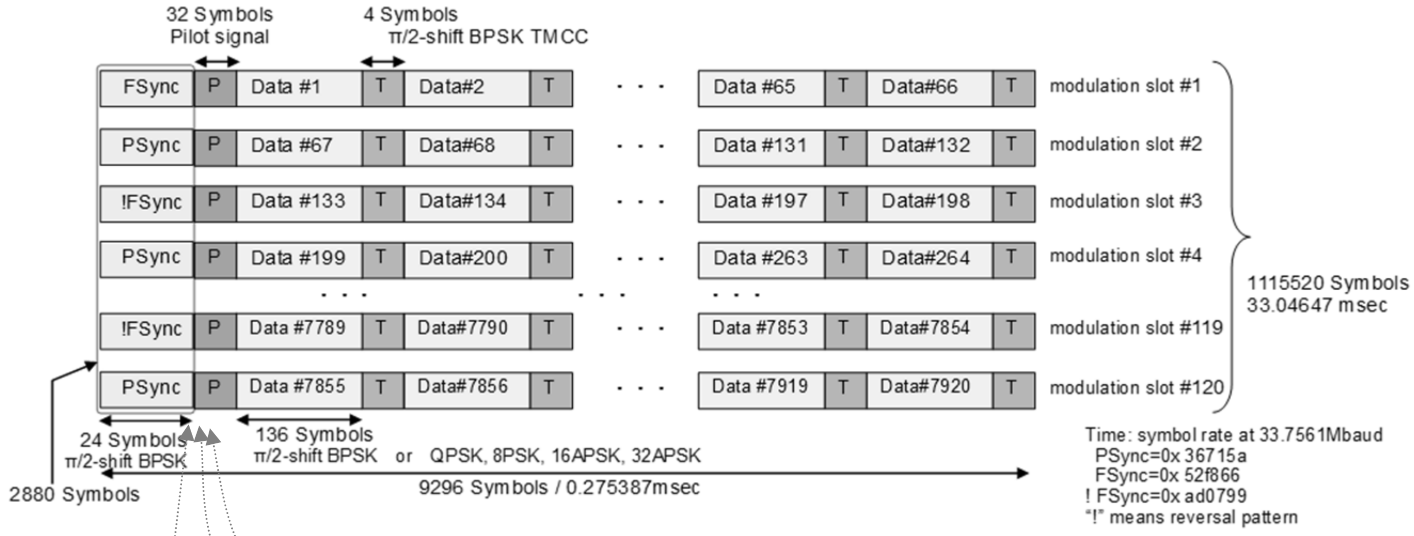


Fig. A-2: modulation signal format

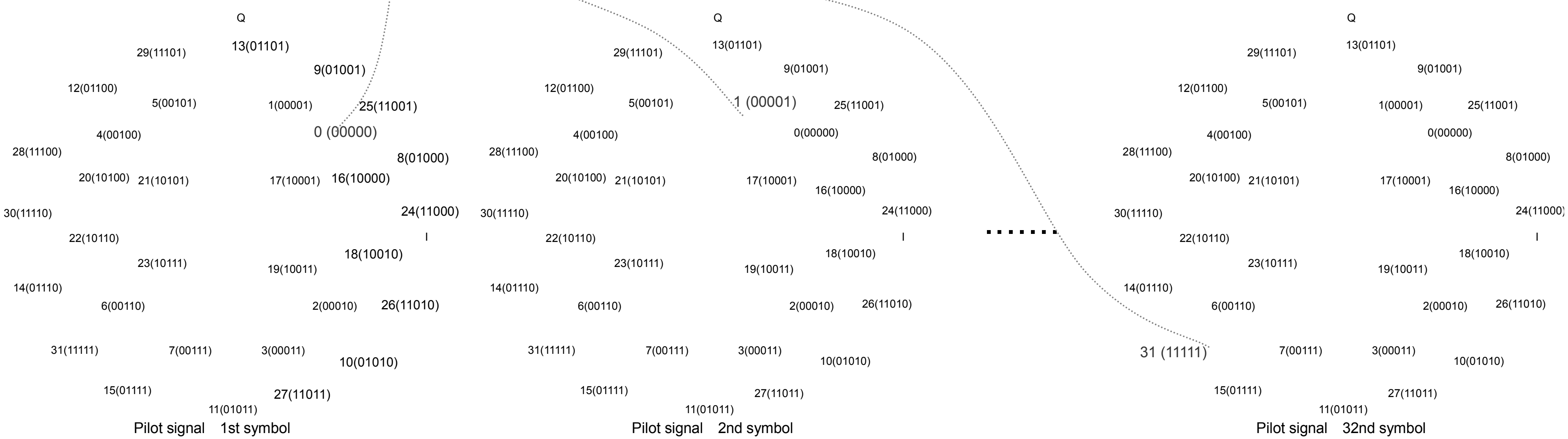
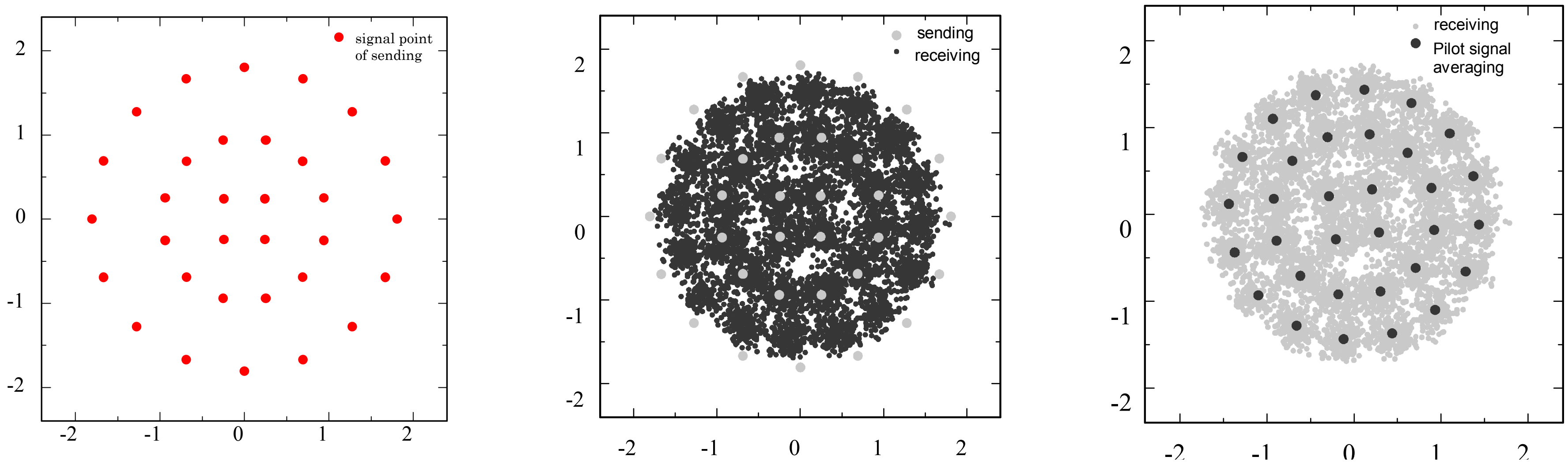


Fig. A-3: An example of pilot signal (32APSK)



(a) transmission signal point

(b) received signal point (after passing non-linearity)

(c) averaging pilot signal

Fig. A-4: Acquisition of signal point allocation by averaging pilot signal after passing non-linearity

A.2.2 Application for a likelihood table and a phase error table

As mentioned above, after acquiring signal points of each symbol for modulation scheme by using pilot signal, and eliminating noise by averaging them for dozens of frames on the same symbol, the signal point allocation can be found after affected by non-linearity of the transmission channel. Fig. A-5 shows an ordinary block diagram of a receiver. Here, the phase error table which is used in orthogonal detection after channel selection and the likelihood table which is used in decoding LDPC code, are generated by the signal point allocation acquired from pilot signal, so it makes possible to regenerate carrier and decode LDPC code in a condition that the influence of non-linearity has been eliminated as much as possible.

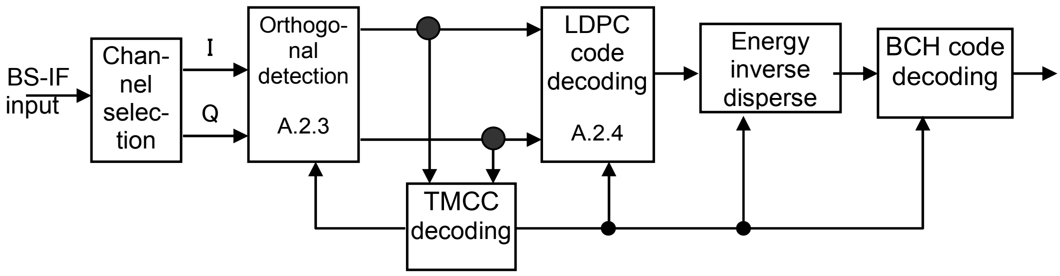


Fig. A-5: Block diagram of a receiver

A.2.3 Phase error table for carrier regeneration

The detail block diagram of the orthogonal detection circuit of the receiver of Fig. A-5 is shown in Fig. A-6. The part which is necessary in case of compensating non-linearity by pilot signal is written as “additional part.” Usually by using phase error table shown in Fig. A-7, for the output of root roll-off filter, the numerical control oscillator is controlled so that the frequency error is made to be small by detecting phase error of positive or negative regenerated carrier by the relation of position between received signal point P and ideal signal point. In this case, if APSK is transmitted in the non-linear channel, on the outer signal point of circle amplitude is more suppressed and phase is more rotated. So the carrier regeneration by using phase error table shown in Fig. A-7 which is assumed in an ideal channel causes a rise of synchronization limit C/N and a rise of the probability of cycle slip.

When using pilot signal, the pilot signal is extracted from the output of root roll-off filter, and the averaging of the pilot signals is made for the same symbol in the slot. By using information of the averaged signal point, data for phase error table is generated and the phase error table is updated.

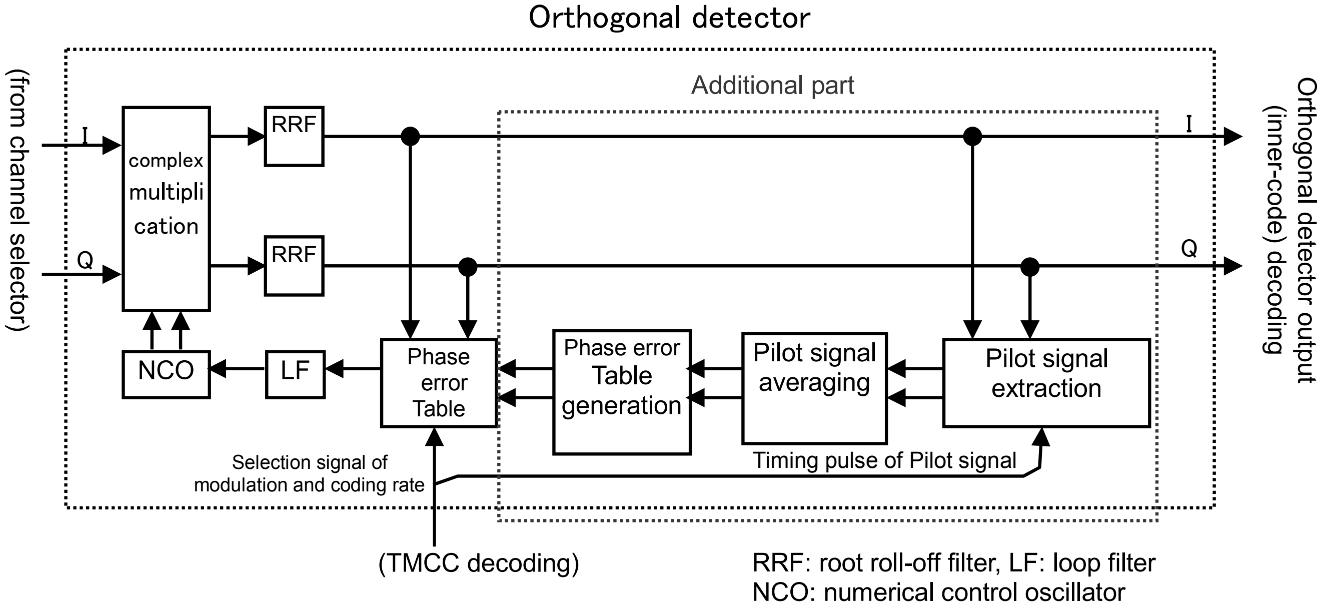


Fig. A-6: An example of orthogonal detection in case of compensating by pilot signal

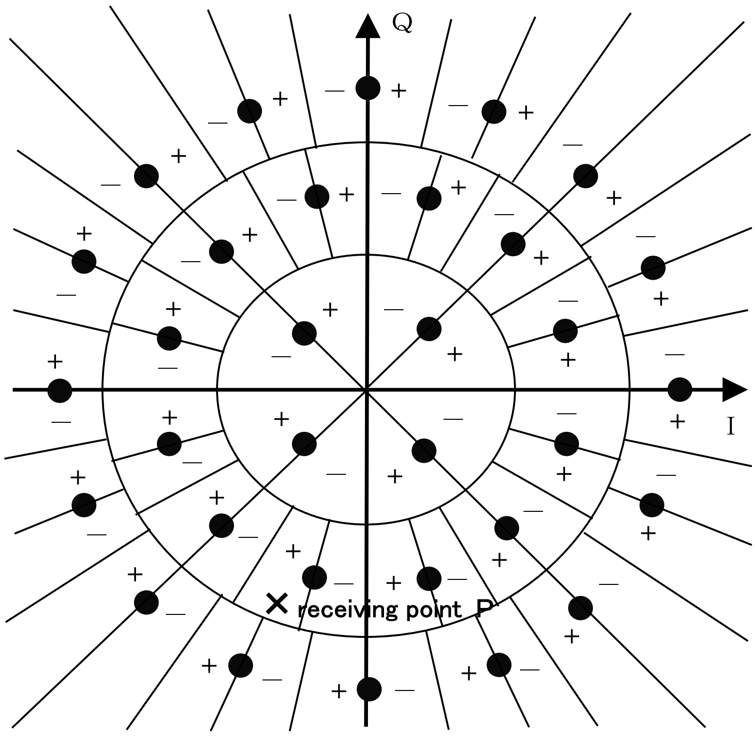


Fig. A-7: An example of phase error table (32APSK)

A.2.4 Likelihood table for LDPC code decoding

The detail block diagram of LDPC code decoding circuit of the receiver of Fig. A-5 is shown in Fig. A-8. The part which is necessary in case of compensating non-linearity by pilot signal is written as "additional part." In case of LDPC code decoding, the likelihood tables for modulation scheme by which the signal is transmitted, coding rate, and each bit (5 bits in case of 32APSK) composing symbol of the modulation are prepared, and at the received signal point which is an output of the root roll-off filter, the log ratio LLR (Log Likelihood Ratio) of the probability which seems to be 1 to the probability which seems to be 0 is calculated, and LDPC code is decoded for the LLR. In this case, if APSK is transmitted in the non-linear channel, on the outer signal point of circle amplitude is more suppressed and phase is more rotated, so LDPC code decoding by using a likelihood table for assumed an ideal channel will cause a bad effect such as a rise of required C/N.

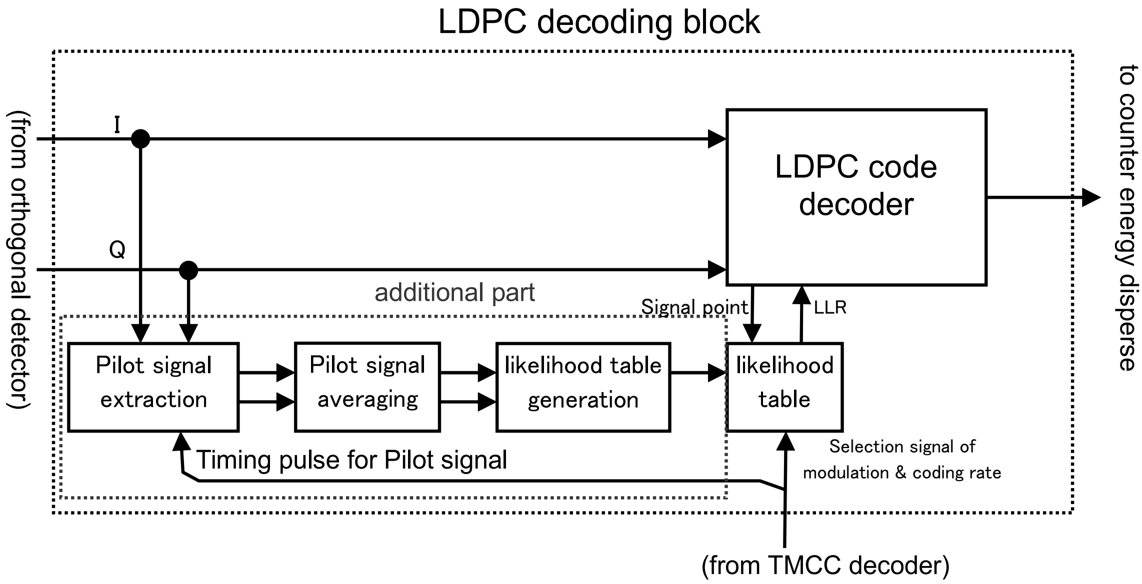


Fig. A-8: Block diagram of LDPC code decoding compensation by pilot signal

In case of using pilot signal, the pilot signal is extracted from an output of root roll-off filter, and it is averaged for the same symbol in the slot. By using averaged information of signal point, data composing likelihood table is generated, and the likelihood table is updated.

A.2.5 Required average time of Pilot signal

Calculating required averaging time that the required C/N deterioration is below 0.1 dB caused by an insufficiency of averaging pilot signal, results in that the number of times for average frame is 44 times (required time is 1.45 sec) for 32APSK97/120 (4/5), 22 times (required time is 0.727 sec) for 16APSK89/120 (3/4), 11 times (required time is 0.364 sec) for 8PSK89/120 (3/4), 6 times (required time is 0.198 sec) for QPSK61/120 (1/2), 3 times (required time is 0.099 sec) for π/2-shift BPSK61/120 (1/2), and 6 times (required time is 0.198 sec) for QPSK33/120. Therefore, averaging pilot signal for about 2 second will give almost enough accuracy.

A.3 Back-off information of satellite transponder in TMCC signal

As a result of consideration in Clause A.2.5, it takes about two seconds to extract the signal point information from pilot signal, so it is difficult to regenerate carrier with less jitter using all modulation symbols during that time. So, TMCC signal involves "information on slot /modulation scheme" shown in Table A-7. By using this, modulation scheme, coding rate and back-off can be designated for slot of each frame. Using this information, the receiver is made to be able to generate phase error table and likelihood table for initial receiving under consideration of back-off.

On designating modulation scheme, as shown in Table A-8, in case of assigning modulation scheme except for 32APSK, a unit of 5 slots is adopted and the degrading rate is replaced to dummy slot comparing with 32APSK. For example, in case of assigning 16APSK to slots, four slots can be used for data transmission among five slots, and dummy data is inserted to one remaining slot. This dummy data is not transmitted in fact, but the same concept is adopted in the present BS and wide band CS digital broadcasting because it is effective to make bit rate of frame constant.

It is also possible to designate 5 slots as a unit on coding rate and back-off. Here, "back-off" means the amplifier working point for the relevant modulation scheme in the satellite transponder, and the average power indicated in dB referring the saturated amplifying level of modulation. It is because the bigger coding rate, the bigger back-off is needed, even in the same modulation, that back-off can be designated for each coding rate.

In the receiver, using back-off information of TMCC signal, signal point allocation for the reference is updated as shown in Fig. A-9, corresponding phase error table and likelihood table are generated or selected, and initial receiving is achieved.

Table A-7: Information on slot/modulation scheme of TMCC signal

name	bit	items	bit	note
Transmission mode / slot information	192	Transmission mode 1 (modulation)	4	5 kinds of modulation 0000 : reserved 0001: π/2-shift BPSK 0010:QPSK 0011:8PSK 0100:16APSK 0101:32APSK 0110-1110:reserved 1111: not assigned 11 kinds of inner-code 0000: reserved 0001: 41/120 (1/3) 0010: 49/120 (2/5) 0011: 61/120 (1/2) 0100: 73/120 (3/5) 0101: 81/120 (2/3) 0110: 89/120 (3/4) 0111: 93/120 (7/9) 1000: 97/120 (4/5) 1001: 101/120 (5/6) 1010: 105/120 (7/8) 1011: 109/120 (9/10) 1100-1110: reserved Back-off (OBO=0～25.5dB) (8bit) Binary indication of OBO[dB]×10
		Transmission mode 1 (coding rate)	4	
		Assigned slot number to transmission mode 1 (integer times 5)	8	
		Satellite output back-off of Transmission mode 1	8	
		・・・	・・・	
		Transmission mode 8 (modulation)	4	
		Transmission mode 8 (coding rate)	4	
		Assigned slot number to transmission mode 8 (integer times 5)	8	
		Satellite output back-off of Transmission mode 8	8	

Table A-8: Rule of slot assignment

modulation	frequency efficiency [bps/Hz]	normalization efficiency	assign unit [slot]	data [slot]	dummy
32APSK	5	1	5	5	0
16APSK	4	4/5	5	4	1
8PSK	3	3/5	5	3	2
QPSK	2	2/5	5	2	3
π/2-shift BPSK	1	1/5	5	1	4

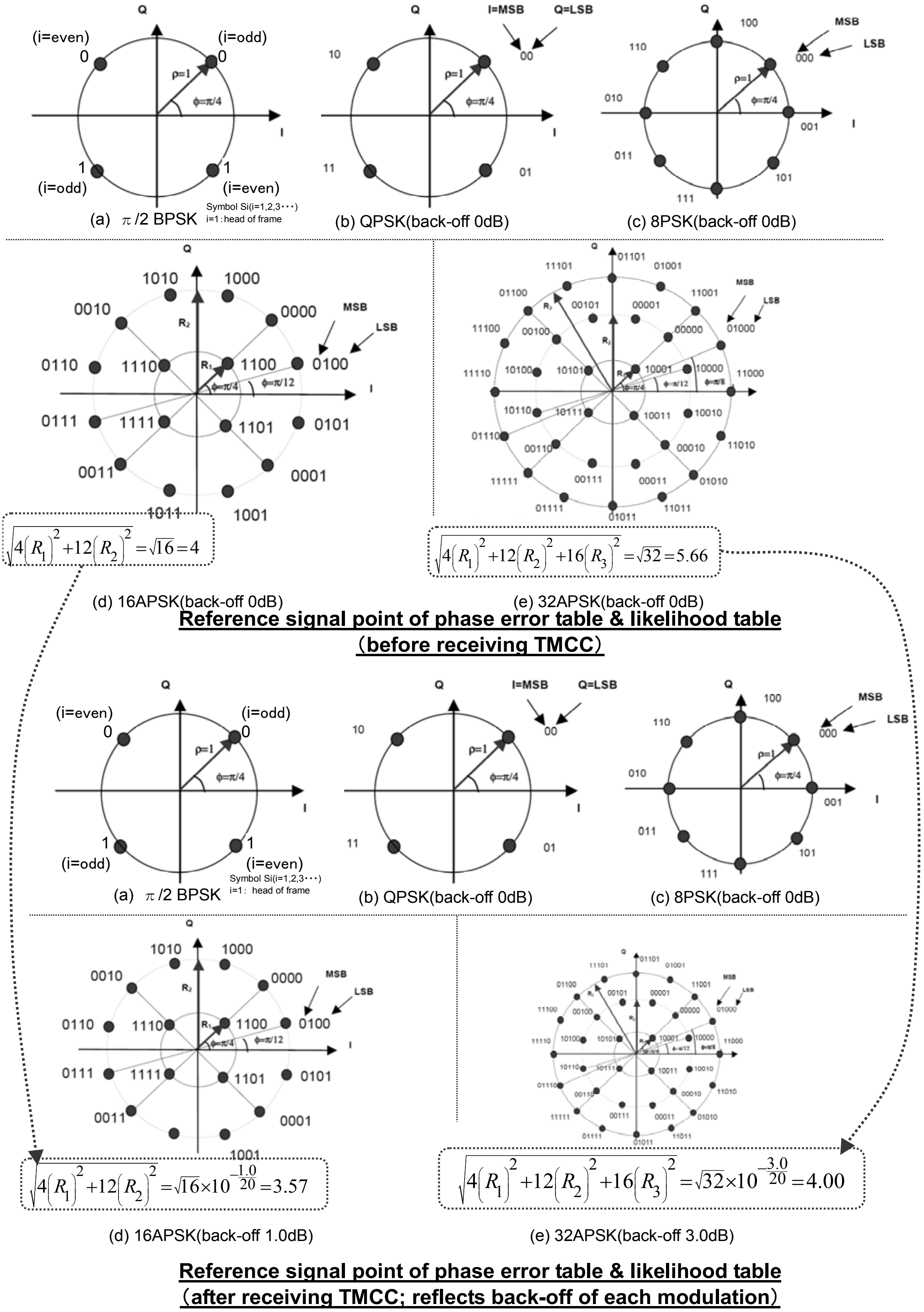


Fig. A-9: Updating reference signal point for phase error table and likelihood table by "slot/modulation information" of TMCC

Explanation B: Stream Control Function by TMCC Signal

B.1 Necessity of stream control

Packet mainly used for the purpose of broadcasting has 188 bytes fixed-length, and 8 bits unique word is added to the head as synchronization byte as shown in Figure B-1. For such fixed-length packet stream to which synchronization byte is added, it is possible to easily acquire the head of packet by searching for the point where known synchronization byte can be acquired at known packet length interval.

On the other hand, taking an example of IP packet as shown in Figure B-2, there is nothing equivalent to synchronization byte at the head of packet and the packet length is variable. In the case of such packet stream transmission/reception, measures of adding synchronization byte or transmitting signals separately are required to recognize the head of packet. Detection of pseudo synchronization becomes difficult in the case of adding synchronization byte because arrival period of the synchronization byte is varied by packet length.

Accordingly, TMCC signal transmits pointer information showing from what number of byte in each slot is multiplexed in the advanced wide band digital satellite broadcasting system. Furthermore, variable-length packet (except for IP packet) stream, MPEG-2 TS packet stream and etc. apply a mechanism capable of multiple assignment per slot and transmission. The chapter below explains stream control function by TMCC signal.

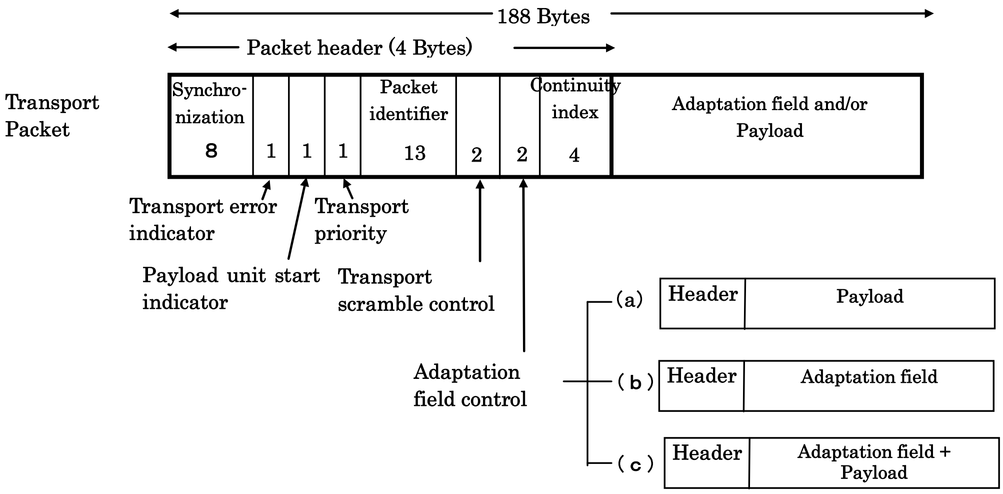


Fig. B-1: Structure of MPEG-2 TS

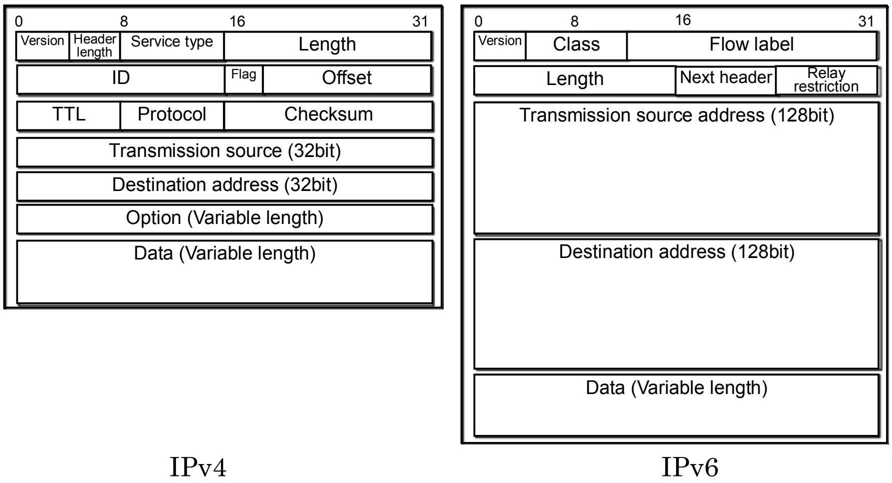


Fig. B-2: IP Packet Structure

B.2 Related information on stream control for TMCC signal

Table B-1 summarizes the related information on stream control for TMCC signal.

Table B-1: Related information on stream control for TMCC signal

Name	bit	Details	bit	Remarks
Relative stream/ slot information	480	Slot 1 relative stream number	4	Relative stream numbers : 0-15
		・・・・		
		Slot 120 relative stream number	4	
Relative stream/ information on correspondence table of transmission stream ID	256	Relative stream number 0 : Transmission stream ID	16	TS_ID in the case of MPEG-2 TS TLV stream ID in the case of TLV
		・・・・	・・・	
		Relative stream number 15 : Transmission stream ID	16	
Stream type/ slot information	128	Relative stream 0 stream type	8	Stream type 00000000: Reserved 00000001: MPEG-2 TS 00000010: TLV 00000011-11111110: Reserved 11111111: Non assignment
		・・・・	・・・	
		Relative stream 15 stream type	8	
Pointer/Slot information	3840	Slot 1 top pointer	16	Top pointer : Designating the head byte in the first packet. However, there is no head byte for 0xFFFF. Last pointer : Designating the final byte + 1 in the last packet completely arranged in slots. However, there is no final byte for 0xFFFF..
		Slot 1 last pointer	16	
		・・・・	・・・	
		Slot 120 top pointer	16	
		Slot 120 last pointer	16	
Packet length	256	Relative stream 0 packet length	16	Specifying packet length in byte unit 0x0000 in the case of unfixed length
		・・・・	・・・	
		Relative stream 15 packet length	16	
Bit length of synchronization pattern	128	Relative stream 0 synchronization pattern bit length	8	Describing synchronization pattern length as 0(0x00)～32(0x20) bit length when synchronization pattern is required to be placed at several top bytes in the case of null replacement
		・・・・	・・・	
		Relative stream 15 synchronization pattern bit length	8	
Synchronization pattern	512	Relative stream 0 synchronization pattern	32	Describing synchronization patterns. Putting bit numbers equivalent to the synchronization pattern bit-length from MSB into effect
		・・・・	・・・	
		Relative stream15 synchronization pattern	32	

(1) **Multiple stream transmission**

Maximum 16 streams can be transmitted through one satellite transponder in the advanced wide band digital satellite broadcasting.

"Relative stream/slot information" assigns any relative stream number from 0 to 15 for each 120 slots consisting of multiplexed frame and slot data having the same relative stream number shows one stream.

In addition, "relative stream/information on correspondence table of transmission stream ID" assignes the transmission stream ID which is 16 bits identification number to each stream with relative stream number from 0 to 15. Transmission stream ID is set as TS ID when the stream is MPEG-2 TS, and set as TLV stream ID when the stream is TLV.

"Stream type/slot information" indicates a stream type for each relative stream number and assigns 0x01 for MPEG-2 TS, 0x02 for TLV and 0xff for non assignment. Any others are reserved for the future use.

(2) **Packet synchronization**

"Pointer/slot information" is composed of top pointer and last pointer for each slot and mainly used for packet synchronization and packet invalidation.

Figure B-3 shows an example to store packets in a slot data area. Top pointer shows the head byte location in the first packet of the stored packets in each slot. Last pointer shows the final byte plus 1 location in the last packet of the stored packets in each slot.

Among them, packet synchronization is performed mainly by using top pointer, and the last pointer is used for packet invalidation mentioned below.

(3) Packet invalidation

When errors exceeding error correction capability by the LDPC code + BCH code occur and unreceivable slots are generated, packet identification and etc. coincide with that of other service by bit errors and may affect the other service if these slots are delivered to the subsequent processing as they are. Therefore it is necessary for the packets stored in the correction disable slots to be replaced to NULL packets or NULL data, or to be delivered to the subsequent processing after invalidating packets by setting error presence flag if there would be error indicator flag.

Figure B-4 shows how to invalidate packets. When decoding BCH code for each slot, it is determined whether the decoding is made correctly. Here, packets transmitted by the slots concerned are invalidated when errors cannot be corrected. Packets invalidation range applies to all the packets of which a whole or a part is included in the correction disable slots. Therefore, when slot #N is uncorrectable, packets invalidation ranges from the last pointer in the slot #N-1 to the top pointer minus 1 in the slot #N+1. Transport error indicator is set to 1 in the case of MPEF-2 TS and is replaced to NULL data otherwise.

As for the packet invalidation in the case of TLV transmission, packets should be replaced to NULL packets with TLV format. The NULL packets length can be selected from any byte length among 4 bytes to 65535 bytes.

Figure B-5 shows a specific example of packet invalidation in the case of TLV transmission. This example in the Figure shows the case that slot #N+1 and slot #N+2 cannot be corrected by BCH. In this case invalidation coverage ranges from the last pointer in slot #N to the top pointer in slot #N+3. In the invalidation replacing to NULL packet specified by TLV is performed. The method to replace each correction disable slot by NULL packet shown in Figure B-5 (a) or the method to replace the correction disable slots by one NULL packet shown in Figure B-5 (b) is considered. For TLV interface any method is available at receiver side, because the interface has common ignored object for any method. However, when TLV null #1 and TVL null #4 are under 4 in the above method (a), exceptional processing such as replacing them to one TVL null packet by connecting TLV null #1 and TLV null #2, and TLV null #3 and TLV null #4 is needed, because minimum TLV byte length is 4.

In addition "packet length" of TMCC signal indicates the packet length when the packet in each relative stream is fixed in length. "Synchronization pattern length" and "synchronization pattern" indicate the synchronization byte length and synchronization pattern, respectively when there is synchronization byte at the head of relative stream packet. From the information unknown TS and unknown stream excluding TLV can be delivered to the subsequent processing after arranging the stream into packet format by overwriting the specified synchronization byte at the head of the portion replaced with NULL data, when packet length is fixed value and synchronization byte is specified.

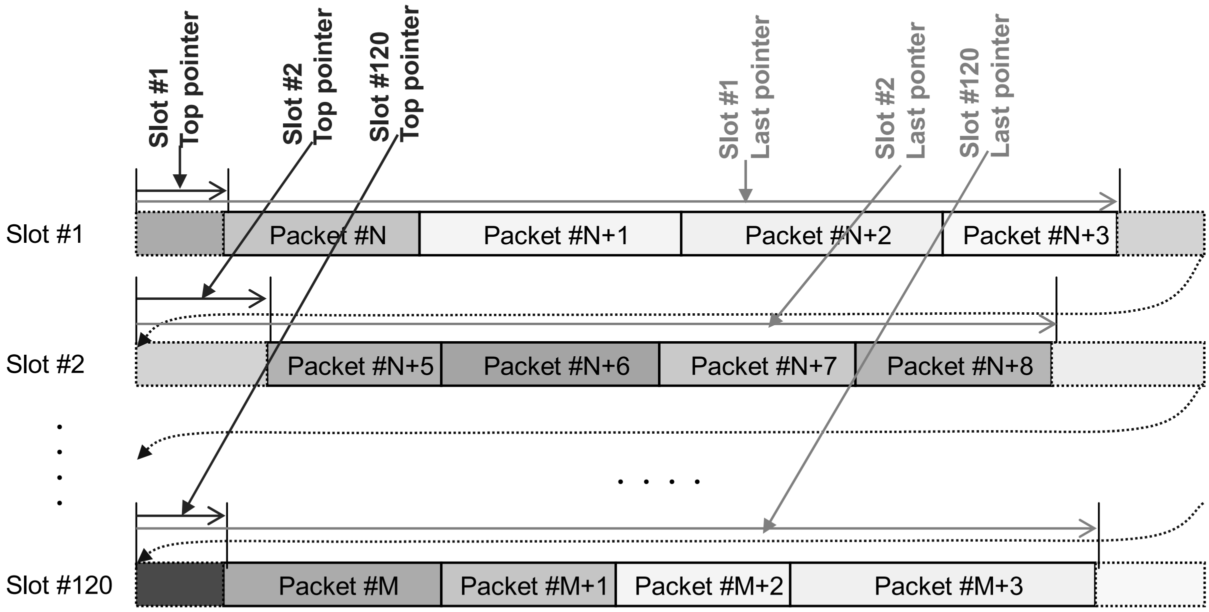


Fig. B-3: Top pointer and last pointer

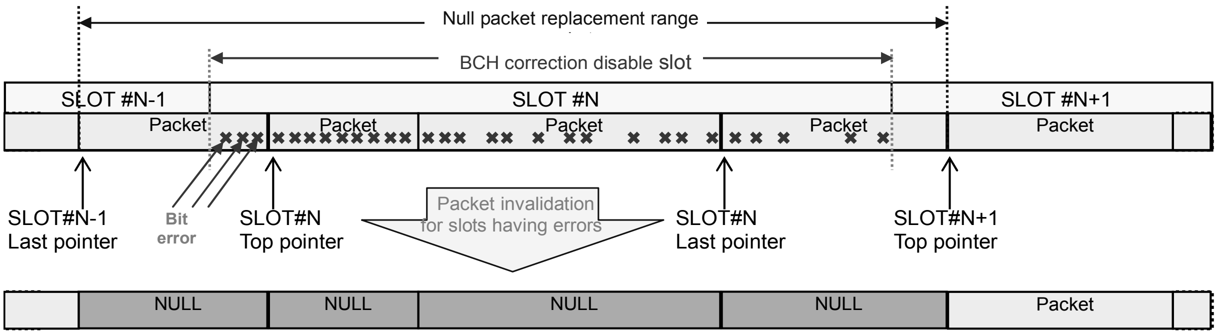


Fig. B-4: NULL packet replacement at receiver

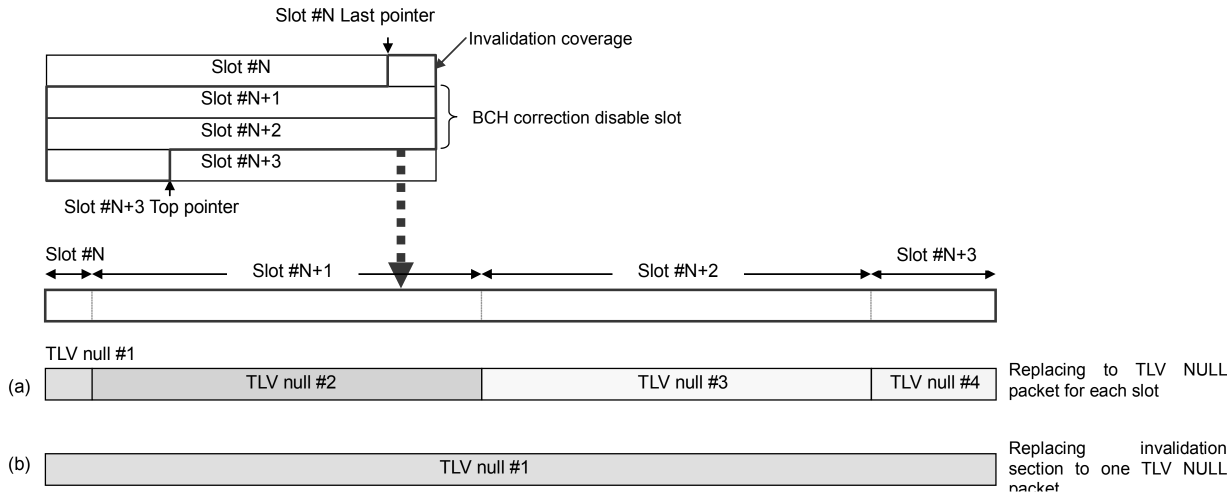


Fig. B-5: TLV NULL packet replacement for invalidation section

ATTACHMENT: OPERATIONAL GUIDELINES FOR THE ADVANCED WIDE BAND DIGITAL SATELLITE BROADCASTING

Attachment: Operational Guidelines for the Advanced Wide Band Digital Satellite Broadcasting

Contents

Chapter 1: General Terms

1.1 Purpose

These operational guidelines show recommended technical requirements for the delivery and transmission services of digital broadcast program as guidelines in actual operation.

1.2 Scope

These operational guidelines are applied to the advanced wide band digital satellite broadcasting and are subject to the operation rules for further details.

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Chapter 2: PCR Operational Guideline

2.1 Efficient Hardware by PCR management

It is possible to assign 1 to 120 slots per frame for one broadcaster in the advanced wide band digital satellite broadcasting. In addition modulation scheme can be selected from 5 types and coding rate can be selected from 11 types. Thus flexibility was ensured. On the other hand transmission capacity per 1 TS takes a number of values over a wide range depending on a combination of number of assigned slots, modulation scheme and coding rate, and thus this will cause complication of hardware.

When multiple modulation schemes are transmitted by the same carrier wave, they are sequentially allocated to the slots from the first slot in transmission frame in order of higher modulation level for the modulation schemes. When multiple coding rates are used for single modulation scheme they are sequentially allocated to the slots from the first slot in transmission frame in order of higher coding rate. When a lower modulation scheme than that of the maximum efficiency is assigned, invalid (dummy) slots are to be placed subsequently to the valid slots. (As a reference example, see Figure 2.1)

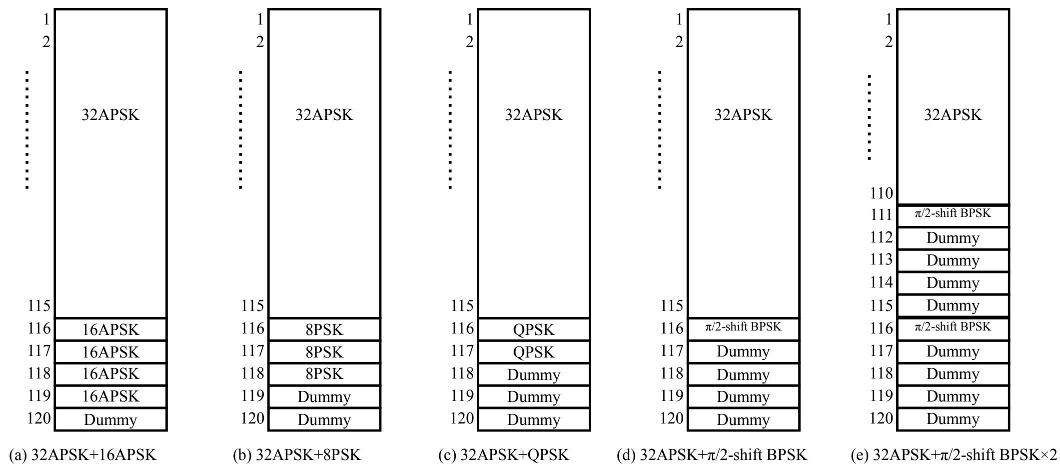

Fig. 2.1: Example of slot allocation

Number of dummy slots per 5 slots takes five values among 0 and 4 corresponding to the allocated modulation scheme. In addition packets included in the slots can be allocated from 10 packets (coding rate 1/3) to 27 packets (coding rate 9/10) corresponding to the assigned coding rates according to Table 2.1 and number of the patterns is 11 equal to that of coding rates.

Under the above conditions, when bit streams transmitted from consignment broadcaster are simply time-compressed at transmitting side and time-extended at receiving side, the transfer from transmission line decoder to information source decoder in the receiver takes a total of 6600 (=120 x 5 x 11) information rates (Actually these values becomes half and more, because dummy bits are inserted in the modulation system except 32APSK and excluded from the combination). Then information rates are in the range of 455kbps to 146.671Mbps and needed to correspond to the clock rates for these rates. Accordingly a large impact to the system implementation is provided. As for a method to reduce the load of such rate conversion, the following explains a technique which combines null packets insertion and PCR replacement.

Table 2.1: Slot structure for each coding rate

Coding rate	Slot Length = LDPC coding length						Total coding rate ※3			Reference
		Slot header	Data length (number of TS packets)	BCH parity	Stuff bit	LDPC parity		LDPC coding rate ※2	BCH + header + stuff coding rate ※1	
1 / 3	44880	176	14960 (10)	192	6	29546	0.333	0.342 (41/120)	0.976	1/3=33.33%
2 / 5	44880	176	17952 (12)	192	6	26554	0.400	0.408 (49/120)	0.980	2/5=40%
1 / 2	44880	176	22440 (15)	192	6	22066	0.500	0.508 (61/120)	0.984	1/2=50%
3 / 5	44880	176	26928 (18)	192	6	17578	0.600	0.608 (73/120)	0.986	3/5=60%
2 / 3	44880	176	29920 (20)	192	6	14586	0.667	0.675 (81/120)	0.988	2/3=66.67%
3 / 4	44880	176	32912 (22)	192	6	11594	0.733	0.742 (89/120)	0.989	3/4=75%
7 / 9	44880	176	34408 (23)	192	6	10098	0.767	0.775 (93/120)	0.989	7/9=77.7%
4 / 5	44880	176	35904 (24)	192	6	8602	0.800	0.808 (97/120)	0.990	4/5=80%
5 / 6	44880	176	37400 (25)	192	6	7106	0.833	0.842 (101/120)	0.990	5/6=83.33%
7 / 8	44880	176	38896 (26)	192	6	5610	0.867	0.875 (105/120)	0.990	7/8=87.5%
9 / 10	44880	176	40392 (27)	192	6	4114	0.900	0.908 (109/120)	0.991	9/10=90%

*1 (Data length) / (data length + BCH parity + slot header + stuffing bits): (a)

*2 (Data length + BCH parity + slot header + stuffing bits) / (data length + BCH parity + slot header + stuffing bits + LDPC parity): (b)

*3 (a) × (b)

2.2 Technique to reduce the load of rate conversion

As a method to reduce the load of rate conversion it is effective to keep transmission rate from consignment broadcaster at a fixed rate corresponding to contract slot numbers[1] and to set PCR taking account of dummy slots and coding rates.

----

[1] Maximum slot number handled freely by operator

Figure 2.2 shows an example of 15 slots per 1 frame. For the case of TS1 (number of contract slot is 10) layered transmission as shown in this figure, dummy slots including null packets inserted in advance are assigned for configuring TS, because dummy slots for parity should be supposed. PCR is set to maintain time base between transmission and reception on the assumption that null packets are assigned to free space determined by coding rates other than dummy slots in each TS and dummy slots. Free space determined by coding rates is further described in the later section by using specific example.

In this way consignment broadcaster generates TS packets corresponding to the number of contract slots. Transmission rate from consignment broadcaster to trust broadcaster becomes constant even if a layered structure is changed, because contract slots including null packets are transmitted in the case of transmission from consignment broadcaster to multiplexer installed at trust broadcaster.

When ①TS1 is regenerated at receiver, TS null packets are placed to the supposed dummy slots during transmission and slots except dummy slots are outputted after null packets assignment to free space determined by coding rates.

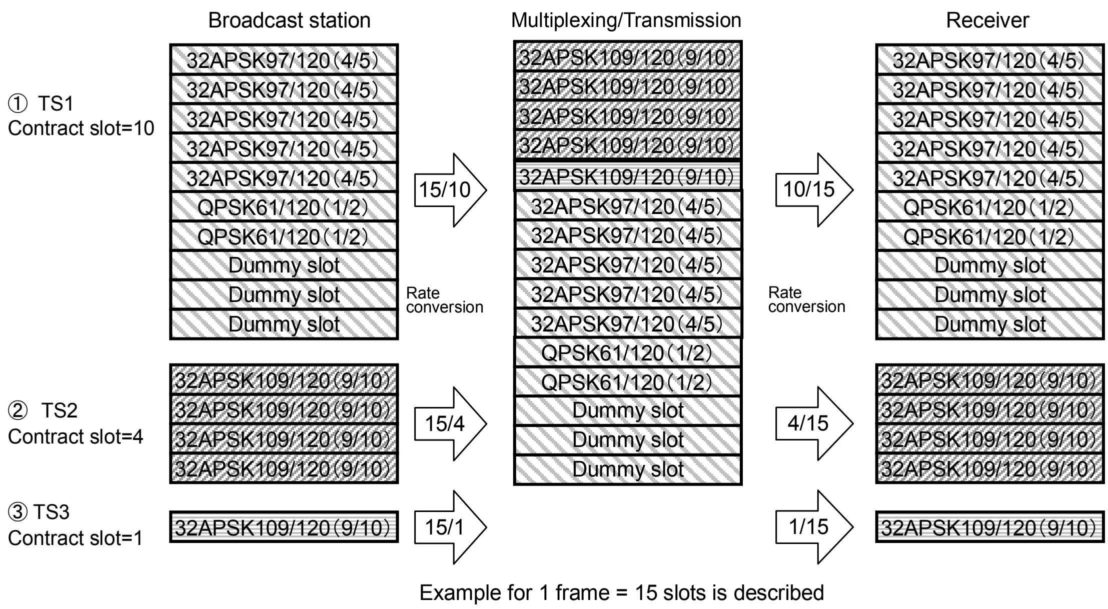

Fig. 2.2: Example of multiple TS assembly

TS time relationship between consignment broadcaster and receiver is preserved by the above processing and time position of time reference PCR existing in the TS is not displaced.

There is a case in which slot numbers are different between TS 2 and TS3 and then contract slots are only transmitted from broadcast station to the multiplexer.

According to the above method, types and range of handled clock rates can be remarkably reduced in comparison with the case of simple time extension at transmission side mentioned in the section 2.1, although rate conversion using clock of "slot number (120) within frame/n" in the multiplexing process at transmission side and that using clock of "n/slot number (120) within frame" at reception side after demultiplexing are needed when number of contract slot in 1 frame is n (integer).

In addition these rate conversion methods require caution so that failure does not occur in switching transmission system and they are realized, for example, by a digital rate conversion using clock thinning.

2.3 Specific example

As for the method mentioned above the details are explained below by indicating specific examples.

As an example the case of transmitting 16 APSK modulation system and encoding rate 41/120 (1/3) using slot #1 - #5 as shown in Figure 2.3 (a) is considered.

Regenerated signal at reception side is shown in the figure (b) and 187-byte TS excluding the synchronization byte is obtained in bursts. At the receiver it is necessary to add the synchronization byte to the head of TS and to transfer equal interval TS packets including appropriate PCR values to MPEG decoder, etc. The method to replace PCR satisfying such a condition is described below.

TS packets per 1 slot which can be transmitted by coding rate 41/120 (1/3) are 10 packets according to Table 2.1. Therefore number of packets which can be transmitted by 4 valid slots becomes 40 (10x4) packets as shown in Figure 2.4 (a).

Consignment broadcaster replaces PCR before slot assignment for this packet streams. Replacement of PCR is performed on the memories (5810×5Byte=46480×5bits=232400bits, refer to Figure 2.5) equivalent to 5 slots (including synchronization, signal position arrangement information and TMCC).

To develop 60160 (188×8×40) bits data included in the time of 5 slots on the 232400 bits memory in the same time period, rate conversion of 232400/60160=2905/752 is performed as shown in Figure 2.4 (b). Every time 1 TS is written when development is performed, the next TS is written at 19.5 byte interval. Here written TS associated with the next 19.5 byte interval is called cell and then 1 memory slot used for development is composed of 28 cells in which only the first 10 cells are used and the other 18 cells are written by null packets. After the above development onto the memory is completed, replacement to PCR having a proper value for the developed TS is performed.

After PCR replacement is completed, readout is performed at 120/5 times writing speed and TS having replaced PCR is placed on the slot in frame together with other similar processed TS after the first synchronization byte is removed as shown in Figure 2.4 (c). In this state, signal is transferred from consignment broadcaster to transmission line encoding part.

Transmission line coding and its transmission for this signal are performed at the transmission line encoding part. In addition this signal is received and time expansion of 120/5 is performed at receiver. In other words, the signal as shown in Figure 2.4 (c) is provided at receiver side.

TS adding synchronization byte to 232,400 bits cell in Figure 2.4 (d) is developed for the signal in the figure (c) at receiver. Every time 1 TS is written when development is performed, the next TS is written at 19.5 byte interval. In addition after 10 cells are written, 18 cells are filled by null packets at the same interval.

When development is completed, time extension of 207.5/188 is performed while disposing the intervals on the memory. By means of this TS stream with 188 bytes length including proper PCR at equal interval is regenerated. In addition time extension of 207.5/188 is not required if the decoder for delivering stream could receive 188 bytes packet in burst.

When streams are multiplexed across multiple 5 slots units and furthermore multiple streams are mixed, similar processing is performed by 5 slots units. Processing of PCR is performed in the single stream when PCR is replaced and packets in the different stream are processed as NULL packets. In addition, packets in other stream can be handled by replacing them to NULL packets in the case of extracting them as stream.

2.4 Applicability to actual operation

It is possible to remarkably reduce the implementation impact of rate conversion with a relatively simple mechanism by the method mentioned above. This method is used in the verification test performed by ARIB and its feasibility is ensured.

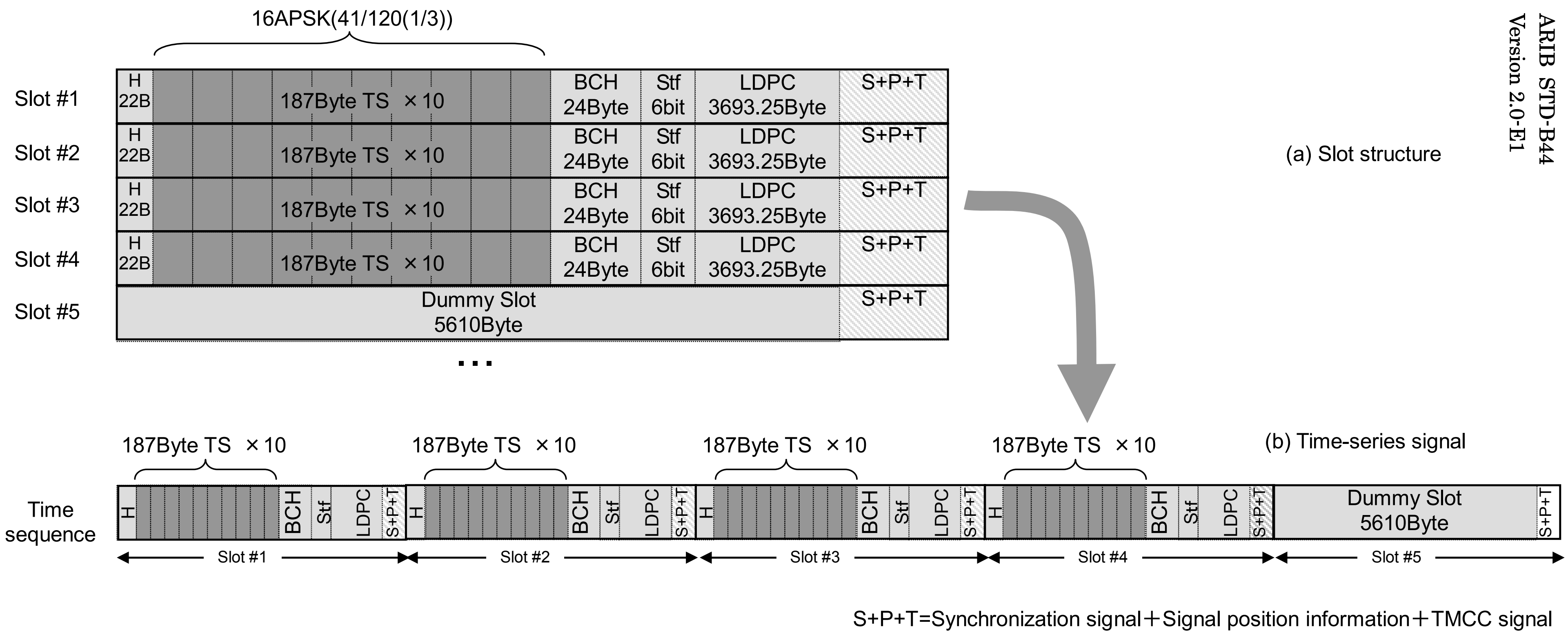

Fig. 2.3: Example of stream regenerated at receiver

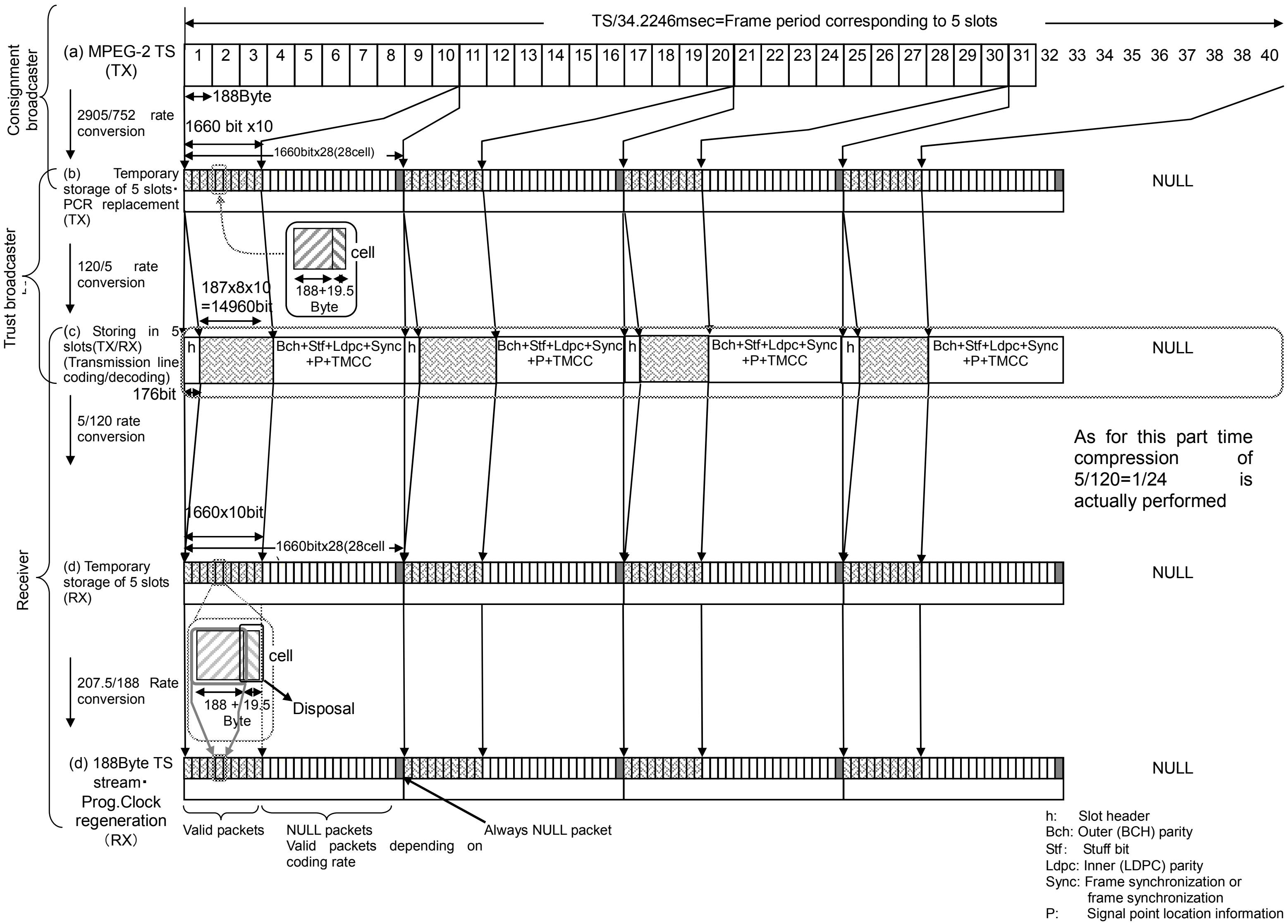

Fig. 2.4: Example of PCR replacement

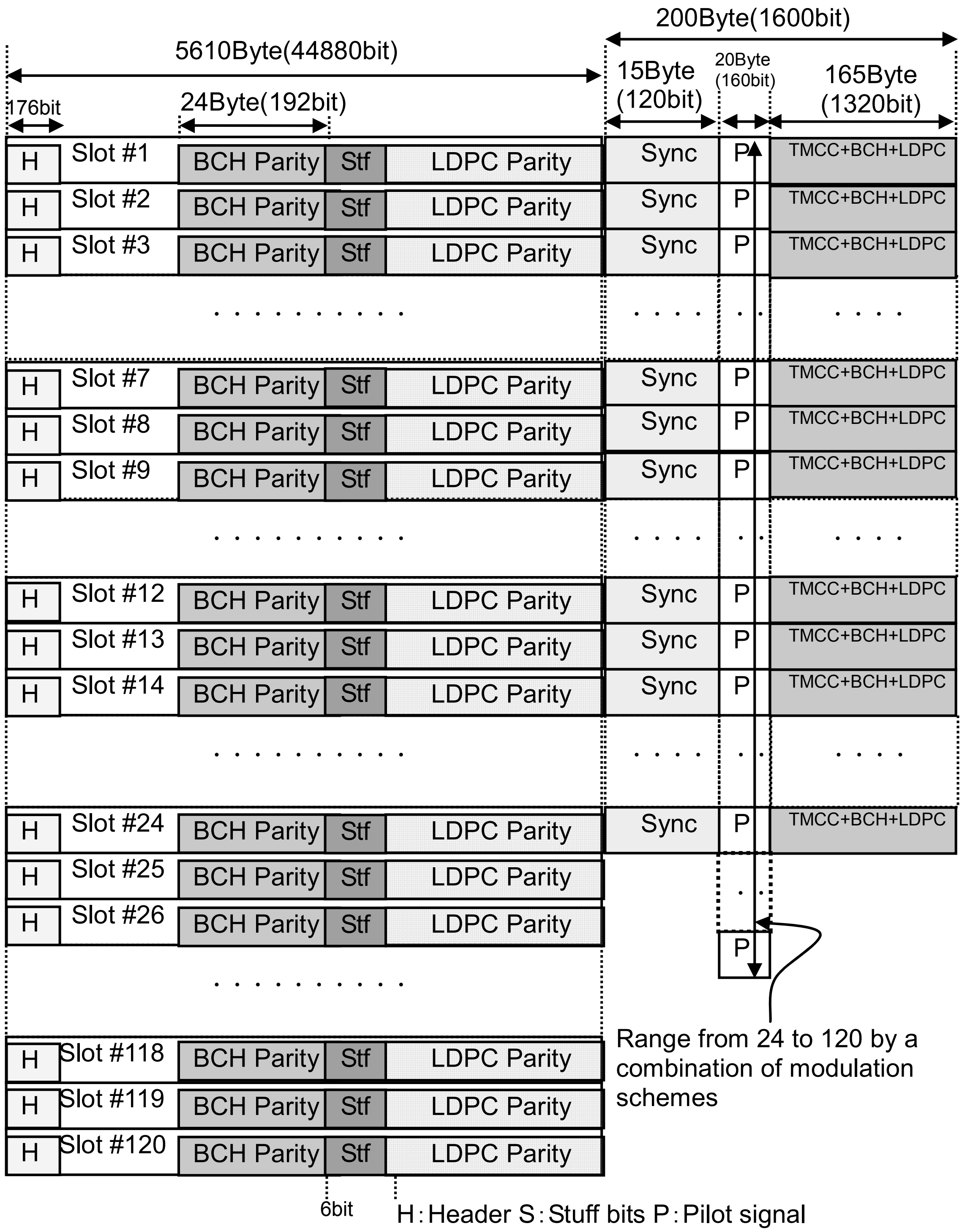

Fig. 2.5: Frame structure

Chapter 3: Guideline for Time Information Transmission

3.1 Transmission of Coordinated Universal Time by NTP in main signal

IP packet with NTP format specified by IETF RFC 5905 "Network Time Protocol Version 4: Protocol and Algorithms Specification" is used to provide Coordinated Universal Time, UTC in main signal.

It is necessary to transmit IP packet including NPT format by suppressing delay variation. Accordingly IP header for IP packet including NTP format is not compressed.

Furthermore TLV packet which stores IP packet including NTP format is placed at the head of the first slot in the slots assigned to each TLV stream ID. It is possible to suppress delay variation for IP packet including NTP format by such TLV packet placement. Table 3-1(a) and 3-1(b) show an example of placing TLV packet including NTP format in slots.

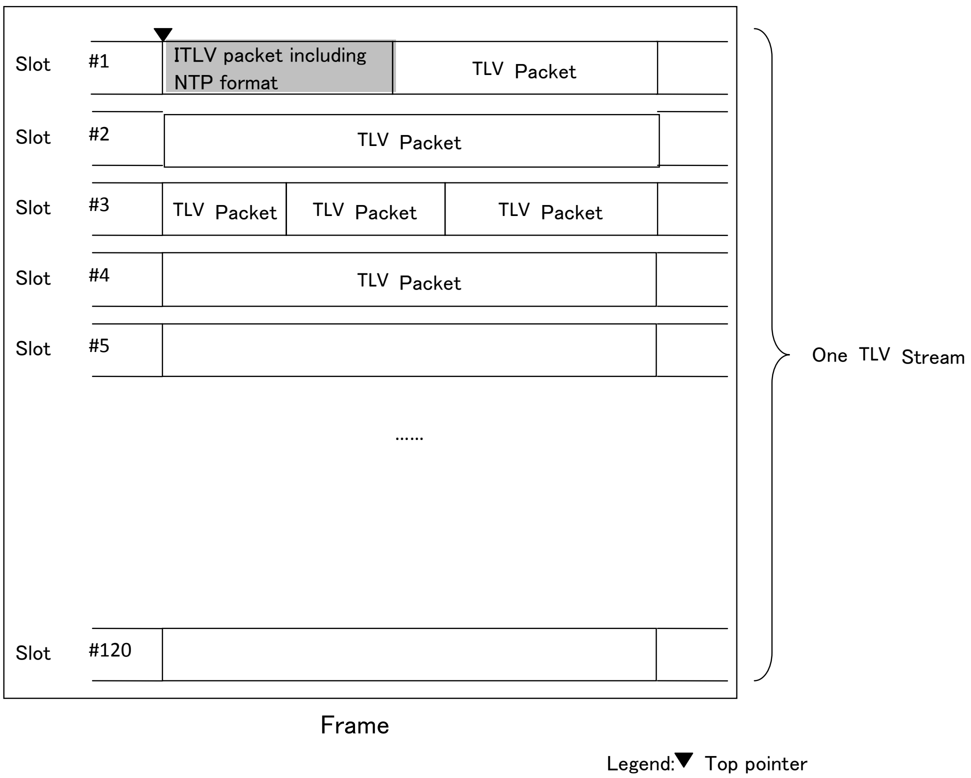

Fig. 3-1(a): Example of assignment of TLV packet including NTP format
Example of the case using 1 frame for 1 TLV stream

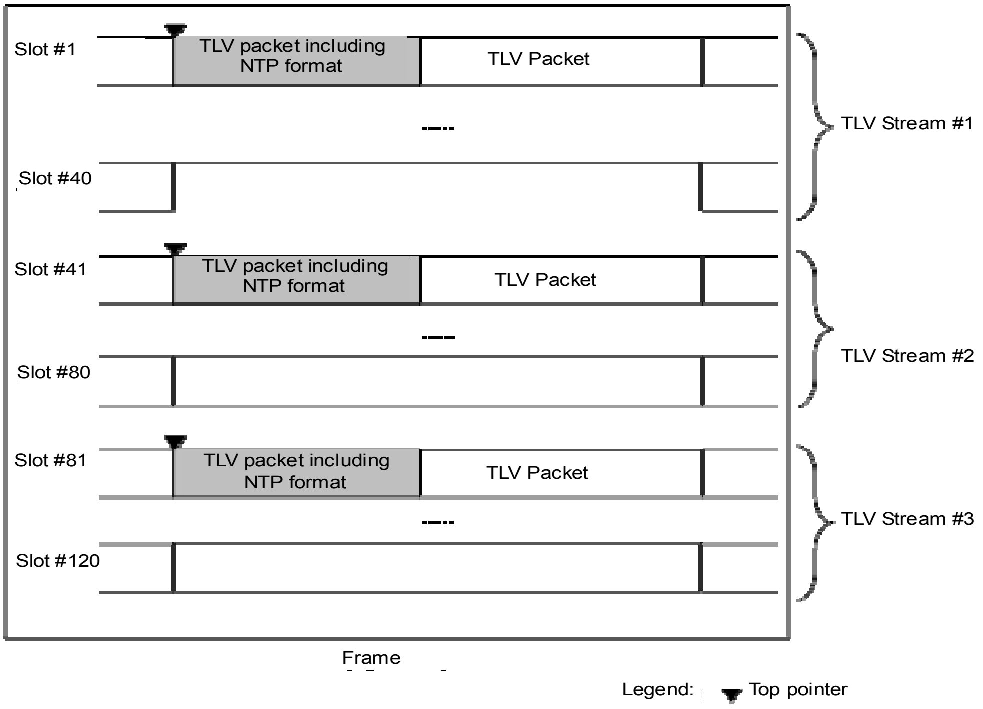

Fig. 3-1(b): Example of assignment of TLV packet including NPT format
Example of the case using 1 frame for 3 TLV stream

3.2 Transmission of Coordinated Universal Time by TMCC information

End 3,614-bits are assigned as extended information and head 16-bits of these bits are used for extension identification to identify extended information. This extended information is used to transmit Coordinated Universal Time by TMCC information as follows.

3.2.1 Extension identification for TMCC extended information

Table 3.1 shows assignment of extension identification for identifying extended information in TMCC information.

Table 3.1: Assignment of extension identification

Extension identification	Meaning
0x0000	Invalid
0x0001	Showing that TMCC extended information area stores time information
0x0002 – 0xFFFF	Undefined

3.2.2 Extended information area

When the value of extension identification is 0x0001, time information area stored in the TMCC extended information area has a structure as shown in Table 3-2.

Table 3-2 Structure of time information area

Data structure	Number of bits	Data notation
TMCC_ Time_Information () {		
reserved	6	bslbf
common_time_indicator	1	bslbf
extended_payload_indicator	1	bslbf
if(common_time_indicator==0){		
time_flag	16	bslbf
for (i=0; i<16; i++) {		
delta	32	simsbf
transmit_timestamp	64	uimsbf
}		
}		
if(common_time_indicator==1){		
reserved	16	bslbf
delta	32	simsbf
transmit_timestamp	64	uimsbf
}		
next_extended_payload_indicator	16	bslbf
}		

Meanings of time information area:

TMCC_Time_Information() (Time information area): showing storage area of time information. All bits for “reserved” are set to “1”.

common_time_indicator (common time information flag): This flag is set to “0” when individual time information is provided for every relative stream and to “1” when common time information is provided for all relative stream numbers.

When common time indicator is “0”, the subsequent data field and transit timestamp field are transmitted 16 times.

When common time indicator is “1”, the subsequent data field and transit timestamp field are transmitted once.

extended_payload_indicator (subsequent extended information presence/absence flag): Flag which distinguishes presence or absence of extended information in the extended area following TMCC_Time_Information()

When this flag is “0”, all extended areas following TMCC_Time_Information() are set to be reserved.

When this flag is “1”, it is subject to the next_extended_payload_indicator field described later.

time_flag (time information transmission flag): When common_time_indicatoris is “0” and time information for kth relative stream is valid, (k+1)th bit from MSB in this field is set to “1”. When time information of kth relative stream is invalid, (k+1)th bit from MSB in this field is set to “0”, and the relevant delta field and trasmit_timestamp field take arbitrary values.

delta (transmission delay): Supposed transmission delay from transmit server which generates TMCC signal to general terminals is described in seconds. This is 32-bit signed fixed-point. High-order 16-bits express an integer part and low-order 16-bits show a decimal point. This field means invalid in the case of 0x0000 0000.

transmit_timestamp (transmit timestamp): The time when this TMCC signal leave transmitting server is described by NTP timestamp length format. Specifically, relative time on the basis of 00:00 on January 1, 1900 is shown in seconds. High-order 32-bits express an integer part and low-order 32-bits show a decimal point. When MSB of high-order 32-bits is "0", base year is 2036.

next_extended_payload_indicator (subsequent extended information identification): Showing extension identification to identify extended information following TMCC_Time_Information(). This assignment is subject to Table 3-1.

In addition specific parameter values described in section 3.1 and 3.2, and addition of change instruction, etc. is provided in the separate operation rule.

Chapter 4: Utilization of TMCC in Site Diversity Operation

4.1 Summary of site diversity operation

Advanced wide band digital satellite broadcasting employs site diversity operation that switchover uplink from main station/substation to avoid uplink interruption due to rainfall. Figure 4.1 shows the concept of site diversity.

When there is a risk that transmission link from main station is interrupted by rain, switchover to substation is performed by main station's control. This action makes it possible to avoid uplink interruption.

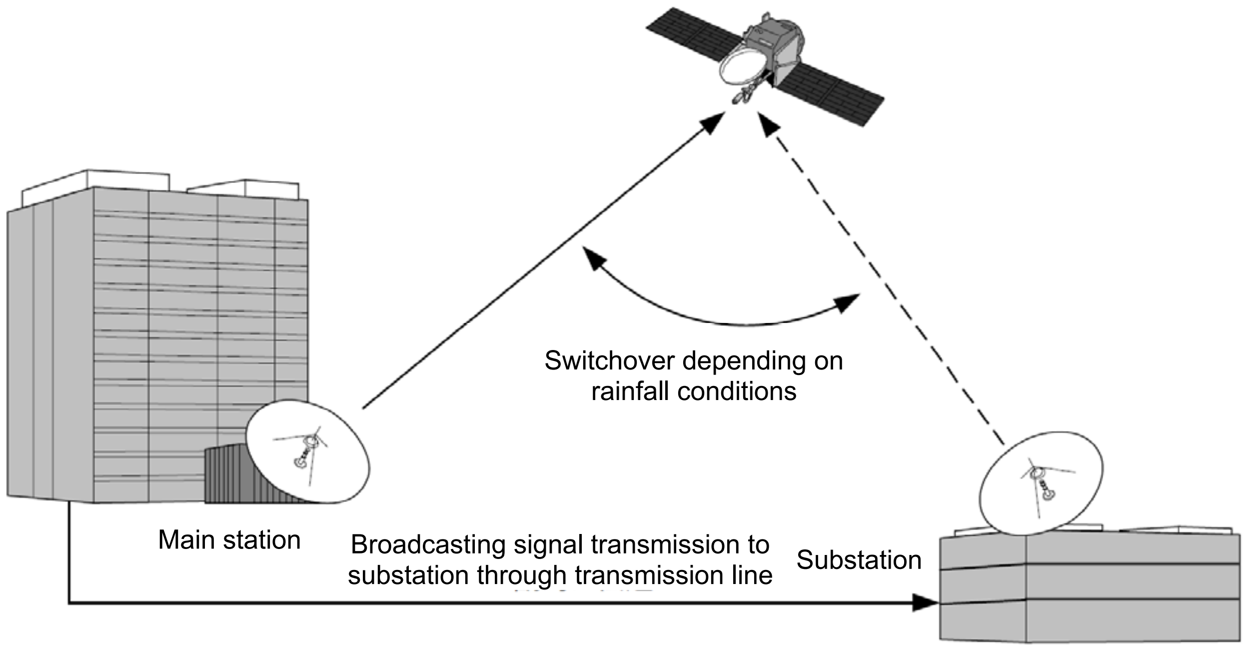

Fig. 4.1: Concept of site diversity

The following and so on are considered as this control method:

① Method which multiplexes switching control signal on transmission line in the direction of substation
② Method which performs switching control using dedicated control line
③ Method which multiplexes switching control signal on broadcast wave

In the above methods, method ③ can be performed by using transmit/receive control information bit. This method transmits or receives switching control signal by radio wave. Consequently, the method is capable of reducing interruption (or overlapping) time of radio wave with high accuracy during the switching control operation and is expected to construct a flexible system.

4.2 Site diversity operation

It is appropriate to transmit operation information on this site diversity by using uplink control signal (3 bit) (in Chapter 3 3.11(9)) in the TMCC information.

As start-up control information for earth station during site diversity operation, bit utilization as shown in Table 4.1 is considered.

Table 4.1: Example of bit for uplink control information

Bit			
3	Instructions for site diversity performing frame		Set to “1” before N* frame in advance of performing site diversity and to “0” after M* frame following the completion of site diversity
2	Uplink control information	Instructions for main station	Set to “1” in case of signal uplinked from main station, otherwise to “0”
1		Instructions for substation	Set to “1” in case of signal uplinked from substation, otherwise to “0”

※N and M: TBD

4.3 Problems and their measures in site diversity operation

Site diversity is operation aiming to secure uplink and TMCC is available for the operation control. Furthermore it is possible to reduce reception troubles by carrier wave interruption (or overlapping) during switchover, because “Instruction of site diversity performing frame” bit becomes ON before N frame in advance of the switchover of transmission station for receiver. There is a method to monitor uplink information periodically by polling processing and so on when receiver takes in the information. As for the timing to instruct site diversity performing frame, for example, the timing before about 16 frame (N=16) is considered to be acceptable from the viewpoint of these receiver control.

Appendix

Appendix

Contents

Appendix 1: Information Bit Rate

A1.1 Information bit rate in the case of MPEG-2 TS transmission

Bit rate R per one transponder for MPEG-2 TS transmission can be calculated by the following expression. Here, Sr, Cr and Fe mean symbol rate, coding rate and the effective slot number per 5 slots in the slot allocation rule, respectively.

$$R = Sr \times Fe \times \frac{44880}{44880+1600} \times \frac{44880-176-192-6-44880\times(1-Cr)}{44880} \times \frac{188}{187} \quad \cdot\cdot\cdot ①$$

Figure A1-1 shows the calculation results of information bit rate for a combination of modulation scheme and coding rate when symbol rate is set to 33.7561Mbaud.

A1.2 Information bit rate in the case of TLV transmission

Bit rate R per one transponder for TLV transmission can be calculated by the following expression. Here, Sr, Cr and Fe mean symbol rate, coding rate and the effective slot number per 5 slots in the slot allocation rule, respectively.

$$R = Sr \times Fe \times \frac{44880}{44880+1600} \times \frac{44880-176-192-6-44880\times(1-Cr)}{44880} \quad \cdot\cdot\cdot ②$$

Figure A1-2 shows the calculation results of information bit rate for a combination of modulation scheme and coding rate when symbol rate is set to 33.7561Mbaud.

Table A1-1: Information bit rate [Mbps/120slots] (In the case of MPEG-2 transmission)

		Coding rate (Approximate value)										
		41/120 (1/3)	49/120 (2/5)	61/120 (1/2)	73/120 (3/5)	81/120 (2/3)	89/120 (3/4)	93/120 (7/9)	97/120 (4/5)	101/120 (5/6)	105/120 (7/8)	109/120 (9/10)
Modulation scheme	π/2 shift BPSK	10.9228	13.1074	16.3842	19.6610	21.8456	24.0302	25.1224	26.2147	27.3070	28.3993	29.3343
	QPSK	21.8456	26.2147	32.7684	39.3221	43.6912	48.0603	50.2449	52.4294	54.6140	56.7986	58.6686
	8PSK	32.7684	39.3221	49.1526	58.9831	65.5368	72.0905	75.3673	78.6442	81.9210	85.1978	88.0029
	16APSK	43.6912	52.4294	65.5368	78.6442	87.3824	96.1206	100.4898	104.8589	109.2280	113.5971	117.3372
	32APSK	54.6140	65.5368	81.9210	98.3052	109.2280	120.1508	125.6122	131.0736	136.5350	141.9964	146.6715

Setting symbol rate = 33.7561Mbaud

Table A1-2: Information bit rate [Mbps/120slots] (In the case of TLV transmission)

		Coding rate (Approximate value)										
		41/120 (1/3)	49/120 (2/5)	61/120 (1/2)	73/120 (3/5)	81/120 (2/3)	89/120 (3/4)	93/120 (7/9)	97/120 (4/5)	101/120 (5/6)	105/120 (7/8)	109/120 (9/10)
Modulation scheme	π/2 shift BPSK	10.8647	13.0376	16.2971	19.5565	21.7294	23.9023	24.9888	26.0753	27.1618	28.2482	29.1783
	QPSK	21.7294	26.0753	32.5941	39.1129	43.4588	47.8047	49.9776	52.1506	54.3235	56.4964	58.3565
	8PSK	32.5941	39.1129	48.8912	58.6694	65.1882	71.7070	74.9664	78.2258	81.4853	84.7447	87.5348
	16APSK	43.4588	52.1506	65.1882	78.2258	86.9176	95.6094	99.9552	104.3011	108.6470	112.9929	116.7131
	32APSK	54.3235	65.1882	81.4853	97.7823	108.6470	119.5117	124.9441	130.3764	135.8088	141.2411	145.8913

Setting symbol rate = 33.7561Mbaud

Appendix 2: Verification Test Results of "Ultra-High Definition Television Broadcasting"

A2.1 Introduction

This appendix summarizes required C/N obtained from satellite transmission tests using 110° CS satellite, N-SAT-110 (January 9 to January 22, 2014) and 110° BS satellite, BSAT-3a (January 28, 2014) of the "Ultra-High Definition Television Broadcasting" verification tests conducted by the Working Group on the advanced satellite digital broadcasting in ARIB Digital Broadcasting System Development Committee.

A2.2 CS satellite transmission test results

Required C/N for each modulation scheme is summarized from Table A2-1 to Table A2-5. C/N-BER characteristics for CS satellite loopback are summarized from Figure A2-1 to Figure A2-5. Here required C/N used in this appendix is defined in section A2-6.

Table A2-1: C/N required for π/2 shift BPSK [dB]

Coding rate (Approximate value)	Simulation	CS satellite loopback
41/120 (1/3)	-4.0	-2.6
49/120 (2/5)	-3.0	-2.3
61/120 (1/2)	-1.8	-1.4
73/120 (3/5)	-0.5	-0.2
81/120 (2/3)	0.3	0.5
89/120 (3/4)	1.0	1.3
93/120 (7/9)	1.5	1.9
97/120 (4/5)	2.0	2.4
101/120 (5/6)	2.5	2.8
105/120 (7/8)	2.9	3.2
109/120 (9/10)	3.8	4.2

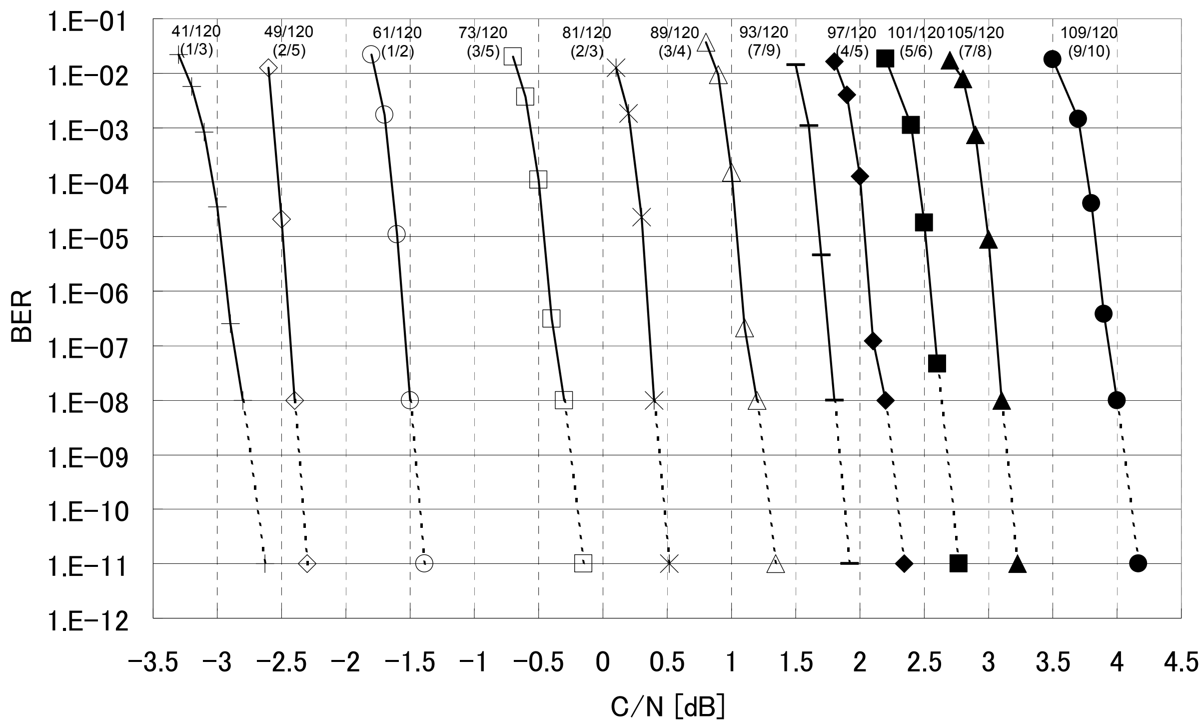

Fig. A2-1: C/N-BER characteristics for π/2 shift BPSK (CS satellite loopback)

Table A2-2: Required C/N for QPSK [dB]

Coding rate (Approximate value)	Simulation	CS satellite loopback
41/120 (1/3)	-1.0	-0.2
49/120 (2/5)	0.0	0.6
61/120 (1/2)	1.2	1.6
73/120 (3/5)	2.5	2.9
81/120 (2/3)	3.3	3.8
89/120 (3/4)	4.0	4.5
93/120 (7/9)	4.5	4.9
97/120 (4/5)	5.0	5.4
101/120 (5/6)	5.5	6.0
105/120 (7/8)	5.9	6.5
109/120 (9/10)	6.8	7.3

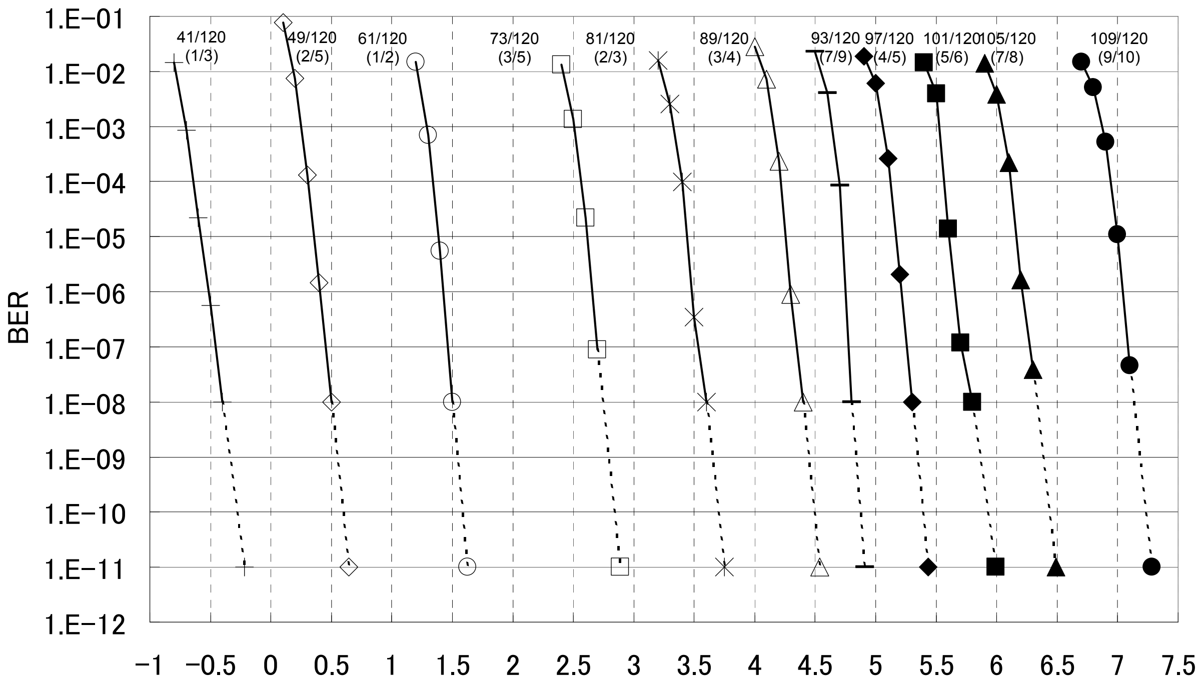

Fig. A2-2: C/N-BER characteristics for QPSK (CS satellite loopback)

Table A2-3: Required C/N for 8PSK [dB]

Coding rate (Approximate value)	Simulation	CS satellite loopback
41/120 (1/3)	2.2	3.4
49/120 (2/5)	3.1	4.2
61/120 (1/2)	4.4	5.5
73/120 (3/5)	5.7	6.7
81/120 (2/3)	6.7	7.5
89/120 (3/4)	7.9	8.7
93/120 (7/9)	8.6	9.4
97/120 (4/5)	9.1	10.1
101/120 (5/6)	9.7	10.6
105/120 (7/8)	10.4	11.4
109/120 (9/10)	11.4	12.6

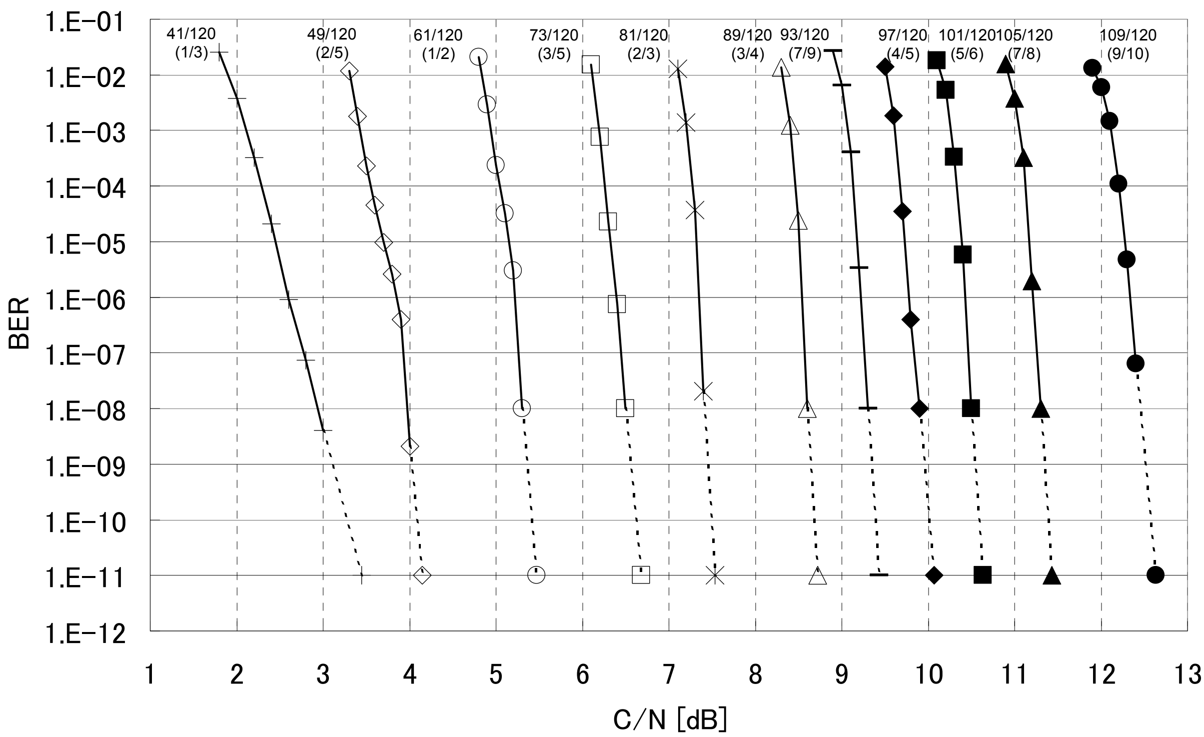

Fig. A2-3: C/N-BER characteristics for 8PSK (CS satellite loopback)

Table A2-4: Required C/N for 16APSK [dB]

Coding rate (Approximate value)	Simulation	CS satellite loopback
41/120 (1/3)	4.1	5.5
49/120 (2/5)	5.1	6.6
61/120 (1/2)	6.6	8.1
73/120 (3/5)	8.0	9.7
81/120 (2/3)	9.1	10.5
89/120 (3/4)	10.2	11.8
93/120 (7/9)	10.8	12.3
97/120 (4/5)	11.3	13.2
101/120 (5/6)	11.9	13.7
105/120 (7/8)	12.5	14.5
109/120 (9/10)	13.5	15.9

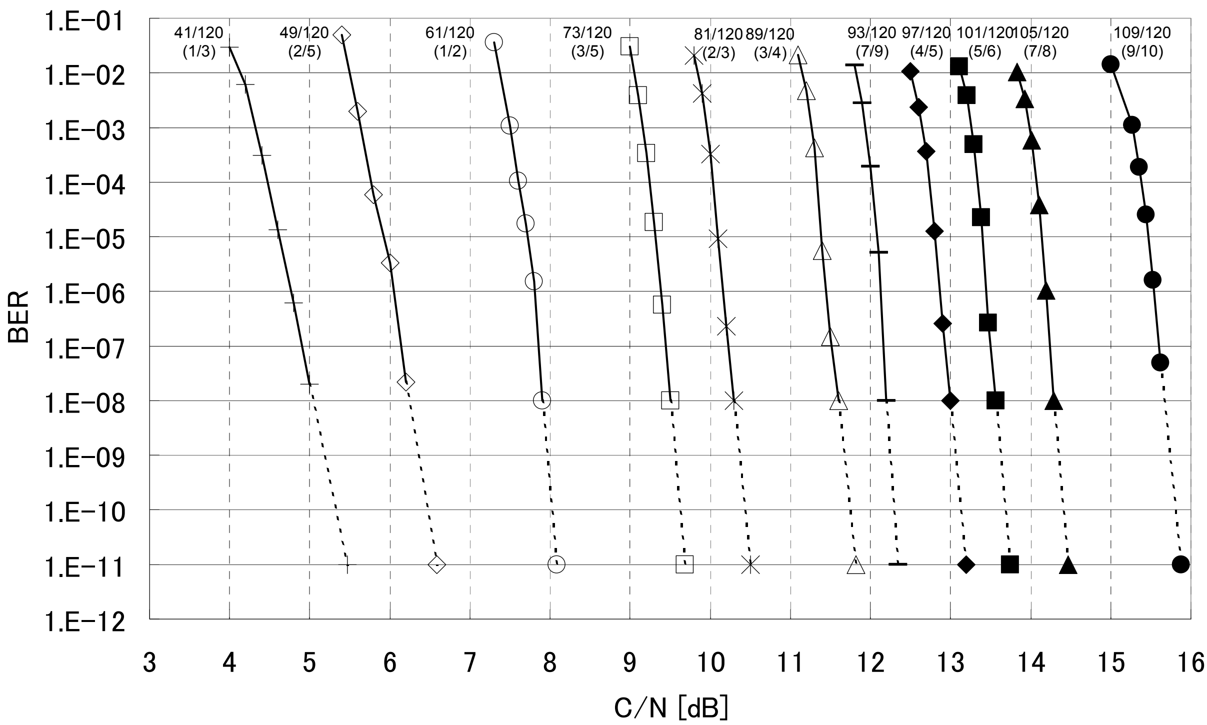

Fig. A2-4: C/N-BER characteristics for 16APSK (CS satellite loopback)

Table A2-5: Required C/N for 32APSK [dB]

Coding rate (Approximate value)	Simulation	CS satellite loopback
41/120 (1/3)	6.4	8.5
49/120 (2/5)	7.2	9.3
61/120 (1/2)	9.2	11.9
73/120 (3/5)	10.6	13.0
81/120 (2/3)	11.7	14.0
89/120 (3/4)	12.8	15.3
93/120 (7/9)	13.4	16.3
97/120 (4/5)	14.0	16.9
101/120 (5/6)	14.5	17.8
105/120 (7/8)	15.3	19.5
109/120 (9/10)	16.3	22.3

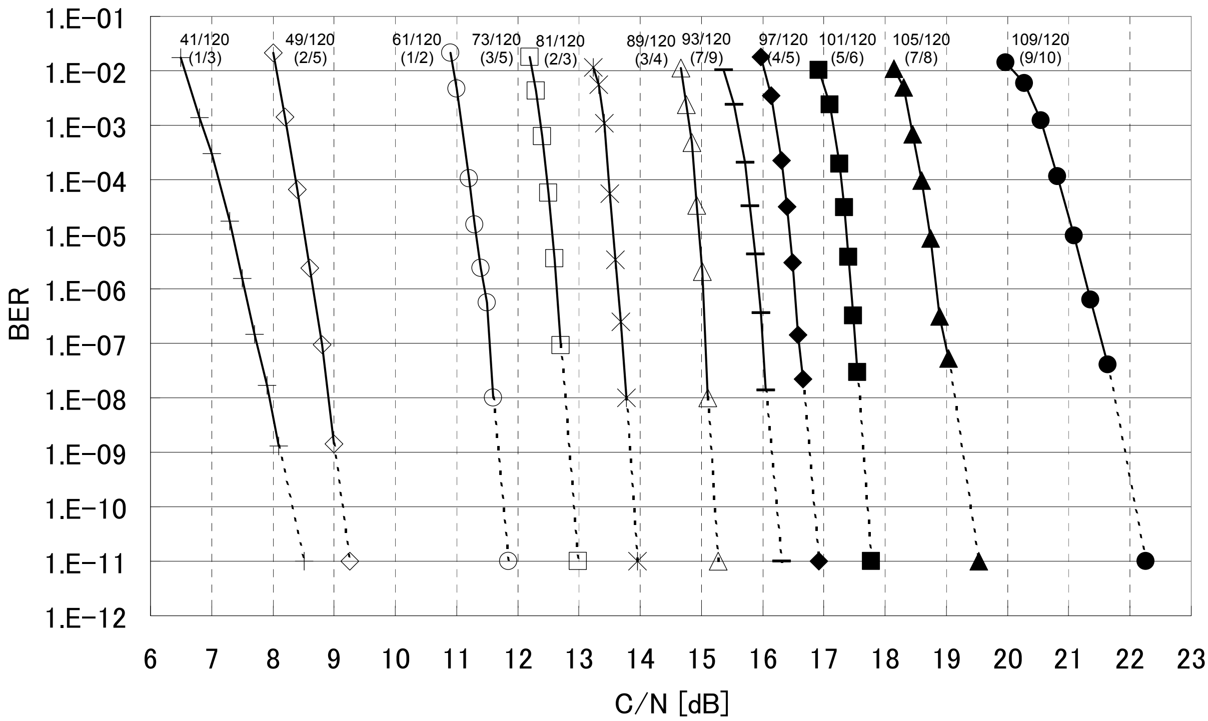

Fig. A2-5: C/N-BER characteristics for 32APSK (CS satellite loopback)

A2.3 BS satellite transmission test result

Table A2.3 summarizes required C/N for each modulation scheme. Figure A2.3 summarizes C/N-BER characteristics for BS satellite loopback. Here required C/N used in this appendix is defined in section A2.6.

Table A2.3: Required C/N [dB] in BS satellite transmission test

Modulation scheme & Coding rate (Approximate value)	Simulation	OBO	BS satellite loopback
8PSK 89/120 (3/4)	7.9	Saturation power	9.3
16APSK 89/120 (3/4)	10.2	2.2	11.8
16APSK 93/120 (7/9)	10.8	2.2	12.6
32APSK 81/120 (2/3)	11.7	2.9	14.2
32APSK 97/120 (4/5)	14.0	2.9	17.4

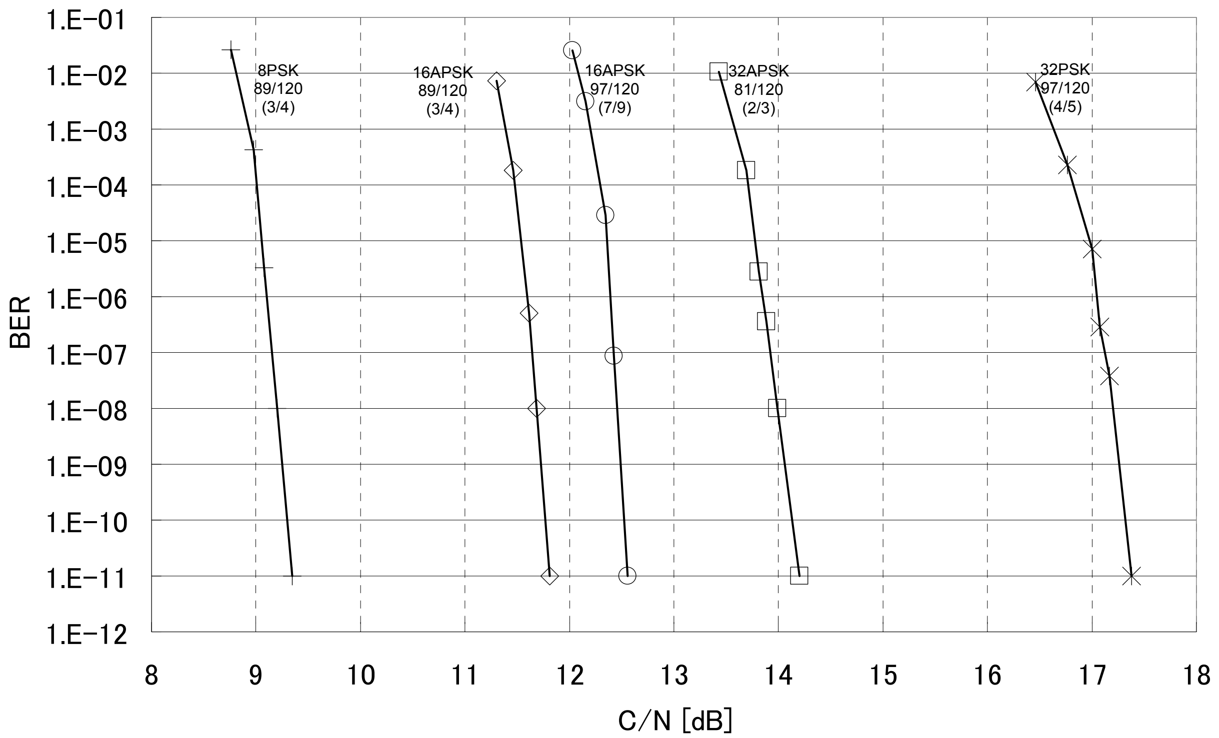

Fig. A2.3: C/N-BER characteristics for BS satellite loopback

A2.4 Satellite transmission testing system

Figure A2.4-1 summarizes system diagram for CS satellite transmission test. Figure A2.4-2 summarizes system diagram for BS satellite transmission test.

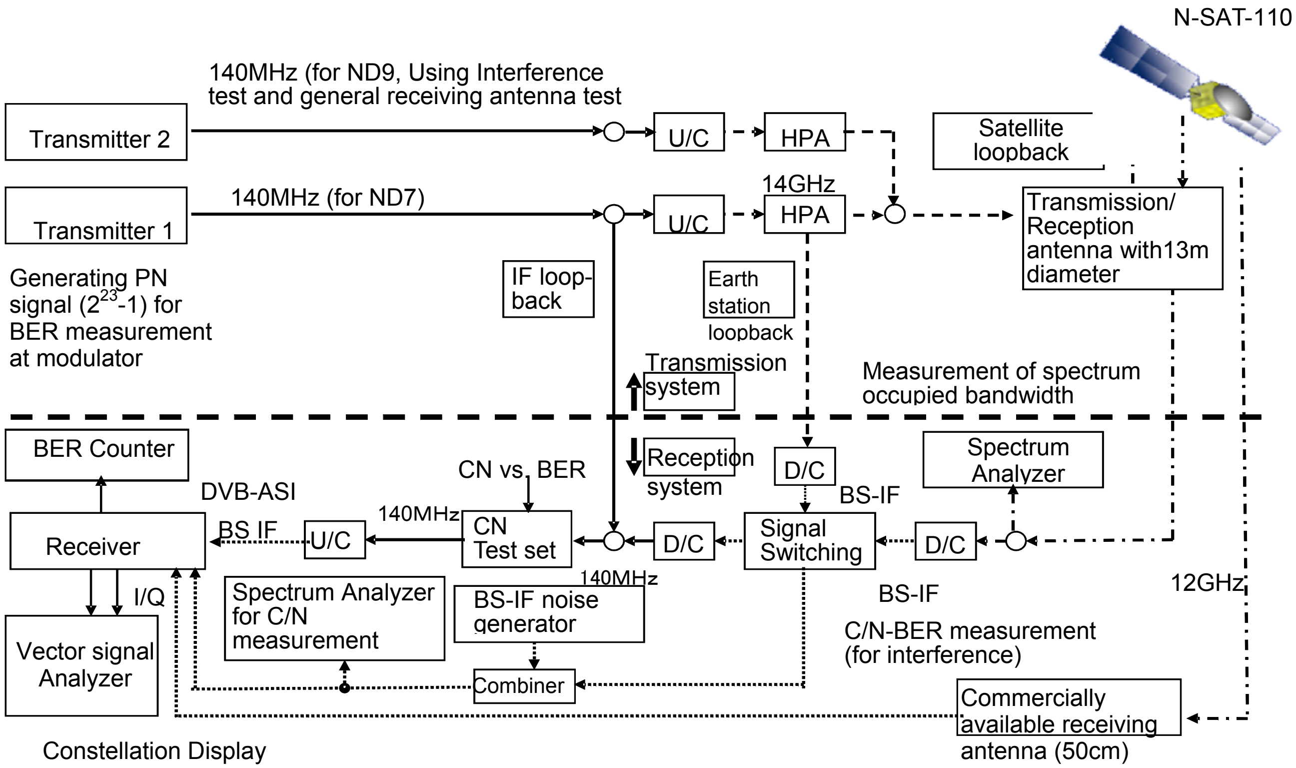

Fig. A2.4-1: System diagram for CS satellite transmission test

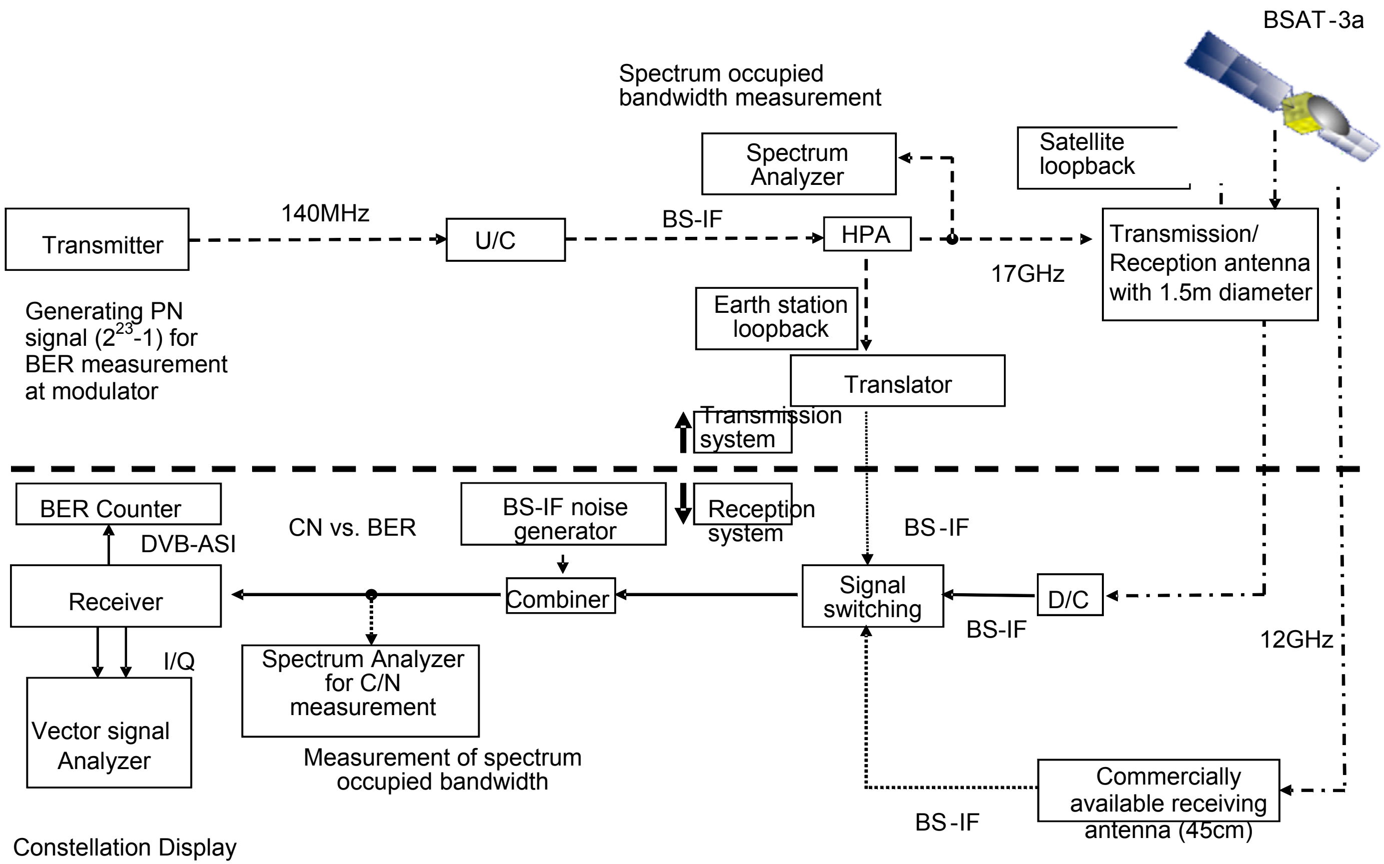

Fig. A2.4-2: System diagram for BS satellite transmission test

A2.5 Definition of back-off

Measured input/output characteristics of satellite transponder which amplifies carrier wave signal (non-modulation) and modulation wave signal become the characteristics as shown in Figure A2.5-1. Satellite output back-off (OBO) is defined as the differential value between output of non-modulation signal at saturation point and that of modulation signal at operation point in OMUX output as shown in Figure A2.5-1.

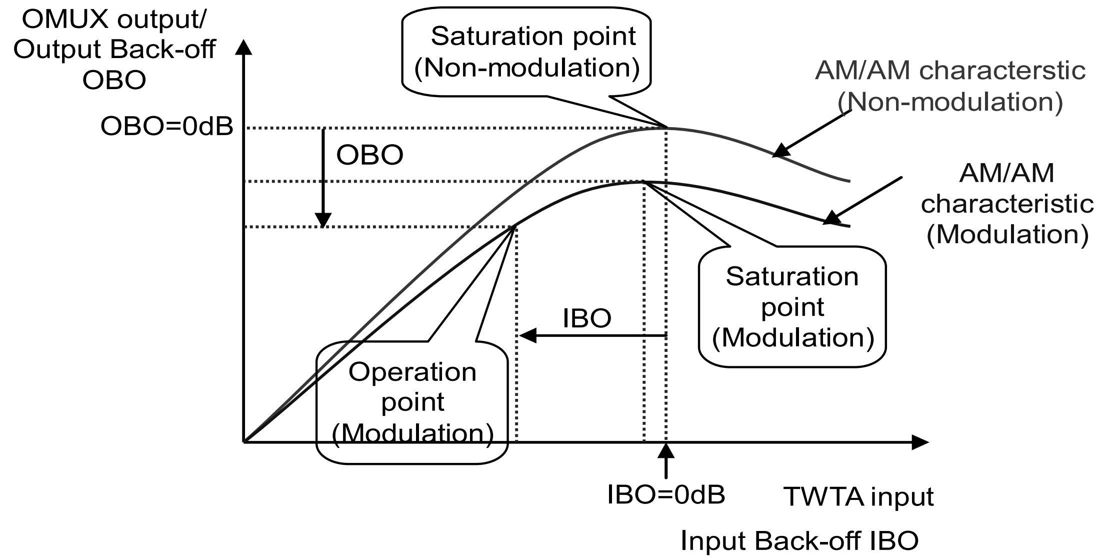

Fig. A2.5-1: Definition of output back-off.

A2.6 Definition of Required C/N

A2.6.1 Data acquired from ARIB verification test

Bit error rate (BER) was measured by measuring numbers of bit error for 10^{10} bits data in the ARIB verification test. BER was acquired at 0.1 dB step of C/N setting from small to large and measurement was finished at C/N corresponding to the zero-valued BER regarded as pseudo error free. Here the noise bandwidth for specifying C/N was set to Nyquist bandwidth (32.5941MHz). Furthermore when BER was non-zero and its minimum value data was over 10^{-7} level, BER corresponding to C/N equivalent to pseudo error free was compensated by 1×10^{-8}. This is because BER mentioned above is highly likely to be 1×10^{-8}, since bit errors are expected to be observed for 10^{-7} level BER with very high possibility.

The most typical pattern of thus obtained C/N vs. BER characteristics was the data such as shown in Figure A2.6-1(a1) or (a2). Here, in Figure A2.6-1 (a1) the data at 10^{-8} level can be acquired and therefore BER is not compensated by 10^{-8} to the BER corresponding to error-free C/N. In Figure A2.6-1 (a2) the data at 10^{-8} level cannot be acquired and therefore BER is compensated by 10^{-8} to the BER corresponding to error-free C/N. However, among them, the data which can be measured at only two measuring points at 10^{-2} and 10^{-4} BER levels are included (e.g. BPSK 2/5 and etc.,) as shown in Figure A2.6-1 (b) due to steep waterfall characteristics of LDPC code. On the other hand waterfall characteristics becomes gradual for a combination of multilevel modulation scheme and low encoding rate's LDPC as shown in Figure A2.6-1 (c).

From these data C/N value satisfying BER=10^{-11} is calculated as required C/N which is generally often used.

A2.6.2 Required C/N calculation method

As shown in Figure A2.6-2, C/N corresponding to BER=10^{-11} is calculated by using three samples (P1, P2, P3) in descending order of C/N and then extrapolation is performed. Specifically, assuming that the mean value of a gradient between P1 and P2 and that between P2 and P3 is the gradient and P4 is the point at which straight line with a starting point P3 intersects BER=10^{-11}, C/N corresponding to P4 was set as required C/N.

Here, setting C/N and BER at each point as P1(CN1, BER1), P2(CN2, BER2), P3(CN3, BER3), and P4(CN4, 10-11), the required C/N is obtained by the following expression.

$$\text{Required } C/N = CN_4 = 2 \cdot \frac{\log(10^{-11}) - \log(BER_3)}{\dfrac{\log(BER_2) - \log(BER_1)}{CN_2 - CN_1} + \dfrac{\log(BER_3) - \log(BER_2)}{CN_3 - CN_2}} + CN_3$$

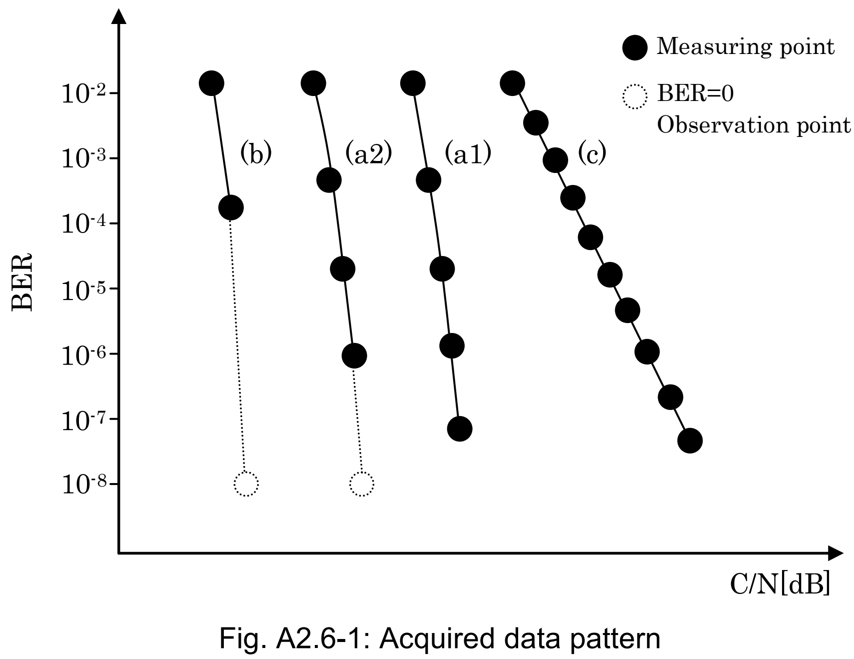

Fig. A2.6-1: Acquired data pattern

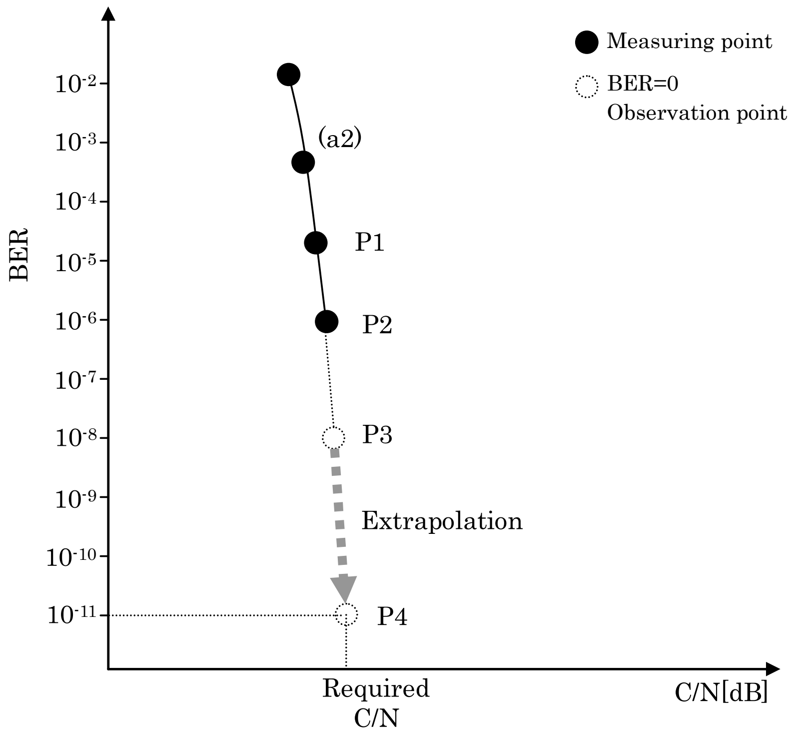

Fig. A2.6-2: Derivation of required C/N by extrapolation of data

A2.7 Operation point of satellite transponder in CS satellite transmission test

Operation point of satellite transponder in CS satellite transmission test was set to the point where output of satellite transponder was as high as possible after the measured input/output characteristics of satellite transponder were confirmed in the case of modulation signal transmission. Figure A2.7-1 shows satellite transponder input/output characteristics in the case of modulation signal transmission using 8PSK or 16APSK. In the measurement transmission power measuring point was set to HPA's output monitoring point of transmitting earth station (horizontal axis in Figure A2.7-1, modulation signal power of earth station). Reception power measuring point was set to LNB output (vertical axis in Figure A2.7-1, modulation signal power in satellite loopback). With reference to the characteristics in Figure A2.7-1, satellite transmission test was conducted by setting satellite transponder output to the maximum operation level (middle right-hand edge in Figure A2.7-1) for BPSK, QPSK, 8PSK and 16APSK, and to the level which is lowered by 0.5dB from the maximum operation level for 32APSK to suppress the influence of degradation due to non-linear distortion.

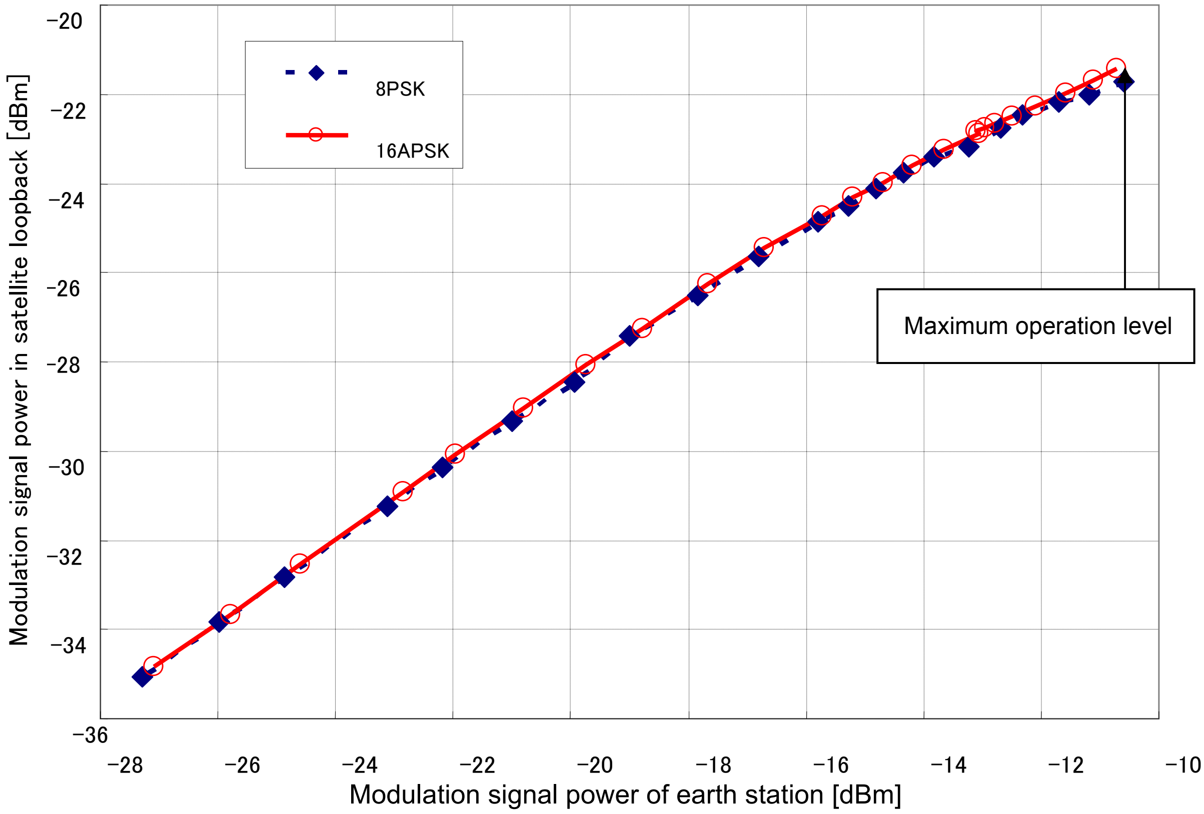

Fig. A2.7-1: CS satellite transmission test : Satellite transponder input/output characteristics in the case of modulation signal transmission

Appendix 3: Examples of .for Satellite Link Design

A3.1 Introduction

In this appendix satellite links for Tokyo, Naha and Tsushima are designed as the typical receiving points from the viewpoint of center of coverage area, edge of coverage area and vicinity of border with foreign countries.

A3.2 Assumptions

Table A3-1 and Table A3-2 show assumptions for satellite link design and rain attenuation at receiving points, respectively.

Table A3-1: Assumptions for BS link budget calculation

<table>
<tr><td colspan="2">Parameter</td><td colspan="6">Calculation conditions</td></tr>
<tr><td colspan="2">Transmission Symbol Rate</td><td colspan="6">33.7561 Mbaud</td></tr>
<tr><td colspan="2">Uplink C/N [Note1]</td><td colspan="6">30 dB</td></tr>
<tr><td colspan="2">Calculated frequency</td><td colspan="6">12 GHz</td></tr>
<tr><td colspan="2">Output backoff (OBO) [Note2]</td><td colspan="6">2.2 dB (8PSK 3/4, 16APSK 3/4, 16APSK 7/9)</td></tr>
<tr><td colspan="2">Satellite EIRP (in the case of 2.2dB back-off operation)</td><td colspan="6">60 dBW(Tokyo), 58 dBW(Sapporo, Kagoshima),
57 dBW(Naha)</td></tr>
<tr><td colspan="2">Satellite cross polarization discrimination degree [Note 3]</td><td colspan="6">27 dB in total</td></tr>
<tr><td colspan="2">Satellite link transmission path</td><td colspan="6">Sapporo ： 38508.8 Km (Antenna elevation angle 31.2°)
Tokyo ： 37935.3 Km（Antenna elevation angle 38.0°)
Kagoshima ： 37278.4 Km (Antenna elevation angle 46.9°)
Naha ： 36861.1 Km (Antenna elevation angle 53.6°)</td></tr>
<tr><td colspan="2">Rain attenuation</td><td colspan="6">According to calculation formula in ITU-R P.618-8</td></tr>
<tr><td colspan="2">Receiving antenna diameter</td><td colspan="6">45cmφ, 60cmφ, 75cmφ, 90cmφ, 120cmφ</td></tr>
<tr><td colspan="2">Receiving antenna aperture efficiency</td><td colspan="6">70%</td></tr>
<tr><td colspan="2">Receiving antenna cross polarization discrimination degree</td><td colspan="6">25 dB [Note3]</td></tr>
<tr><td colspan="2">Antenna noise temperature</td><td colspan="6">The following calculation equation is used assuming that antenna noise temperature is 50K at clear sky [Note4].
Ta [K] = To { 1－10^(－Lr/10)} +50</td></tr>
<tr><td colspan="2">LNC noise figure</td><td colspan="6">1 dB</td></tr>
<tr><td colspan="2">Nyquist bandwidth</td><td colspan="6">33.7561 MHz</td></tr>
<tr><td colspan="2">Occupied frequency bandwidth (containing 99% of the total power)</td><td colspan="6">34.5 MHz</td></tr>
<tr><td colspan="2" rowspan="5">Interference from foreign satellite（C/I） [Note5]
(Korean satellite location：116° east longitude)</td><td>Antenna diameter</td><td>45cm</td><td>60cm</td><td>75cm</td><td>90cm</td><td>120cm</td></tr>
<tr><td>Sapporo</td><td>58.1dB</td><td>60.6dB</td><td>62.6dB</td><td>64.2dB</td><td>66.7dB</td></tr>
<tr><td>Tokyo</td><td>60.3dB</td><td>62.8dB</td><td>64.7dB</td><td>66.3dB</td><td>68.8dB</td></tr>
<tr><td>Kagoshima</td><td>36.6dB</td><td>39.1dB</td><td>41.0dB</td><td>42.6dB</td><td>45.1dB</td></tr>
<tr><td>Naha</td><td>50.1dB</td><td>52.6dB</td><td>54.5dB</td><td>56.1dB</td><td>58.6dB</td></tr>
<tr><td rowspan="4">Required C/N</td><td>TC8PSK 2/3 (Reference)</td><td colspan="6">10.7 dB [Note6]</td></tr>
<tr><td>8PSK 3/4</td><td colspan="6">9.3 dB (OBO is not included) [Note7]</td></tr>
<tr><td>16APSK 3/4</td><td colspan="6">11.8 dB (OBO is not included) [Note7]</td></tr>
<tr><td>16APSK 7/9</td><td colspan="6">12.6 dB (OBO is not included) [Note7]</td></tr>
</table>

(Notes)

1. It was considered that uplink C/N employed C/N ratio obtained from satellite transmission test results as required C/N.

2. For definition of OBO, refer to the Appendix.

3. Satellite cross polarization discrimination degree was set to 30dB for satellite reception (uplink), 30dB for satellite transmission (downlink) and 27dB in total.
   Cross polarization discrimination degree for receiving antenna was quoted from ITU-R Recommendation BO.1213 and set to 25 dB.

4. Quoted from "Television broadcasting standard through communication satellite using 12.5 - 12.75GHz" in the Telecommunications Technology Council's report (in fiscal year 1990) on "Technical requirements for satellite broadcasting using 12.5 - 12.75GHz"

5. As for adjacent channel interference, adjacent channel interference in satellite transponder (considering that required C/N employs the C/N ratio obtained from satellite transmission test) and interference from Korean satellite were considered.

   Interference from Korean satellite (C/I) = {(e.i.r.p. of Japanese satellite) – (Interference e.i.r.p. of Korean satellite)} + (Cross polarization discrimination degree) + (Frequency overlap amount)

   The following conditions were used for calculation.

   (1) Evaluation points

   Sapporo (141.3° east longitude, 43.1° north latitude)
   Tokyo (139.7° east longitude, 35.7° north latitude)
   Kagoshima (130.6° east longitude, 31.6° north latitude)
   Naha (127.7° east longitude, 26.2° north latitude)

   (2) Korean satellite 116 degrees east longitude (e.i.r.p. 63.7dBW), Bandwidth 27MHz

   (3) Japanese satellite 110 degrees east longitude, Bandwidth 34.5MHz

   E.i.r.p. for the direction toward Sapporo 58dBW
   E.i.r.p. for the direction toward Tokyo 60dBW
   E.i.r.p. for the direction toward Kagoshima 58dBW
   E.i.r.p. for the direction toward Naha 57dBW

   (4) Interference e.i.r.p. from Korean satellite (Korean planned beam is assumed)

   Spacing between satellites on 110° and 116° seen from Sapporo 6.58degrees,
   Interference e.i.r.p. 34.2dBW

Spacing between satellites on 110° and 116° seen from Tokyo 6.68degrees,
Interference e.i.r.p. 34.2dBW

Spacing between satellites on 110° and 116° seen from Kagoshima 6.80degrees,
Interference e.i.r.p. 56.1dBW

Spacing between satellites on 110° and 116° seen from Naha 6.88degrees,
Interference e.i.r.p. 41.7dBW

(5) Cross polarization discrimination degree (Recommendation ITU-R BO.1213)
(corresponding to antenna diameter)

Sapporo (elongation 6.58°)	45cm reception : 32.6dB, 60cm reception : 35.1dB, 75cm reception : 37.1dB, 90cm reception : 38.7dB 120cm reception : 41.2dB
Tokyo (elongation 6.68°)	45cm reception : 32.8dB, 60cm reception : 35.3dB, 75cm reception : 37.2dB, 90cm reception : 38.8dB 120cm reception : 41.3dB
Kagoshima (elongation 6.80°)	45cm reception : 33.0dB, 60cm reception : 35.5dB, 75cm reception : 37.4dB, 90cm reception : 39.0dB 120cm reception : 41.5dB
Naha (elongation 6.88°)	45cm reception : 33.1dB, 60cm reception : 35.6dB, 75cm reception : 37.5dB, 90cm reception : 39.1dB 120cm reception : 41.6dB

(6) Frequency overlap amount 1.7dB (=10*log(34.5/23.14)

- Channel spacing in broadcasting satellite plan 38.36MHz
- Channel bandwidth of Japanese satellite 34.5MHz
- Channel bandwidth of Korean satellite 27MHz

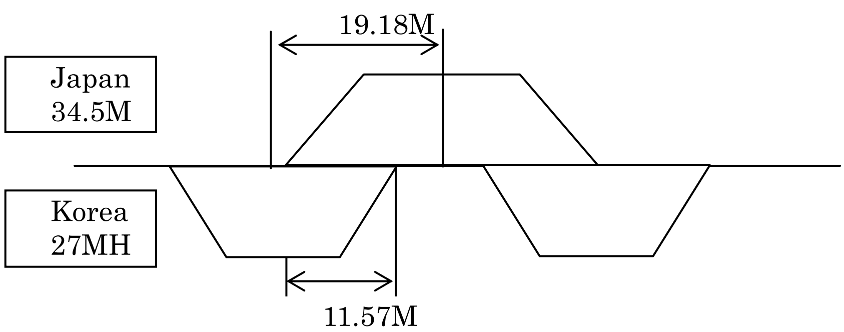

Fig. A3-1: Channel allocation

6. Quoted from "Technical requirements for satellite digital broadcasting system using the frequency which is higher than 11.7GHz to 12.2GHz" in the Telecommunications Technology Council's Report (in fiscal year 1997) on "Technical requirements regarding digital broadcasting system". Required C/N for the existing system (ISDB-S, TC8PSK 2/3) employed 10.7dB as the value including difference (OBO is called in this study) between output power of carrier wave at transponder saturated point and that of modulated wave (at operation point).
7. Required C/N (considering LNC, receiver and interference) and satellite transponder OBO value employed the values in the satellite transmission test results.

Table A3-2: Rain attenuation amount at BS receiving point

Receiving point	Service availability in the worst month	
	99.5 %	99.7 %
Sapporo	1.5 dB	2.1 dB
Tokyo	2.4 dB	3.4 dB
Kagoshima	2.9 dB	4.0 dB
Naha	3.5 dB	4.7 dB

A3.3 Calculation Results

Tables A3-3 to A3-14 show examples of calculated results for satellite link design based on the assumptions mentioned above.

Table A3-3: BS link design

(8PSK (3/4), Receiving point: Sapporo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	58.0	58.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.7	205.7
Overall atmospheric absorption attenuation	dB	0.3	4.6
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	4.4
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-114.6	-118.9
p.f.d.	dBW/m2	-104.7	-104.7
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	233.9
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF’	K	75.1	75.1
Receiver noise temperature T	K	125.1	309.0
Receiver noise temperature T’	dBK	21.0	24.9
Figure of merit G/T	dB/K	12.5	8.6
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B’	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.4
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	17.8	9.5
Adjacent channel interference	dB	58.1	58.1
Overall C/(N+I)	dB	16.6	9.3
Required C/N	dB	9.3	9.3
System margin	dB	7.3	0.0
Annual service availability	%	-	99.98
Service availability in the worst month	%	-	99.91

Table A3-4: BS link design

(8PSK (3/4), Receiving point: Tokyo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	60.0	60.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.6	205.6
Overall atmospheric absorption attenuation	dB	0.2	6.3
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	6.1
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-112.4	-118.5
p.f.d.	dBW/m2	-102.6	-102.6
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	268.2
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF’	K	75.1	75.1
Receiver noise temperature T	K	125.1	343.2
Receiver noise temperature T’	dBK	21.0	25.4
Figure of merit G/T	dB/K	12.5	8.1
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B’	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.0
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	60.0	60.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	19.9	9.5
Adjacent channel interference	dB	60.3	60.3
Overall C/(N+I)	dB	18.1	9.3
Required C/N	dB	9.3	9.3
System margin	dB	8.8	0.0
Annual service availability	%	-	99.98
Service availability in the worst month	%	-	99.89

Table A3-5: BS link design
(8PSK (3/4), Receiving point: Kagoshima, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	58.0	58.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.5	205.5
Overall atmospheric absorption attenuation	dB	0.2	4.8
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	4.6
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-114.3	-118.8
p.f.d.	dBW/m2	-104.4	-104.4
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	239.3
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	314.4
Receiver noise temperature T'	dBK	21.0	25.0
Figure of merit G/T	dB/K	12.5	8.5
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.3
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	18.1	9.5
Adjacent channel interference	dB	36.6	36.6
Overall C/(N+I)	dB	16.8	9.3
Required C/N	dB	9.3	9.3
System margin	dB	7.5	0.0
Annual service availability	%	-	99.94
Service availability in the worst month	%	-	99.76

Table A3-6: BS link design

(8PSK (3/4), Receiving point: Naha, Receiving antenna diameter: 75cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	57.0	57.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.4	205.4
Overall atmospheric absorption attenuation	dB	0.2	7.7
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	7.5
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	75.0	75.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	37.9	37.9
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-110.7	-118.2
p.f.d.	dBW/m2	-105.3	-105.3
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	288.5
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	363.6
Receiver noise temperature T'	dBK	21.0	25.6
Figure of merit G/T	dB/K	17.0	12.3
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-127.7
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	57.0	57.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	21.6	9.5
Adjacent channel interference	dB	54.5	54.5
Overall C/(N+I)	dB	19.2	9.3
Required C/N	dB	9.3	9.3
System margin	dB	9.9	0.0
Annual service availability	%	-	99.97
Service availability in the worst month	%	-	99.87

Table A3-7: BS link design

(16APSK (3/4), Receiving point: Sapporo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	58.0	58.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.7	205.7
Overall atmospheric absorption attenuation	dB	0.3	2.8
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	2.6
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-114.6	-117.1
p.f.d.	dBW/m2	-104.7	-104.7
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	179.0
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	254.1
Receiver noise temperature T'	dBK	21.0	24.1
Figure of merit G/T	dB/K	12.5	9.4
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-129.3
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	17.8	12.2
Adjacent channel interference	dB	58.1	58.1
Overall C/(N+I)	dB	16.6	11.8
Required C/N	dB	11.8	11.8
System margin	dB	4.8	0.0
Annual service availability	%	-	99.95
Service availability in the worst month	%	-	99.78

Table A3-8: BS link design
(16APSK (3/4), Receiving point: Tokyo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	60.0	60.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.6	205.6
Overall atmospheric absorption attenuation	dB	0.2	4.2
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	4.0
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-112.4	-116.4
p.f.d.	dBW/m2	-102.6	-102.6
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	224.4
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	299.4
Receiver noise temperature T'	dBK	21.0	24.8
Figure of merit G/T	dB/K	12.5	8.7
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.6
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	60.0	60.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	19.9	12.2
Adjacent channel interference	dB	60.3	60.3
Overall C/(N+I)	dB	18.1	11.8
Required C/N	dB	11.8	11.8
System margin	dB	6.3	0.0
Annual service availability	%	-	99.95
Service availability in the worst month	%	-	99.77

Table A3-9: BS link design

(16APSK (3/4), Receiving point: Kagoshima, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	58.0	58.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.5	205.5
Overall atmospheric absorption attenuation	dB	0.2	3.0
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	2.7
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-114.3	-117.0
p.f.d.	dBW/m2	-104.4	-104.4
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	185.7
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF’	K	75.1	75.1
Receiver noise temperature T	K	125.1	260.8
Receiver noise temperature T’	dBK	21.0	24.2
Figure of merit G/T	dB/K	12.5	9.3
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B’	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-129.2
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	18.1	12.2
Adjacent channel interference	dB	36.6	36.6
Overall C/(N+I)	dB	16.8	11.8
Required C/N	dB	11.8	11.8
System margin	dB	5.0	0.0
Annual service availability	%	-	99.85
Service availability in the worst month	%	-	99.45

Table A3-10: BS link design
(16APSK (3/4), Receiving point: Naha, Receiving antenna diameter: 75cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	57.0	57.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.4	205.4
Overall atmospheric absorption attenuation	dB	0.2	5.5
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	5.3
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.4
Receiving antenna diameter D	cm	75.0	75.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	37.9	37.9
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-110.7	-116.0
p.f.d.	dBW/m2	-105.3	-105.3
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	254.0
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	329.1
Receiver noise temperature T'	dBK	21.0	25.2
Figure of merit G/T	dB/K	17.0	12.8
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.1
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	57.0	57.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	21.6	12.2
Adjacent channel interference	dB	54.5	54.5
Overall C/(N+I)	dB	19.2	11.8
Required C/N	dB	11.8	11.8
System margin	dB	7.4	0.0
Annual service availability	%	-	99.94
Service availability in the worst month	%	-	99.75

Table A3-11: BS link design

(16APSK (7/9), Receiving point: Sapporo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	58.0	58.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.7	205.7
Overall atmospheric absorption attenuation	dB	0.3	2.3
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	2.0
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-114.6	-116.6
p.f.d.	dBW/m2	-104.7	-104.7
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	158.8
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	233.9
Receiver noise temperature T'	dBK	21.0	23.7
Figure of merit G/T	dB/K	12.5	9.8
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-129.6
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	17.8	13.0
Adjacent channel interference	dB	58.1	58.1
Overall C/(N+I)	dB	16.6	12.6
Required C/N	dB	12.6	12.6
System margin	dB	4.0	0.0
Annual service availability	%	-	99.92
Service availability in the worst month	%	-	99.68

Table A3-12: BS link design
(16APSK(7/9), Receiving point: Tokyo, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	60.0	60.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.6	205.6
Overall atmospheric absorption attenuation	dB	0.2	3.6
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	3.4
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter D	cm	45.0	45.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-112.4	-115.8
p.f.d.	dBW/m2	-102.6	-102.6
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	206.8
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	281.9
Receiver noise temperature T'	dBK	21.0	24.5
Figure of merit G/T	dB/K	12.5	9.0
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.8
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	60.0	60.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	19.9	13.0
Adjacent channel interference	dB	60.3	60.3
Overall C/(N+I)	dB	18.1	12.6
Required C/N	dB	12.6	12.6
System margin	dB	5.5	0.0
Annual service availability	%	-	99.93
Service availability in the worst month	%	-	99.70

Table A3-13: BS link design

(16APSK(7/9), Receiving point: Kagoshima, Receiving antenna diameter: 45cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP　Pe	dBW	58.0	58.0
Output back-off　Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.5	205.5
Overall atmospheric absorption attenuation	dB	0.2	2.4
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation　Lr	dB	0.0	2.2
Attenuation due to cloud　Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter　D	cm	45.0	45.0
Receiving antenna aperture efficiency　η	%	70.0	70.0
Receiving antenna gain　Gr	dBi	33.5	33.5
Pointing loss	dB	0.1	0.1
Receiver input　C	dB	-114.3	-116.5
p.f.d.	dBW/m2	-104.4	-104.4
Boltzmann constant　K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	165.6
LNC noise figure　NF	dB	1.0	1.0
LNC noise figure　NF’	K	75.1	75.1
Receiver noise temperature　T	K	125.1	240.7
Receiver noise temperature　T’	dBK	21.0	23.8
Figure of merit　G/T	dB/K	12.5	9.7
Reception bandwidth　B	MHz	33.7561	33.7561
Reception bandwidth　B’	dB・Hz	75.3	75.3
Noise input　N	dBW	-132.3	-129.5
Cross polarized wave interference　C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	58.0	58.0
Satellite reception (uplink)　XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna　XPD	dB	25.0	25.0
Downlink C/N	dB	18.1	13.0
Adjacent channel interference	dB	36.6	36.6
Overall C/(N+I)	dB	16.8	12.6
Required C/N	dB	12.6	12.6
System margin	dB	4.2	0.0
Annual service availability	%	-	99.78
Service availability in the worst month	%	-	99.25

Table A3-14: BS link design
(16APSK(7/9), Receiving point: Naha, Receiving antenna diameter: 75cm)

Parameter	Unit	At clear sky	At rainfall
Satellite EIRP Pe	dBW	57.0	57.0
Output back-off Bo	dB	2.2	2.2
Free space propagation loss Lf	dB	205.4	205.4
Overall atmospheric absorption attenuation	dB	0.2	4.8
Atmospheric attenuation	dB	0.1	0.1
Rain attenuation Lr	dB	0.0	4.6
Attenuation due to cloud Lc	dB	0.1	0.1
Scintillation	dB	0.1	0.3
Receiving antenna diameter D	cm	75.0	75.0
Receiving antenna aperture efficiency η	%	70.0	70.0
Receiving antenna gain Gr	dBi	37.9	37.9
Pointing loss	dB	0.1	0.1
Receiver input C	dB	-110.7	-115.3
p.f.d.	dBW/m2	-105.3	-105.3
Boltzmann constant K	dB/Hz	-228.6	-228.6
Antenna noise temperature	K	50.0	239.4
LNC noise figure NF	dB	1.0	1.0
LNC noise figure NF'	K	75.1	75.1
Receiver noise temperature T	K	125.1	314.5
Receiver noise temperature T'	dBK	21.0	25.0
Figure of merit G/T	dB/K	17.0	13.0
Reception bandwidth B	MHz	33.7561	33.7561
Reception bandwidth B'	dB・Hz	75.3	75.3
Noise input N	dBW	-132.3	-128.3
Cross polarized wave interference C/I	dB	22.9	22.9
Cross polarized wave EIRP	dBW	57.0	57.0
Satellite reception (uplink) XPD	dB	30.0	30.0
Satellite transmission (downlink) XPD	dB	30.0	30.0
Receiving antenna XPD	dB	25.0	25.0
Downlink C/N	dB	21.6	13.0
Adjacent channel interference	dB	54.5	54.5
Overall C/(N+I)	dB	19.2	12.6
Required C/N	dB	12.6	12.6
System margin	dB	6.6	0.0
Annual service availability	%	-	99.92
Service availability in the worst month	%	-	99.68

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DIGITAL SATELLITE BROADCASTING

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