ARIB STD-B11
Version 2.2-E1

ENGLISH TRANSLATION

PORTABLE MICROWAVE DIGITAL TRANSMISSION SYSTEM FOR TELEVISION PROGRAM CONTRIBUTION

ARIB STANDARD

ARIB STD-B11 Version 2.2

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Association of Radio Industries and Businesses

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 Microwave 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)

<table>
<tr><th>Patent applicant</th><th>Name of invention</th><th>Patent number</th><th>Remarks</th></tr>
<tr><td rowspan="2">Japan Broadcasting Corporation (NHK)*</td><td>Transmitter, receiver and FPU with variable transmission capacities</td><td>Patent release
1997-284354</td><td>Japan</td></tr>
<tr><td>Digital transmission system and transmitting and receiving devices</td><td>Patent release
1997-321813</td><td>Japan</td></tr>
<tr><td rowspan="3">Japan Broadcasting Corporation (NHK)*
Hitachi Kokusai Electric Inc.*

(Joint patent application)</td><td>Error correction encoder and decoder and error correcting transmission devices</td><td>Patent release
1999-373754</td><td>Japan
US
UK
Germany
France</td></tr>
<tr><td>Automatic equalization circuit</td><td>Patent application
2000-99185</td><td>Japan</td></tr>
<tr><td>Error correction encoder and decoder and error correcting transmission devices</td><td>Patent application
2000-99194</td><td>Japan
US
UK
Germany
France</td></tr>
<tr><td>Sony Corporation*</td><td colspan="2">Submitted comprehensive written confirmation of ARIB STD-B11 Version 2.0.</td><td></td></tr>
</table>

* Valid for the revised parts of ARIB STD-B11 Version 2.0.

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Chapter 1 General Matters

1.1 Purpose

This standard specifies the digital transmission system for the FPU, a kind of portable microwave 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 QPSK/QAM digital transmission system for the FPU (Field Pick-up Unit), a kind of portable microwave transmission equipment for television program contribution. Standards applicable to digital 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 system FPUs are used together. Therefore, another standard may be specified when the digital system alone is used in future.

Table 1.1 shows the frequency band and channel spacing for the digital radio transmission system (microwave FPU) to which this standard is applicable.

Table 1.1 Frequency Band for the FPU to which this Standard is Applicable

Name of the frequency band	Frequency band	Channel spacing
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	

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Chapter 2　Technical Specifications

2.1　Modulation

2.1.1.　Modulation

QPSK or QAM modulation shall be used.

2.1.2　Maximum Transmission Bit Rate

Table 2.1 shows the maximum transmission bit rate when each type of modulation is used.

Table 2.1 Maximum Transmission Bit Rate

Type of Modulation	Maximum Transmission Bit Rate
QPSK	27 Mbit/s
16QAM	54 Mbit/s
32QAM	67.5 Mbit/s
64QAM	81 Mbit/s

2.1.3　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 2.2.

Table 2.2 Modulation Mode

Type of Modulation	Modulation Mode
QPSK	G7W
16QAM	D7W
32QAM	
64QAM	

2.2　Technical Transmitter Specifications

2.2.1　Frequency Tolerance (Ministerial Ordinance)

The frequency tolerance shall be 20×10^{-6} or lower.

2.2.2 Radiated Power (Ministerial Ordinance)

The radiated transmission power shall be 0.5 W or lower. However, it can be 1.5 W or lower in the absence of problems such as interference with existing analogue links; for example when it has been confirmed that no analogue system is being used in an adjacent channel.

The radiated transmitting power shall be 0.5 W or lower under any circumstances in the frequency band between 10.6 and 10.68 GHz.

2.2.3 Spurious Emission or Unwanted Emisson Intensity (Ministerial Ordinance)

2.2.3.1 Specification applied after December 1, 2005

Spurious Emission Intensity in area outside band	Unwanted Emission Intensity in spurious area
50 μW or lower	50 μW or lower

This specification meets the requirements as 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.)

2.2.3.2 Specification applied before November 30, 2005

The spurious emission intensity shall be 50 μW or lower.

(ARIB STD-B11 Version 2.1)

2.2.4 Spectral Mask (Ministerial Ordinance)

The spectral mask is shown in Fig. 2.1.

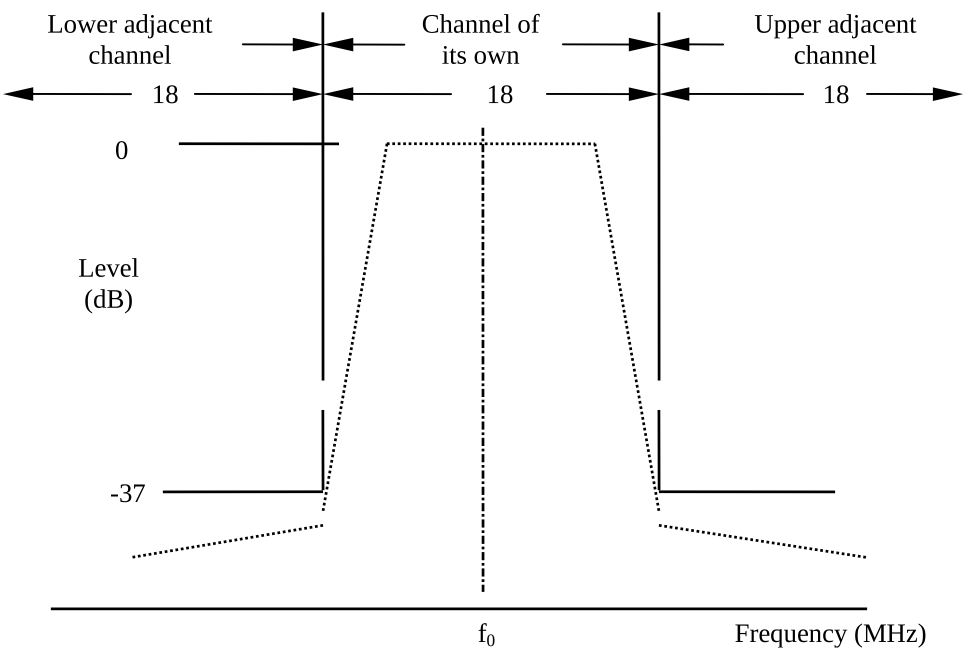


Fig. 2.1 Spectral Mask

2.2.5 Maximum Symbol Rate (Ministerial Ordinance)

The maximum symbol rate shall be 13.5 M symbol/s or less.

2.2.6 Roll-off Factor (Ministerial Ordinance)

The roll-off factor of the square root raised cosine filter for transmitter and receiver shall be 0.3 or lower.

2.2.7 Occupied Bandwidth (Ministerial Ordinance)

The occupied bandwidth shall be 15.5 MHz or lower.

2.2.8 Aerial

The transmitting aerial shall be applied as the specifications for the analogue existing FPU. As for polarization, circular (clockwise/counter-clockwise) as well as linear polarization (vertical/horizontal) can be used.

2.3 Link Quality

2.3.1 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 3/4) shall be 22 dB (fixed degradation of 4 dB of the transmitting and receiving devices summed to the theoretical value of 18 dB).

2.3.2 C/N Distribution

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

2.3.3 Required 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, as the rate of the time for the bit error rate after decoding of the inner code exceeds 1×10^{-4}, shall be as shown in Table 2.3.

Since the FPU is used for field transmission of video signal rather than being 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 the required parameters and so on.

Table 2.3 Required Link Quality (Annual Rates of Instantaneous Link Interruption and Link Unavailability)

Operating frequency band	Rates of instantaneous link interruption and link unavailability
B band (5,850 to 5,925 MHz)	0.5% or lower annually†
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 link interruption due to fading
‡Annual rate of link unavailability due to rainfall

2.4 Link Budget

2.4.1 Link Distance

The FPU is not permanently installed for use, meaning link and meteorological conditions change according to how it is used. This means that it is impractical to design the link budget in consideration of the fading margin, whenever a FPU is set up. It is therefore practical to include a transmission margin of 15 dB in the radiated power when the link budget is designed for the digital and analogue systems respectively. 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 circumstances of the typical link distances as shown in Table 2.4 and the required parameters such as the typical reception input level for each frequency band is calculated. Examples of link budget and calculation procedures of the required fading and rainfall margins over typical link distances are shown in References 1 and 2, respectively.

Table 2.4 Typical Link Distance

Frequency band	B, C and D	E and F	G
Typical link distance	50 km	7 km	5 km

2.4.2 Desired Received Power

The desired received power is -61 dBm.

Chapter 3 Specifications for Manufacturers' Compatibility

3.1 Block Diagram and Basic Parameters of Digital FPU

Fig. 3.1 shows the digital FPU in block diagram form, and Table 3.1 shows the basic parameters.

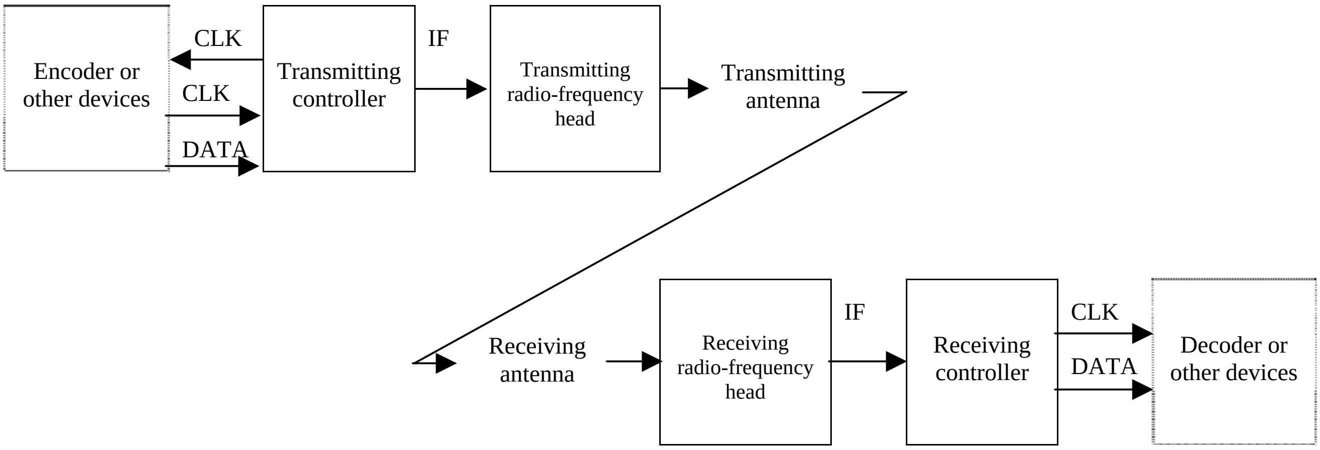


Fig. 3.1 Block Diagram of the Digital FPU

Table 3.1 Basic Parameters for the Digital FPU

Item/Modulation	QPSK	16QAM	32QAM	64QAM
Transmission bandwidth	15.5 MHz or lower (99% occupied bandwidth)			
Symbol rate	13.35403 MHz			
Roll-off factor	0.3 square root raised cosine filter for transmitter and receiver			
Bandwidth efficiency	2 bit/symbol	4 bit/symbol	5 bit/symbol	6 bit/symbol
Maximum TS+RS bit rate	26.352 Mbit/s	52.704 Mbit/s	65.880 Mbit/s	79.056 Mbit/s
Theoretical CNR ($BER=10^{-4}$)	12 dB	19 dB	22 dB	25 dB

3.2 Interface

3.2.1 Connection Configuration

When connecting an encoder, a re-multiplexer (ReMUX) or another digital FPU receiver (Rx) to 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 outer Interleave with inner code error correction, “Interface for Separate-Cable Transmission of Data and Clock for Television Program Contribution (ARIB Standard ARIB STD-B18) ” shall be applied.

(Connection configuration 2) For the connection source coding/multiplexing with 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 used.

The clock signal and data flow shall be in the same direction. The digital FPU transmitter shall be operated with an external clock and shall be able to supply the clock to an encoder or re-multiplexer.

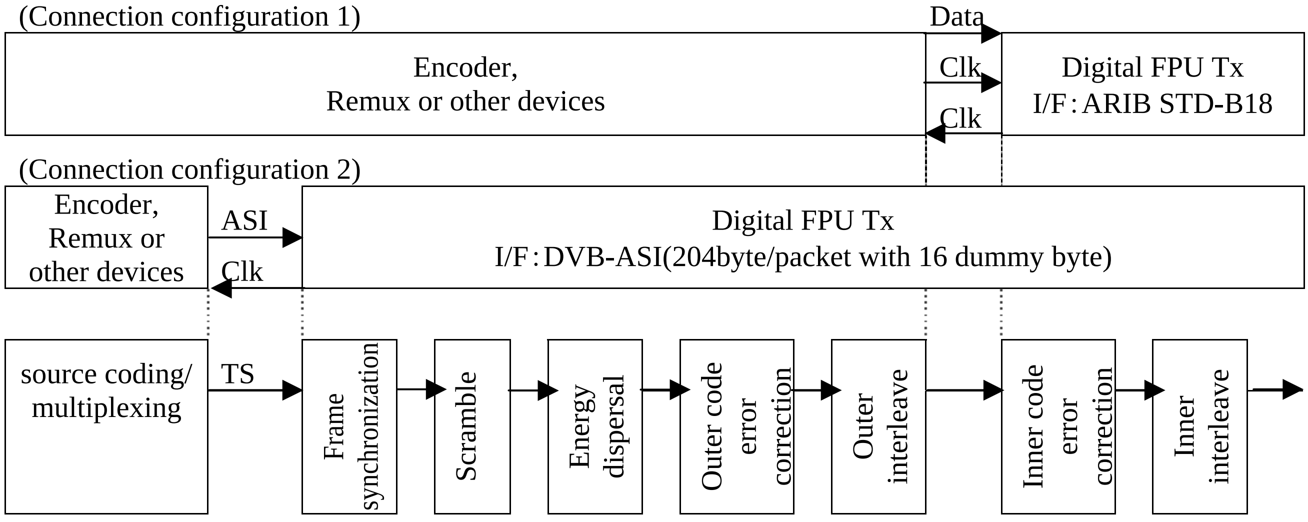


Fig. 3.2 Configuration and Interface of digital FPU transmitter

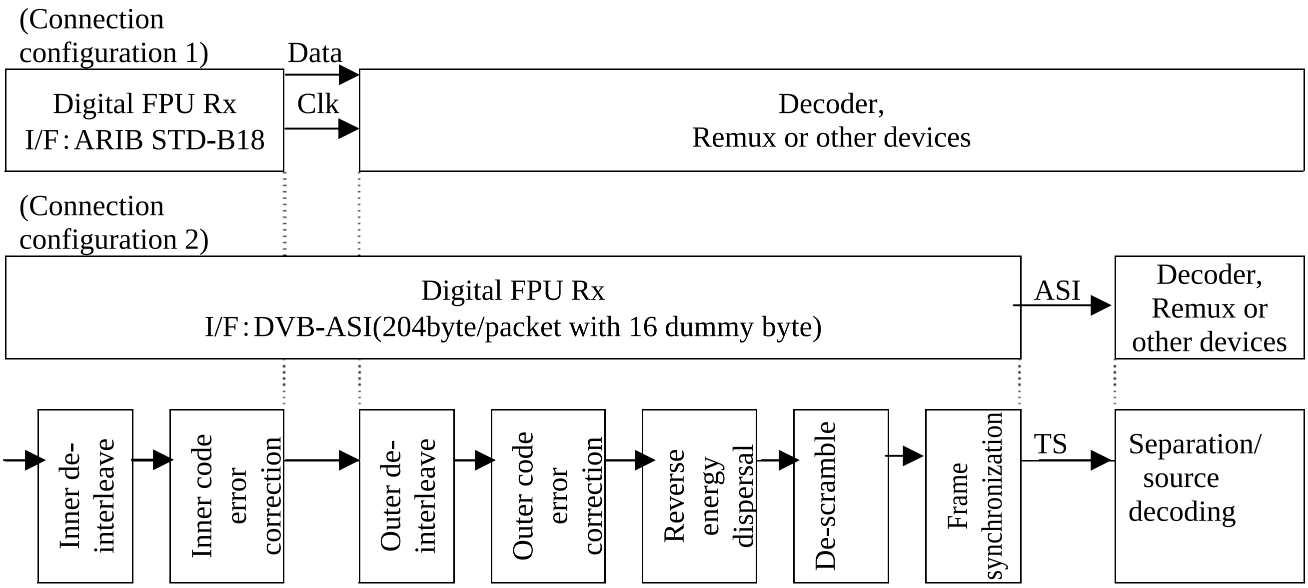


Fig. 3.3 Configuration and Interface of digital FPU receiver

3.2.2 Interface Bit Rate

The block structure of the modulated signal by the digital FPU is shown in Fig. 3.4 while the bit rates for interface are specified in Tables 3.2 and 3.3.

For interface bit rates such as 59.648 [Mbit/s] and 44.736 [Mbit/s], a stuffing area shall be set up in the physical layer outside the mapping area. The bit rate D for interface for the TS (204-byte mode) is calculated using the following equation:

$D = C \times (B - P - S)/B \times \eta \times R$

Here,

D: Bit rate for interface for the TS (204-byte mode) [Mbit/s]
C: Clock frequency = 13.35403 [MHz]
B: Block length = 19200 [symbol]
P: Reference signal length = 256 [symbol]
S: Stuffing length = 16 × N [symbol] (N: natural number)
η: Bandwidth efficiency = $\log_2$ (multiple modulation values) [bit/symbol]
R: Coding rate of the inner code error correction

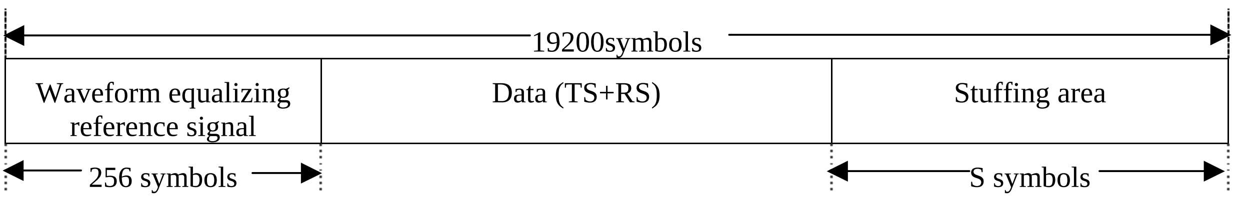


Fig. 3.4 Block Structure

Table 3.2 Bit Rate for Interface (Maximum Rate/SNG Mode)

Bandwidth efficiency η [bit/symbol]	Modulation and coding rate	TS+RS rate [Mbit/s]	Stuffing S [symbols]
6	64QAM (No inner code)	79.056	0
5	64QAM (5/6 trellis) or 32QAM (No inner code)	65.880	0
		59.648	112 × 16
		44.736	380 × 16
		33.552	581 × 16
		29.824	648 × 16
		22.368	782 × 16
4	32QAM (4/5 trellis) or 16QAM (No inner code)	52.704	0
		49.5435	71 × 16
		44.736	179 × 16
		29.824	514 × 16
3	16QAM (3/4 trellis)	39.528	0
		36.85712	80 × 16
		33.552	179 × 16
		29.824	290 × 16, 291 × 16, 291 × 16 (*1)
		23.859	469 × 16, 469 × 16, 470 × 16 (*2)
2	QPSK (No inner code)	26.352	0
		24.57142	80 × 16
		22.368	179 × 16

*1: Table 3.6 D00 bits in the TMCC signal: 1, 0, 0
*2: Table 3.6 D00 bits in the TMCC signal: 1, 1, 0

Table 3.3 Bit Rate for Interface (64QAM Trellis Mode)

Bandwidth efficiency η [bit/symbol]	Modulation and coding rate	TS+RS rate [Mbit/s]	Stuffing S [symbols]
5	64QAM (5/6 trellis) or 32QAM (No inner code)	52.52585	240 × 16
		39.39439	476 × 16
		26.26293	712 × 16
		13.13146	948 × 16
4	32QAM (4/5 trellis) or 16QAM (No inner code)	52.52585	4 × 16
3	16QAM (3/4 trellis)	39.39439	4 × 16
2	QPSK (No inner code)	26.26293	4 × 16
1	QPSK (1/2 trellis)	13.13146	4 × 16

If link conditions do not allow 64QAM trellis transmission (bandwidth efficiency $\eta = 5$), it is assumed that 32QAM, 16QAM or QPSK transmission with bandwidth efficiency $\eta \leq 4$ may be used.

To use other FPUs and TSLs (Transmitter to Studio Links) for tandem connection, it is preferable to connect to a trellis-coded 64QAM without rate conversion. For this purpose it is necessary that the stuffing bits for 32QAM, 16QAM and QPSK be specified as $(5n-1) \times 16$ $(n=1,2,\cdots)$. To maximize the TS + RS rate, Table 3.3 lists the minimum required stuffing bits of 4×16 $(n = 1)$.

3.3 Transmitting Controller

3.3.1 Block Diagram

Fig. 3.5 shows the block diagram of the transmitting controller.

The transmitting controller includes error correction coding and QAM modulation, and outputs the IF signal. The following subsections describe the functions of each block of the transmitting controller.

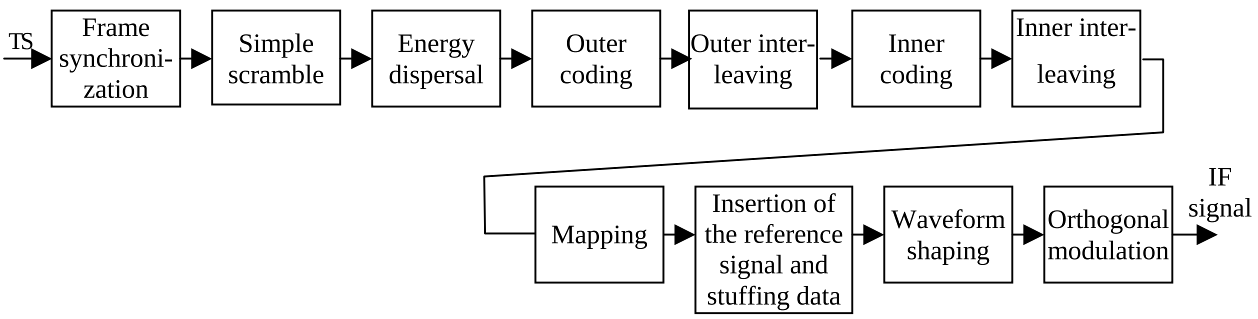


Fig. 3.5 Block Diagram of the Transmitting Controller

3.3.2 Frame Synchronization

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

3.3.3 Simple Scramble (Optional)

The digital transmission system specified in this standard is used for communication to 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 signal (generator polynomial $X^{16} + X^{12} + X^3 + X + 16$). Since the FPU transmitter and receiver 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 conform to the specifications in this section.

The scramble area shall be payloads that exclude the transport packet header (four bytes) and adaptation field. However, the NIT (PID=0x0010) packet which includes identification codes of the transmitting point and Null (PID=0x1FFF) packet, shall not be scrambled. Other types of packets with other PIDs may also 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 used as assigned in "Service Information for Digital Broadcasting System (ARIB Standard ARIB STD-B10) ”.

The scramble key shall be the initial value; loaded to the LFSR (Linear Feedback Shift Register) to generate the above mentioned pseudo-random signal. The key will not be transmitted.

The initial value shall be loaded into the LFSR immediately after frame synchronization and the LFSR shall continue operating until the next frame synchronization. The pseudo-random signal shall not be added in where scrambling is prohibited. The pseudo-random signal cycle shall be 1503 ($188 \times 8 - 1$) bytes.

3.3.4 Energy Dispersal

The pseudo-random signal shall be added to the multiplexed signal in accordance with ISO/IEC13818-1 for energy dispersal.

The generator polynomial of the pseudo random signal shall be $X^{15} + X^{14} + 1$. The initial value of the pseudo random signal shall be "0000 0001 0101 001b". The pseudo-random signal is added *in* 1,496 bytes ((204 – 16 – 1) per frame × 8 packets) (as a result of excluding 16 dummy bytes, data frame sync byte (0xB8) and TS sync byte (0x47) from each 204 byte packet). The pseudo-random signal cycle shall be 1503 ($188 \times 8 - 1$) bytes. The initial value shall be loaded immediately after the sync byte (0xB8) of the first frame.

3.3.5 Outer Code Error Correction

Reed-Solomon (204, 188) shall be used for outer code error correction. The 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 (255, 239) are shown below.

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

λ=02h

Field generator polynomial: $p(x) = x^8+x^4+x^3+x^2+1$

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.

3.3.6 Outer interleave

Outer interleave refers to convolutional 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 a delay of (n-1) blocks and each block has a 17-byte delay. Here, the transport packet and frame sync bytes shall always traverse the 0-th path with no delays. The de-interleave circuit shall be 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. 3.6.

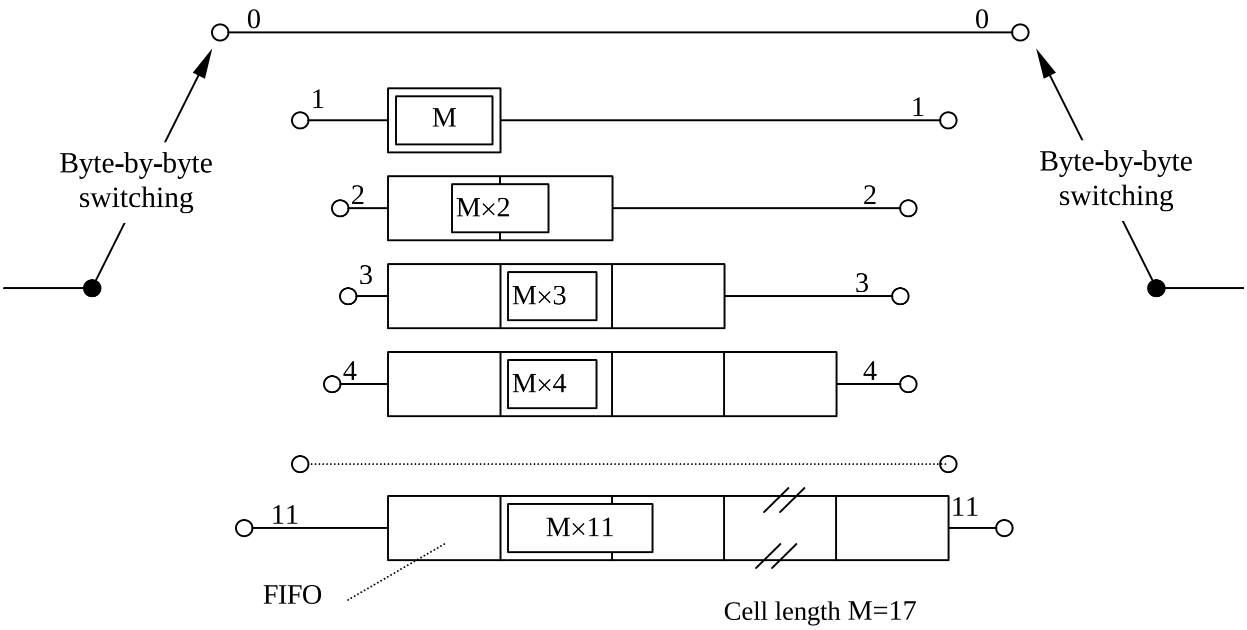


Fig. 3.6 Configuration of an Outer Interleave Circuit

3.3.7 Inner Code Error Correction

Trellis coding shall be used for inner code error correction. If the link condition does not require the use of the inner code, it can be omitted. The coding rate of $(\eta - 1)/\eta$ shall be used for the trellis coding, as shall the convolutional encoder shown in Fig. 3.7.

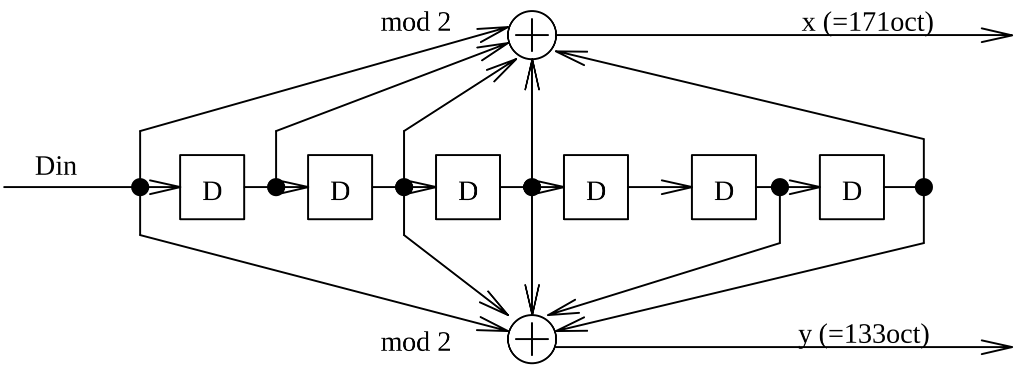


Fig. 3.7 Convolutional Encoder

3.3.8 Inner interleave

To enhance the inner code error correction ability for burst errors, the convolutional time interleaving, shown in Fig. 3.8, shall be used. To ensure synchronization at the receiver, the start of the data that comes after the reference signal shall be the 0-th time interleaving path.

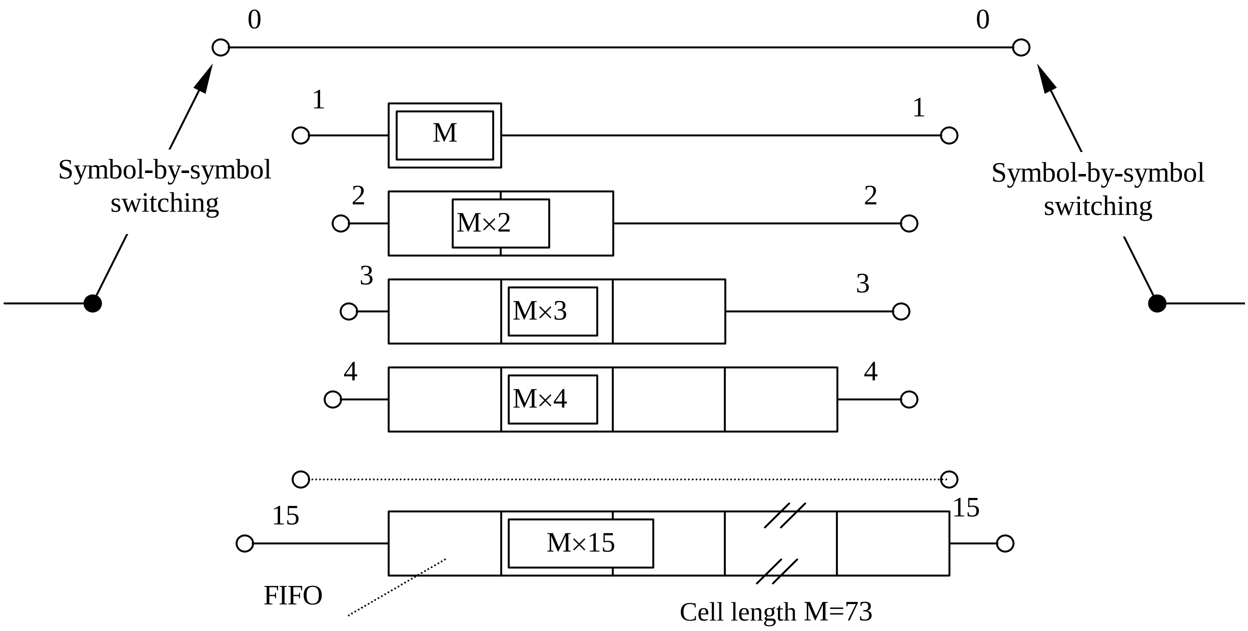


Fig. 3.8 Configuration of an Inner Interleave Circuit

3.3.9 Mapping

By using the reference signal to be mentioned in §3.3.10, the receiver will be able to determine the orthogonal axis and eliminate phase uncertainty. This makes it possible to use trellis coded modulation, which has a high transmission efficiency and which cannot be used for differential coding. If using trellis coding, the mapping shown in Figs. 3.9 to 3.12 shall be used. Otherwise, data is directly input one by one from the MSB as shown in parentheses underneath the input signal for inner interleaving.

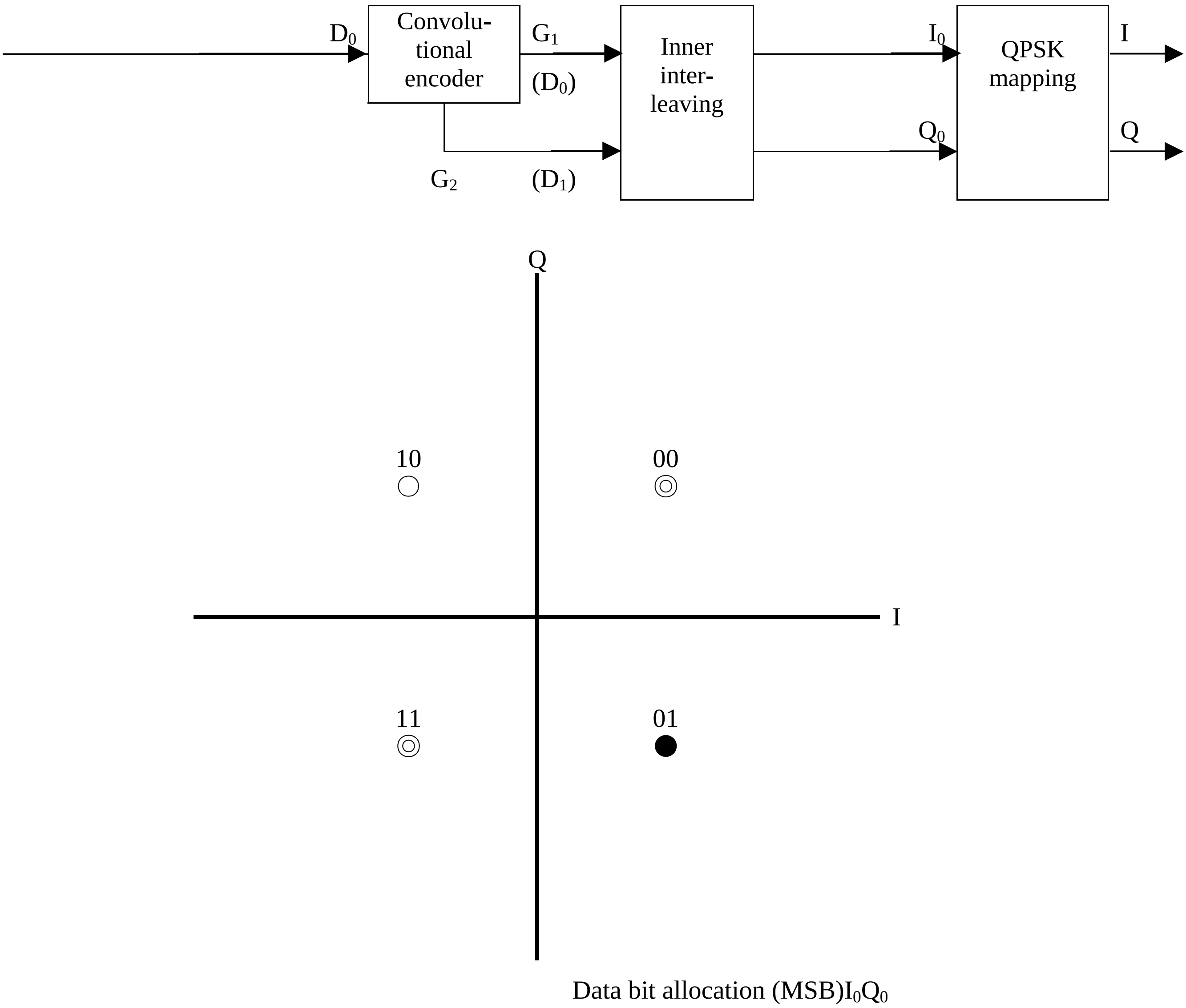
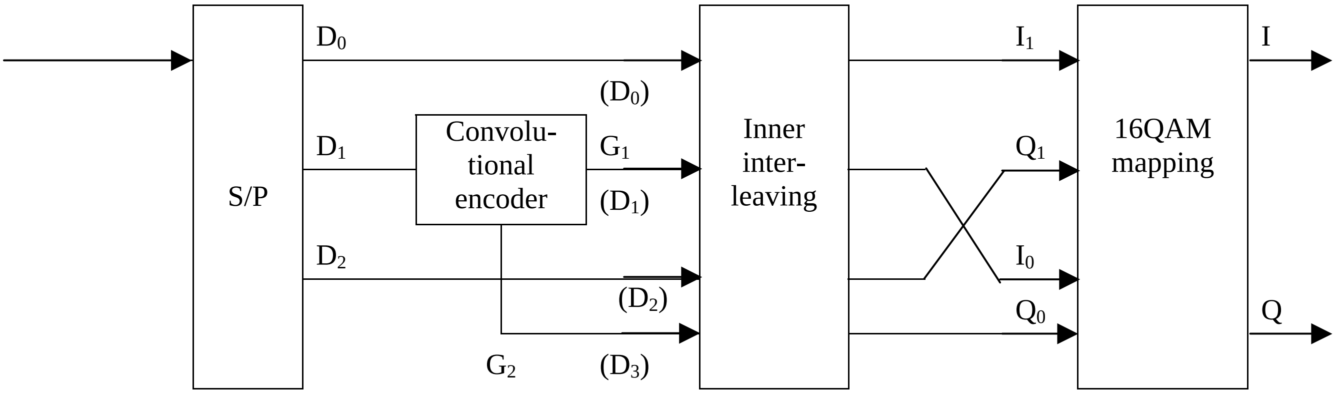


Fig. 3.9 Mapping for QPSK Trellis Coded Modulation (◎: Reference Signal for Equalization ○: Q Pulse)



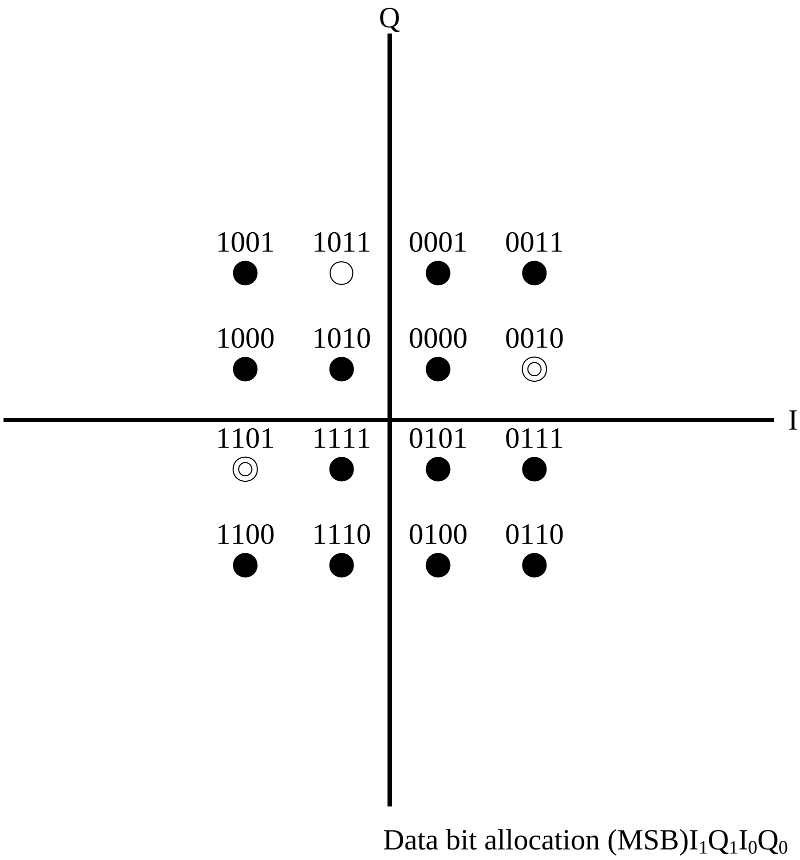


Fig. 3.10 Mapping for 16QAM Trellis Coded Modulation (◎: Reference Signal for Equalization ○: Q Pulse)

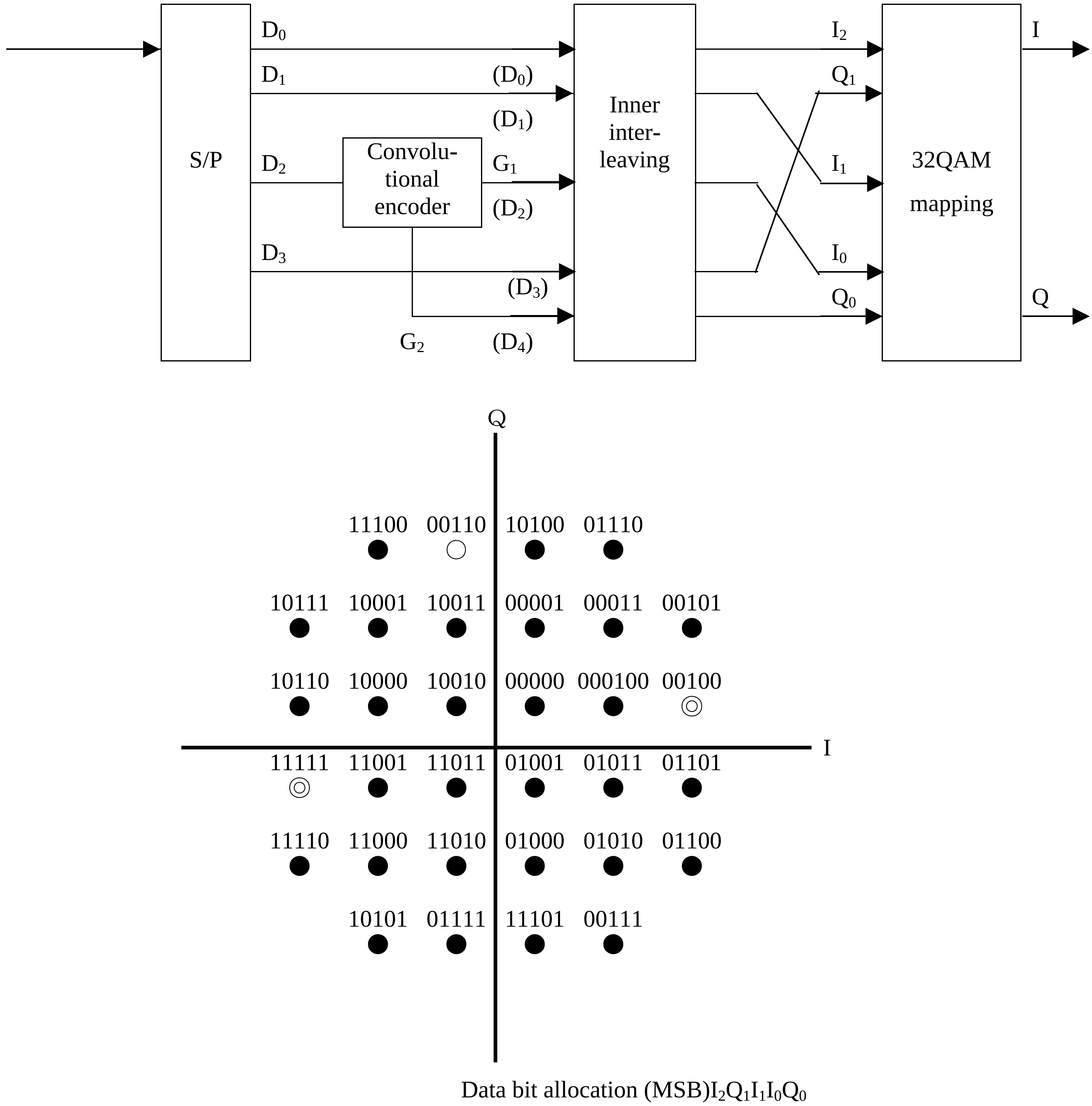


Fig. 3.11 Mapping for 32QAM Trellis Coded Modulation (◎: Reference Signal for Equalization ○: Q Pulse)

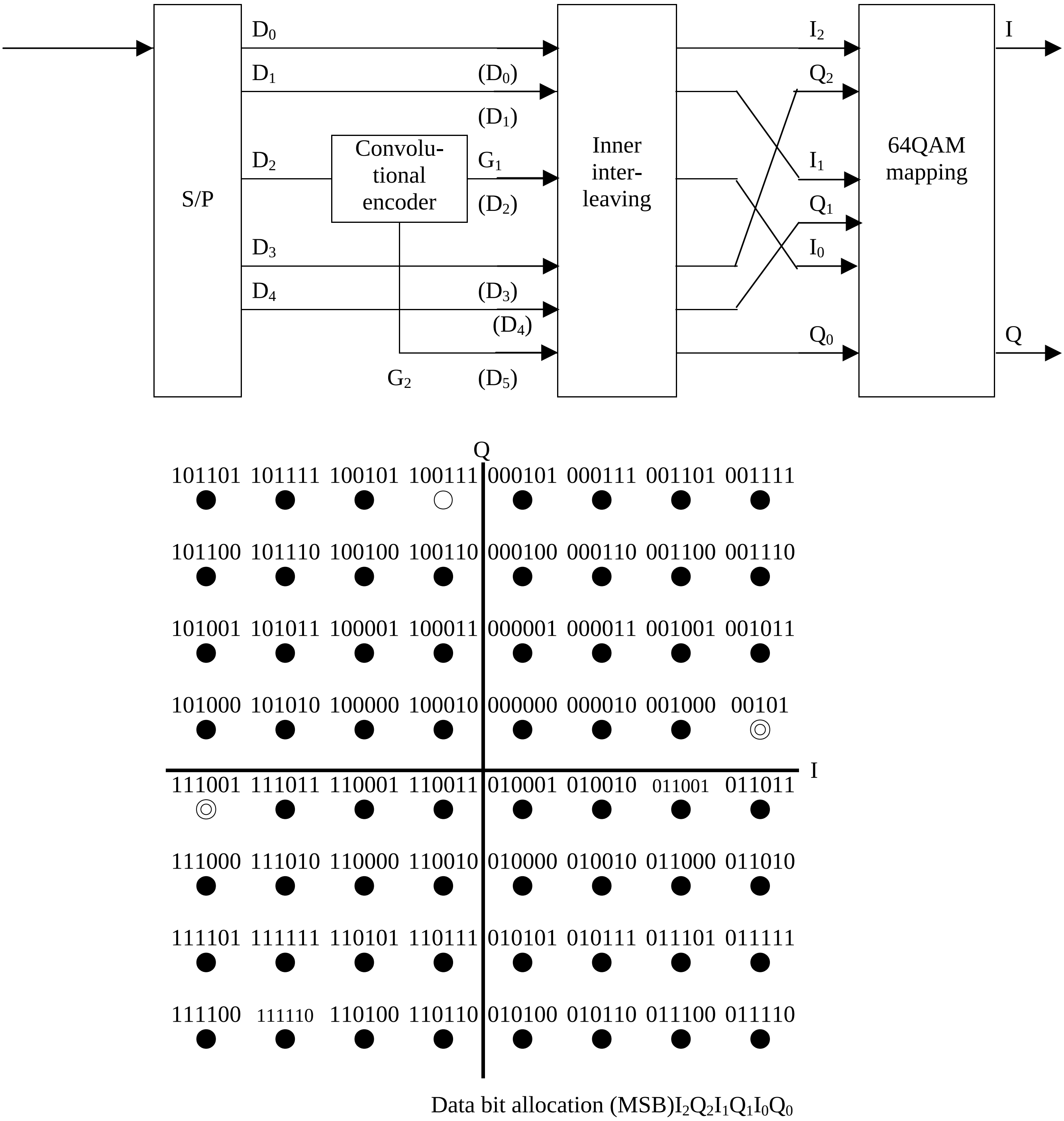


Fig. 3.12 Mapping for 64QAM Trellis Coded Modulation (◎: Reference Signal for Equalization ○: Q Pulse)

3.3.10 Reference Signal for Waveform Equalization and Insertion of Stuffing Data

The multiplexing procedure of the reference signal for waveform equalization is shown in Table 3.4, and Fig. 3.13. The reference signal generating circuit is shown in Fig. 3.14. At each start point of the reference signal for waveform equalization, the initial value shall be loaded into the reference signal generating circuit. The Q (Quadrature) pulse at the end of the reference signal represents the symbol to confirm the phase, since the reference and TMCC signals are BPSK modulated and include a 180° phase uncertainty.

Table 3.4 Reference Signal for Waveform Equalization

Reference signal length: L	block length: B	Reference signal rate	Reference signal insertion cycle	Occupation rate of the reference signal	symbol rate	Maximum transmission rate
256 symbols (19.17 μs)	19200 symbols (1.438 ms)	178.1 kHz	695.5 Hz (1.438 ms)	1/75 (1.333%)	13.18 Msymbol/s	QPSK: 26.352 Mbit/s 16QAM: 52.704 Mbit/s 32QAM: 65.880 Mbit/s 64QAM: 79.056 Mbit/s

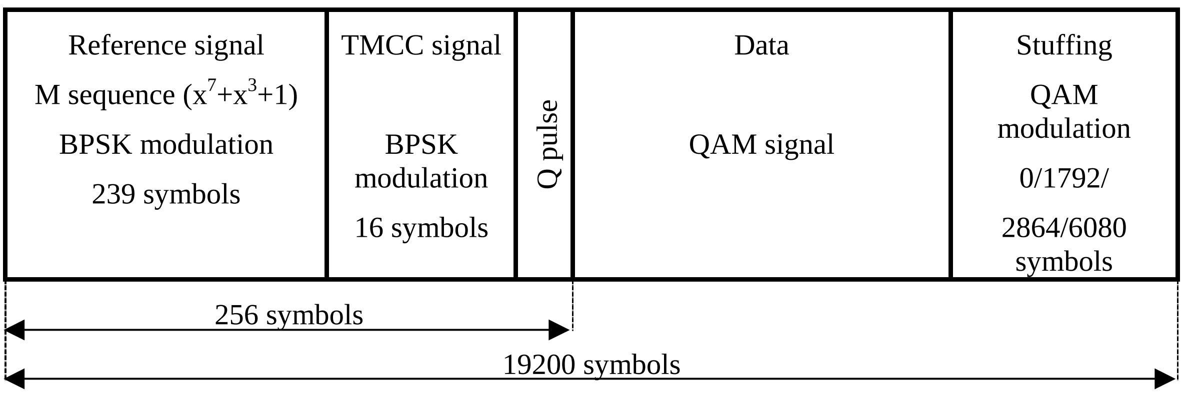


Fig. 3.13 Format of the Reference Signal for Waveform Equalization

Generator polynomial for M-sequence codes: $g(x) = x^7 + x^3 + 1$

Initial register value: 1 1 1 1 1 1 1 in ascending order

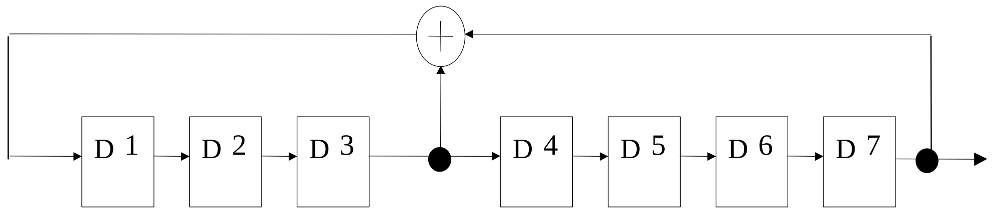


Fig. 3.14 Reference Signal Generating Circuit

Table 3.5 shows the mapping values for the QPSK, 16QAM, 32QAM and 64QAM modulation of the waveform equalization signal. The amplitude of the equalizing reference signal shall be the same as the average amplitude. When using 32QAM and 64QAM modulations, however, the average amplitudes become exactly $\sqrt{10/13}$ times (-1.14 dB) and $\sqrt{21/25}$ times (-0.76 dB), respectively, of the mapping values in the table. Nonetheless, given the fact that the variations are minor and to simplify the circuit configuration, the approximate values shown in Table 3.5 shall be used.

Table 3.5 Mapping Values for the Reference Signal for Waveform Equalization

Modulation	Value	Mapping values (I, Q)
QPSK	0	(+1, +1)
	1	(-1, -1)
	Q pulse	(-1, +1)
16QAM	0	(+3, +1)
	1	(-3, -1)
	Q pulse	(-1, +3)
32QAM	0	(+5, +1)
	1	(-5, -1)
	Q pulse	(-1, +5)
64QAM	0	(+7, +1)
	1	(-7, -1)
	Q pulse	(-1, +7)

The TMCC (Transmission and Multiplexing Configuration Control) signal is assigned in the waveform equalizing reference signal. The TMCC signal is specified as shown in Table 3.6.

Table 3.6 Bits Allocation and Assignment for the TMCC Signal

Bit	Assignment	Code (MSB first)
D15	Modulation	001: QPSK 010: 16QAM 011: 32QAM100: 64QAM 000, 101 to 111: Undefined(*1)
D14		
D13		
D12	Error correction	0: Error corrected (Trellis code) 1: Error not corrected
D11	Bit rate(*2) (M bit/s)	0000: Use prohibited 0001: 44.736 0010: 59.648 0011: 29.824 0100: 23.859 0101: 13.131 0110: 22.368 0111: 24.571 1000: 26.263 1001: 33.552 1010: 36.857 1011: 39.394 1100: 49.544 1101: 52.523 1110: Bit rate #1 1111: (*4)
D10		
D09		
D08		
D07	Inner interleave	00: Not inner interleaved 10: Inner interleaved (Undefined)(*1) 01: Inner interleaved (Undefined)(*1) 11: Depth 16-cell length 73
D06		
D05	Test mode	0: Test mode(*3) 1: Normal operation mode
D04	Alarm	0: Input signal - Normal 1: Input signal - Abnormal
D03		0: PS/FAN - Normal 1: PS/FAN - Abnormal
D02	Connection rate	0: Compatible rate 1: Defined by the user
D01	Undefined(*1)	
D00	Stuffing	0: Not punctured(*5) 1: Punctured(*5)

*1: “Undefined” codes will be defined for additional modes in future.

*2: When the “Compatible rate” is used for “Connection rate”(D02 = 0), these bit rates shall be commonly used among users.

Bit rate #1 is undefined. However, if already in use, no change will be required until it is defined in future. If a user defines a bit rate independently, the “Connection rate” shall be set to “user defined” (D02 = 1).

*3: PN Code 2^{23-1} for BER Measurement compatible with ITU-T O.151 shall be inserted prior to the inner code.

*4: The rate is determined by the modulation system (D13 to D15) and the error correction system (D12) (equivalent to stuffing 0).

*5: The puncture pattern is defined by the bit pattern of the TMCC signal shown in Notes 1 and 2 in Table 3.2.

For the stuffing, the same modulation shall be used as that for the data signal and the same pseudo-random signal (generator polynomial: $X^{15} + X^{14} + 1$) as specified in §3.3.4 "Energy Dispersal". During the stuffing of each block (comprised of 19,200 symbols) starts, the initial value, 0000 0001 0101 001b, shall be loaded into the register. Ancillary data energy-dispersed by the above pseudo-random signal can be used as stuffing. If the TS signal is used as ancillary data, error correction and interleaving shall comply with the transmission system for video and audio TS signals. Otherwise, the interface for ancillary data input shall be as shown in Fig. 3.15; since the ancillary data signal, waveform equalizing reference signal and FPU data synchronize with the symbol clock, the FPU Tx shall output the symbol clock and enable signal of ancillary data to the multiplexer of ancillary data and this multiplexer shall output ancillary data that synchronizes with the symbol clock only during the enable period. The bit width of the ancillary data shall be the transmission bit per symbol for each modulation (Examples: 64QAM – 6 bits and 32QAM – 5 bits). There are no specifications for the error correction system.

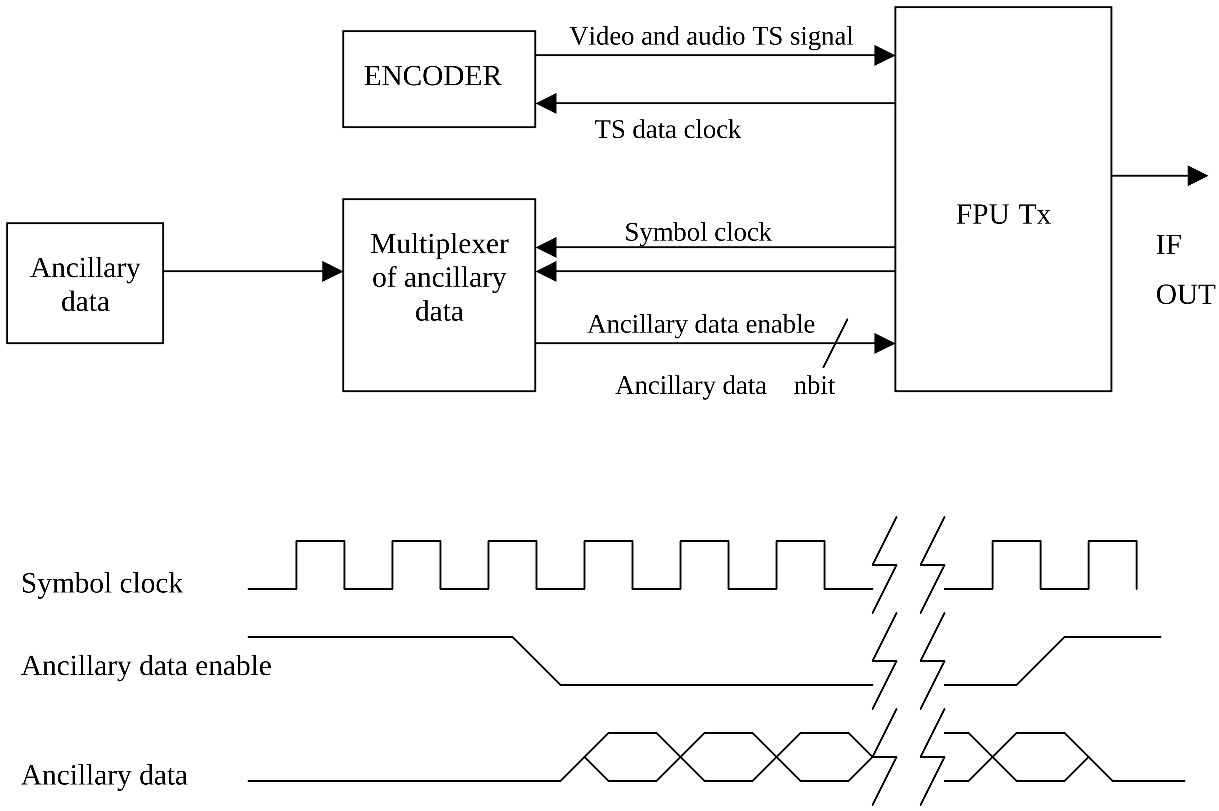


Fig. 3.15 Interface for Ancillary Data Input when not using the TS Signal

3.3.11 Waveform Shaping

The roll-off factor shall be 0.3 square root raised cosine for the transmitter and receiver. The aperture correction of x/sin (x) shall be added to the transmitter, while the gain shall be adjusted in accordance with the average power of QPSK, 16QAM, 32QAM or 64QAM modulation.

3.3.12 Orthogonal Modulation

The IF frequency shall be 130 MHz.

3.4 Radio-frequency Head

3.4.1 Configuration

The transmitting radio-frequency head converts the IF signal to B to G band RF signals and amplifies the power for RF signal transmission.

The configurations of the transmitting and receiving radio-frequency heads are shown in Fig. 3.16.

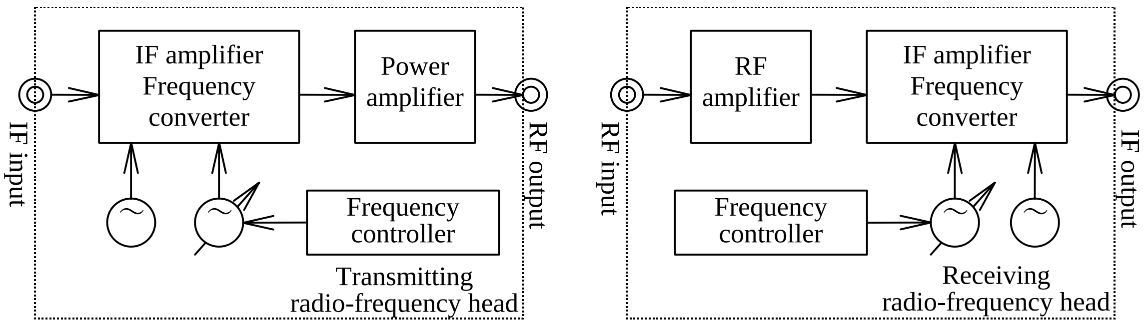


Fig. 3.16 Configurations of the Radio-frequency Heads

3.4.2 Functions

(1) IF amplifier and frequency converter

The IF shall be 130 MHz.

(2) Power amplifier

The converted microwave signal shall be amplified to 1.5 W (excluding F3 to F7), 0.5W and 0.1W.

(3) Allocated channel selection

Selection between multiple allocated channels shall be allowed on a single unit.

3.4.3 Target Performance

The target performance of the transmitting radio-frequency head is shown in Table 3.7.

Table 3.7 Target Performance of the Transmitting Radio-frequency Head

	Item	Specification	Remarks
1	Transmit frequency	B, C, D, E, F and G bands	
2	Transmission output	Within 1.5 W†+1.5 dB/-1.0 dB Within 0.5 W+1.5 dB/-1.0 dB Within 0.1 W+1.5 dB/-1.0 dB	Switching system (Excluding F3 to F7)
3	Third order distortion within the band	-40 dBc or lower	
4	Frequency stability	Within $\pm 1 \times 10^{-6}$	
5-1	Spurious emission in area outside band	50µW or lower	
5-2	Unwanted emission in spurious area	50µW or lower	
6	IF input level IF frequency	0 to -20 dBm 130 MHz	Cable length 200 m

†In the absence of problems such as interference with existing analogue links

Reference 1 Examples of Link Budget

Examples of FPU Link Budget (B, C and D Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (0.6 m in diameter)

FPU B, C and D bands	FM system	64QAM 3/4
Transmit frequency f [GHz]	6.5	6.5
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	29.2	29.2
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	65.0	58.9
Transmission distance d [km]	50.0	50.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	142.7	142.7
Receiving antenna diameter lr [m]	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	29.2	29.2
Receiving feeder loss Lr [dB]	1.3	1.3
Annual rate of instantaneous link interruption (Fading)[%]	0.5	0.5
Required fading margin Fmr [dB]	5.1	5.1
Received power Ci [dBm]	-54.9	-61.0
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-96.8	-97.9
Receiver thermal noise C/N [dB]	42.0	37.0
Required C/N [dB]	27.0	22.0
Transmission margin [dB]	15.0	15.0

Examples of FPU Link Budget (B, C and D Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (1.2 m in diameter)

FPU B, C and D bands (Reception at the base station)	FM system	64QAM 3/4
Transmit frequency f [GHz]	6.5	6.5
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	29.2	29.2
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	65.0	58.9
Transmission distance d [km]	50.0	50.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	142.7	142.7
Receiving antenna diameter lr [m]	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	35.0	35.0
Receiving feeder loss Lr [dB]	7.0	7.0
Annual rate of instantaneous link interruption (Fading)[%]	0.5	0.5
Required fading margin Fmr [dB]	5.1	5.1
Received power Ci [dBm]	-54.8	-60.9
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise Ni = kT_0BF [dBm]	-96.8	-97.9
Receiver thermal noise C/N [dB]	42.0	37.0
Required C/N [dB]	27.0	22.0
Transmission margin [dB]	15.0	15.0

Examples of FPU Link Budget (E and F Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (0.6 m in diameter)

FPU E and F bands	FM system	64QAM 3/4
Transmit frequency f [GHz]	10.5	10.5
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	33.4	33.4
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	69.2	63.1
Transmission distance d [km]	7.0	7.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	129.8	129.8
Receiving antenna diameter lr [m]	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	33.4	33.4
Receiving feeder loss Lr [dB]	1.2	1.2
Annual rate of link unavailability (Rainfall)[%]	0.00125	0.00125
Required rainfall margin Zr [dB]	26.3	26.3
Received power Ci [dBm]	-54.7	-60.8
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-96.8	-97.9
Receiver thermal noise C/N [dB]	42.1	37.1
Required C/N [dB]	27.0	22.0
Transmission margin [dB]	15.1	15.1

Examples of FPU Link Budget (E and F Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (1.2 m in diameter)

FPU E and F bands (Reception at the base station)	FM system	64QAM 3/4
Transmit frequency f [GHz]	10.5	10.5
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	33.4	33.4
Transmitting feeder loss Lt [dB]	1.2	1.2
Effective radiated power (WGt/Lt) [dBm]	69.2	63.1
Transmission distance d [km]	7.0	7.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	129.8	129.8
Receiving antenna diameter lr [m]	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	39.1	39.1
Receiving feeder loss Lr [dB]	6.9	6.9
Annual rate of link unavailability (Rainfall)[%]	0.00125	0.00125
Required rainfall margin Zr [dB]	26.3	26.3
Received power Ci [dBm]	-54.6	-60.8
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	4.0	4.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-96.8	-97.9
Receiver thermal noise C/N [dB]	42.2	37.2
Required C/N [dB]	27.0	22.0
Rainfall margin [dB]	15.2	15.2

Examples of FPU Link Budget (G Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (0.6 m in diameter)

FPU G band	FM system	64QAM3/4
Transmit frequency f [GHz]	13.0	13.0
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	35.2	35.2
Transmitting feeder loss Lt [dB]	1.7	1.7
Effective radiated power (WGt/Lt) [dBm]	70.5	64.4
Transmission distance d [km]	5.0	5.0
Free space propagation loss $(\lambda/4\pi d)^2$ [dB]	128.7	128.7
Receiving antenna diameter lr [m]	0.6	0.6
Receiving antenna gain Gr [dBi] (Antenna efficiency 50%)	35.2	35.2
Receiving feeder loss Lr [dB]	1.7	1.7
Annual rate of link unavailability (Rainfall)[%]	0.00125	0.00125
Required rainfall margin Zr [dB]	29.5	29.5
Received power Ci [dBm]	-54.2	-60.3
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	5.0	5.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-95.8	-96.9
Receiver thermal noise C/N [dB]	41.7	36.7
Required C/N [dB]	27.0	22.0
Rainfall margin [dB]	14.7	14.7

Examples of FPU Link Budget (G Band)

When using a transmitting antenna (0.6 m in diameter) and a receiving antenna (1.2 m in diameter)

FPU G band (Reception at the base station)	FM system	64QAM3/4
Transmit frequency f [GHz]	13.0	13.0
Transmission output power W [W]	5.00	1.23
Transmission output power W [dBm]	37.0	30.9
Transmitting antenna diameter lt [m]	0.6	0.6
Transmitting antenna gain Gt [dBi] (Antenna efficiency 50%)	35.2	35.2
Transmitting feeder loss Lt [dB]	1.7	1.7
Effective radiated power (WGt/Lt) [dBm]	70.5	64.4
Transmission distance d [km]	5.0	5.0
Free space propagation loss $(\lambda/4\pi\ d)^2$ [dB]	128.7	128.7
Receiving antenna diameter lr [m]	1.2	1.2
Receiving antenna gain Gr [dBi] (Antenna efficiency 47%)	41.0	41.0
Receiving feeder loss Lr [dB]	7.4	7.4
Annual rate of link unavailability Rainfall)[%]	0.00125	0.00125
Required rainfall margin Zr [dB]	29.5	29.5
Received power Ci [dBm]	-54.1	-60.2
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]	20.0	15.5
Signal bandwidth B [dBHz]	73.0	71.9
Receiver noise figure F [dB]	5.0	5.0
Receiver thermal noise $Ni = kT_0BF$ [dBm]	-95.8	-96.9
Receiver thermal noise C/N [dB]	41.7	36.7
Required C/N [dB]	27.0	22.0
Rainfall margin [dB]	14.7	14.7

Reference 2 Calculation Procedures for the Fading and Rain Attenuation Margins

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

1. Calculation procedure for the required fading margin

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

$Fmr = 10\log [k \times P_R/\{Pis(d/D) \times A\}]$

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

Pis: Required instantaneous link interruption rate 5×10^{-3}

d: Link interval distance (km)

D: Link distance (km)

Since single interval link 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: Propagation path length (km)

Q: Coefficient determined by propagation path conditions (Table below)

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

The average link height (h) in the table shall be calculated using the following equation:

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

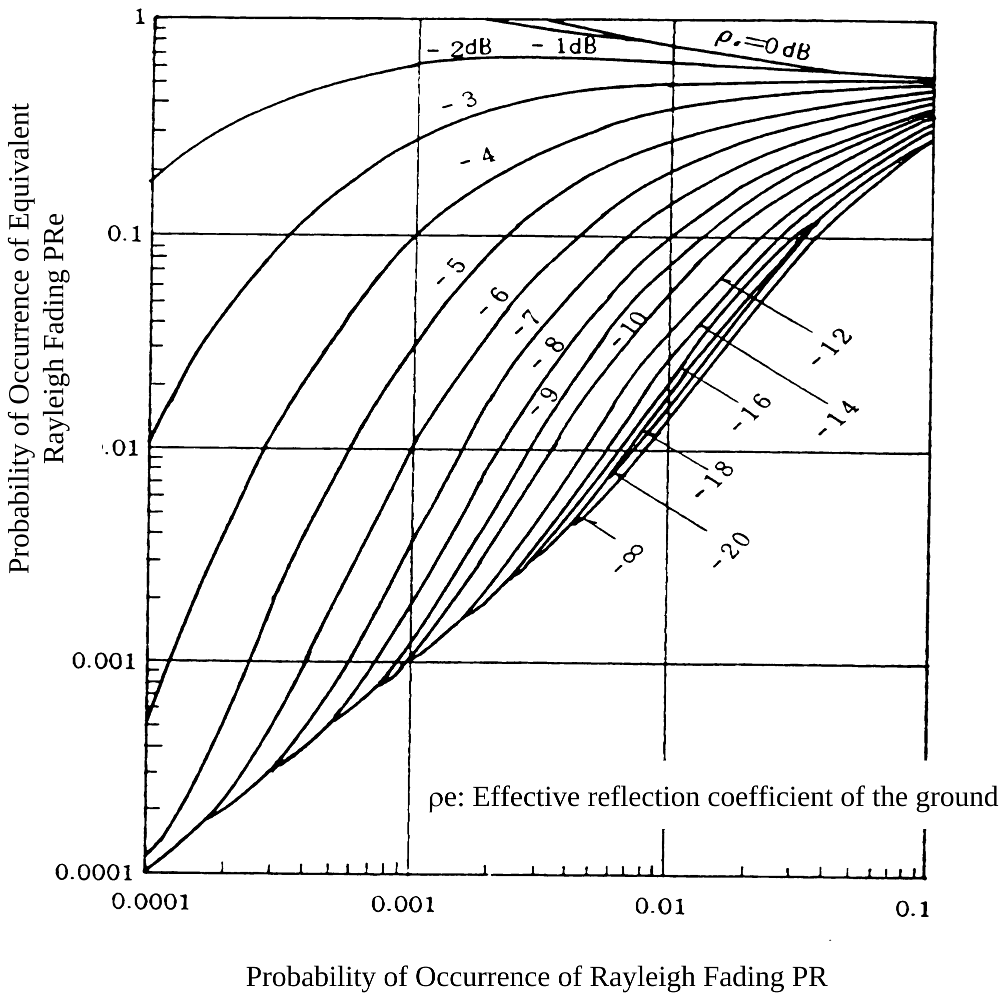
h_1, h_2: Altitude of the aerial at both stations (m)

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 of the transmitting and receiving antennae, ridge reflection loss 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. Calculation procedure for the rain attenuation margin

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 the annual rate of link unavailability, p%) shall be calculated using the following equation:

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

$Zp = (\gamma \times R_{0.0075\%}{}^{n}) \times d \times Tp \times Kp \times Cp$ [dB]

Here,

$R_{0.0075\%}$: 0.0075% value of the one minute cumulative rainfall distribution at each point [mm/min]

γ, α : Parameter for calculating the rainfall attenuation coefficient ($\gamma \times R_{0.0075\%}{}^{n}$)

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

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

$t = \log f$

f: Center frequency [GHz]

d: Link distance [km]

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

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

$S = \log p$ ($0.00001\% \leq p \leq 0.1\%$)

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

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

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

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

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

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

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

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

$Cp = \exp(-\beta \cdot d)$ ($0\text{ km} \leq d \leq 30\text{ km}$, $0.00001\% \leq p \leq 0.1\%$)

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

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

$s = \log p$ ($0.00001\% \leq p \leq 0.1\%$)

3. Examples of Calculating the Required Fading Margin and the Required Margin for Rain Attenuation

When the link condition is “transmission in flatland”, the required fading margin and the required margin for rain attenuation in Tokyo are shown in the tables below.

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

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

Required Margin for Rain Attenuation (Tokyo)

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

PORTABLE MICROWAVE DIGITAL TRANSMISSION SYSTEM
FOR TELEVISION PROGRAM CONTRIBUTION

ARIB STANDARD

ARIB STD-B11 Version 2.2-E1
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