ENGLISH TRANSLATION

PORTABLE OFDM DIGITAL TRANSMISSION SYSTEM FOR TELEVISION PROGRAM CONTRIBUTION

ARIB STANDARD

ARIB STD-B33 Version 1.1

Established on March 28, 2002 Version 1.0
Revised on November 30, 2005 Version 1.1

Association of Radio Industries and Businesses

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Preface

ARIB (Association of Radio Industries and Businesses) establishes the "ARIB Standards" for the basic technical conditions of standard specifications related to variety of radio communication equipments, broadcasting transmission equipments, and its reception equipments using radio wave with the participation of radio communication equipment manufacturers, broadcasting equipment manufacturers, electric communication companies, service providers and other users.

"ARIB Standards" are nongovernmental standards established by combining governmental technical standards established for the purpose of effective use of frequency and to avoid interference of other users, and nongovernmental optional standards established for convenience for radio communication equipment manufacturers, broadcasting equipment manufacturers, electric communication companies, service providers and users, in order to secure appropriate quality and compatibility of radio communication equipment and broadcast equipment, etc.

This standard is established for “Portable OFDM Digital Transmission System for Television Program Contribution”, by the approval of the standardization committee, participated by radio communication equipment manufacturers, broadcast equipment manufacturers, electric communication companies, service providers and users irrespectively, to secure impartiality and clearness.

We hope that this standard will be put to practical use actively by radio communication equipment manufacturers, broadcast equipment manufacturers, electric communication companies, service providers, users, and so on.

Notice:

This standard does not describe industrial proprietary rights mandatory to this standard. However, the right proprietor of the industrial proprietary rights has expressed that "Industrial proprietary rights related to this standard, listed in the annexed table below, are possessed by the applicator shown in the list. However, execution of the right listed in the annexed table below is permitted indiscriminately, without exclusion, under appropriate condition, to the user of this standard. In the case when the user of this standard possesses the mandatory industrial proprietary rights for all or part of the contents specified in this standard, and when he asserts his rights, it is not applied."

Annexed table

(Selection of Option 2)

Patent applicant	Name of invention	Patent number	Remarks
Japan Broadcasting Corporation (NHK) Hitachi Kokusai Electric Inc.	Orthogonal frequency division multiplex (OFDM) modulated transmission device	Patent release 2002-009728	Japan US UK Germany France
	Digitally modulated transmission device	Patent release 2002-009729	Japan US UK Germany France
	Transmitting device, transmission device, receiving device and signal configuration	Patent application 2001-222841	Japan
Japan Broadcasting Corporation (NHK)	Carrier arrangement, transmitting device and receiving device for the orthogonal frequency division multiplex transmission system	Patent release 2002-009724	Japan
	Arrangement of control information carriers and additional information carriers and their transmission device for the orthogonal frequency division multiplex transmission system	Patent application 2002-060227	Japan
	Coded modulation device and demodulation device	Patent No. 2883238	Japan
Sony Corporation	Submitted comprehensive written confirmation of ARIB STD-B33 Version 1.0.		

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Chapter 1 General Matters

1.1 Purpose

This standard specifies the OFDM digital transmission system for the FPU, a kind of portable radio transmission equipment for television program contribution, so that this system may be used to ensure smooth contribution to television programs.

1.2 Scope

This standard applies to the OFDM digital transmission system for the FPU, a kind of portable radio transmission equipment for television program contribution. Standards applicable to digital radio transmission systems using other methods will be considered if necessary.

This standard is intended to apply only during the period when the analogue and digital FPU systems are used together. Therefore, another standard may be specified when the digital system will be used alone in the future.

1.3 References

1.3.1 Normative References

This standard incorporates excerpts from the following documents:

- Ministerial Ordinance to Partially Amend the Ordinance Regulating Radio Equipment (Ordinance No. 49 of the Ministry of Posts and Telecommunications, 2000) (hereafter referred to as the “Ministerial Ordinance”)
- Ministerial Ordinance to Partially Amend the Ordinance Regulating Radio Equipment (Ordinance No. 21 of the Ministry of Posts and Telecommunications, 2002) (hereafter referred to as the “Ministerial Ordinance”)

1.3.2 Informative References

- “SERVICE INFORMATION FOR DIGITAL BROADCASTING SYSTEM” ARIB Standard ARIB STD-B10
- “SERIAL INTERFACE FOR SEPARATE-CABLE TRANSMISSION OF DATA AND CLOCK FOR TELEVISION PROGRAM CONTRIBUTION” ARIB Standard ARIB STD-B18

1.4 Terminology

1.4.1 Definitions

Full mode	Mode in which electronic news are gathered in the occupied bandwidth of 17.5 MHz
Half mode	Mode in which electronic news are gathered in the occupied bandwidth of 8.5 MHz
Data frame	The frame unit comprised of eight TS packets
Frame	The frame unit comprised of 408 (1K) or 204 (2K) OFDM symbols
OFDM frame	Synonymous with the frame (Used to stress that the frame is the OFDM frame)

Super frame	The frame unit comprised of eight OFDM frames

1.4.2 Abbreviations

AC	**A**uxiliary **C**hannel
BCH code	**B**ose-**C**haudhuri-**H**ocquegham code
BPSK	**B**inary **P**hase **S**hift **K**eying
C/N	**C**arrier to **N**oise ratio
CP	**C**ontinual **P**ilot
DBPSK	**D**ifferential **B**inary **P**hase **S**hift **K**eying
DQPSK	**D**ifferential **Q**uaternary **P**hase **S**hift **K**eying
FFT	**F**ast **F**ourier **T**ransform
FPU	**F**ield **P**ick-up **U**nit
MSB	**M**ost **S**ignificant **B**it
OFDM	**O**rthogonal **F**requency **D**ivision **M**ultiplexing
PID	**P**rogram **ID**entifier
PRBS	**P**seudo-**R**andom **B**inary **S**equence
QAM	**Q**uadrature **A**mplitude **M**odulation
QPSK	**Q**uaternary **P**hase **S**hift **K**eying
RS	**R**eed-**S**olomon
ReMUX	**Re-Mu**ltiple**X**
SNG	**S**atellite **N**ews **G**athering
S/P	**S**erial **P**arallel conversion
TMCC	**T**ransmission and **M**ultiplexing **C**onfiguration **C**ontrol
TS	**T**ransport **S**tream

Chapter 2 Technical Specifications

2.1 Frequency Band and Channel Spacing

Table 2-1 shows the frequency band and channel spacing for FPU to which this standard is applicable.

Table 2-1 Frequency Band for the FPU to which This Standard is Applicable

Name of the Frequency Band	Frequency Band	Channel Spacing	
		Full Mode	Half Mode
800 MHz band	770 MHz to 806 MHz		9 MHz
B band	5,850 MHz to 5,925 MHz	18 MHz	
C band	6,425 MHz to 6,570 MHz		
D band	6,870 MHz to 7,125 MHz		
E band	10.25 GHz to 10.45 GHz		
F band	10.55 GHz to 10.68 GHz		
G band	12.95 GHz to 13.25 GHz		

2.2 Transmission Method

The transmission method shall be one-way communication. (Ministerial Ordinance)

2.3 Modulation

2.3.1 Modulation

Modulation shall be OFDM (orthogonal frequency division multiplex) modulation. (Ministerial Ordinance)

Carrier modulation includes 64QAM, 32QAM, 16QAM, QPSK, DQPSK, BPSK and DBPSK modulation.

2.3.2 Maximum Transmission Bit Rate

Table 2-2 shows the maximum transmission bit rate when each type of modulation is used in each transmission mode.

Table 2-2 Type of Modulation and Maximum Transmission Bit Rate

Type of Modulation	Maximum Transmission Bit Rate Note)	
	Full Mode	Half Mode
BPSK/DBPSK	17.5 Mbit/s	8.5 Mbit/s
QPSK/DQPSK	35 Mbit/s	17 Mbit/s
16QAM	70 Mbit/s	34 Mbit/s
32QAM	87.5 Mbit/s	42.5 Mbit/s
64QAM	105 Mbit/s	51 Mbit/s

Note) In the 800 MHz band, carrier modulation in which the maximum transmission bit rate (half mode) is 16.2 Mbit/s or lower (Table 3-2) are used.

2.3.3 Modulation Mode

The modulation mode used by each type of modulation shall be as per Article 4-2 of the Regulations for Enforcement of the Radio Law, as shown in Table 2-3.

Table 2-3 Type of Modulation and Modulation Mode

Type of Modulation	Modulation Mode
BPSK/DBPSK	X7W
QPSK/DQPSK	
16QAM	
32QAM	
64QAM	

(Ministerial Ordinance)

2.4 Technical Specifications for the Transmitter

2.4.1 Frequency Tolerance

Table 2-4 shows the transmit frequency tolerance.

Table 2-4 Transmit Frequency Tolerance

Name of the Frequency Band	Frequency Band	Transmit Frequency Tolerance
800 MHz band	770 MHz to 806 MHz	1.5×10^{-6} or lower
B band	5,850 MHz to 5,925 MHz	7×10^{-6} or lower
C band	6,425 MHz to 6,570 MHz	
D band	6,870 MHz to 7,125 MHz	
E band	10.25 GHz to 10.45 GHz	
F band	10.55 GHz to 10.68 GHz	
G band	12.95 GHz to 13.25 GHz	

(Ministerial Ordinance)

2.4.2 Radiated Power

Table 2-5 shows the radiated transmitting power.

Table 2-5 Radiated Transmitting Power

(a) Full mode (Occupied bandwidth of 17.5 MHz or lower)

Name	Frequency Band	Maximum Value of the Radiated Power When the Adjacent Channel is Analogue (W)	Maximum Value of the Radiated Power When the Adjacent Channel is Not Analogue (W)
B band	5,850 MHz to 5,925 MHz	0.2	5
C band	6,425 MHz to 6,570 MHz	0.2	5
D band	6,870 MHz to 7,125 MHz	0.2	5
E band	10.25 GHz to 10.45 GHz	0.2	5
F band	10.55 GHz to 10.60 GHz 10.60 GHz to 10.68 GHz†	0.2 0.2	5 0.5
G band	12.95 GHz to 13.25 GHz	0.2	5

† Shared with Radio Astoronomy

(b) Half mode (Occupied bandwidth of 8.5 MHz or lower)

Name	Frequency Band	Maximum Value of the Radiated Power When the Adjacent Channel is Analogue (W)	Maximum Value of the Radiated Power When the Adjacent Channel is Not Analogue (W)
800 MHz band	770 MHz to 806 MHz	—	5
B band	5,850 MHz to 5,925 MHz	0.1	2.5
C band	6,425 MHz to 6,570 MHz	0.1	2.5
D band	6,870 MHz to 7,125 MHz	0.1	2.5
E band	10.25 GHz to 10.45 GHz	0.1	2.5
F band	10.55 GHz to 10.60 GHz 10.60 GHz to 10.68 GHz†	0.1 0.1	2.5 0.25
G band	12.95 GHz to 13.25 GHz	0.1	2.5

† Shared with Radio Astoronomy

2.4.3 Spurious Emission or Unwanted Emisson Intensity

2.4.3.1 Specification applied after December 1, 2005

Frequency Band	Spurious Emission Intensity in area outside band	Unwanted Emission Intensity in spurious area
B to G band	50 μW or lower	50 μW or lower
800 MHz band	25 μW or lower	25 μW or lower

This specification meets the requirements specified in attached table 3-2(1) of the Ordinance Regulating Radio Equipment.

Please note that there are interim measures in this specification. (Depend on the Ordinance Regulating Radio Equipment (No.119 of the administration ministerial ordinance on august 9, 2005) additional clause.)

2.4.3.2 Specification applied before November 30, 2005

The spurious emission intensity shall be 50 μW or lower in the B to G bands and 25 μW or lower in the 800 MHz band.

(ARIB STD-B33 Version 1.0)

2.4.4 Spectral Mask

The spectral mask is shown in Fig. 2-1.

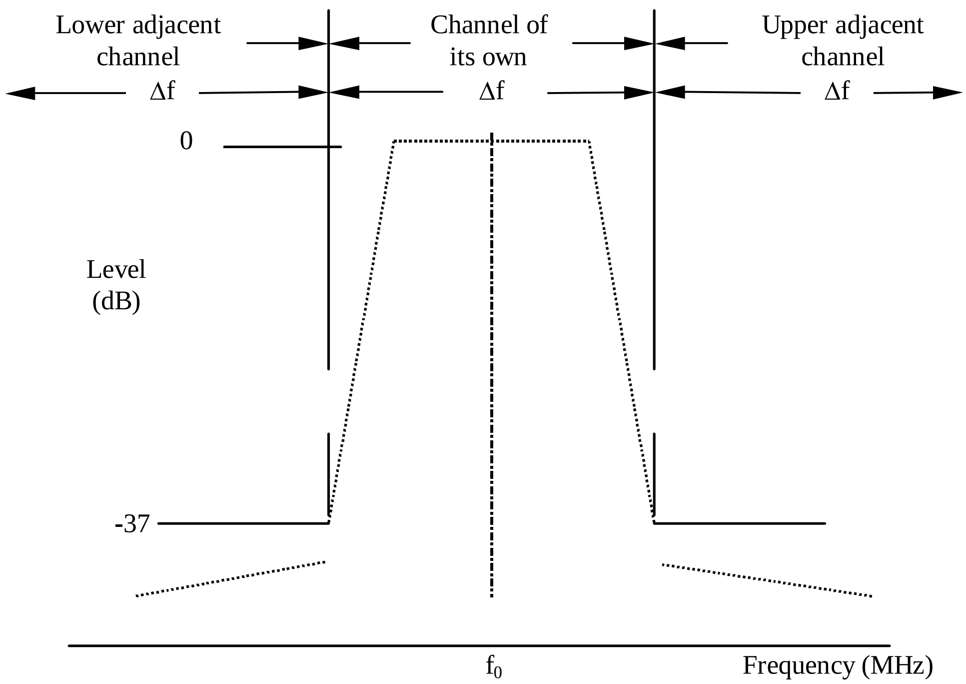


Fig. 2-1 Spectral Mask

Full mode: Δf = 18 MHz

Half mode: Δf = 9 MHz

2.4.5 Occupied Bandwidth

The occupied bandwidth shall be 17.5 MHz or lower in full mode, and 8.5 MHz or lower in half mode.

2.4.6 Aerial

The transmitting aerial shall be as per the requirements specified for the existing analogue FPU.

As for polarization, the circular polarization (clockwise/counter-clockwise) as well as the linear polarization (vertical/horizontal) can be used. (Ministerial Ordinance)

2.5 Link Quality

2.5.1 Required C/N

The C/N required for the bit error rate of 10^{-4} after decoding the inner code modulated in 64QAM (convolution coding rate of 5/6) shall be 28 dB (fixed degradation of 4dB of the transmitting and receiving devices and the margin for multiple-paths of 5 dB summed to the theoretical value of 19 dB). The definition of the margin for multiple paths in the OFDM system is shown in Reference 1.

2.5.2 C/N Distribution

The C/N distribution is 48% (thermal), 2% (strain) and 50% (interference).

2.5.3 Required Annual Rates of Instantaneous Link Interruption and Link Unavailability

The annual rate of instantaneous link interruption due to fading and the annual rate of link unavailability due to rainfall, the rate of the time which the symbol error rate after decoding the inner code exceeds $1x10^{-4}$, shall be as shown in Table 2-6.

Since the FPU is used for field transmission of video signal and is not permanently installed for use, the link can be set up in consideration of the link conditions. The specification for the rate of instantaneous link interruption shown here can be used to set target values for required parameters and so on.

**Table 2-6 Required Link Quality
(Annual Rates of Instantaneous Link Interruption and Link Unavailability)**

Operating Frequency Band	Rates of Instantaneous Link Interruption and Link Unavailability
800 MHz band (770 to 806 MHz)	0.5% or lower annually†
B band (5,850 to 5,925 MHz)	
C band (6,425 to 6,570 MHz)	
D band (6,870 to 7,125 MHz)	
E band (10.25 to 10.45 GHz)	0.00125% or lower annually‡
F band (10.55 to 10.68 GHz)	
G band (12.95 to 13.25 GHz)	

†Annual rate of instantaneous path interruption due to fading
‡Annual rate of path unavailability due to rainfall

2.6 Link Budget

2.6.1 Link Distance

The FPU is not permanently installed for use, meaning the link and meteorological conditions change according to how the FPU is used. This means that it is impractical to design the link budget to take the fading margin and so on into consideration whenever the FPU is set up. It is therefore practical to include a transmission margin of 15 dB in the radiated power during the design of the link budget for the digital as well as the analogue system. In addition, to ensure proper reception input during operation, the radiated power shall be reduced in accordance with the actual link conditions. The typical link budget for each frequency band is designed based on the conditions of the typical link distances as shown in Table 2-7 and the values of the required parameters, such as the typical reception input for each frequency band, are calculated. Examples of a link budget and the calculation procedures of the required fading and rainfall margins are shown in References 2 and 3, respectively.

Table 2-7 Typical Link Distance

<table>
<tr><th colspan="2">Frequency Band</th><th>800 MHz, B, C and D</th><th>E and F</th><th>G</th></tr>
<tr><td rowspan="2">Typical Link Distance</td><td>Fixed transmission</td><td>50 km</td><td>7 km</td><td>5 km</td></tr>
<tr><td>Mobile transmission</td><td colspan="3">4 km</td></tr>
</table>

2.6.2 Typical Received Power

The typical reception input is as shown in Table 2-8.

Table 2-8 Typical Reception Input

	Full mode	Half mode
Fixed transmission	-55 dBm	-58 dBm
Mobile transmission	-61 dBm	-64 dBm

2.7 Radio-frequency Head

2.7.1 Configuration

The transmitting radio-frequency head converts the IF signal to an 800 MHz band or B to G bands and amplifies the power for RF signal transmission.

The configurations of the transmitting and receiving radio-frequency heads are shown in Fig. 2-2:

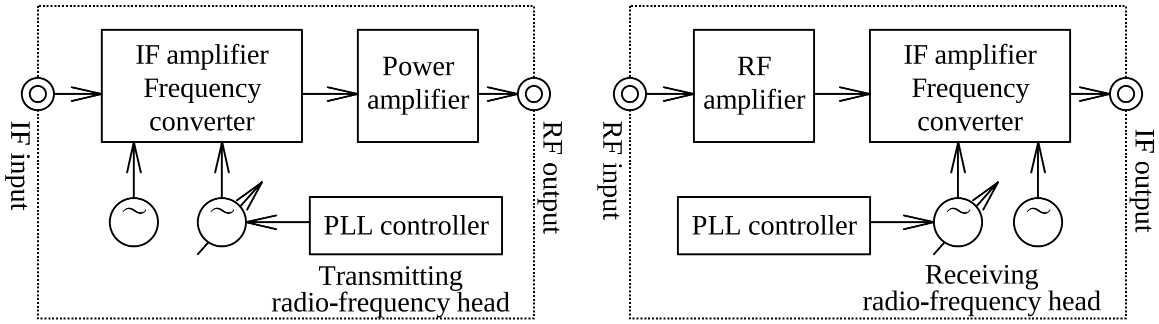


Fig. 2-2 Configurations of the Radio-frequency Heads

2.7.2 Function

(1) IF amplifier and frequency converter
The IF shall be 130 MHz.

(2) Power amplifier
The power amplifier amplifies the power of the converted radio frequency signal.

(3) Allocated channel selection
Selection between multiple allocated channels shall be allowed on a single unit.

2.7.3 Target Performance

The target performance of the transmitting radio-frequency head is shown in Table 2-9 and Table 2-10.

Table 2-9 Target Performance of the Transmitting Radio-frequency Head in the Microwave Band

	Item	Specification		Remarks
		Full mode	Half mode	
1	Transmit frequency	B, C, D, E, F and G band		
2	Transmission output*1) [W] within +1.5 dB/-1.0 dB <Switching system>	1.0† 0.5 0.2 0.1	1.0† 0.5† 0.2 0.1	† F4 to F7 are excluded. The maximum power shall be as follows when the adjacent channel is analogue: 0.2 in full mode and 0.1 in half mode.
3	Third order distortion within the band [dBc]	-40 or lower		
4	Frequency stability	Within $\pm 1\times10^{-6}$		
5-1	Spurious emission in area outside band[μW]	50 or lower		
5-2	Unwanted emission in spurious area[μW]	50 or lower		
6	IF input level [dBm] IF frequency [MHz]	0 to -20 130		Cable length 200 m

*1) A switching increment of 3 dB will be appropriate for the transmission output value since it is equivalent to the variable output width of the existing device. In consideration of the situation where the adjacent channel is analogue, it is desirable that the following transmission output values are used: 0.2 W in full mode and 0.1 W in half mode.

Table 2-10 Target Performance of the Transmitting Radio-frequency Head in the 800 MHz Band

	Item	Specification	Remarks
1	Transmit frequencies	800 MHz band	
2	Transmission output*1) [W] within +1.5 dB/-1.0 dB <Switching system>	1.0 0.5 0.2 0.1	
3	Third order distortion within the band [dBc]	-40 or lower	
4	Frequency stability	Within $\pm 1\times10^{-6}$	
5-1	Spurious emission in area outside band[μW]	25 or lower	
5-2	Unwanted emission in spurious area[μW]	25 or lower	

6	IF input level [dBm] IF frequency [MHz]	0 to -20 130	Cable length 200 m

*1) A switching increment of 3 dB will be appropriate for the transmission output value since it is equivalent to the variable output width of the existing device.

Chapter 3 Specifications for Manufacturers' Compatibility

3.1 Block Diagram and Basic Parameters

Fig. 3-1 shows the digital FPU in block diagram form.

The digital FPU transmitter (Tx) is comprised of a transmitting controller and radio-frequency head. The transmitting controller receives the TS (Transport Stream) signal from an encoder, encodes the transmission channel coding and then outputs the IF signal. The transmitting radio-frequency head receives the IF signal, converts the frequency, amplifies the power and then outputs the RF signal.

The digital FPU receiver (Rx) comprises a receiving radio-frequency head and controller. The receiving radio-frequency head receives the RF signal, converts the frequency and outputs the IF signal. The receiving controller receives the IF signal, decodes for the transmission channel coding and outputs the TS signal to a decoder.

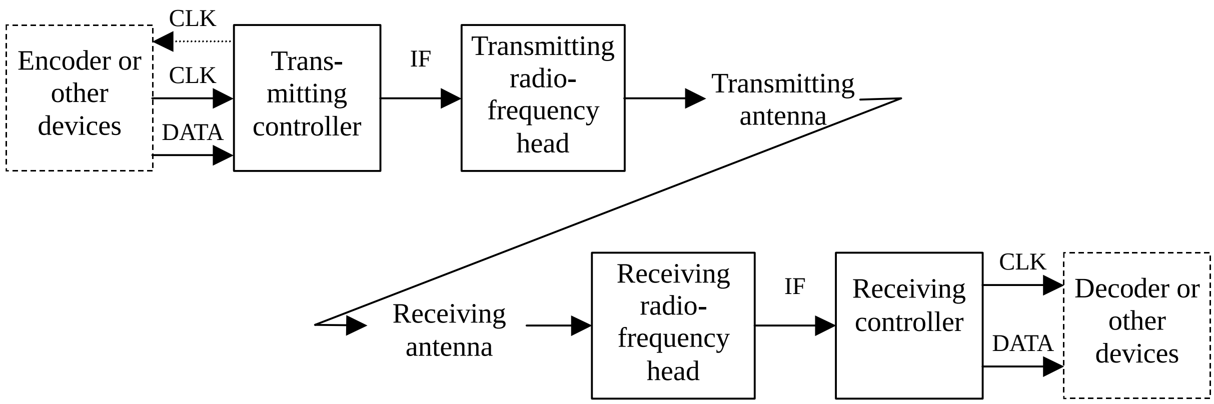


Fig. 3-1 Digital FPU System Diagram

3.2 Basic Parameters

Table 3-1 shows the OFDM transmission parameters, while Table 3-2 shows the transmission capacities. The transmission parameters specifications are determined in consideration of the TS rate compatibility in the tandem connection with SNG. The FFT sampling clock for the transmission parameters was selected to retain transmission capacities of 59.648 (Mbit/s) and 44.736 (Mbit/s) in the combination of the modulation type and the inner coding rate. The following section shows how to find the FFT sampling clock.

The target TS rate, TSR (Mbit/s), is calculated using the following equation.

$$TSR = D \times M \times R/(Te \times (1 + Gr)) \qquad (1)$$

Here

D: the number of data carriers
M (bit/Hz): the bandwidth utilization efficiency determined by the type of modulation
R: the inner coding rate
Te (μs): the effective symbol duration
Gr: the guard interval ratio

Te is calculated as follows.

$$Te = D \times M \times R/(TSR \times (1 + Gr)) \qquad (2)$$

The following equation is established by substituting equation (2) on the basis of Fs equaling 1/(Te/P).

$$Fs = TSR \times (1 + Gr) \times P/(D \times M \times R) \quad (3)$$

Here
P: the number of FFT points
Fs (MHz): the FFT sampling clock

When TSR equals 59.648 (Mbit/s), Gr equals 1/8, P equals 1024, D equals 672 and the type of modulation is 64QAM, Fs is calculated as follows by substituting the bandwidth utilization efficiency represented by M of 6 and the inner coding rate represented by R of 5/6 into equation (3).
Fs = 20.45074 [MHz]

Table 3-1 Transmission Parameters

Item		Standard			
Mode		Half mode		Full mode	
Number of FFT points		1024	2048	1024	2048
Occupied bandwidth [MHz]		8.49	8.40	17.12	17.19
Carrier spacing [kHz]		19.97	9.99	19.97	9.99
Number of carriers	Total	425	841	857	1721
	Data *1)	336 (408)	672 (816)	672 (840)	1344 (1680)
	CP *1)	54 (0)	106 (0)	108 (0)	216 (0)
	TMCC	10	16	10	16
	AC *1)	24 (6)	46 (8)	66 (6)	144 (24)
	NULL	1			
Carrier modulation		BPSK, DBPSK, QPSK, DQPSK, 16QAM, 32QAM, 64QAM			
FFT sampling clock [MHz]		20.45074			
Number of symbols/frame		408	204	408	204
Number of frames/super frame		8			
Effective symbol duration [μs]		50.07	100.14	50.07	100.14
Guard interval length [μs]		6.26	12.52	6.26	12.52
Symbol duration [μs]		56.33	112.66	56.33	112.66
Frame length [ms]		22.98			
Super frame length [ms]		183.86			
Inner code		Convolutional code (1/2, 2/3, 3/4 and 5/6) *2)			
Outer code		RS(204,188,t=8)			
Inner interleave		Bit interleave Frequency Interleave Time Interleave			
Outer interleave		Byte interleave			

*1) The figures in parentheses are applicable to DBPSK and DQPSK

*2) Not applicable to DBPSK since the number of packets in a frame is not an integral number when the coding rate is 3/4.

Table 3-2 Transmission Capacities

Carrier modulation	Convolutional code	Number of TSPs in a frame		TS (204 Byte) rate [Mbit/s]	
		Half mode	Full mode	Half mode	Full mode
BPSK	1/2	42	84	2.982	5.965
	2/3	56	112	3.977	7.953
	3/4	63	126	4.474	8.947
	5/6	70	140	4.971	9.941
	None	84	168	5.965	11.930
DBPSK *1)	1/2	51	105	3.621	7.456
	2/3	68	140	4.829	9.941
	5/6	85	175	6.036	12.427
	None	102	210	7.243	14.912
QPSK	1/2	84	168	5.965	11.930
	2/3	112	224	7.953	15.906
	3/4	126	252	8.947	17.894
	5/6	140	280	9.941	19.883
	None	168	336	11.930	23.859
DQPSK	1/2	102	210	7.243	14.912
	2/3	136	280	9.657	19.883
	3/4	153	315	10.864	**22.368**
	5/6	170	350	12.072	24.853
	None	204	420	14.486	**29.824**
16QAM	1/2	168	336	11.930	23.859
	2/3	224	448	15.906	31.812
	3/4	252	504	17.894	35.789
	5/6	280	560	19.883	39.765
	None	336	672	23.859	47.718
32QAM	1/2	210	420	14.912	**29.824**
	2/3	280	560	19.883	39.765
	3/4	315	630	**22.368**	**44.736**
	5/6	350	700	24.853	49.707
	None	420	840	**29.824**	**59.648**
64QAM	1/2	252	504	17.894	35.789
	2/3	336	672	23.859	47.718
	3/4	378	756	26.842	53.683
	5/6	420	840	**29.824**	**59.648**
	None	504	1008	35.789	71.578

Underlined bold figures are applicable to the SNG compatible mode.

*1) Not applicable to DBPSK since the number of packets in a frame is not an integral number when the coding rate is 3/4.

3.3 Interface

3.3.1 Connection Configuration

When connecting an encoder, a re-multiplexer (ReMUX) or another digital FPU receiver (Rx) with the digital FPU transmitter (Tx), one of the two connection configurations shown below shall be used, as shown in Fig. 3-2. The connection configurations between the digital FPU receiver (Rx) and a decoder are shown in Fig. 3-3.

(Connection configuration 1) For the connection the outer Interleave with the inner code error correction, the "Serial Interface for Separative-Cable Transmission of Data and Clock for Television Program Contribution (ARIB STD-B18) " shall be applied.

(Connection configuration 2) For the connection source coding/multiplexing with data frame synchronization, the 204 byte/packet (with 16 dummy bytes) of DVB-ASI (ETSI EN 50083-9 "Cabled distribution systems for television, sound and interactive multimedia signals Part 9 : Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams") shall be applied.

The clock signal (solid line) and data flow shall be in the same direction. The digital FPU transmitter shall be operated with an external clock (dotted line). The digital FPU transmitter shall be able to supply the clock to an encoder or re-multiplexer. The "Serial Interface for the Separative-Cable Transmission of Data and Clock for Television Program Contribution" (ARIB STD-B18) shall be applied to the clock to be supplied to an encoder or re-multiplexer.

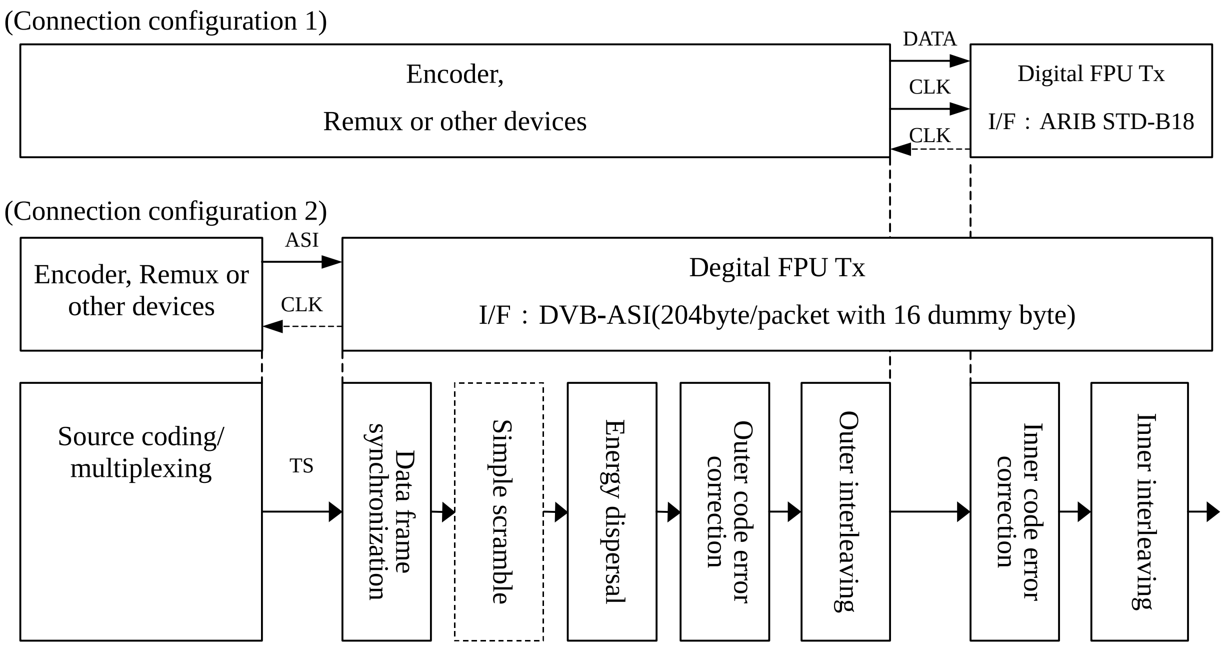


Fig. 3-2 Configuration and Interface of digital FPU transmitter

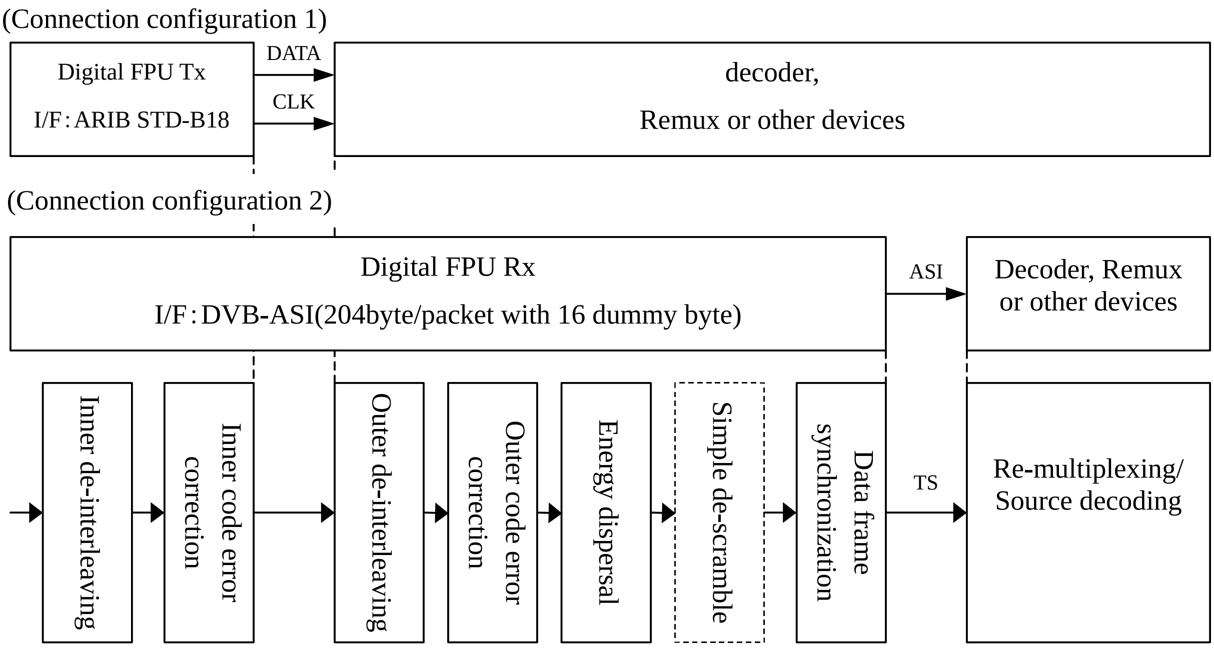


Fig. 3-3　Configuration and Interface of digital FPU receiver

3.4 Transmitting Controller

3.4.1 Block Diagram

Fig. 3-4 shows the block diagram of the transmitting controller.

The transmitting controller includes data frame synchronization, simple scramble (optional), energy dispersal, error correction coding, interleaving, mapping, OFDM frame configuration and orthogonal frequency division multiplexing, and output the IF signal. The following subsections describe the functions of each block of the transmitting controller.

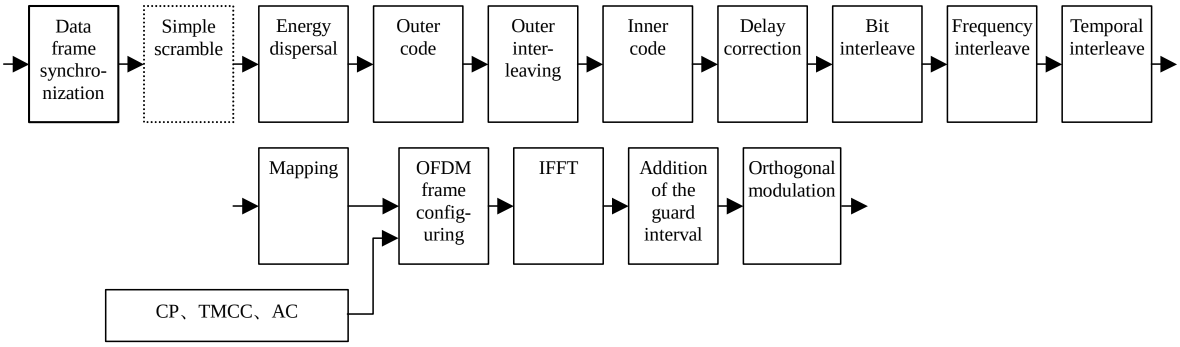


Fig. 3-4 Block Diagram of the Transmitting Controller

3.4.2 Data Frame Synchronization

The TS input data from an encoder or a re-multiplexer to the transmitting controller is framed into eight TS packet units. The first sync byte of the data frame is 0xB8 -- an inverted sync byte (the normal TS sync byte is 0x47).

Super frames are also structured in order to specify the timing of the subsequent signal processing. The start point of the super frame and the data frame shall be aligned. The data timing chart after data frame synchronization is shown in Fig. 3-5.

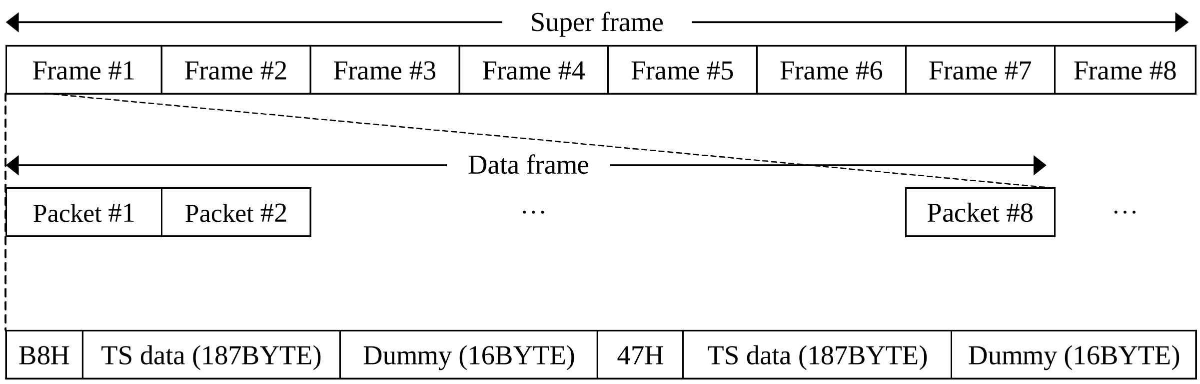


Fig. 3-5 Timing Chart after Data Frame Synchronization

3.4.3 Simple Scramble (Optional)

The digital transmission system specified in this standard is used for communication with identified partners. In order to reduce the size and power consumption of the equipment, a simple scramble shall be used, which involves adding a 16-bit pseudo random binary sequence (generator polynomial $X^{16}+X^{12}+X^{3}+X+1$). Since the FPU must be directionally adjusted to receive signals, and privacy protection is less important, a simple scramble function can be additionally installed, if necessary. Even when another scramble system is used together, the scramble area shall follow the specifications in this section.

The area of scramble shall be the payloads that exclude the transport packet header (four bytes) and adaptation field.

However, the NIT (PID=0x0010) packet, which includes the identification code of the transmitting point, and Null (PID=0x1FFF) packet, shall not be scrambled. Other types of packets with other PIDs may be unscrambled.

Whether a packet is scrambled or not shall be indicated by the transport_scrambling_control bit in each packet header. The packet identification code (PID) shall be applied as assigned in the "Service Information for Digital Broadcasting System (ARIB STD-B10) ".

The scramble key shall be the initial value, which is loaded to the LFSR (Linear Feedback Shift Register) to generate the above mentioned pseudo random binary sequence. The key will not be transmitted.

The initial value shall be loaded to the LFSR immediately after data frame synchronization and the LFSR shall continue operating until the next data frame synchronization. The pseudo random binary sequence shall not be added in where scramble is prohibited. Fig. 3-6 shows the configuration of a simple scramble circuit (when the key is 0xFFFF).

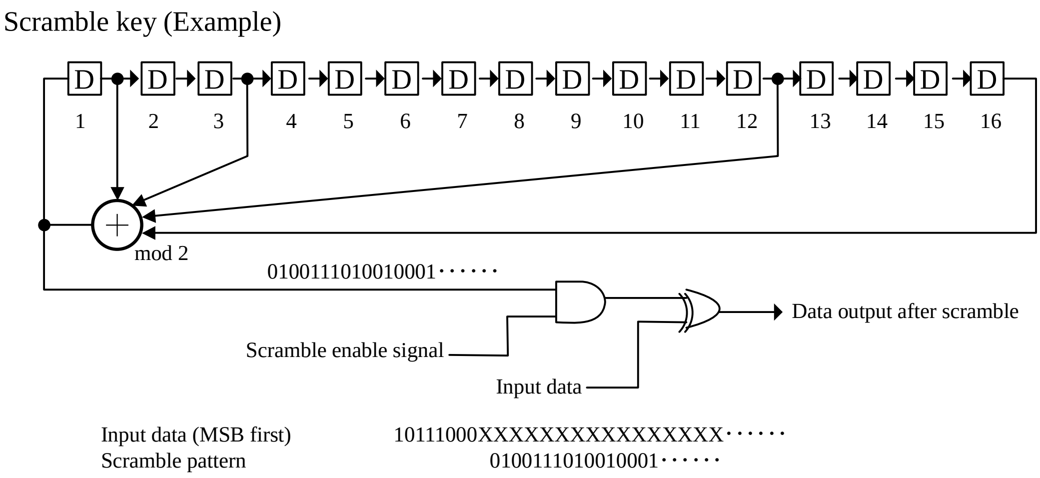


Fig. 3-6 Configuration of A Simple Scramble Circuit

3.4.4 Energy Dispersal

The pseudo random binary sequence shall be added to the TS packet multiplexed in accordance with ISO/IEC13818-1 for the purpose of energy dispersal. The generator polynomial of the pseudo random binary sequence shall be $X^{15}+X^{14}+1$. The initial value of the pseudo random binary sequence shall be "1001 0101 0000 000" in ascending order. The pseudo random binary sequence shall be added to the location of the 187 byte packet (204 – 16 – 1) (as a result of excluding 16 dummy bytes, data frame sync byte (0xB8) or TS sync byte (0x47) from each 204 byte packet). The initial value shall be loaded immediately after the sync byte (0xB8) of the first TS packet. While the shift register shall continue operating in the sync byte, the pseudo random binary sequence shall not be added here. Fig. 3-7 shows the configuration of an energy dispersal circuit.

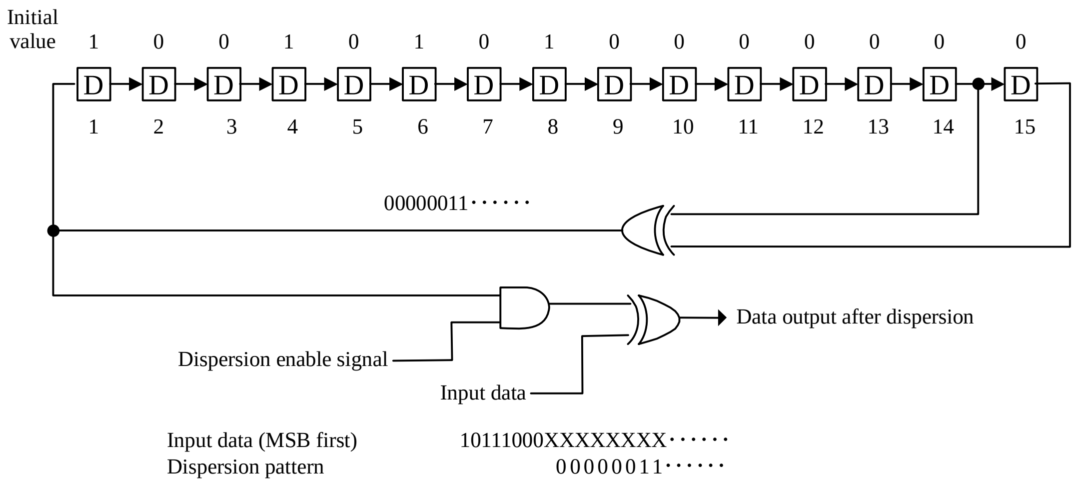


Fig. 3-7 Configuration of an Energy Dispersal Circuit

3.4.5 Outer Code Error Correction

Reed-Solomon (204, 188) shall be used for the outer code error correction. The shortened Reed-Solomon code shall be generated by the Reed-Solomon (255, 239) encoder by adding 51 byte zeros before the 188 bytes (the total input data of 204 bytes when the 16 dummy bytes are included) and by removing the 51 bytes after coding. The generator polynomials for Reed-Solomon (204, 188) are shown below:

Code generator polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)\ldots\ldots\ldots(x+\lambda^{15})$

λ=02h

Field generator polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)\ldots\ldots\ldots(x+\lambda^{15})$

The Reed-Solomon (204, 188) can correct byte errors as follows; 10^{-11} or lower for 10^{-3} input and 10^{-19} or lower for 10^{-4} input.

3.4.6 Outer Interleave

The outer interleave refers to convolution interleaving that involves byte-by-byte feeding of a 204 byte bit stream (Reed-Solomon coded) to each of the 12 paths. The n-th path has the delay of the (n-1) blocks and each block has a 17-byte delay. Here, the transport packet and frame sync bytes shall always traverse the path without delay. The start point of the super frame after outer Interleaving shall be located at the delayed position of the 11th packet. The de-interleave circuit shall configured such that the first path has 11 delay blocks while the “n”-th path also has (12-n) delay blocks. The configuration of an outer interleave circuit is shown in Fig. 3-8.

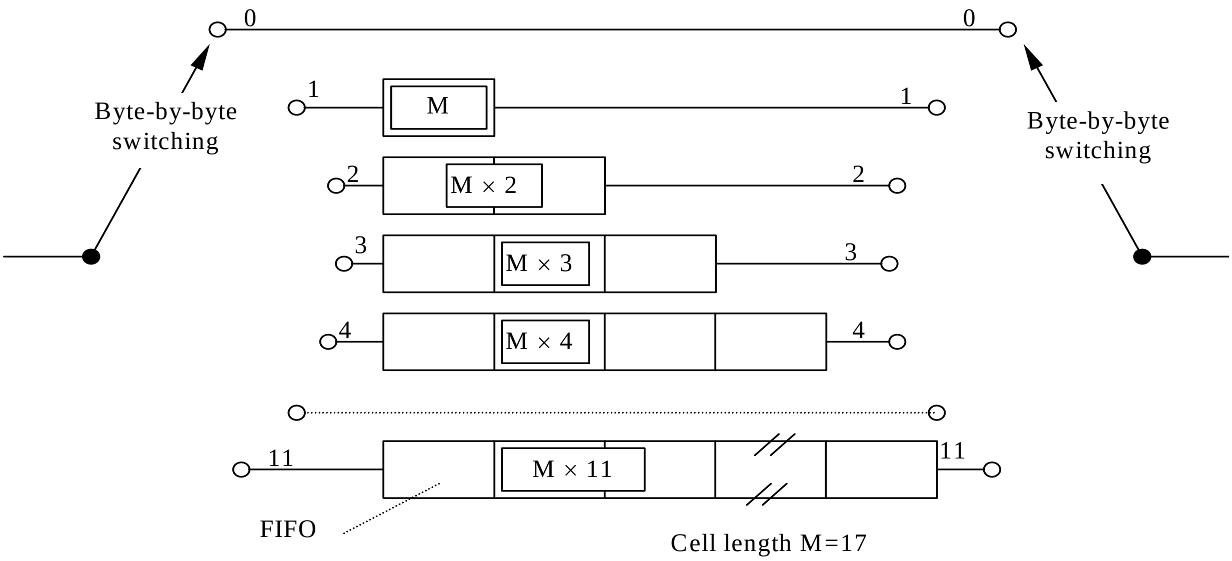


Fig. 3-8 Configuration of an Outer Interleave Circuit

3.4.7 Inner Code Error Correction

Inner code error correction uses punctured convolution coding with a constraint length of 7 and a coding rate of 1/2. The generator polynomial of the source code uses G1 (171 oct) and G2 (133 oct) and four coding rates (R=1/2, 2/3, 3/4 and 5/6) can be used when punctured. Fig. 3-9 shows a convolution coding circuit with a constraint length of 7 and coding rate of 1/2, while Table 3-3 shows a punctured pattern. This latter is reset at the position of the frame synchronization signal. In this case, the first bit of a frame and the 6 bit data in the preceding frame are calculated using modulo 2 arithmetic and the output (X, Y) is used as the start point of the punctured pattern.

If the link condition does not require the use of the inner code, this can be omitted. In this case, the input signal is simply used as the output signal.

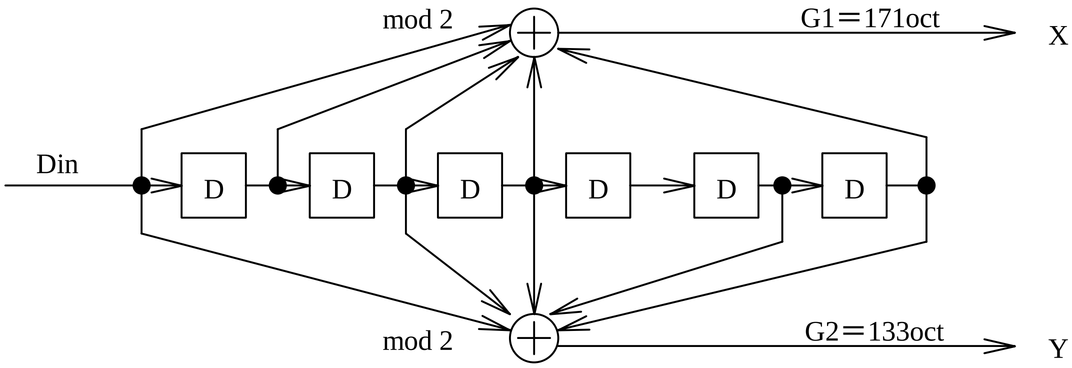


Fig. 3-9 Convolution Coding Circuit

Table 3-3 Punctured Patterns

Coding rate	Punctured patterns	Transmission signal series
1/2	X : 1 Y : 1	X_1, Y_1
2/3	X : 1 0 Y : 1 1	X_1, Y_1, Y_2
3/4	X : 1 0 1 Y : 1 1 0	X_1, Y_1, Y_2, X_3
5/6	X : 1 0 1 0 1 Y : 1 1 0 1 0	X_1, Y_1, Y_2, X_3 Y_4, X_5

3.4.8 Delay Correction

Bit interleaving, as explained in §3.4.9, causes a delay in 120 carrier symbols during transmission and reception. Therefore, by inserting delay correction, as shown in Fig. 3-10, the delay shall be equivalent to one OFDM symbol period during transmission and reception. The amount of delay insertion applicable to each type of modulation is shown in Table 3-4. The start point of the super frame is delayed equivalent to one OFDM symbol period.

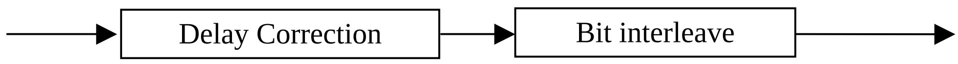


Fig. 3-10 Insertion of Delay Correction

Table 3-4 Amount of the Delay Caused by Bit Interleaving

Carrier modulation	Amount of delay insertion (Number of bit)				Amount of delay insertion of the OFDM Super Frame (Number of bit)			
	Half mode		Full mode		Half mode		Full mode	
	1K	2K	1K	2K	1K	2K	1K	2K
BPSK	336	672	672	1344	336	672	672	1344
DBPSK	408	816	840	1680	408	816	840	1680
QPSK	432	1104	1104	2448	672	1344	1344	2688
DQPSK	576	1392	1440	3120	816	1362	1680	3360
16QAM	864	2208	2208	4896	1344	2688	2688	5376
32QAM	1080	2760	2760	6120	1680	3360	3360	6720
64QAM	1296	3312	3312	7344	2016	4032	4032	8064

3.4.9 Bit interleave

When using multiple level modulation, carriers' errors become burst errors. To reduce the influence of burst errors, bit-by-bit interleaving is used. Convolution interleaving that involves inserting a delay line in each bit, is used for bit interleaving. Bit interleaving used for each type of modulation is shown below and no interleaving is used for (D) BPSK.

3.4.9.1 (D) QPSK

Bit interleaving involves de-multiplexing the input signal into two bit streams and inserting a delay element shown in Fig. 3-11 into b1.

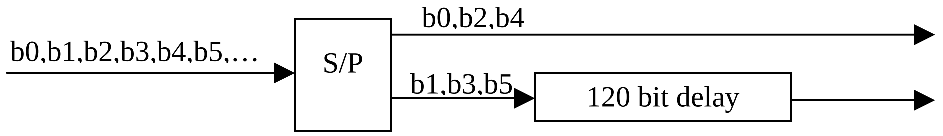


Fig. 3-11 Bit Interleaving Used by QPSK

3.4.9.2 16QAM

Bit interleaving involves de-multiplexing the input signal into four bit streams and inserting a delay element shown in Fig. 3-12 into b1 to b3.

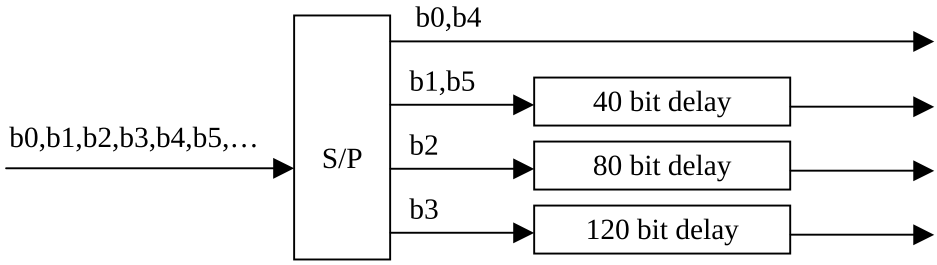


Fig. 3-12 Bit Interleaving Used by 16QAM

3.4.9.3 32QAM

Bit interleaving involves de-multiplexing the input signal into five bit streams and inserting a delay element shown in Fig. 3-13 into b1 to b4.

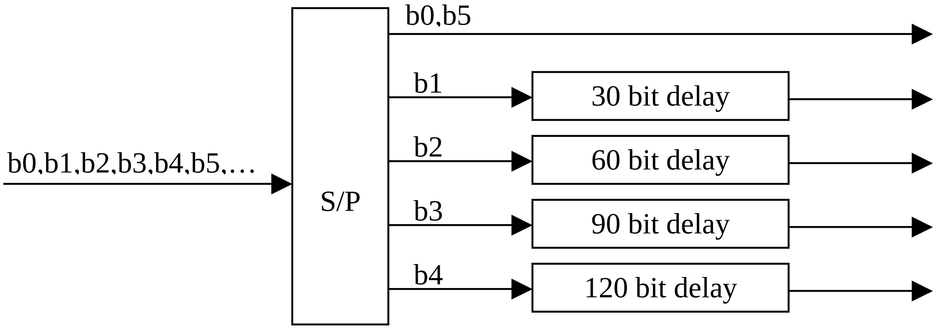


Fig. 3-13 Bit Interleaving Used by 32QAM

3.4.9.4 64QAM

Bit interleaving involves de-multiplexing the input signal into six bit streams and inserting a delay element shown in Fig. 3-14 into b1 to b5.

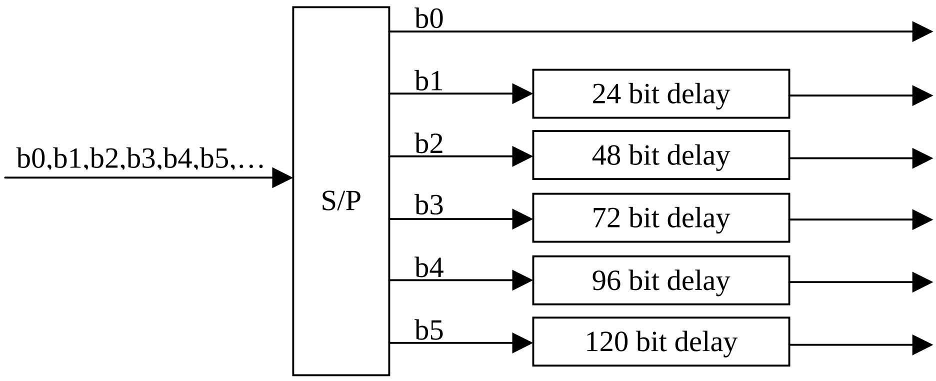


Fig. 3-14 Bit Interleaving Used by 64QAM

3.4.10 Frequency Interleave

Frequency interleaving uses the frequency interleaving function shown in Table 3-5.

mseq11(reg) in Table 3-5 returns the shift register value of the circuit to generate the pseudo random binary sequence shown in Fig. 3-15. The initial shift register value shall be “1111 1111 111.”

Here, function, F (i), converts the carrier position (i) prior to interleaving to the carrier position after interleaving.

generator polynomial g (x) = $x^{11} + x^2 + 1$

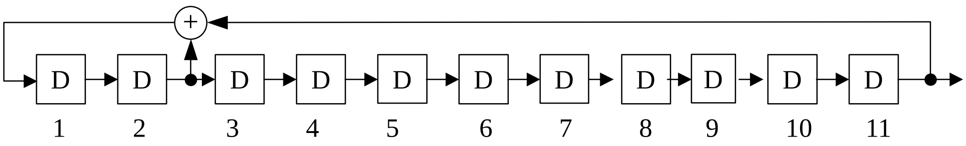


Fig. 3-15 Pseudo Random Binary Sequence Generating Circuit

Table 3-5 Frequency Interleaving Function frequency_interleaver

```
frequency_interleaver()
{
        reg = 0x7ff;
        i = 0;
        for ( j=0 ; j<2048 ; j++ )
        {
                n = mseq11(reg);
                 if (n<=336/672/1344/408/816/840/1680) {
                   // 336:1K_Half; 672:2K_Half,1K_Full; 1344:2K_Full;
                   // 408:1K_Half(D), 816:2K_Half(D), 840:1K_Full(D), 1680:2K_Full(D);
                        F( i ) = n - 1;
                        i++;
                }
                reg = n;
        }
}
```

n = register value

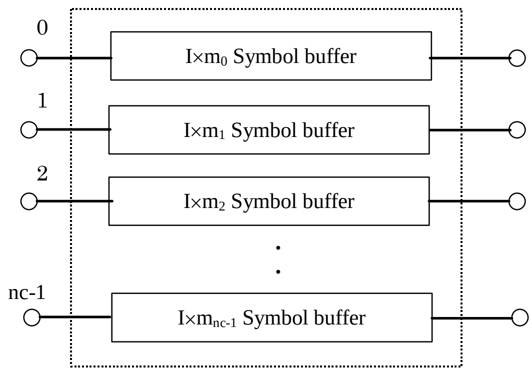
3.4.11 Time Interleave

Time interleaving, designed to spread out carriers along the time domain in order to improve declining robustness, uses convolution interleaving. The time interleaving length, as shown in Table 3-6, can be selected from four parameters by changing the value of the cell length (I). Fig. 3-16 shows how time interleaving is used.

The start point of the super frame after time interleaving shall be set as the start point of the symbol in which the most delayed data is present.

Table 3-6 Time Interleaving Length

Cell length (I)		Time interleaving length	
1K	2K	Depth	Time [ms]
0	0	No interleaving	
2	1	3.29 frame	75.60
10	5	16.45 frame	377.98
20	10	32.89 frame	755.95



Here, m_i = (ix5) mod 672

nc represents the number of data carriers and i represents the carrier No. in a symbol.

nc values: 336 (1K half mode), 672 (2K half mode, 1K full mode), 1344 (2K full mode)
<u>408 (1K half mode), 816 (2K half mode), 840 (1K full mode), 1680 (2K full mode)</u>

Note) Non-underlined values are applicable when synchronous modulation is used and underlined values are applicable when differential modulation is used.

Fig. 3-16 How Time Interleaving is Used

3.4.12 Mapping

Mapping for each type of modulation is shown below.

3.4.12.1 BPSK

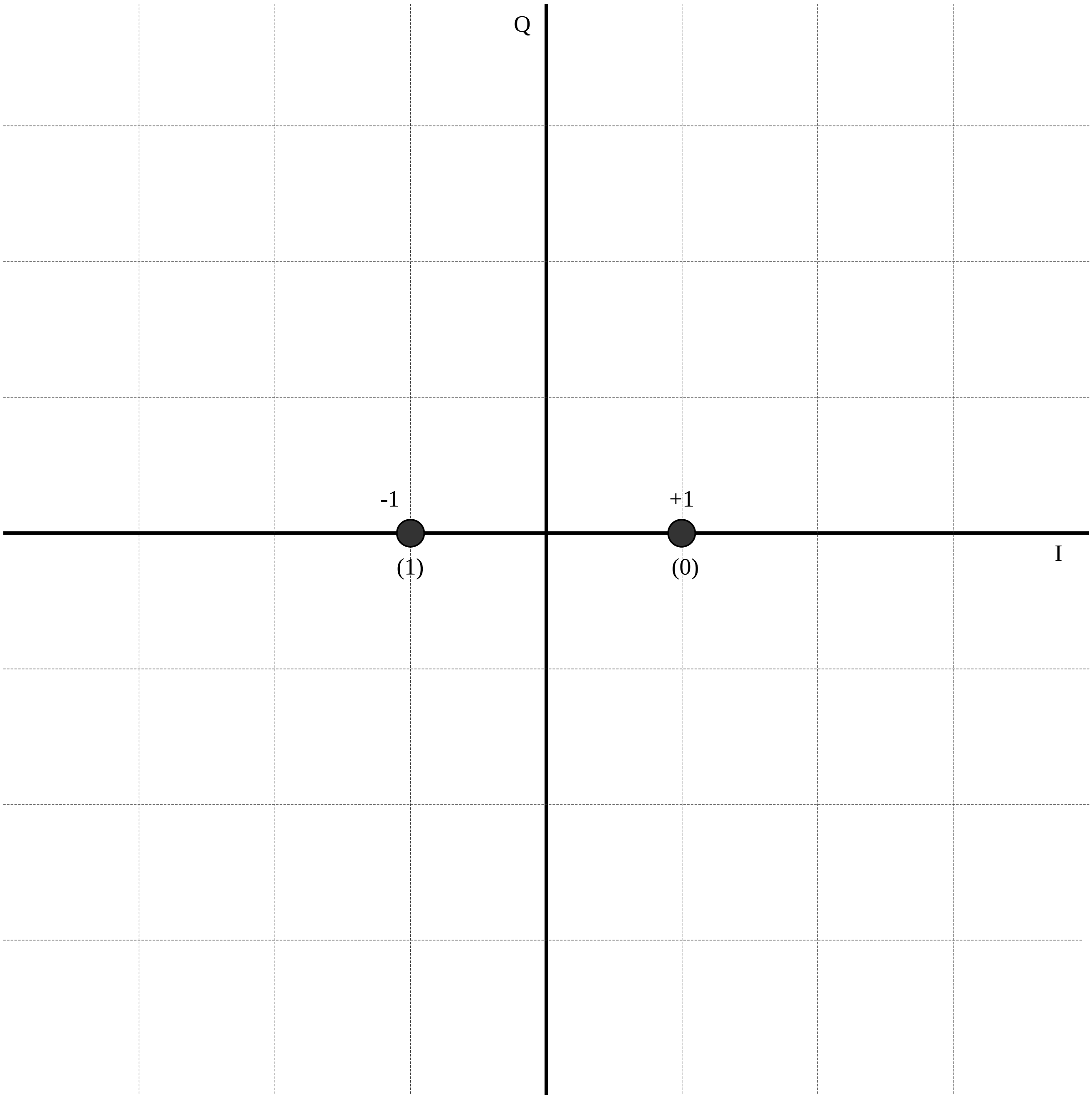


Fig. 3-17 BPSK Mapping

3.4.12.2 DBPSK

DBPSK mapping shall use a one bit (b0) input signal, to output the I axial data of one bit. Fig. 3-18 shows DBPSK modulation, Table 3-7 shows phase calculation and Fig. 3-19 shows mapping.

The delay in Fig. 3-18 is equivalent to one OFDM symbol period.

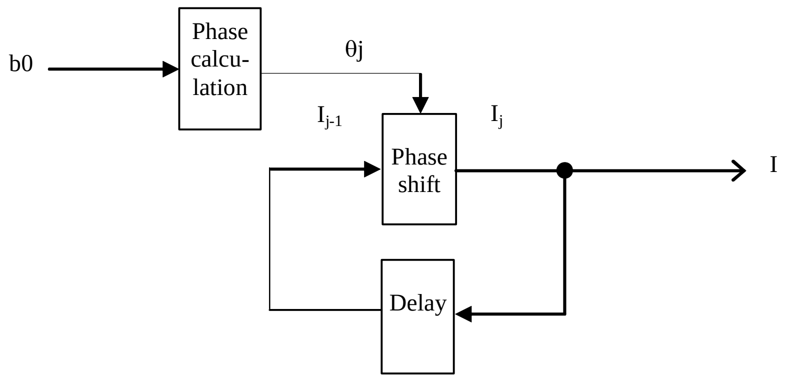


Fig. 3-18 DBPSK Modulation

Table 3-7 Phase Calculation

Input b0	Output θj
0	0
1	π

The phase calculation shown in Table 3-7 shall be performed, using a one bit (b0) input signal to calculate θj.

The phase shift is shown below.

$$I_j = \cos\theta j \times I_{j-1}$$

Here, I_j : j-th output OFDM symbol

I_{j-1} : (j-1)-th output OFDM symbol

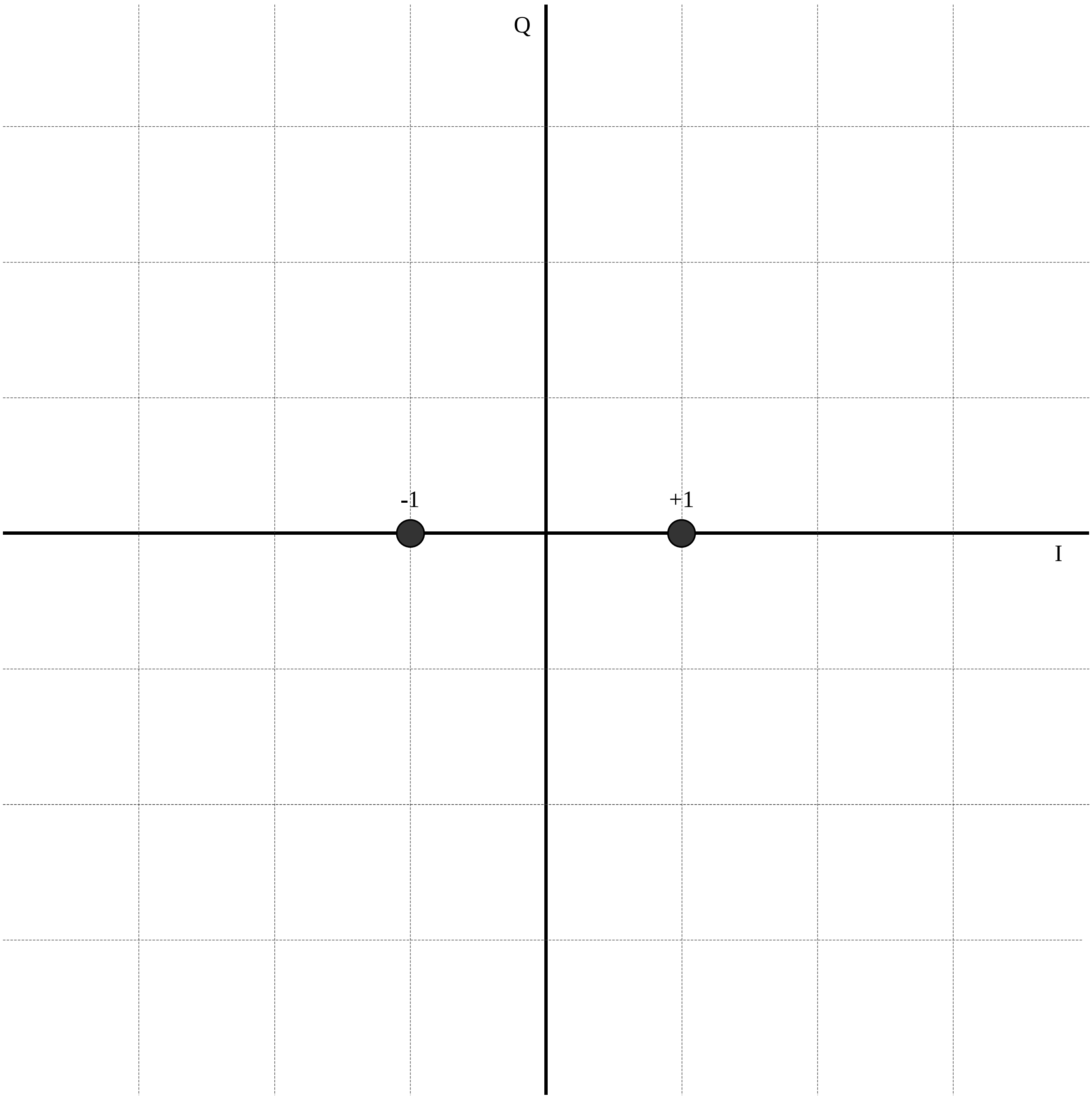
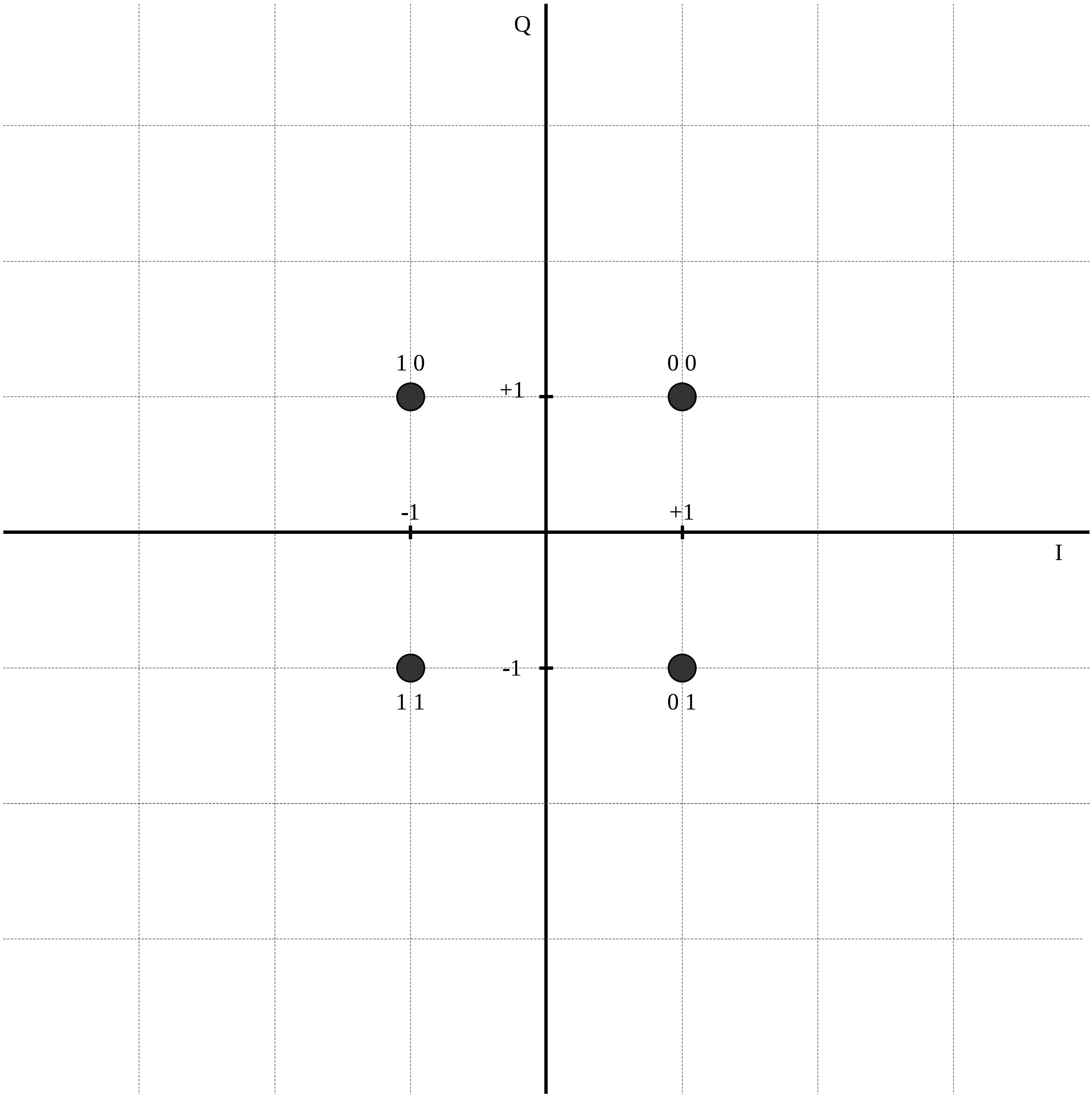


Fig. 3-19 DBPSK Mapping

3.4.12.3 QPSK



Data bit sequence (MSB) b0, b1

Fig. 3-20 QPSK Mapping

3.4.12.4 DQPSK

π/4 shift DQPSK mapping shall use two bits (b0 and b1) input signal, to output the I and Q axial data of multiple bits.

Fig. 3-21 shows DQPSK modulation, Table 3-8 shows phase calculation and Fig. 3-22 shows mapping.

The delay in Fig. 3-21 is equivalent to one OFDM symbol period.

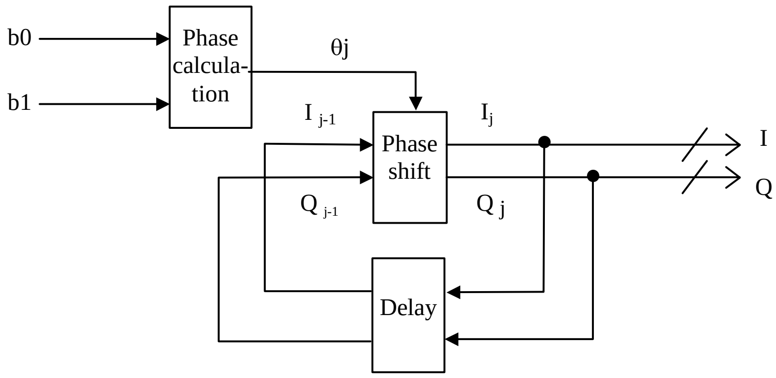


Fig. 3-21 π /4 Shift DQPSK Modulation

Table 3-8 Phase Calculation

Input b0 b1	Output θj
0 0	π /4
0 1	-π/4
1 0	3π/4
1 1	-3π/4

The phase calculation shown in Table 3-8 shall be performed, using two bits (b0 and b1) input signal to calculate θj.

The phase shift is shown below.

$$\begin{pmatrix} I_j \\ Q_j \end{pmatrix} = \begin{pmatrix} \cos\theta_j & -\sin\theta_j \\ \sin\theta_j & \cos\theta_j \end{pmatrix} \begin{pmatrix} I_{j-1} \\ Q_{j-1} \end{pmatrix}$$

Here, (I_j, Q_j): j-th output OFDM symbol

(I_{j-1}, Q_{j-1}) : (j-1)-th output OFDM symbol

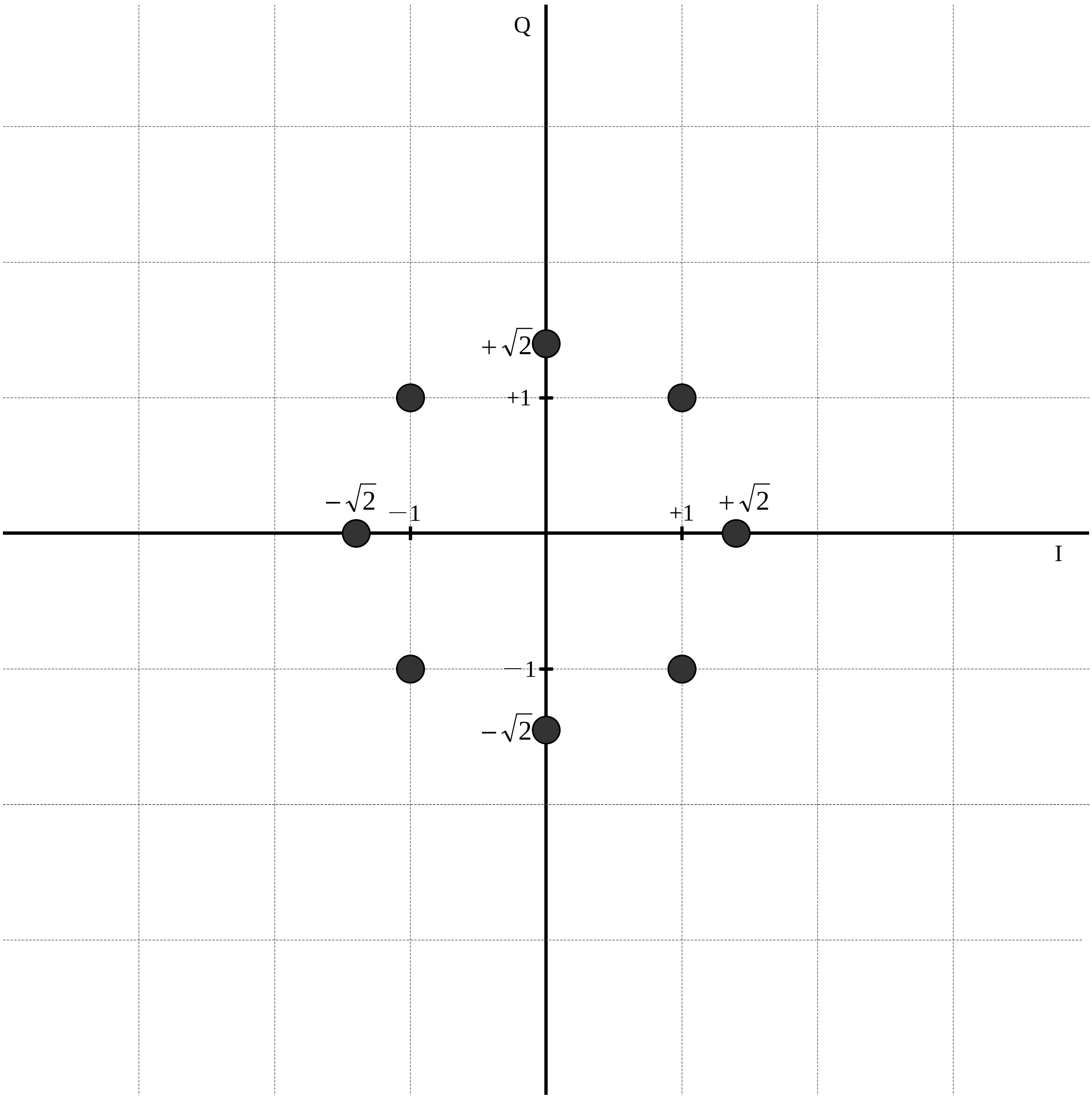
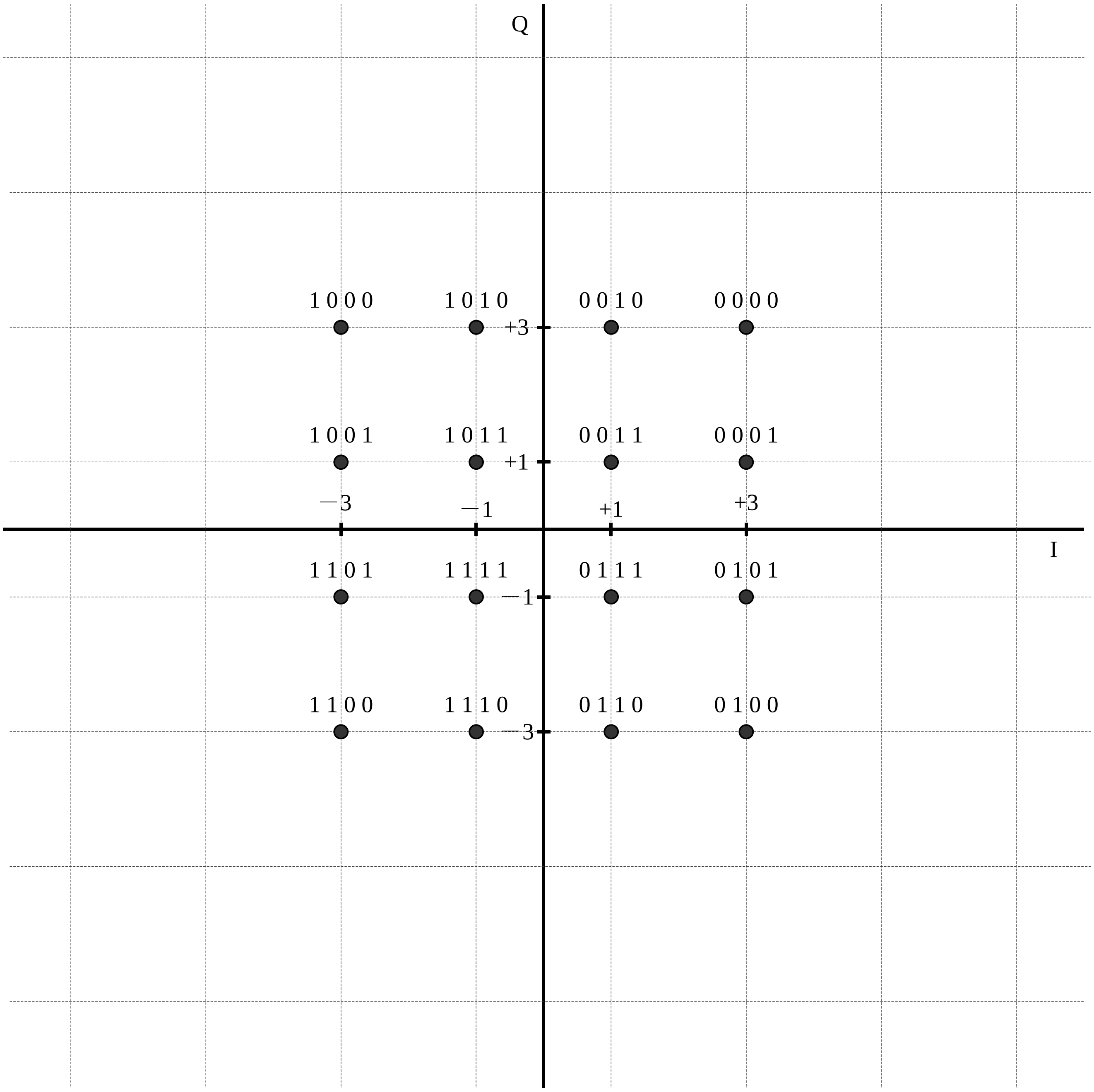


Fig. 3-22 DQPSK Mapping

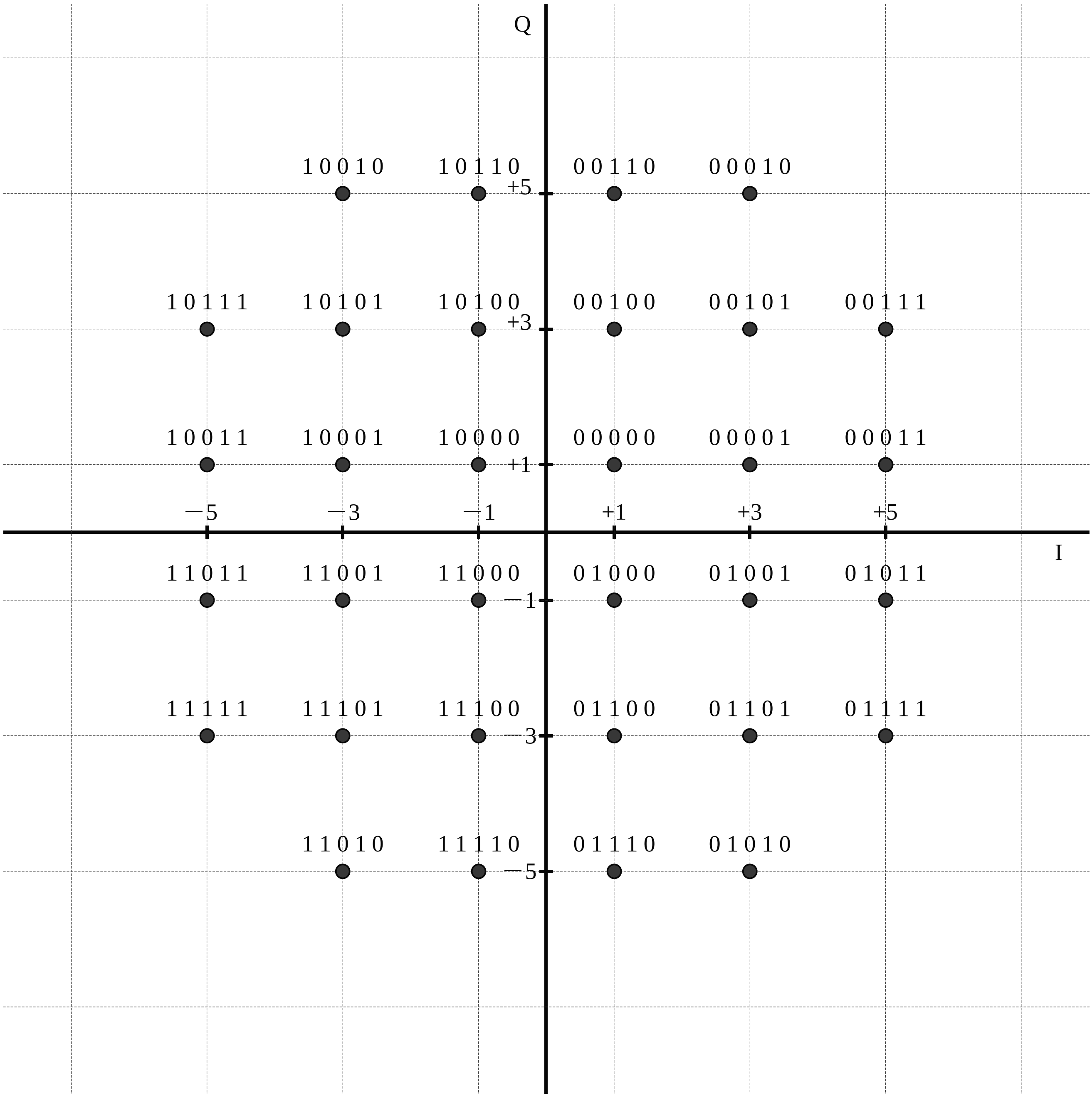
3.4.12.5 16QAM



Data bit sequence (MSB) b0, b1, b2, b3

Fig. 3-23 16QAM Mapping

3.4.12.6 32QAM



Data bit sequence (MSB) b0, b1, b2, b3, b4

Fig. 3-24 32QAM Mapping

3.4.12.7 64QAM

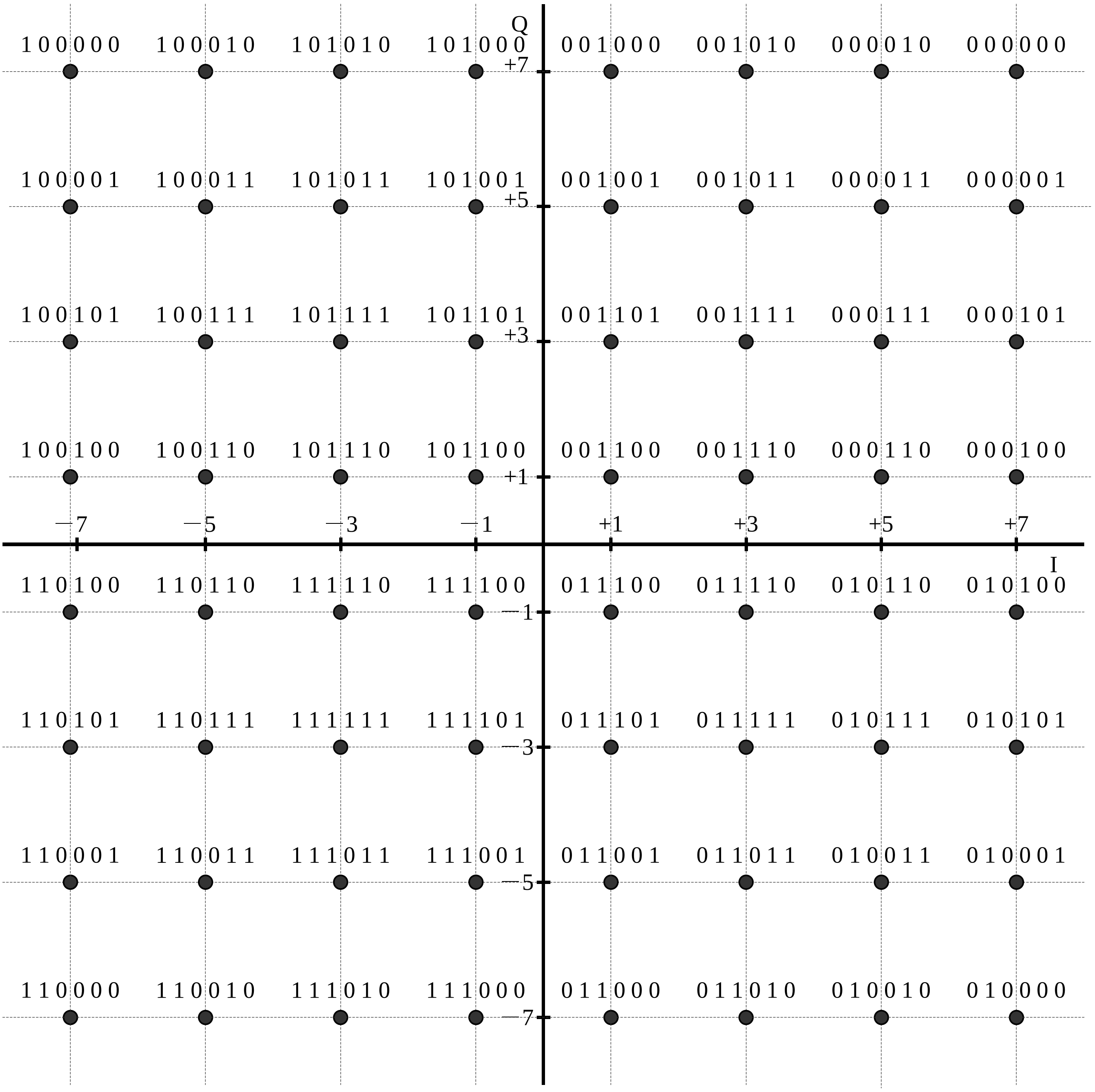


Fig. 3-25 64QAM Mapping

3.4.13 Normalization of the Modulation Level

The transmitted signal level shall be normalized as shown in Table 3-9. Here Z (=I+jQ) represents the mapping point for each type of modulation shown in §3.4.12. As a result, the mean power normalizes to 1 for all type of modulation used.

Table 3-9 Normalization of the Modulation Level

Carrier modulation	Normalization
BPSK	Z
DBPSK	Z
QPSK	$Z/\sqrt{2}$
DQPSK	$Z/\sqrt{2}$
16QAM	$Z/\sqrt{10}$
32QAM	$Z/\sqrt{20}$
64QAM	$Z/\sqrt{42}$

3.4.14 OFDM frame configuration

In 1K mode, one frame is composed of 408 OFDM symbols, and in 2K mode, one frame is composed of 204 OFDM symbols. One super frame is comprised of eight consecutive frames. The section below shows the OFDM frame structure in each mode. See Fig. 3-5 for more information about the super frame structure.

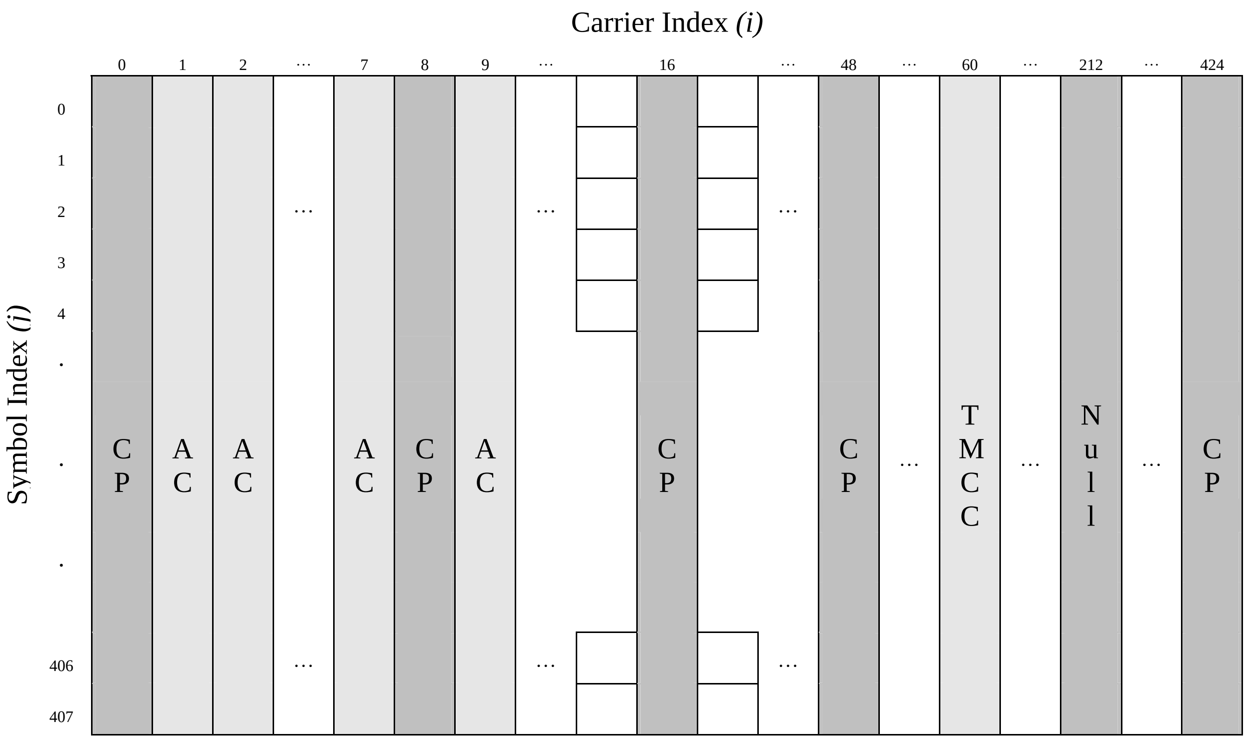


Fig. 3-26-1 OFDM Frame Structure (1K Half Mode)

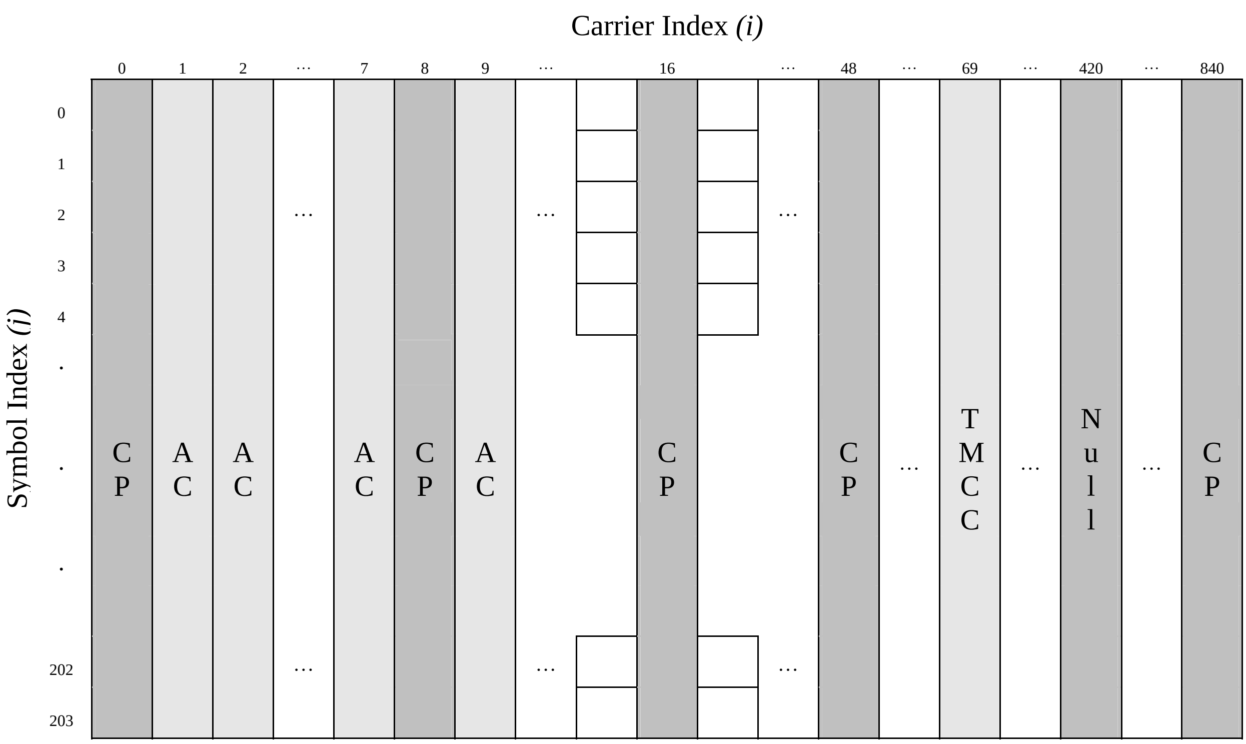


Fig. 3-26-2 OFDM Frame Structure (2K Half Mode)

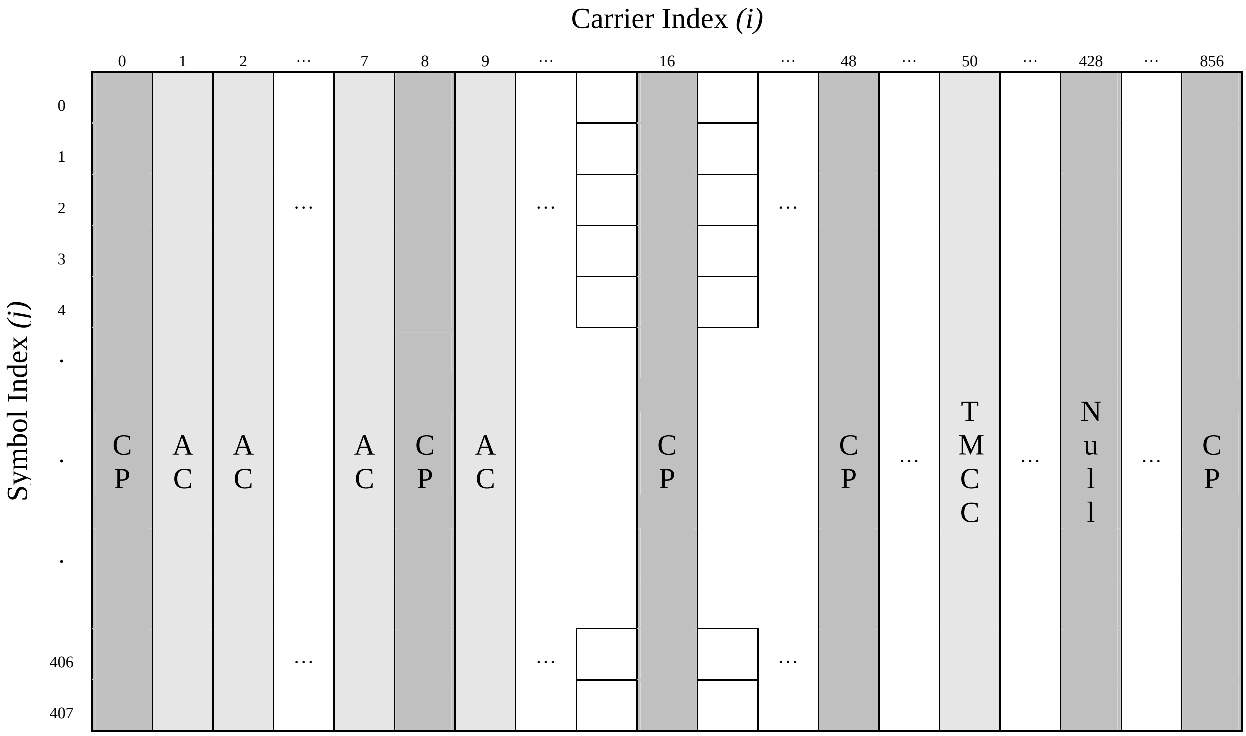


Fig. 3-26-3 OFDM Frame Structure (1K Full Mode)

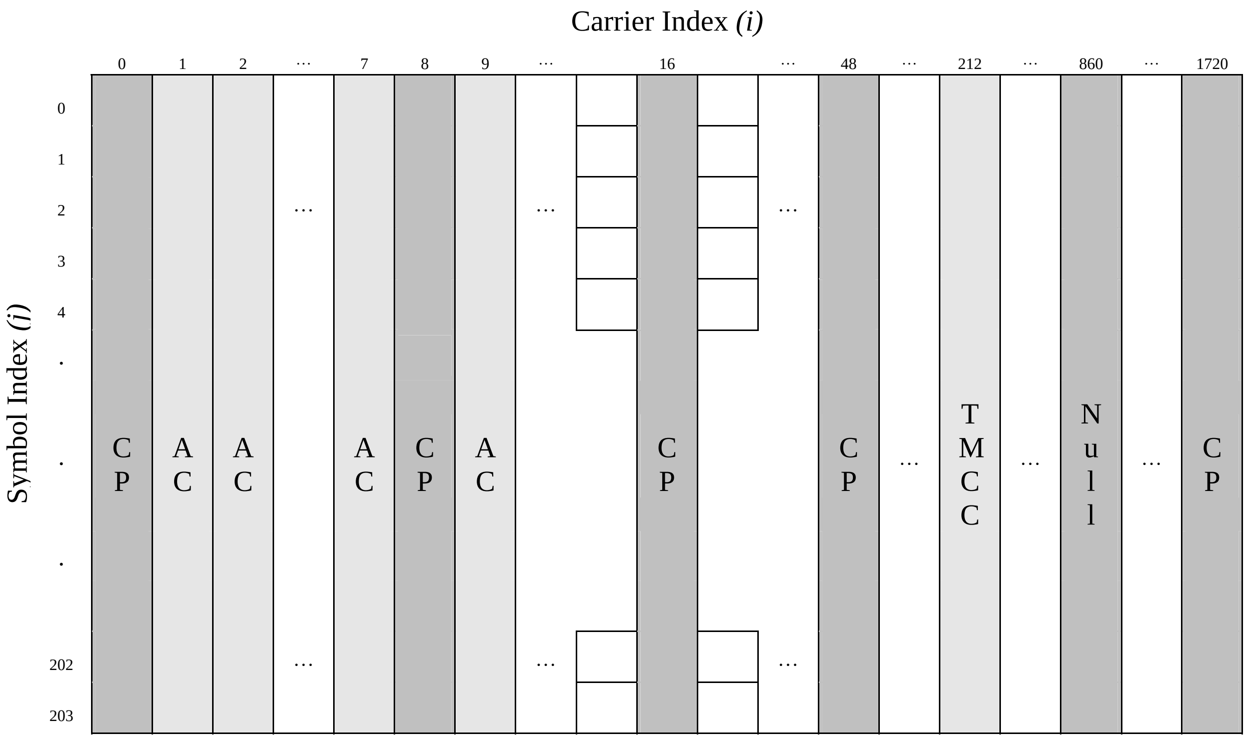


Fig. 3-26-4 OFDM Frame Structure (2K Full Mode)

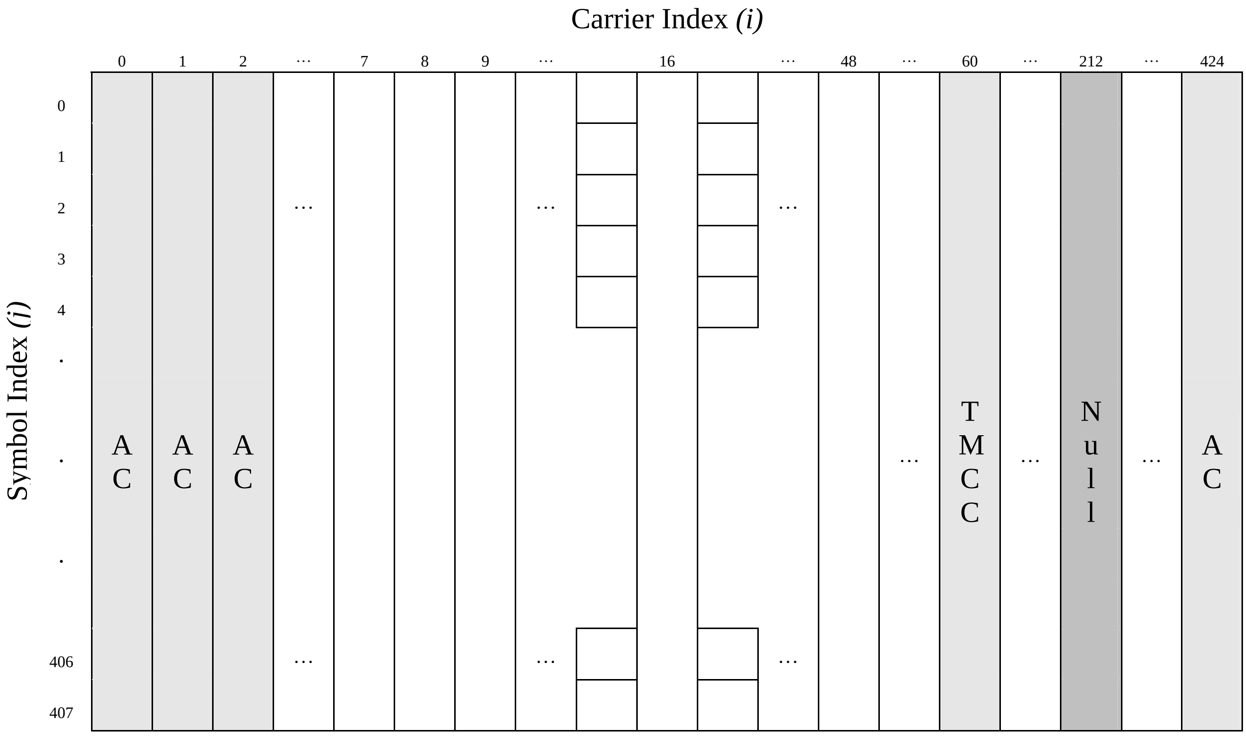


Fig. 3-26-5 OFDM Frame Structure (1K Half Mode Differential Modulation)

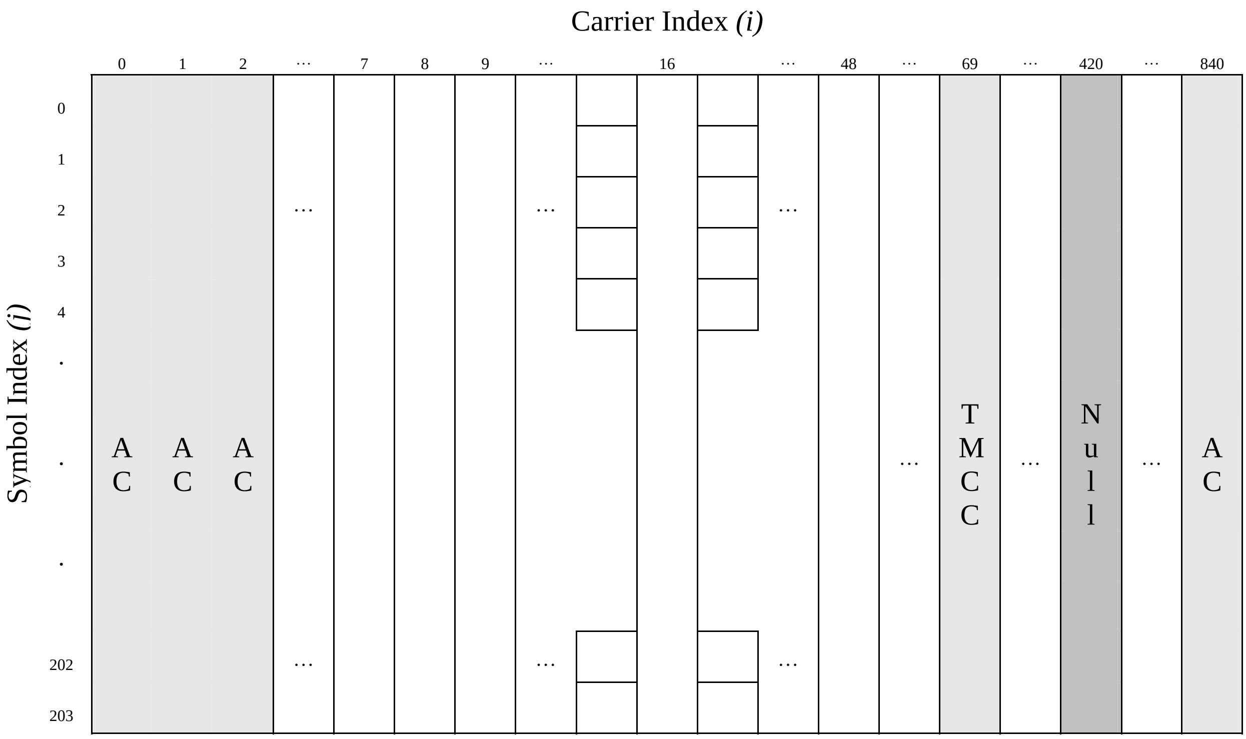


Fig. 3-26-6 OFDM Frame Structure (2K Half Mode Differential Modulation)

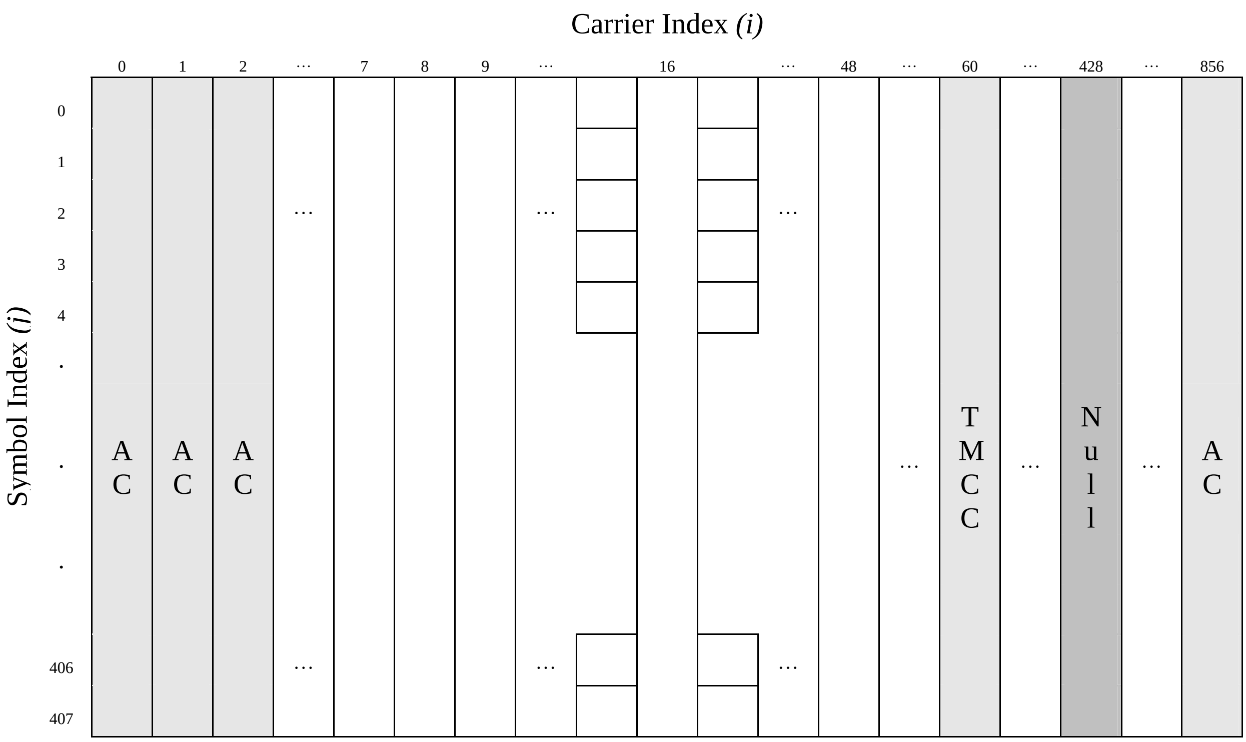


Fig. 3-26-7 OFDM Frame Structure (1K Full Mode Differential Modulation)

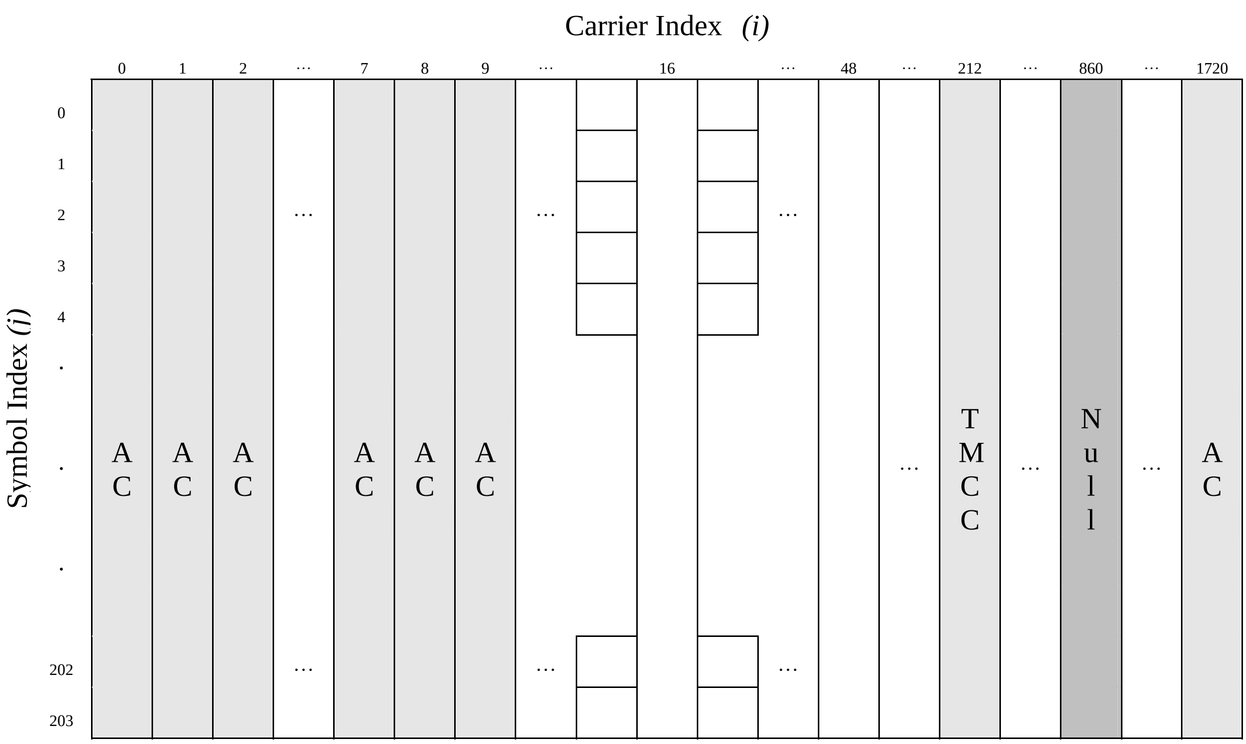


Fig. 3-26-8 OFDM Frame Structure (2K Full Mode Differential Modulation)

3.4.15 Carrier Allocation

An OFDM frame is comprised of five types of carriers shown below.

－ CP (Continual Pilot)

－ TMCC (Transmission and Multiplexing Configuration Control)

－ AC (Auxiliary Channel)

－ Null (Null Carrier)

－ Data (Data Carrier)

The CP is inserted once in every eight carriers in the carrier direction.

Table 3-10 shows the allocation of carriers except data carriers and CP.

Table 3-10-1 1K Half Mode Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	10	20 60 102 147 205 243 294 324 355 388
AC	24	1 2 3 4 5 6 7 9 10 11 12 13 411 412 413 414 415 417 418 419 420 421 422 423
Null	1	212

Table 3-10-2 2K Half Mode Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	16	19 69 138 181 253 276 339 414 475 506 572 621 674 715 755 794
AC	46	1 2 3 4 5 6 7 9 10 11 12 13 31 62 91 145 167 198 237 290 309 361 385 435 459 507 525 580 618 643 676 725 740 803 827 828 829 830 831 833 834 835 836 837 838 839
Null	1	420

Table 3-10-3 1K Full Mode Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	10	50 157 220 314 356 470 597 628 707 798
AC	66	1 2 3 4 5 6 7 9 10 11 12 13 20 37 63 87 111 122 148 155 174 191 211 227 249 267 293 310 327 348 373 379 402 421 454 458 482 493 529 534 567 586 601 620 631 647 681 699 717 721 742 759 790 825 843 844 845 846 847 849 850 851 852 853 854 855
Null	1	428

Table 3-10-4 2K Full Mode Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	16	19 212 291 380 450 582 724 779 958 1077 1164 1218 1309 1413 1558 1699
AC	144	1 2 3 4 5 6 7 9 10 11 12 13 20 37 47 61 74 94 111 122 142 148 162 177 191 201 222 238 251 269 279 284 299 313 327 347 354 379 382 402 410 431 449 452 467 486 502 521 530 538 558 575 579 598 611 629 647 654 669 686 694 708 731 737 758 764 778 790 804 829 843 852 862 874 898 909 919 929 943 969 973 997 1004 1017 1035 1042 1063 1076 1084 1109 1111 1131 1151 1158 1175 1180 1201 1209 1222 1239 1251 1265 1278 1294 1308 1332 1338 1351 1363 1387 1402 1415 1428 1437 1458 1462 1474 1501 1506 1516 1532 1556 1563 1580 1595 1601 1614 1633 1650 1658 1681 1695 1707 1708 1709 1710 1711 1713 1714 1715 1716 1717 1718 1719
Null	1	860

Table 3-10-5 1K Half Mode (Differential Modulation) Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	10	20 60 102 147 205 243 294 324 355 388
AC	6	0 1 2 422 423 424
Null	1	212

Table 3-10-6 2K Half Mode (Differential Modulation) Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	16	19 69 138 181 253 276 339 414 475 506 572 621 674 715 755 794
AC	8	0 1 2 3 837 838 839 840
Null	1	420

Table 3-10-7 1K Full Mode (Differential Modulation) Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	10	50 157 220 314 356 470 597 628 707 798
AC	6	0 1 2 854 855 856
Null	1	428

Table 3-10-8 2K Full Mode (Differential Modulation) Allocation of TMCC, AC and Null Carriers

Carrier	Number of Carriers	Carrier No. (i)
TMCC	16	19 212 291 380 450 582 724 779 958 1077 1164 1218 1309 1413 1558 1699
AC	24	0 1 2 3 4 5 6 7 8 9 10 11 1709 1710 1711 1712 1713 1714 1715 1716 1717 1718 1719 1720
Null	1	860

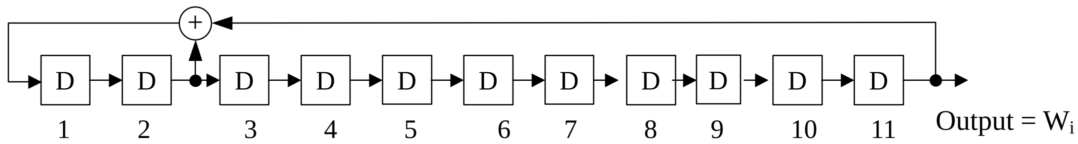
3.4.16 Modulation for the Pilot Signal

This section provides specifications for CP, TMCC, AC and Null carrier modulation.

3.4.16.1 CP (Continual Pilot)

The CP carrier is modulated by BPSK in accordance with the value, Wi (equivalent to carrier No. i); the output bit stream, Wi, of the pseudo random binary sequence is generated by the circuit shown in Fig. 3-27. The amplitude and phase of the modulating signal are shown in Table 3-11-1, while the initial register value is shown in Table 3-11-2. The initial value is loaded when the carrier No. is 0.

generator polynomial $g(x) = x^{11} + x^2 + 1$



B60 ~ b61

Carrier No.	PRBS	W_i
0 (CP)	“1010 0010 001”	1
1	“1101 0001 000”	0
⋮		⋮
7	“0101 1111 010”	0
8 (CP)	“1010 1111 101”	1
⋮		⋮

Fig. 3-27 Pseudo Random Binary Sequence Generating Circuit

Table 3-11-1 Pseudo-random Binary Sequence, Wi, and Modulating Signal

Value of W_i	Amplitude of the Modulating Signal *1 (I, Q)
1	(-4/3, 0)
0	(+4/3, 0)

*1: Rate against the average signal amplitude

Table 3-11-2 Initial Register Value

Mode	FFT size	Initial value (in ascending order)
Half mode	1K	0 1 1 0 0 0 0 1 1 0 1
	2K	1 0 1 0 0 0 1 0 0 0 1
Full mode	1K	1 0 1 0 0 0 1 0 0 0 1
	2K	0 0 1 1 1 0 0 0 0 0 1

3.4.16.2 TMCC (Transmission and Multiplexing Configuration Control)

The TMCC carrier, with assignments shown in Tables 3-13 and 3-14, is modulated by DBPSK for transmission. The amplitude and phase of the modulating signal are shown in Table 3-12. The modulated signal is transmitted along the Q axis to facilitate discrimination from CP.

Table 3-12 TMCC Value and Modulating Signal

TMCC value	Amplitude of the Modulating Signal1*1 (I, Q)
1	(0, -4/3)
0	(0, +4/3)

*1: Rate against the average data signal amplitude

(1) TMCC signal for 2K mode

In 2K mode, one frame is comprised of 204 symbols.
Table 3-13 shows the assignments of 204 TMCC signal bits.

The OFDM-FPU setting mode information is assigned to b26 to b41 (16 bits that carry the same information as those of single QAM TMCC signal). The MSB (the left end) is assigned to a TMCC signal bit of a small number symbol. For example, the bit rate of 59.648 Mbit/s is assigned to b30 to b33 as follows: b30=0, b31=0, b32=1 and b33=0.

The settings information that cannot be carried by the above mentioned 16 bits shall be carried by b42 to b65 (basic and extended information bits for OFDM). "0 to 0” shall be set if there is no need to set extended information bits because the information is already set in common QAM settings or settings defined by basic OFDM information.

To help detect the start point of the TMCC signal, a frame is divided into three sub-frames. A secondary synchronization code word shall be inserted into two points: the start point of the second sub-frame, b69 to b90, and that of the third sub-frame, b137 to b158.

To enable confirmation of the ID and frame Nos., the TMCC signal shall precede the data symbol by a total of 23 symbols (1+16+3+3). The timing between the TMCC signal and data symbol is shown in Fig. 3-28.

Reference: The synchronization code word can be detected for the first time after the passage of the 17th symbol in which the 16th bit of the synchronization code word appears. If the TMCC signal precedes the data symbol by 23 symbols, the start symbol appears when the ID and frame Nos. that follow the synchronization code word are detected.

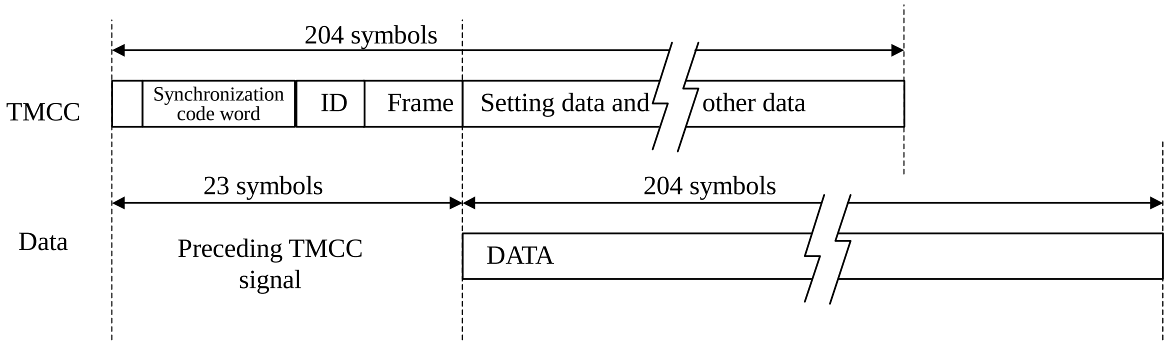


Fig. 3-28 Timing between TMCC and Data (in 2K Mode)

Table 3-13 TMCC Signal Bit Assignment in 2K Mode (b0 to b41)

	Bit	Meaning	Detailed information
Synchro-nization 23bit	b0	Differential reference	Given by Wi in §3.4.16.1 in Chapter 3
	b1 to b16	Synchronization code word	35EEh
	b17 to b19	ID No.	000
	b20 to b22	Frame No.	000: 0 to 111: 7
System 3bit	b23 to b25	System ID	000: Compatible with Ver1 001 to: Undefined
Common QAM information 16bit	b26 to b28	Modulation	000: See b50 to b52 001: QPSK 010: 16QAM 011: 32QAM 100: 64QAM 101 to: Undefined
	b29	Error correction	0: See b53 to b57 1: No error correction
	b30 to b33	Bit rate (Mbit/s)	0000: Use prohibited 0001: 44.736 0010: 59.648 0011 to: Defined by the user*1) 1111: Use prohibited
	b34 to b35	Inner interleave	00: Not inner interleaved 01: Undefined 10: See b58 to b60 11: For QAM
	b36	Test mode	0: See b61 to b62 1: Normal operation mode
	b37	Alarm	0: Normal input signal 1: Abnormal input signal
	b38	Alarm	0: Normal PS/fan 1: Abnormal stop of PS/fan
	b39 to b41	Undefined	

Table 3-13 TMCC Signal Bit Assignment in 2K Mode (b42 to b68) (Continued)

	Bit	Meaning	Detailed information
Common OFDM information 8bit	b42	Mode	1: 2K
	b43 to b44	Band	00: Full 01: Undefined 10: Lower half 11: Upper half
	b45	Scramble	0: Unscrambled 1: Scrambled
	b46 to b48	AC modulation mode	000: Undefined 001: No AC 010: DBPSK 011: DQPSK 100: BPSK 101: QPSK 110: 16QAM 111: Undefined
	b49	AC mode	0: See b62 to b65 1: No interleaving or correction
Extended OFDM information 17bit	b50 to b52	Extended modulation	000: No reference needed 001: Undefined 010: DBPSK 011: BPSK 100: DQPSK 101 to: Undefined*2)
	b53 to b57	Extended error correction	00000: No reference needed 00001: Convolution coding rate 1/2 00010: Convolution coding rate 2/3 00011: Convolution coding rate 3/4 00100: Convolution coding rate 5/6 00101 to: Undefined*2)
	b58 to b60	Extended time interleave	000: No reference needed 001: Cell length 1 010: Cell length 5 011: Cell length 10 100 to: Undefined*2)
	b61 to b62	Extended test mode	00: No reference needed 01: Inner coding (Front end)*3) 10: Energy dispersal (Front end)*4) 11: Undefined
	b63 to b64	Extended AC error correction	00: No reference needed 01 to: Undefined*2)
	b65 to b66	Extended AC interleave	00: No reference needed 01 to: Undefined*2)
Reserve 2bit	b67 to b68		Set to “0” when not used Reason; To reduce the load when BCH code is processed by software

Table 3-13 TMCC Signal Bit Assignment in 2K Mode (b69 to b203) (Continued)

	Bit	Meaning	Detailed information
Secondary synchro-nization 22bit	b69 to b84	First secondary synchronization code word	CA11h
	b85 to b87	ID No.	001: Indicates the first secondary synchronization code word
	b88 to b90	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 46bit	b91 to b136		Set to "0" when not used
Secondary synchro-nization 22bit	b137 to b152	Second secondary synchronization code word	CA11h
	b153 to b155	ID No.	010: Indicates the second secondary synchronization code word
	b156 to b158	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 29bit	b159 to b187		Set to "0" when not used
Parity 16bit	b188 to b203		Error correction coding of the TMCC information b17 to b187 is performed using shortened codes (187,171, t=2) of BCH codes (255,239). The generator polynomial is as follows. $g(x) = x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^9 + + x^8 + x^6 + x^5 + x + 1$

*1): Bit rates of 44.736 Mbit/s and 59.648 Mbit/s shall be commonly used between users. Other bit rates can be specified and used by users.

*2): "Undefined" codes will be defined for another modes in the future.

*3): PN Code 2^{23}-1 for BER Measurement compatible with ITU-T O.151, the generator polynomial $x^{23} + x^{18} + 1$ shall be inserted as the test signal.

*4): PN Code 2^{23}-1 for BER Measurement compatible with ITU-T O.151 that are operational except the TS packet sync byte (0x47 or 0xB8) shall be inserted as the test signal.

Fig. 3-29 shows the general structure of the TMCC signal for 2K mode, which is comprised of 204 bits that include one synchronization code word and two secondary synchronization code words.

The synchronization code word and secondary synchronization code words can be identified by ID No. b17 to b19, which indicate the ID No. of the synchronization code word, shall be set to “000”, while b85 to b87, which indicate the ID No. of the first secondary synchronization code word, shall be set to “001” and b153 to b155, which indicate the ID No. of the second secondary synchronization code word, shall be set to “010.”

The synchronization code word and secondary synchronization code words are inserted every 68 bits, a third of the total of 204 bits.

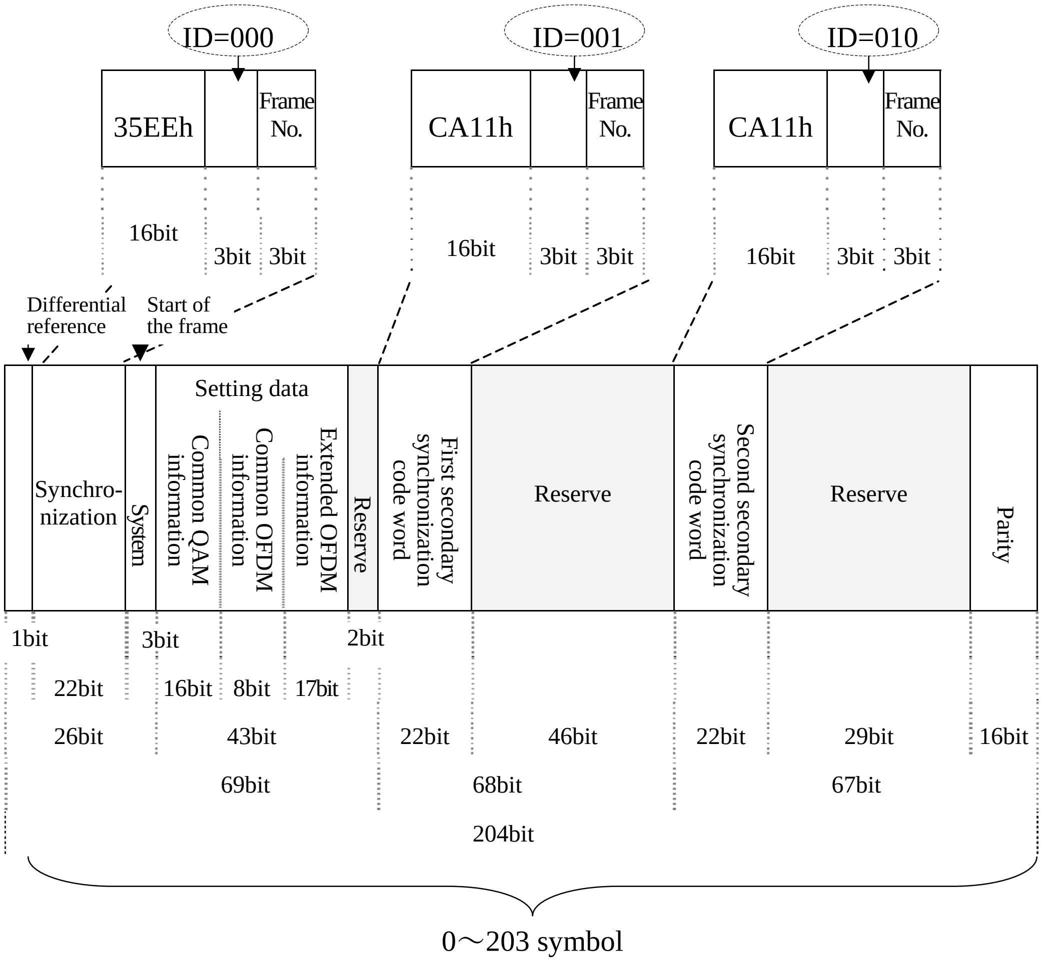


Fig. 3-29 TMCC Signal Comprised of 204 Symbols/Frame

(2) TMCC signal for 1K mode

In 1K mode, one frame is comprised of 408 symbols.

The TMCC signal is comprised of a total of 408 bits; the information contained in the first half of the frame (0 to 203 symbols) is repeated in the second half of the frame except for the ID No. and parity.

Table 3-14 shows the assignments of TMCC signal bits (408 symbols) in 1K mode.

To help detect the start point of the TMCC signal, a frame is divided into six sub-frames. A secondary synchronization code word shall be inserted into four points: the start point of the second sub-frame, b69 to b90, the start point of the third sub-frame, b137 to b158, the start point of the fifth sub-frame, b273 to b294 and the start point of the sixth sub-frame, b341 to b362.

A synchronization code word with ID = 111 is present in the start point of the fourth sub-frame, b205 to b226.

The OFDM-FPU setting mode information in the 1K mode is assigned the same as in the 2K mode, using 16 bits with the same information as the single QAM and the subsequent basic and extended information bits for OFDM. The TMCC signal shall precede the data symbol by 23 symbols as in the 2K mode. The timing between the TMCC signal and data symbol is shown in Fig. 3-30.

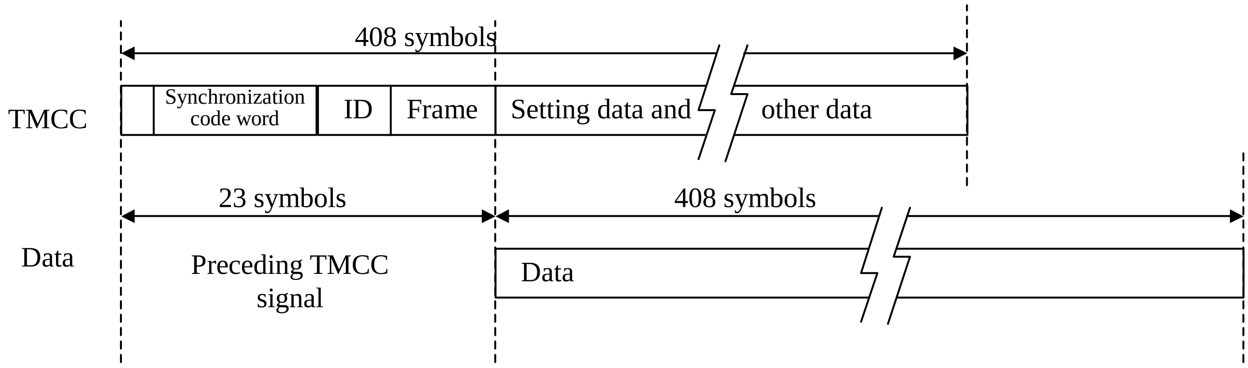


Fig. 3-30 Timing between TMCC and Data (in 1K Mode)

Table 3-14 TMCC Signal Bit Assignment in 1K Mode (b0 to b41)

	Bit	Meaning	Detailed information
Synchro-nization 23bit	b0	Differential reference	Given by Wi in §3.4.16.1 in Chapter 3
	b1 to b16	Synchronization code word	35EEh
	b17 to b19	ID No.	000: Indicates the first half of the frame
	b20 to b22	Frame No.	000: 0 to 111: 7
System 3bit	b23 to b25	System ID	000: Compatible with Ver1 001 to: Undefined
Common QAM infomration 16bit	b26 to b28	Modulation	000: See b50 to b52 001: QPSK 010: 16QAM 011: 32QAM 100: 64QAM 101 to: Undefined
	b29	Error correction	0: See b53 to b57 1: No error correction
	b30 to b33	Bit rate (Mbit/s)	0000: Use prohibited 0001: 44.736 0010: 59.648 0011~: Defined by the user*1) 1111: Use prohibited
	b34 to b35	Inner interleave	00: Not inner interleaved 01: Undefined 10: See b58 to b60 11: Inner interleaved
	b36	Test mode	0: See b61 to b62 1: Normal operation mode
	b37	Alarm	0: Normal input signal 1: Abnormal input signal
	b38		0: Normal PS/fan 1: Abnormal stop of PS/fan
	b39 to b41	Undefined	

Table 3-14 TMCC Signal Bit Assignment in 1K Mode (b42 to b68) (Continued)

	Bit	Meaning	Detailed information
Common OFDM information 8bit	b42	Mode	0: 1K
	b43 to b44	Band	00: Full 01: Undefined 10: Lower half 11: Upper half
	b45	Scramble	0: Unscrambled 1: Scrambled
	b46 to b48	AC modulation mode	000: Undefined 001: No AC 010: DBPSK 011: DQPSK 100: BPSK 101: QPSK 110: 16QAM 111: Undefined
	b49	AC mode	0: See b62 to b65 1: No interleaving or correction
Extended OFDM information 17bit	b50 to b52	Extended modulation	000: No reference needed 001: Undefined 010: DBPSK 011: BPSK 100: DQPSK 101 to: Undefined*2)
	b53 to b57	Extended error correction	00000: No reference needed 00001: Convolution coding rate 1/2 00010: Convolution coding rate 2/3 00011: Convolution coding rate 3/4 00100: Convolution coding rate 5/6 00101 to: Undefined*2)
	b58 to b60	Extended time interleave	000: No reference needed 001: Cell length 2 010: Cell length 10 011: Cell length 20 100 to: Undefined*2)
	b61 to b62	Extended test mode	00: No reference needed 01: Inner coding (Front end)*3) 10: Energy dispersal (Front end)*4) 11: Undefined
	b63 to b64	Extended AC error correction	00: No reference needed 01 to: Undefined*2)
	b65 to b66	Extended AC interleave	00: No reference needed 01 to: Undefined*2)
Reserve 2bit	b67 to b68		Set to “0” when not used Reason; To reduce the load when BCH code is processed by software

Table 3-14 TMCC Signal Bit Assignment in 1K Mode (b69 to b203) (Continued)

	Bit	Meaning	Detailed information
Secondary synchro-nization 22bit	b69 to b84	First secondary synchronization code word	**CA11h**
	b85 to b87	ID No.	001: Indicates the first secondary synchronization code word
	b88 to b90	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 46bit	b91 to b136		Set to “0” when not used
Secondary synchro-nization 22bit	b137 to b152	Second secondary synchronization code word	CA11h
	b153 to b155	ID No.	010: Indicates the second secondary synchronization code word
	b156 to b158	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 29bit	b159 to b187		Set to “0” when not used
Parity 16bit	b188 to b203		Error correction coding of the TMCC information b17 to b187 is performed using shortened codes (187,171, t=2) of BCH codes (255,239). The generator polynomial is as follows. $g(x) = x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^9 + x^8 + x^6 + x^5 + x + 1$

Table 3-14 TMCC Signal Bit Assignment in 1K Mode (b204 to b272) (Continued)

	Bit	Meaning	Detailed information
Synchro-nization 23bit	b204	Differential reference	Same as b0
	b205 to b220	Synchronization code word	35EEh
	b221 to b223	ID No.	111: Indicates the second half of the frame
	b224 to b226	Frame No.	000: 0 to 111: 7 Same as b20 to b22
System 3bit	b227 to b229	System ID	Same as b23 to b25
Common QAM information 16bit	b230 to b245	Same as the common QAM information in the first half of the frame	Same as b26 to b41
Common OFDM information 8bit	b246 to b253	Same as the common OFDM information in the first half of the frame	Same as b42 to b49
Extended OFDM information 17bit	b254 to b270	Same as the information for OFDM extension in the first half of the frame	Same as b50 to b66
Reserve 2bit	b271 to b272		Set to “0” when not used Reason; To reduce the load when BCH code is processed by software

Table 3-14 TMCC Signal Bit Assignment in 1K Mode (b273 to b407) (Continued)

	Bit	Meaning	Detailed information
Secondary synchro-nization 22bit	b273 to b288	Third secondary synchronization code word	CA11h
	b289 to b291	ID No.	110: Indicates the third secondary synchronization code word
	b292 to b294	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 46bit	b295 to b340		Set to "0" when not used
Secondary synchro-nization 22bit	b341 to b356	Fourth secondary synchronization code word	CA11h
	b357 to b359	ID No.	101: Indicates the fourth secondary synchronization code word
	b360 to b362	Frame No.	000: 0 to 111: 7 Same as b20 to b22
Reserve 29bit	b363 to b391		Set to "0" when not used
Parity 16bit	b392 to b407		Error correction coding of the TMCC information b221 to b391 is performed using shortened codes (187,171, t=2) of BCH codes (255,239). The generator polynomial is as follows. $g(x) = x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^9 + x^8 + x^6 + x^5 + x + 1$

*1): Bit rates of 44.736 Mbit/s and 59.648 Mbit/s shall be commonly used between users. Other bit rates can be independently specified and used by individual users.

*2): "Undefined" codes shall be used to define a mode to be added in the future.

*3): PN Code 2^{23}-1 for BER Measurement compatible with ITU-T O.151, the generator polynomial $x^{23} + x^{18} + 1$ shall be inserted as the test signal.

*4): PN Code 2^{23}-1 for BER Measurement compatible with ITU-T O.151 that are operational except the TS packet sync byte (0x47 or 0xB8) shall be inserted as the test signal.

In 1K mode, the TMCC signal is comprised of 408 symbols that include two synchronization code words and four secondary synchronization code words. Fig. 3-31 shows the configuration of the TMCC signal.

The TMCC signal (204 to 407 symbols) in the second half of the frame is identical with the TMCC signal (0 to 203 symbols) in the first half of the frame except ID No. and parity.

The synchronization code word and secondary synchronization code words are inserted every 68 bits, one sixth of the total of 408 bits.

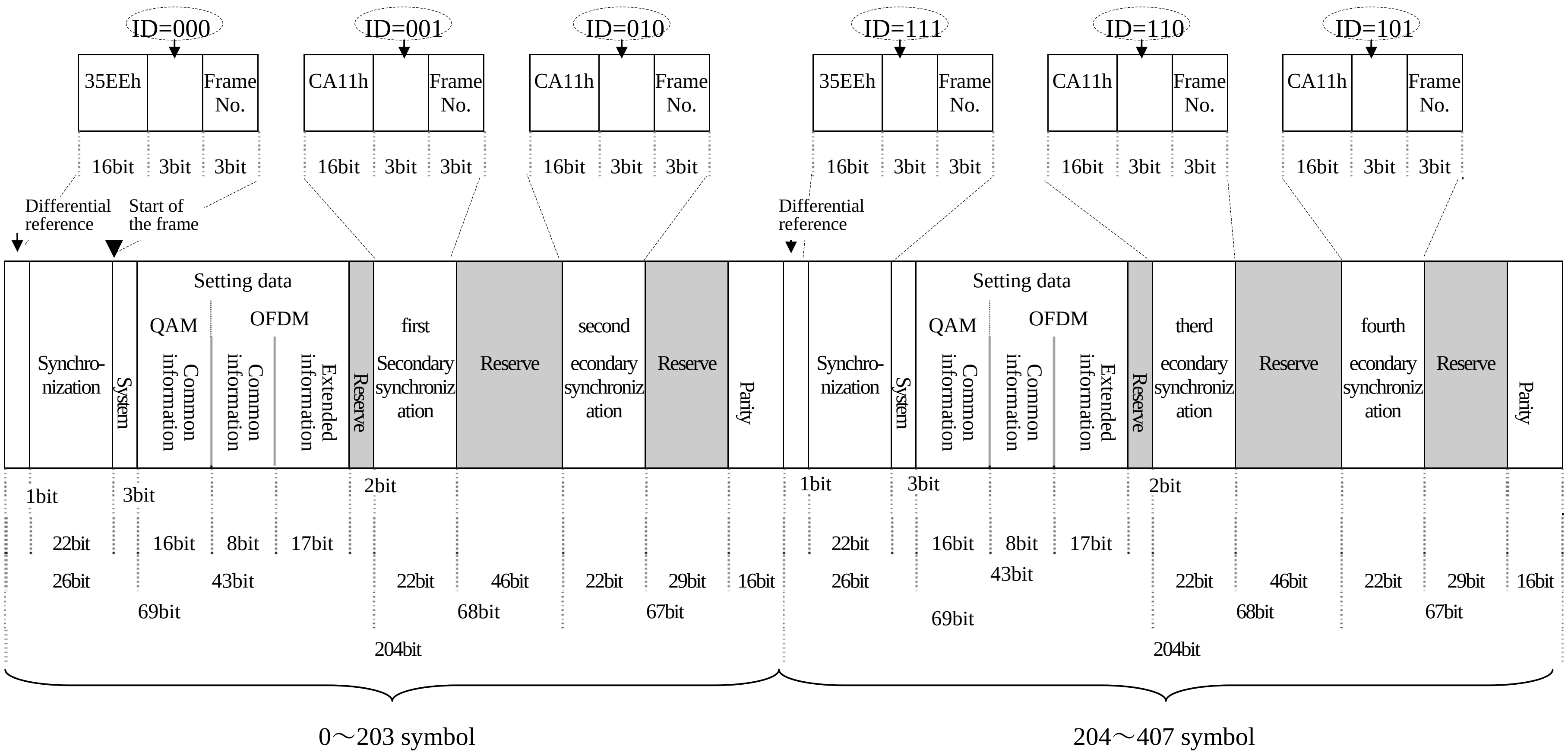


Fig. 3-31 TMCC Signal Comprised of 408 Symbols/Frame

3.4.16.3 AC (Auxiliary Channel)

The AC carrier transmits additional information such as communication data.
BPSK, DBPSK, QPSK, DQPSK and 16QAM modulation can also be applied separately from the carrier system for data signal. However, mapping shall be applied as in the specifications in §3.4.12 and modulation level shall be applied as in the specifications in §3.4.13.

The AC transmission bit rate for each type of modulation is shown in Table 3-15.
The choice to use the AC carrier or not is optional. However, if the AC carrier is not used, the Null carrier shall be used.

Table 3-15 AC Signal Transmission Bit Rate [kbit/s]

Carrier modulation	Half mode		Full mode	
	1K	2K	1K	2K
BPSK	426	408	1172	1278
DBPSK	426 (107)	408 (142)	1172 (107)	1278 (426)
QPSK	852	817	2343	2556
DQPSK	852 (213)	817 (284)	2343 (213)	2556 (852)
16QAM	1704	1633	4687	5113

Note) The figures in parentheses are applicable when the data is differentially modulated.

3.4.16.4 Null (Null Carrier)

The center carrier of the transmission signal shall be used as the Null carrier. The Carrier should not be used for data transmission.

3.4.17 Addition of the Guard Interval

As shown in Fig. 3-32, the guard interval in the rear end of the effective symbol shall be copied and pasted in front of the effective symbol.

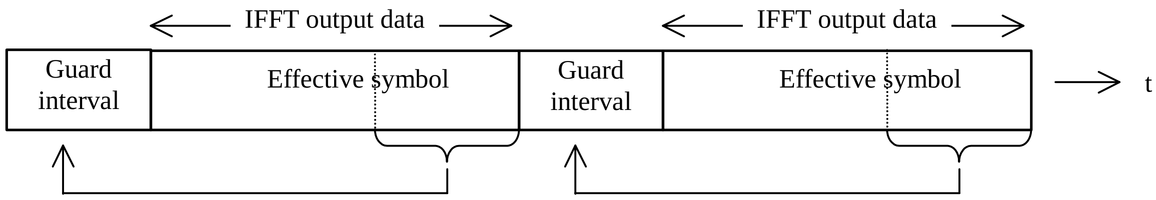


Fig. 3-32 Addition of the Guard Interval

3.4.18 IF/RF Signal Format

The signal format in IF/RF bands is defined as shown below.

Definitions

k : Carrier No.

n : Symbol No.

K : Total number of carriers

Ts : Symbol period length

Tg : Guard period length

Tu : Effective symbol period length

fc : Center frequency of the IF/RF signal

Kc : Carrier No. for the center frequency of the IF/RF signal (Equivalent to the Null carrier)

c (n,k) : Complex signal point vector for symbol No. n and carrier No. k

s (t) : IF/RF signal

$$s(t) = \mathrm{Re}\left\{ e^{j \cdot 2\pi \cdot f_c \cdot t} \cdot \sum_{n=0}^{\infty} \sum_{k=0}^{K-1} c(n,k) \cdot \Psi(n,k,t) \right\}$$

where

$$\Psi(n,k,t) = \begin{cases} e^{j \cdot 2\pi \cdot \frac{k-K_c}{T_u} \cdot (t - T_g - n \cdot T_s)} & n \cdot T_s \le t < (n+1) \cdot T_s \\ 0 & \text{else} \end{cases}$$

References

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References

Contents

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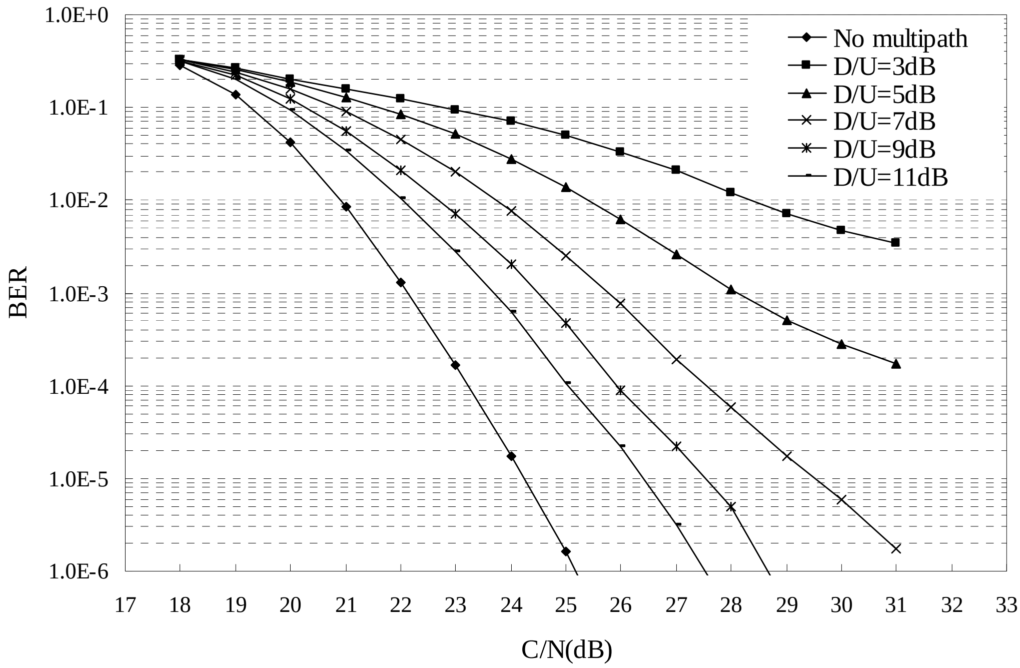
Reference 1 Definition of the Margin for Multiple-paths

Since the OFDM system uses the guard interval to reduce the influence of multiple paths, it can be used even under circumstances when many of the latter are present. The OFDM system, thanks to this advantage, can be used to ensure operational stability in urban areas where radio waves are more likely to be reflected by buildings. Even when subject to the influence of multiple paths, the system can remain functional, since there is no inter-symbol interference between direct and delayed signals in the guard interval. However, since intra-symbol interference will occur, the interference will cause phase differences and frequency dips. This will result in a deterioration of the bit error rate and more C/N ratio will be required. If an increase in C/N is considered as a margin for multiple-paths, a similar link budget design is possible, as that under additive white Gaussian noise conditions. The figure below shows the relationship between the DU ratio (when basic parameters (64QAM-OFDM and coding rate 5/6) are used during the fixed transmission) and the bit error rate. The graph includes the fixed degradation of 4 dB.



Bit Error Rate (64QAM-OFDM and coding rate 5/6 including the fixed degradation of 4 dB)

It is known that multiple paths, corresponding to about 7 dB of DU ratio, are present in urban areas from the reports [(1)(2)]. The figure above shows that the deterioration of the bit error rate (DU ratio of 7 dB) is 5 dB (BER=1×10^{-4}). Therefore, 5 dB margin for multiple-paths shall be added. Consequently, the required C/N is 28 dB.

(1) Hamazumi et al.: “Examination of the Performance Required for the 7 GHz Band Digital FPU and the Waveform Equalizing System for the QAM FPU,” the Journal of the Institute of Image Information and Television Engineers, Vol. 51, No. 9, pp.1550 to 1559 (1997)

(2) Iai et al.: ”Measurement of the Multiple Path Characteristics of the 7 GHz Band FPU ”, National Convention of the Institute of Television Engineers of Japan, 1995, 16-6, pp. 243-244

Reference 2 Examples of Link Budget

Fixed transmission – An example of FPU link budget (B, C and D bands)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (0.6 mϕ)

FPU B, C and D bands	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	6.5	6.5	6.5
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	29.2	29.2	29.2
Transmitting feeder loss Lt [dB]	1.2	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	65.0	65.0	62.0
Transmission distance d [km]	50.0	50.0	50.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	142.7	142.7	142.7
Receiving antenna diameter lt [m]	0.6	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	29.2	29.2	29.2
Receiving feeder loss Lr [dB]	1.3	1.3	1.3
Annual rate of instantaneous link interruption (Fading) [%]	0.5	0.5	0.5
Required fading margin Fmr [dB]	5.1	5.1	5.1
Received power Ci [dBm]	-54.9	-54.9	-57.9
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0	4.0
Receiver thermal noise Ni = kT_0BF [dBm]	-96.8	-97.4	-100.5
Receiver thermal noise C/N [dB]	42.0	42.5	42.7
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.5	14.7

Fixed transmission – An example of FPU link budget (B, C and D bands)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (1.2 mϕ)

FPU B, C and D bands (Reception at the base station)	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	6.5	6.5	6.5
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	29.2	29.2	29.2
Transmitting feeder loss Lt [dB]	1.2	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	65.0	65.0	62.0
Transmission distance d [km]	50.0	50.0	50.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	142.7	142.7	142.7
Receiving antenna diameter lt [m]	1.2	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	35.0	35.0	35.0
Receiving feeder loss Lr [dB]	7.0	7.0	7.0
Annual rate of instantaneous link interruption (Fading) [%]	0.5	0.5	0.5
Required fading margin Fmr [dB]	5.1	5.1	5.1
Received power Ci [dBm]	-54.8	-54.8	-57.8
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0	4.0
Receiver thermal noise Ni = kT_0BF[d Bm]	-96.8	-97.4	-100.5
Receiver thermal noise C/N [dB]	42.0	42.6	42.7
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.6	14.7

Fixed transmission – An example of FPU link budget (E and F bands)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (0.6 mϕ)

FPU E and F bands	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	10.5	10.5	10.5
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	33.4	33.4	33.4
Transmitting feeder loss Lt [dB]	1.2	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	69.2	69.2	66.2
Transmission distance d [km]	6.8	6.8	6.8
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	129.6	129.6	129.6
Receiving antenna diameter lt [m]	0.6	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	33.4	33.4	33.4
Receiving feeder loss Lr [dB]	1.2	1.2	1.2
Annual rate of link unavailability (Rainfall) [%]	0.00125	0.00125	0.00125
Required rainfall margin Zr [dB]	26.6	26.6	26.6
Received power Ci [dBm]	-54.9	-54.9	-57.9
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0	4.0
Receiver thermal noise Ni = kT_0BF [dBm]	-96.8	-97.4	-100.5
Receiver thermal noise C/N [dB]	42.0	42.5	42.7
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.5	14.7

Fixed transmission – An example of FPU link budget (E and F bands)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (1.2 mϕ)

FPU E and F bands (Reception at the base station)	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	10.5	10.5	10.5
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	33.4	33.4	33.4
Transmitting feeder loss Lt [dB]	1.2	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	69.2	69.2	66.2
Transmission distance d [km]	6.8	6.8	6.8
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	129.6	129.6	129.6
Receiving antenna diameter lt [m]	1.2	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	39.1	39.1	39.1
Receiving feeder loss Lr [dB]	6.9	6.9	6.9
Annual rate of link unavailability (Rainfall) [%]	0.00125	0.00125	0.00125
Required rainfall margin Zr [dB]	26.6	26.6	26.6
Received power Ci [dBm]	-54.8	-54.8	-57.8
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0	4.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-96.8	-97.4	-100.5
Receiver thermal noise C/N [dB]	42.0	42.6	42.7
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.6	14.7

Fixed transmission – An example of FPU link budget (G band)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (0.6 mϕ)

FPU G band	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	13.0	13.0	13.0
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	35.2	35.2	35.2
Transmitting feeder loss Lt [dB]	1.7	1.7	1.7
Effective radiated power (WGt/Lt) [dBm]	70.5	70.5	67.5
Transmission distance d [km]	4.9	4.9	4.9
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	128.5	128.5	128.5
Receiving antenna diameter lt [m]	0.6	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	35.2	35.2	35.2
Receiving feeder loss Lr [dB]	1.7	1.7	1.7
Annual rate of link unavailability (Rainfall) [%]	0.00125	0.00125	0.00125
Required rainfall margin Zr [dB]	29.4	29.4	29.4
Received power Ci [dBm]	-53.8	-53.8	-56.8
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	5.0	5.0	5.0
Receiver thermal noise Ni = kT_0BF [dBm]	-95.8	-96.4	-99.5
Receiver thermal noise C/N [dB]	42.0	42.6	42.7
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.6	14.7

Fixed transmission – An example of FPU link budget (G band)
When using a transmitting antenna (0.6 mϕ) and a receiving antenna (1.2 mϕ)

FPU G band (Reception at the base station)	FM system	64QAM5/6 Full mode	64QAM5/6 Half mode
Transmit frequencies f [GHz]	13.0	13.0	13.0
Transmission output power W [W]	5.00	5.00	2.50
Transmission output power W [dBm]	37.0	37.0	34.0
Transmitting antenna diameter lt [m]	0.6	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	35.2	35.2	35.2
Transmitting feeder loss Lt [dB]	1.7	1.7	1.7
Effective radiated power (WGt/Lt) [dBm]	70.5	70.5	67.5
Transmission distance d [km]	4.9	4.9	4.9
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	128.5	128.5	128.5
Receiving antenna diameter lt [m]	1.2	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	41.0	41.0	41.0
Receiving feeder loss Lr [dB]	7.4	7.4	7.4
Annual rate of link unavailability (Rainfall) [%]	0.00125	0.00125	0.00125
Required rainfall margin Zr [dB]	29.4	29.4	29.4
Received power Ci [dBm]	-53.8	-53.8	-56.8
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6	-198.6
Standard temperature T0 [dBK]	24.8	24.8	24.8
Signal bandwidth B [MHz]	20.0	17.5	8.5
Signal bandwidth B [dBHz]	73.0	72.4	69.3
Receiver noise figure F [dB]	5.0	5.0	5.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-95.8	-96.4	-99.5
Receiver thermal noise C/N [dB]	42.0	42.6	42.8
Required C/N [dB]	27.0	28.0	28.0
Transmission margin [dB]	15.0	14.6	14.8

Mobile transmission－An example of FPU link budget (800M)
When using a Tx (two-stage colinear) and an Rx (12-element 1-stack Yagi antenna)

FPU 800M	16QAM2/3 Half mode	DQPSK Half mode
Transmit frequencies f [GHz]	0.8	0.8
Transmission output power W [W]	5.00	5.00
Transmission output power W [dBm]	37.0	37.0
Transmitting antenna gain Gt [dBi] (Two-step colinear)	5.2	5.2
Transmitting feeder loss Lt [dB]	1.5	1.5
Effective radiated power (WGt/Lt) [dBm]	40.6	40.6
Transmission distance d [km]	4.5	4.5
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	103.6	103.6
Receiving antenna gain Gr [dBi] (12 elements)	12.0	12.0
Receiving feeder loss Lr [dB]	1.5	1.5
Single-interval instantaneous link interruption time rate (Fading) [%]	0.5	0.5
Required fading margin Fmr_rice [dB]	10.0	10.0
Received power Ci [dBm]	-62.4	-62.4
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6
Standard temperature T0 [dBK]	24.8	24.8
Signal bandwidth B [MHz]	8.5	8.5
Signal bandwidth B [dBHz]	69.3	69.3
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-100.5	-100.5
Receiver thermal noise C/N [dB]	38.1	38.1
Required C/N [dB]	20.0	23.0
Transmission margin [dB]	18.1	15.1

Mobile transmission – An example of FPU link budget (B, C and D bands)
When using a transmitting antenna (Electromagnetic horn) and a receiving antenna (0.3 mϕ)

FPU B, C and D bands	16QAM3/4 Full mode	16QAM3/4 Half mode
Transmit frequencies f [GHz]	6.5	6.5
Transmission output power W [W]	5.00	2.50
Transmission output power W [dBm]	37.0	34.0
Transmitting antenna gain Gt [dBi] (Electromagnetic horn)	12.0	12.0
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	47.8	44.8
Transmission distance d [km]	3.7	3.7
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	120.1	120.1
Receiving antenna diameter lt [m]	0.3	0.3
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	23.2	23.2
Receiving feeder loss Lr [dB]	1.3	1.3
Single-interval instantaneous link interruption time rate (Fading) [%]	0.5	0.5
Required fading margin Fmr_rice [dB]	10.0	10.0
Received power Ci [dBm]	-60.4	-63.4
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8
Signal bandwidth B [MHz]	17.5	8.5
Signal bandwidth B [dBHz]	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise Ni = kT_0BF [dBm]	-97.4	-100.5
Receiver thermal noise C/N [dB]	37.0	37.1
Required C/N [dB]	22.0	22.0
Transmission margin [dB]	15.0	15.1

Mobile transmission – An example of FPU link budget (E and F bands)
When using a transmitting antenna (Electromagnetic horn) and a receiving antenna (0.3 mϕ)

FPU E and F bands	16QAM3/4 Full mode	16QAM3/4 Half mode
Transmit frequencies f [GHz]	10.5	10.5
Transmission output power W [W]	5.00	2.50
Transmission output power W [dBm]	37.0	34.0
Transmitting antenna gain Gt [dBi] (Electromagnetic horn)	12.0	12.0
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	47.8	44.8
Transmission distance d [km]	3.4	3.4
Free space propagation loss (λ/4πd)2 [dB]	123.5	123.5
Receiving antenna diameter lt [m]	0.3	0.3
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	27.4	27.4
Receiving feeder loss Lr [dB]	1.2	1.2
Single-interval instantaneous link interruption time rate (Fading) [%]	0.5	0.5
Required fading margin Fmr_rice [dB]	10.0	10.0
Single-interval link unavailability time rate (Rainfall) [%]	0.5	0.5
Required rainfall margin Zr [dB]	0.9	0.9
Received power Ci [dBm]	-60.4	-63.5
Boltzmann constant k [W/ (Hz･K)]	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz･K)]	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8
Signal bandwidth B [MHz]	17.5	8.5
Signal bandwidth B [dBHz]	72.4	69.3
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise Ni = kT_0BF [dBm]	-97.4	-100.5
Receiver thermal noise C/N [dB]	37.0	37.1
Required C/N [dB]	22.0	22.0
Transmission margin [dB]	15.0	15.1

Mobile transmission – An example of FPU link budget (G bands)
When using a transmitting antenna (Electromagnetic horn) and a receiving antenna (0.3 mϕ)

FPU G band	16QAM3/4 Full mode	16QAM3/4 Half mode
Transmit frequencies f [GHz]	13.0	13.0
Transmission output power W [W]	5.00	2.50
Transmission output power W [dBm]	37.0	34.0
Transmitting antenna gain Gt [dBi] (Electromagnetic horn)	12.0	12.0
Transmitting feeder loss Lt [dB]	1.7	1.7
Effective radiated power (WGt/Lt) [dBm]	47.3	44.3
Transmission distance d [km]	2.6	2.6
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	123.1	123.1
Receiving antenna diameter lt [m]	0.3	0.3
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	29.2	29.2
Receiving feeder loss Lr [dB]	1.7	1.7
Single-interval instantaneous link interruption time rate (Fading) [%]	0.5	0.5
Required fading margin Fmr_rice [dB]	10.0	10.0
Single-interval link unavailability time rate (Rainfall) [%]	0.5	0.5
Required rainfall margin Zr [dB]	1.1	1.1
Received power Ci [dBm]	-59.4	-62.4
Boltzmann constant k [W/ (Hz・K)]	1.38E-23	1.38E-23
Boltzmann constant k [dBm/ (Hz・K)]	-198.6	-198.6
Standard temperature T_0 [dBK]	24.8	24.8
Signal bandwidth B [MHz]	17.5	8.5
Signal bandwidth B [dBHz]	72.4	69.3
Receiver noise figure F [dB]	5.0	5.0
Receiver thermal noise Ni = kT_0BF [dBm]	-96.4	-99.5
Receiver thermal noise C/N [dB]	37.0	37.1
Required C/N [dB]	22.0	22.0
Transmission margin [dB]	15.0	15.1

Reference 3 Calculation Procedures for the Fading and Rain Attenuation Margins

The Calculation Procedures for the required fading margin (10 GHz or lower) and rain attenuation margin (10 GHz or higher) for the link budget design are shown below.

A3.1 Calculation procedure for the required fading margin

(1) Fixed transmission

The required fading margin, Fmr, to satisfy the target link quality, is calculated using the following equation:

$$Fmr = 10\log\left[k \times P_R / \{P_{is}(d/D) \times A\}\right]$$

However, when Fmr is lower than 5 dB, it shall be considered to be 5 dB.

- k : Coefficient of increase due to annual variation 2
- P_R : Probability of occurrence of Rayleigh fading
- P_{is} : Required instantaneous link interruption rate 5×10^{-3}
- d : Interval distance (km)
- D : Distance of the transmission interval (km)

  Since single interval transmission is used for TSL, d equals D.
- A : Rate of improvement by space diversity. Set to 1 for single reception

P_R shall be calculated using the following equation.

$$P_R = (f/4)^{1.2} \times d^{3.5} \times Q$$

- f : Frequency (GHz)
- d : link length (km)
- Q : Coefficient determined by link conditions (Table below)

Category	Link Condition	Average link height h (m)	Link Coefficient Q
Mountainous areas	When the majority of the propagation path includes mountainous areas	—	2.1×10^{-9}
Flatland areas	1. When the majority of the propagation path includes flatland areas. 2. When the majority of the propagation path includes harbors, estuaries, coasts (up to about 10 km from the shoreline) and offshore areas as well as mountainous areas	h≥100	5.1×10^{-9}
		h<100	$2.35\times10^{-8}\times h^{-1/3}$
Oceanic and coastal areas	1. Offshore areas 2. Flat coastal areas (up to about 10 km from the shoreline)	h≥100	$3.7\times10^{-7}\times h^{-1/2}$
		h<100	$3.7\times10^{-6}\times h^{-1}$

Average link height (h) in the table shall be calculated using the following equation.

$h = (h_1 + h_2)/2 - h_m$

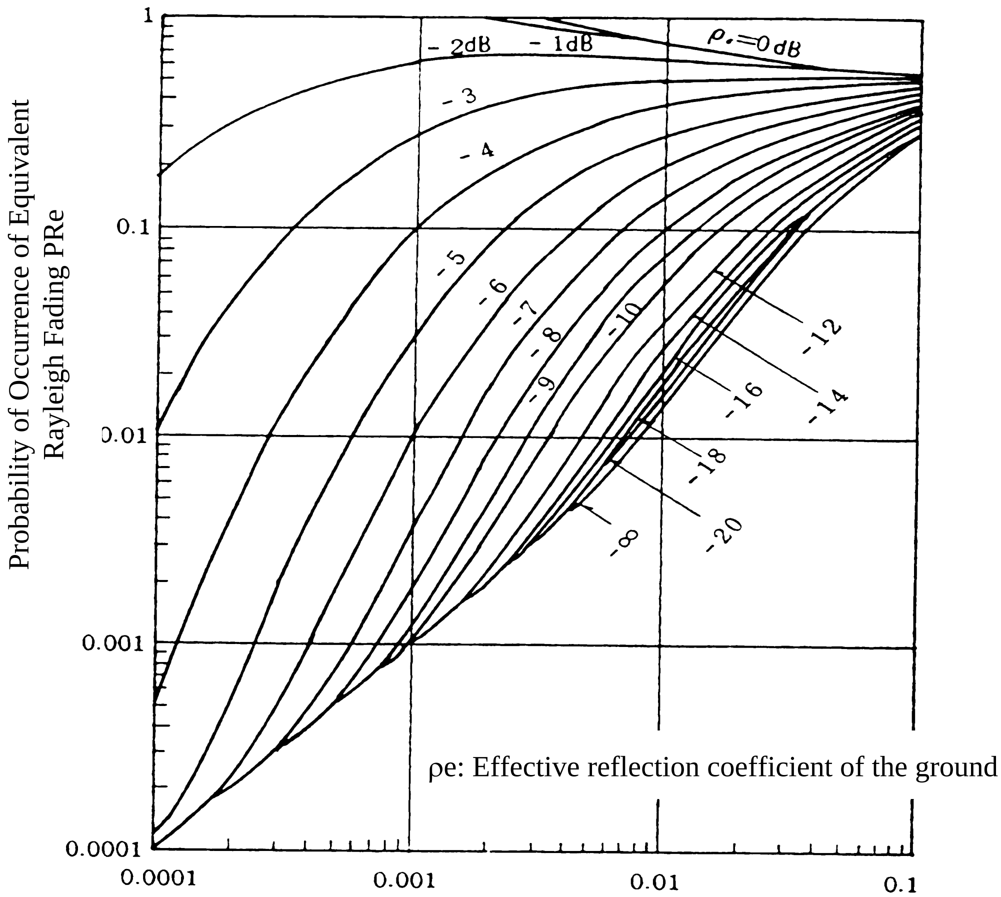
h_1, h_2: Altitude of the aerial at both stations (m)

h_m: Average ground height (m). Set to 0 when the link is over offshore areas.

When the effective reflection loss (D/Ur) is equal to or lower than 20 dB in the presence of reflection, the probability of equivalent Rayleigh fading occurrence, P_{Re}, as shown in the figure below, shall be used to replace P_R. Here, D/Ur (Effective reflection loss［dB］) is defined by the total sum of the directional gain and ridge reflection loss of the transmitting and receiving antennae and the reflection loss shown below. However, if the ridge reflection loss is 6 dB or higher, D/Ur shall be considered infinite assuming that no reflected wave is present.

Reflection Loss

Reflection point	Water surface	Paddy field	Dry field and dry rice field	Urban area, forest and mountain
Reflection loss	0 dB	2 dB	6 dB	14 dB



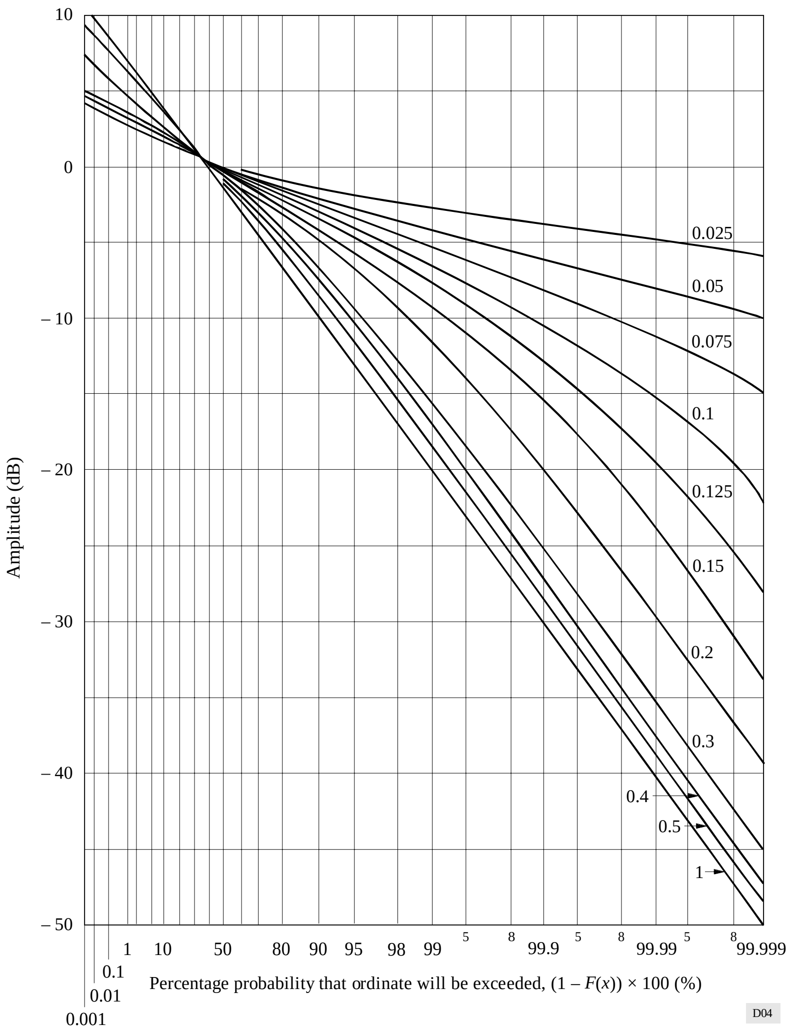
Probability of Occurrence of Equivalent Rayleigh Fading In the Presence of Reflection

(2) Mobile transmission

The Nakagami-Rice Fading Model shall be used as the typical link model for fading margin calculation. The relationship between the amplitude of the receiving electric field (vertical scale) of the above model and the percentage probability of exceeding the value of the vertical scale (horizontal scale) is shown in the figure below. The CMR (Carrier to Multipath Ratio) of the direct and reflected waves (fading wave) are used as parameters, determined by link conditions such as the urban structure. Here, CMR is set to 0.125 to 0.15 (8 dB to 9 dB) -- these values correspond to visibly good conditions.
The figure below shows the amplitude of the receiving electric field to be -10 dB, where the rate of instantaneous link interruption is 0.5% or lower (the value of the horizontal scale is 99.5% in the figure below). This makes the required fading margin 10 dB. The required fading margin, Fmr_rice, shall be 10 dB during mobile transmission.

FIGURE 4

Nakagami-Rice distribution for a constant total power (with the fraction of power carried by the random vector as parameter)



Reference: Rec. ITU-R P.1057 “Probability distributions relevant to radio-wave propagation modeling”, 1994

[Reasons]

For fixed transmission, it is proper to use the same method for calculating the required fading margin as that used for the digital (single carrier) FPU.

The Nakagami-Rice Fading Model was used as the typical link model for mobile transmission because of the precondition of effective visibility in the microwave band where the radio wave spreads only straight. CMR values of 8 to 9 dB are accurate, based on field experimental results [(1)]. In this case, the required fading margin is 10 dB[(2)]. Reference 2 shows examples of link budget B to G bands. Reference 3 shows how to calculate the required fading margin.

References:

(1) Taira et al.: "Microcell Propagation Loss Characteristics due to the Antenna Height Variations at the Base Station at Low Altitude Using a Microwave Band", the Journal of the Institute of Electronics, Information and Communication Engineers, A・P95-137, EMCJ95-111, NW95-188 (1996-02)

(2) Ikeda et al.: "Mobile Transmission Characteristics of the QAM-OFDM Digital FPU in the Microwave Band", the 2000 Annual Winter Convention of the Institute of Image Information and Television Engineers , 6-5, p. 91

A3.2 Calculation procedure of the margin for rain attenuation

(1) Fixed transmission

The following applies in the frequency band exceeding 10 GHz.

Zp, the p% value representing the distribution of rain attenuation (the required rainfall margin for annual link unavailability, p%) shall be calculated using the following equation.

The annual link unavailability for the known rainfall margin, Zp, shall be calculated using the inverse function of the above equation.

$$Zp = (\gamma \times R0.0075\%^{n}) \times d \times Tp \times Kp \times Cp \text{ [dB]}$$

Here,

R0.0075% : 0.0075% value of the one minute cumulative rainfall distribution at each point [mm/min]

γ, n : Parameter for calculating the rainfall attenuation coefficient ($\gamma \times R0.0075\%^{n}$)

$\gamma = -170.3971+584.2627t-742.788t^{2}+412.6263t^{3}-82.0161t^{4}$

$n = 12.47145-31.28249t+32.49227t^{2}-14.97753t^{3}+2.542102t^{4}$

$t = \log f$

f : Center frequency [GHz]

d : Link distance [km]

Tp : The p% value representing the Gamma distribution normalized by the 0.0075% value

$Tp = 7.102406 \times 10^{-3} - 3.8465364 \times 10^{-1}s + 4.5883133 \times 10^{-2}s^{2} + 3.2882329 \times 10^{-3}s^{3}$

$s = \log p$ (0.00001%≦p≦0.1%)

p : The annual link unavailability of the interval 0.00125[%]

Kp : The compensation coefficient used since the instantaneous rainfall is not uniform along the link

$Kp = \exp(-a \times d^{b})$ (0km≦d≦30km, 0.001%≦p≦0.1%)

$a = 3.54789 \times 10^{-2} \times 10^{0.280409/\log p}$ (0km≦d≦15km)

$= 4.92856 \times 10^{-2} \times 10^{0.315439/\log p}$ (15km≦d≦30km)

$b = 0.93974 - 3.1846 \times 10^{-2}/\log p$ (0km≦d≦15km)

$= 0.81364 - 6.2562 \times 10^{-2}/\log p$ (15km≦d≦30km)

Cp : The compensation coefficient used since the distribution of calculated values and actual distribution do not match

$Cp = \exp(-\beta \times d)$ (0km≦d≦30km, 0.00001%≦p≦0.1%)

$\beta = -0.0126 - 7.8632 \times 10^{-3}s$ (0.00001%≦p≦0.001%)

$= -4.245 \times 10^{-3} - 8.74 \times 10^{-4}s + 1.3884 \times 10^{-3}s^{2}$ (0.001%≦p≦0.1%)

$s = \log p$ (0.00001%≦p≦0.1%)

(2) Mobile transmission

The following applies in the frequency band exceeding 10 GHz.

Ap, the p% value representing the distribution of rain attenuation (the required rainfall margin for interval link unavailability, p%), shall be calculated using the following equation.

The interval link unavailability for the known rainfall margin, Ap, shall be calculated using the inverse function of the above equation.

$$Ap = (k \times R_{0.01}^{\alpha}) \times d \times r \times Tp \text{ [dB]}$$

Here,

$R_{0.01}$: 0.01% value of the one minute cumulative rainfall distribution at each point [mm/h]

k , α : Parameter for calculating the rainfall attenuation coefficient ($k \times R_{0.01}^{\alpha}$)

$$k = [k_H + k_V + (k_H - k_V)\cos^2\theta\cos 2\tau]/2$$

$$\alpha = [k_H \alpha_H + k_V \alpha_V + (k_H \alpha_H - k_V \alpha_V)\cos^2\theta\cos 2\tau]/2k$$

k_H , α_H , k_V , α_V : Parameters for calculating k and α (The subscripts, H and V, represent values for the horizontal and vertical polarization, respectively.) [Calculated using the table below.]

θ : Elevation angle [deg]

τ : An angle of inclination from the horizontal plane of the polarization (τ=45°for the circular polarization)

d : Actual distance of the link [km]

r : Compensation coefficient for the distance factor

$$r = 1 / (1 + d/d_0)$$

$$d_0 = 35e^{-0.015R0.01} \quad (R_{0.01} \leqq 100\text{mm/h})$$

Tp : Compensation coefficient used for conversion from 0.01% to p%

$$Tp = 0.12p^{-(0.546+0.0431 \log10^{P})} \quad (0.001\% \leqq p \leqq 1\%)$$

p: Interval link unavailability [%]

Frequency (GHz)	k_H	k_V	α_H	α_V
1	0.0000387	0.0000352	0.912	0.880
2	0.000154	0.000138	0.963	0.923
4	0.000650	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
7	0.00301	0.00265	1.332	1.312
8	0.00454	0.00395	1.327	1.310
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.200
15	0.0367	0.0335	1.154	1.128

Reference:

(1) Rec. ITU-R P.530-8, “Propagation data and prediction methods required for the design of terrestrial line-of-sight systems”, 1978-1999

(2) Rec. ITU-R P.837-2, “Characteristics of precipitation for propagation modeling”, 1992-1999

(3) Rec. ITU-R P.838-1, “Specific attenuation model for rain for use in prediction methods”, 1992-1999

A3.3 Examples of the Required Fading and Rain Attenuation Margins

When the link condition is “fixed transmission in flatland”, the required fading and rain attenuation margins in Tokyo are shown in the following tables:

Required Fading Margin When the Link Condition is
“Flatland (Average Link Height of 100 m or Higher)”

Band	10 km	20 km	30 km	40 km	50 km	60 km
800 MHz band	5.0 dB	5.0 dB	5.0 dB	5.0 dB	5.1 dB	7.9 dB
B band						
C band						
D band						

Required Rain Attenuation Margin for (in Tokyo)

Band	2 km	4 km	6 km	8 km	10 km	12 km
E band	9.2 dB	17.0 dB	23.5 dB	28.8 dB	33.1 dB	36.6 dB
F band						
G band	13.3 dB	24.6 dB	34.0 dB	41.7 dB	48.0 dB	53.0 dB

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PORTABLE OFDM DIGITAL TRANSMISSION SYSTEM FOR TELEVISION PROGRAM CONTRIBUTION

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