ISDB-T technical seminar(2007) in Brazil

Section 3

Transmission system

June, 2007

Digital Broadcasting Expert Group (DiBEG)

Japan

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In this section, mainly the principle of channel coding and OFDM Modulation technology are presented.

Preface

Transmission system of ISDB-T is most feature of ISDB-T. Different from another DTTB standard, ATSC and DVB-T.

For examples, (1)One segment service within same bandwidth, (2)High performances for mobile/portable reception, (3)Robustness against multi-path and impulse noise, etc. These features re mainly led from ISDB-T transmission system.

So, it is very important to study the structure of ISDB-T transmission system for understanding the background of the features of ISDB-T.

This seminar document is prepared according ARIB STD-B31. But ,as described in seminar #2, SBTVD-T 01 is almost same as B31. Therefore, it is useful for Brazilian engineer to know this section.

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1. Outline of ISDB-T transmission system

1.1 Features of ISDB-T and technical baseline

1.2 Block diagrams of transmission system

1.3 transmission parameter

Requirement for transmission system →Solutions

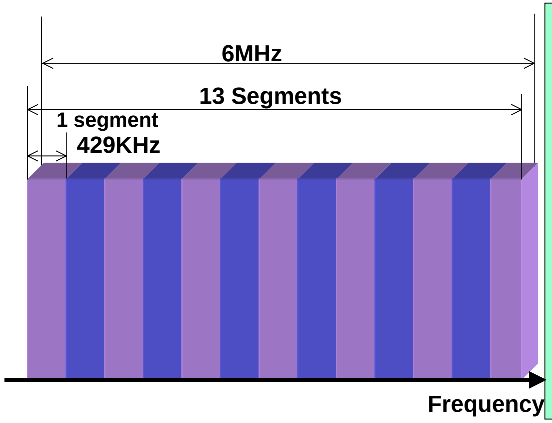
- **High-Quality, Multi-Channels** → -HDTV 1CH or SDTV 3CH within 6MHz band. / -Robustness against multi-path
- **Multimedia-Service** → -Integrated Service(Video/Audio/Data) / -High quality Data Service / -Bi-directional Service
- **Flexible/Versatile** → -Integrated Service(Video/Audio/Data) / -High quality Data Service / -Bi-directional Service
- **Efficient Spectrum utilization** → Single Frequency Network(SFN)
- **Mobile and handheld service** → -Robustness against mobile/portable reception / -fixed/mobile/portable service within same band / --- Layer Transmission Technology
- **Commonality of receiver** → - Commonality for BS/Cable/Terrestrial Broadcasting.

Features of ISDB-T transmission system

Technical Specification	Japanese Requirements for DTTB
OFDM	Robustness, SFN
Segment Structure	Extensible, Partial Reception
Time Interleaving	Mobile Reception, Indoor Reception
TMCC	Flexible, Versatile

ISDB-T system

Band Segmented OFDM : Orthogonal Frequency Division Multiplexing

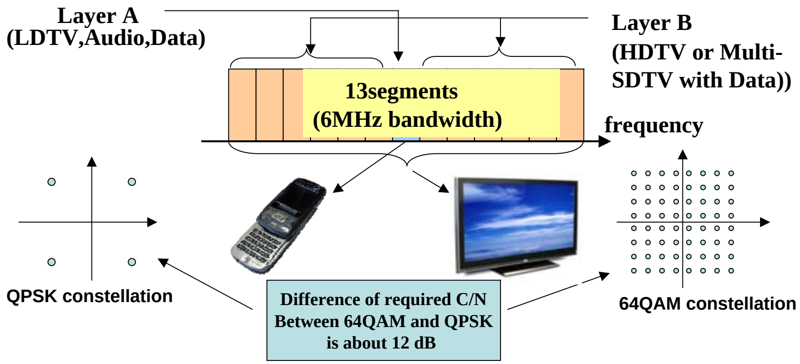


Features

- Modulation: DQPSK, QPSK, 16QAM, 64QAM
- 1HDTV or N SDTV/channel
- Net data rate: 23.42Mbps (6MHz)
- Single Frequency Network
- Mobile reception (time interleaving)

Segmented Structure and Partial Reception

(Example; 1seg + 12 seg)



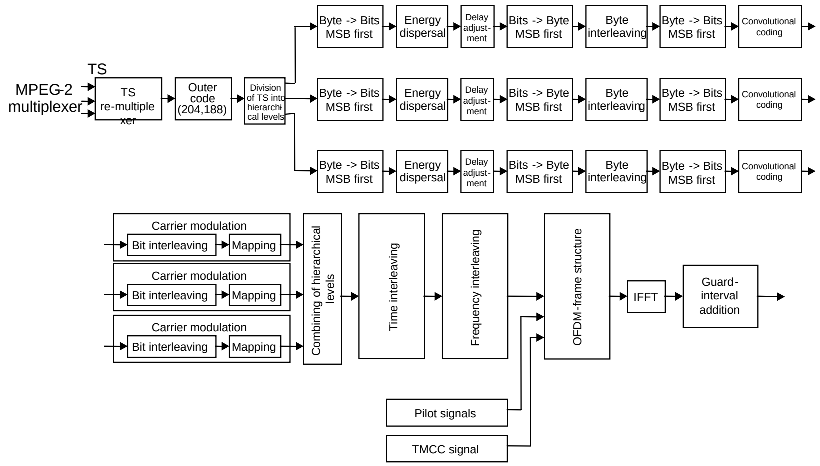
*13 segments are divided into layers, maximum number of layers is 3.

*Any number of segment for each layers can be selected (totally 13 segment)

*Transmission parameter sets of each layer can be set independently
(In above example, modulation index of each layer are different)

Feature of ISDB-T transmission system

1. Efficient frequency utilization
   (1)Adopt OFDM transmission system; SFN operation
   (2)Adopt hierarchical transmission; service for different type of reception in one frequency channel
2. Mobile/ handheld service in one transmission standard
   (1)Time interleave; Improve mobile reception quality
   (2)Partial reception; handheld service in same channel
3. Robustness against interference
   (1) Adopt concatenated error correction with plural interleave
   (2)Time interleave; very effective for impulse noise (urban noise)
4. Flexibility for several type of service/ reception style
5. Commonality of TV/audio transmission standard
6. Auxiliary (AC) channel can be used for transmission network management



Transmission system blockdiagram(B31 Fig.3-2)

Parameters of ISDB-T (6MHz Bandwidth)

ISDB-T mode	Mode 1 (2k)	Mode 2 (4k)	Mode 3 (8k)
Number of OFDM segment	13		
Useful bandwidth	5.575MHz	5.573MHz	5.572MHz
Carrier spacing	3.968kHz	1.984kHz	0.992kHz
Total carriers	1405	2809	4992
Modulation	QPSK , 16QAM , 64QAM , DQPSK		
Number of symbols / frame	204		
Active symbol duration	252 μs	504 μs	1.008ms
Guard interval duration	1/4 , 1/8 , 1/16 , 1/32 of active symbol duration		
Inner code	Convolutional code (1/2 , 2/3 , 3/4 , 5/6 , 7/8)		
Outer code	RS (204,188)		
Time interleave	0 ～ 0.5s		
Useful bit rate	3.651Mbps ～ 23.234Mbps		

Equation for calculating bit rate

STEP 1: calculate the bit rate of one(1) segment

ISDB-T is composed 13 segments, so, to calculate transmission bit rate, at first, calculate the bit rate of one(1) segment, and multiply number of Segment of each layer. Then lead total bit rate of each layer

(1) reed-Solomon coding rate; (188/204), fixed value

(2) r: convolutional coding rate(depends on coding rate)

(3) M: modulation index(bit/ symbol); QPSK=2, 16QAM=4 , 64QAM=6

(4) Ts/(Ts+Tg); ratio of total symbol length and effective symbol length

(5) (effective data carrier)/(total carrier) =96/108 – fixed value for mode 1, 2, 3
(note) total carrier; including pilot carrier, TMCC, and scattered pilot symbol

(6)Nf : Number of carrier in one segment; mode 1=108,mode 2=216, mode 3=432

(7) fd: carrier spacing = effective symbol transmission speed
mode 1=(6/14)/108*10^3 kHz=3.9682540kHz, mode 2= (1/2) of mode 1
mode 3=(1/4) of mode 1

(note) (6/14)*10^3 kHz = bandwidth of one(1) segment

Example

Mode 3, guard interval ratio=1/16, modulation=QPSK, coding rate(r)=2/3

Bit rate of 1 segment=0.9920635 *432 * (16/17) * 2 * (2/3) * (188/204) =440.56 kbps

fd Nf Ts/(Ts+Tg) M r RS coding rate

STEP 2 : multiply number of segment (Nseg)

Example 1 : 1 layer fixed reception, mode 3, guard interval ratio=1/16,

Modulation =64QAM, coding rate(r)=3/4 Number of segment

Bit rate of 1 segment=0.9920635 *432 * (16/17) * 6 * (3/4) * (188/204) * 13 =19.329 Mbps

Example 2 : 2 layer ,1 segment for portable, 12 segment for fixed

Layer A: Nseg=1, mode 3, Tg/Ts=1/16, M=2(QPSK), r=2/3

Bit rate of A layer=0.9920635 *432 * (16/17) * 2 * (2/3) * (188/204) * 1 =440.56 kbps

Layer B: Nseg=12, mode 3, Tg/Ts=1/16, M=6(64QAM), r=3/4

Bit rate of A layer=0.9920635 *432 * (16/17) * 6 * (3/4) * (188/204) * 12 =17.842 Mbps

2. Segment construction and Hierarchical Transmission

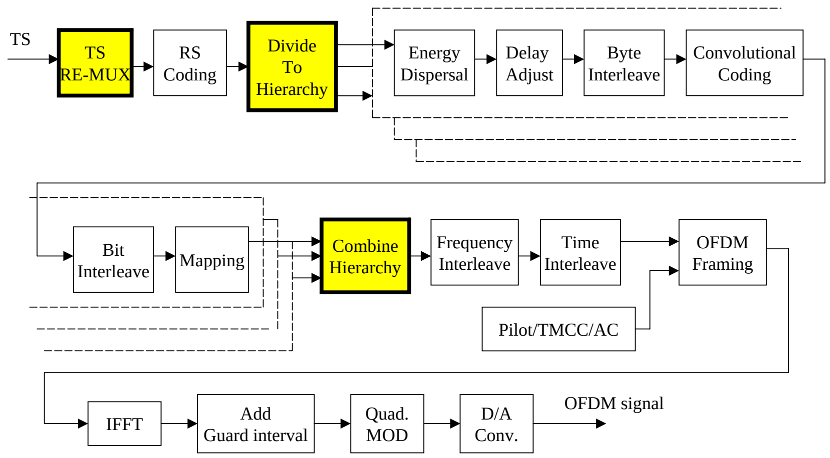
2.1 Concept and feature of hierarchical transmission system

2.2 The rules of hierarchical transmission

2.3 Segment construction and hierarchical transmission

Relating clause of ARIB standard; B31 clause 3.2

Blockdiagram of ISDB-T Transmission coding



These functions are presented in this section

2.1 Concept and feature of hierarchical transmission system

Hierarchical transmission is the feature of ISDB-T, this concept is not in DVB-T system. The concept of hierarchical transmission system is shown in figure.2-1after.

The transmission parameters can be assigned as each service ID. This transmission system is called **"hierarchical transmission"**

For example, the service which should be strong against interference such as noise should be assigned to QPSK layer, other service is assigned to 64QAM layer.

In this case, service of QPSK layer could be received under serious receiving condition such as handheld reception.

In case of DVB-T system, for handheld reception service, another frequency should be prepared separately. But, in ISDB-T system, different reception service can be achieved within one frequency channel by making use of this transmission system.,

TSP's are divided into plural layers at Re-multiplexer, and re-arranged in each layer. After re-arranged, these TSP's are combined to 1 transport stream and feed to OFDM modulator. (see figure. 2-2)

Fig.2-1 Image of hierarchical transmission

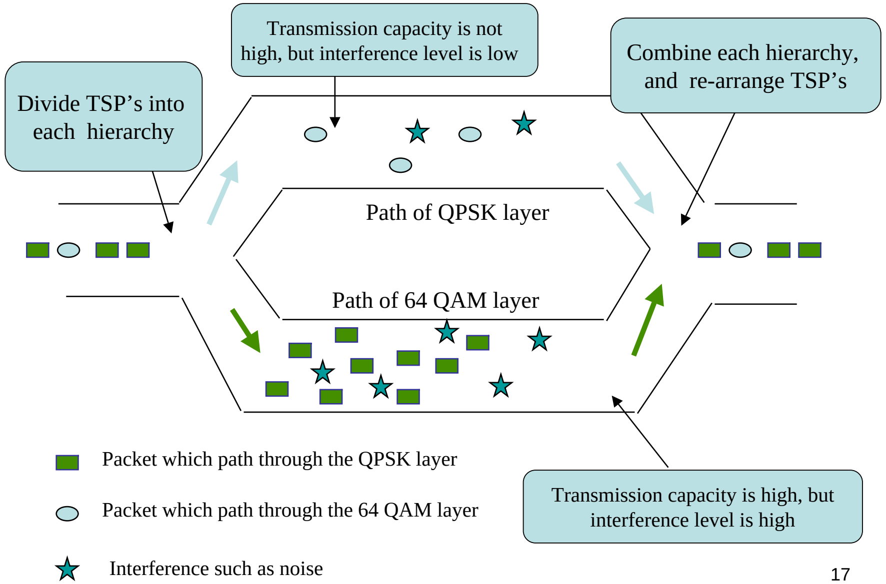


Fig. 2-2 Blockdiagram of TS re-multiplexer

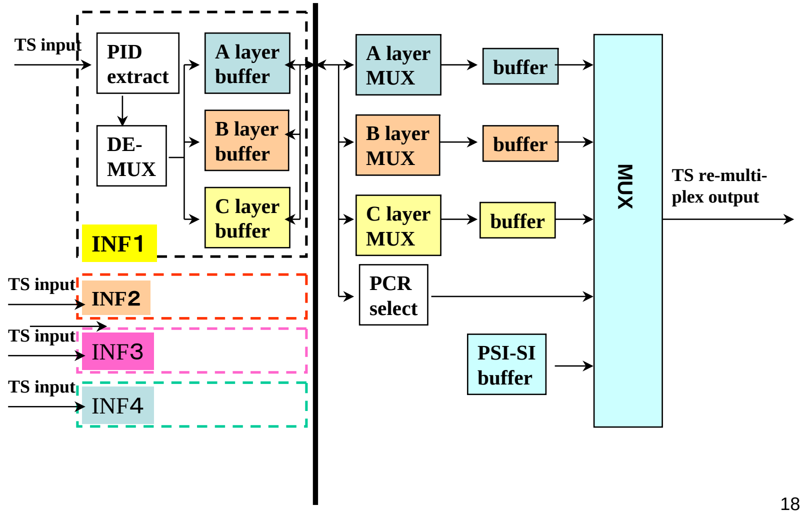
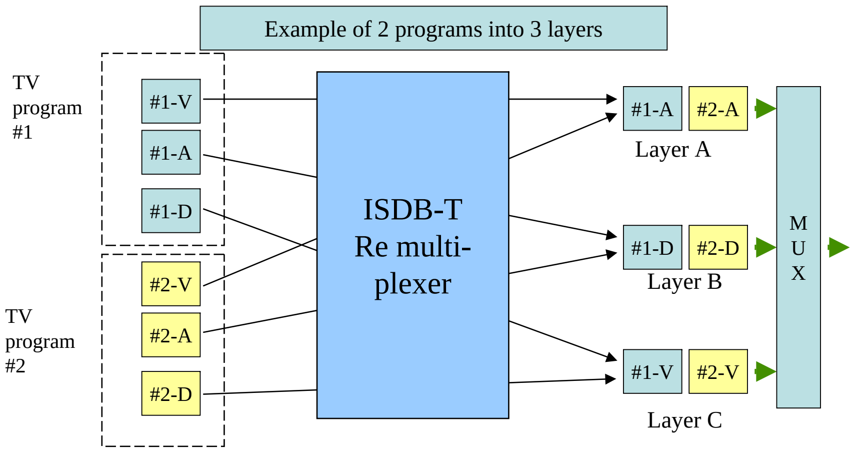


Fig. 2-3 Image of multiple layer transmission



2.2 The rules of hierarchical transmission

(a) The strongest hierarchy layer should be able to be demodulated and decoded alone .
Reason; to be able to demodulate and decode, PCR and minimum required PSI should be transmitted by strongest layer. (see Fig.2-4)

(b) Transmission delay difference between hierarchy should be compensated at the transmission side. The compensated transport stream is called "Multi-frame pattern"
Image of Multi-frame pattern is shown in Fig. 2-5 later

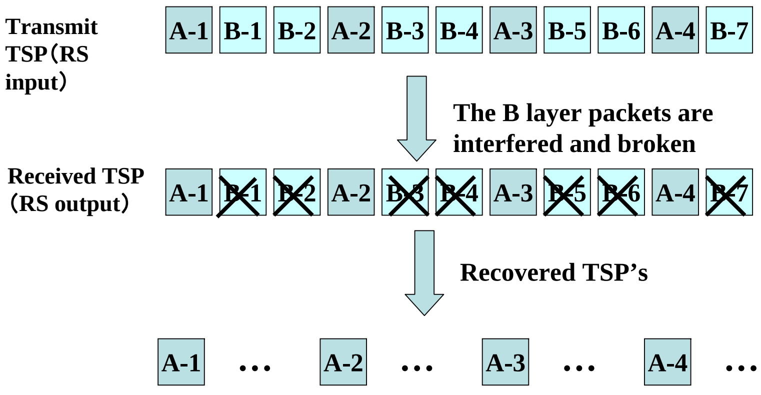
(c) Multi-frame pattern should be completed within 1 OFDM frame.

(d) The number of packet in 1 segment should be integer in any combination of transmission parameter and coding rate.
Reason; minimum unit of hierarchical transmission is the segment.

(e) Even though the information transmission speed is different because of its transmission parameters, the clock rate of TS at the output of receiver RS decoder should be constant(for TV, clock rate is 4fs). To adjust the clock rate, Null packets are inserted. See details in fig. 2-6 later.

Fig. 2-4 Concept of hierarchical transmission

(strongest layer should be recovered alone)



TSP's of layer A should include PCR and minimum required PSI which are necessary to recover TSP

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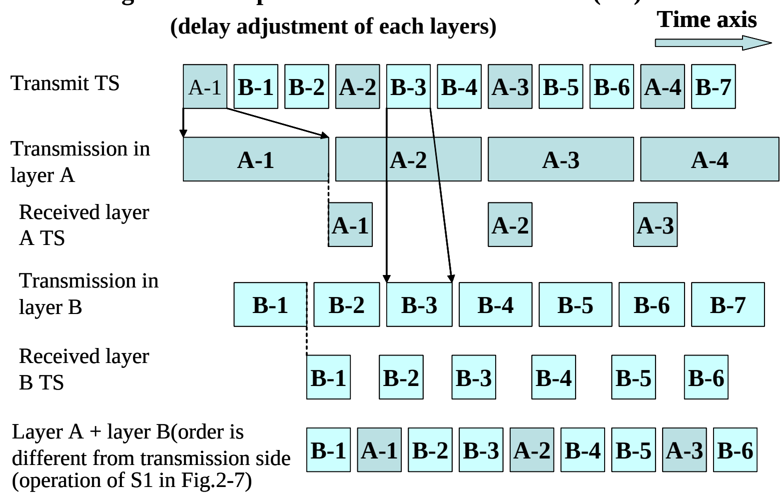
Fig. 2-5 Concept of hierarchical transmission(1/2)

(delay adjustment of each layers)



As shown above, Transmission delay of each layer is different according to each layer transmission parameter set. As a result, because of its transmission parameter set. Therefore, order of TSPof receiver side is different from transmitter side

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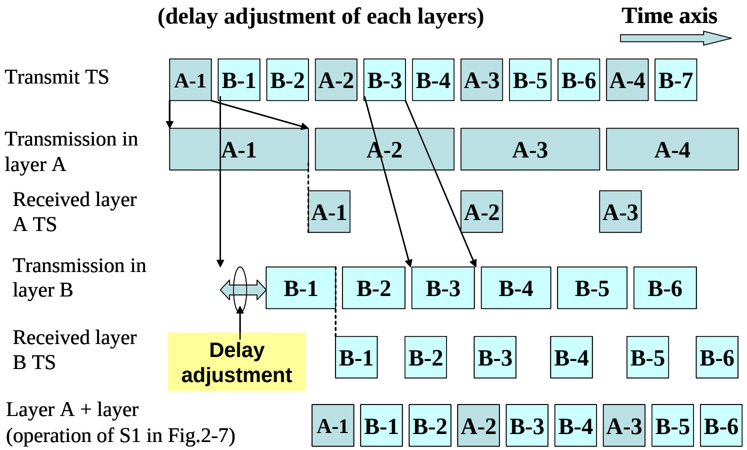
Fig. 2-5 Concept of hierarchical transmission(2/2)

(delay adjustment of each layers)



As shown above, delay adjustment is inserted at transmitter side. As a result, same order of TSP is recovered in receiver side.

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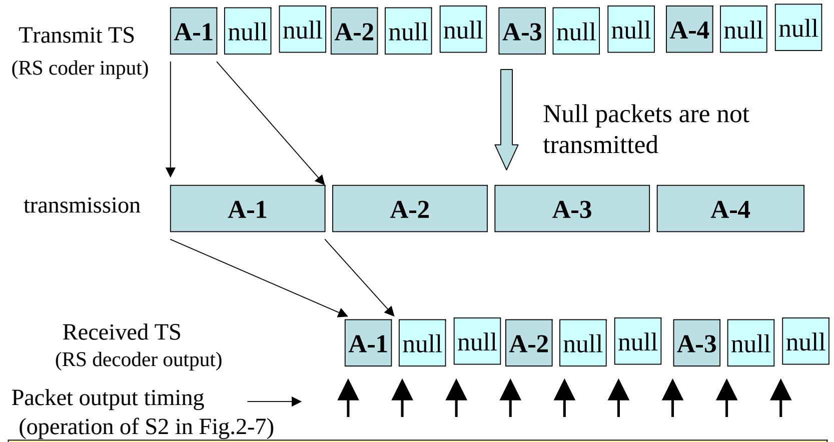
Fig. 2-6 Concept of hierarchical transmission

(How to adjust constant clock rate)



At the output portion of receiver RS decoder, TS is read by same clock rate of transmit TS (for TV, clock rate is 4fs). At the timing of head packet, packet does Not decoded yet, in this case, RS decoder feeds null packet. If decoded, RS decoder feeds decoded packet.

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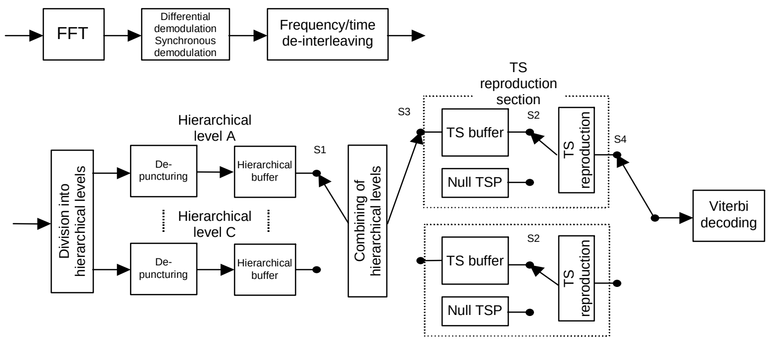
Figure 2-7 Model receiver for multi-frame reproducing



S1; select the layer. If all data of 1 packet has been input to buffer, S1 select the buffer and send data to next stage

S2; select TS/Null packet, according to TS buffer status

2.3 Segment construction and hierarchical transmission

Segment of ISDB-T is the concept for hierarchical transmission. The segment is decided as follows considering the rule shown in clause 2.2

(1) Number of TSP in one OFDM frame is integer for all cases of transmission parameter set. Number of TSP is shown in Table 2-1.

(2) For easy tuning operation of receiver, bandwidth of 1 segment is set to 6/14 MHz.

(3) Number of multi-frame pattern is proportional to number of set of hierarchy. For this reason, number of hierarchy is limited as many as 3.

Table 2-1 Number of TSP in one OFDM frame

(mode 1)

coding rate / modulation	1/2	2/3	3/4	5/6	7/8
DQPSK／QPSK	**12**	**16**	**18**	**20**	**21**
16QAM	**24**	**32**	**36**	**40**	**42**
64QAM	**36**	**48**	**54**	**60**	**63**

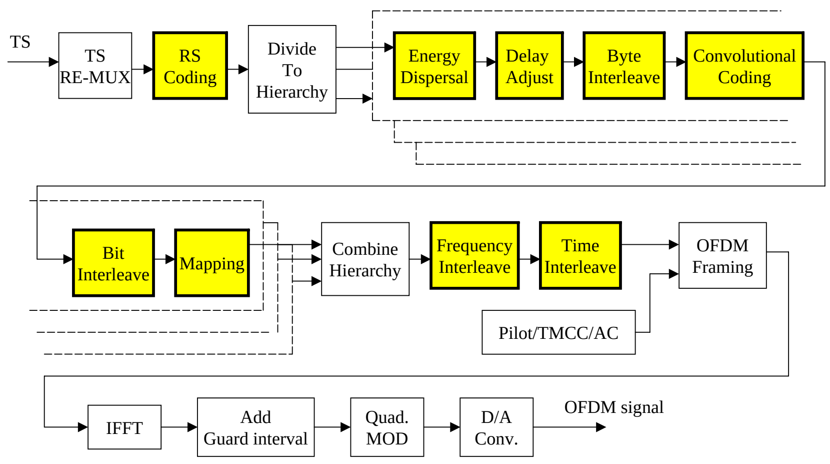
(note1) number of TSP/segment

(note 2) in case of mode 2 , number of TSP is twice , and in case of mode 3, four times

3. Channel coding

Relating clause of ARIB standard; B31 clause 3.3 – clause 3.11

Blockdiagram of ISDB-T Transmission coding



These functions are presented in this section

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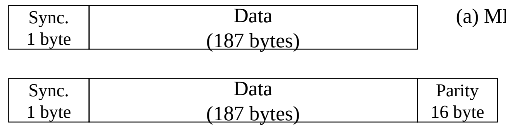
Outer coder (Reed-Solomon coding)

A shortened Reed-Solomon code (204,188) is used in every TSP as an outer code. The shortened Reed-Solomon (204,188) code is generated by adding 51-byte 00HEX at the beginning of the input of the data bytes of Reed-Solomon (255,239) code, and then removing these 51 bytes.
The GF (28) element is used as the Reed-Solomon code element. The following primitive polynomial p (x) is used to define GF (28):
p (x) = x8 + x4 + x3 + x2 + 1
Note also that the following polynomial g (x) is used to generate (204,188) shortened Reed-Solomon code:
g (x) = (x - λ0) (x - λ1) (x - λ2) ---- (x - λ15) provided that λ = 02 HEX



(b) TSP error-protected by RS code (transmission TSP)

MPEG2 TSP and Transmission TSP(B31, Fig. 3-6)

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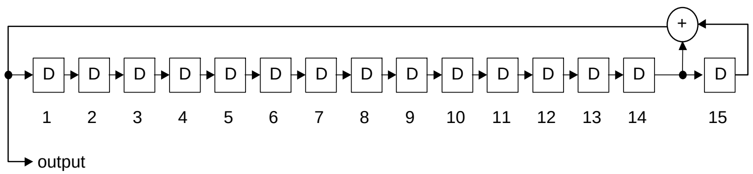
Energy Dispersal

Energy dispersal is conducted at each hierarchical layer using a circuit, shown in Fig. 3-8, that is generated by a PRBS (Pseudo Random Bit Sequence). All signals other than the synchronization byte in each of the transmission TSPs at different hierarchical layers are EXCLUSIVE ORed using PRBSs, on a bit-by-bit basis.

$$g(x) = X^{15} + X^{14} + 1$$



PRBS-Generating Polynomial and Circuit (B31,Fig. 3-8)

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Inner coding

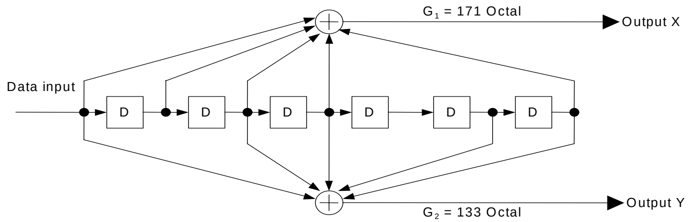

Fig. 3-10: Coding Circuit of a Convolutional Code with Constraint Length k of 7 and a Coding Rate of 1/2

Coding rate	Puncturing pattern	Transmission-signal sequence
1/2	X : 1 Y : 1	X1, Y1
2/3	X : 1 0 Y : 1 1	X1, Y1, Y2
3/4	X : 1 0 1 Y : 1 1 0	X1, Y1, Y2, X3
5/6	X : 1 0 1 0 1 Y : 1 1 0 1 0	X1, Y1, Y2, X3 Y4, X5
7/8	X : 1 0 0 0 1 0 1 Y : 1 1 1 1 0 1 0	X1, Y1, Y2, Y3, Y4, X5, Y6, X7

Table 3-8: Inner-Code Coding Rates and Transmission-Signal Sequence

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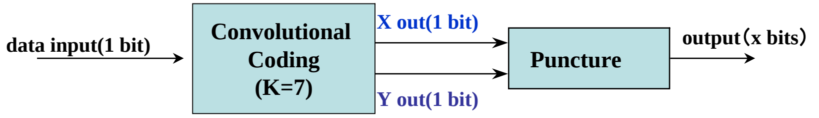
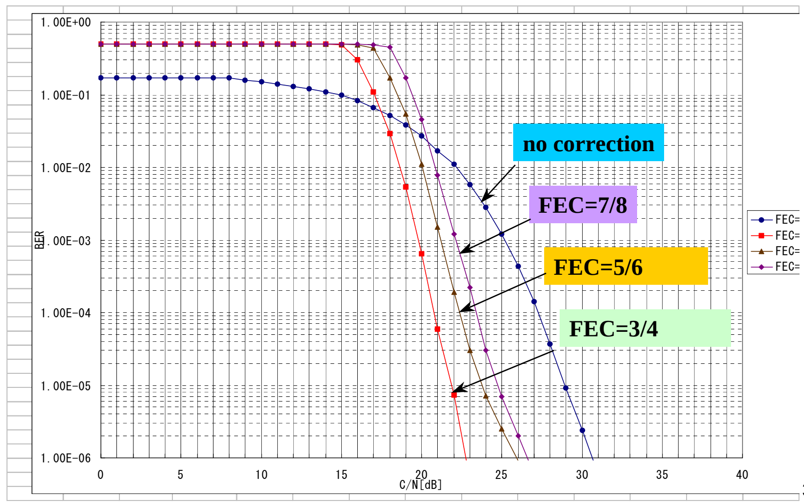
Puncturing Pattern



coding rate	Number of input bits	Number of output bits	Puncturing pattern	Output of puncturing
1/2	1	2	X:1 Y:1	X1, Y1 (2)
2/3	2	4	X: 10 Y: 11	X1, Y1, Y2 (3)
3/4	3	6	X: 101 Y: 110	X1, Y1, Y2 ,Y3 (4)
5/6	5	10	X: 10101 Y: 11010	X1, Y1, Y2 ,Y3 ,Y4, Y5 (6)
7/8	7	14	X: 1000101 Y: 1111010	X1, Y1, Y2 ,Y3 ,Y4, Y5,Y6,Y7 (8)

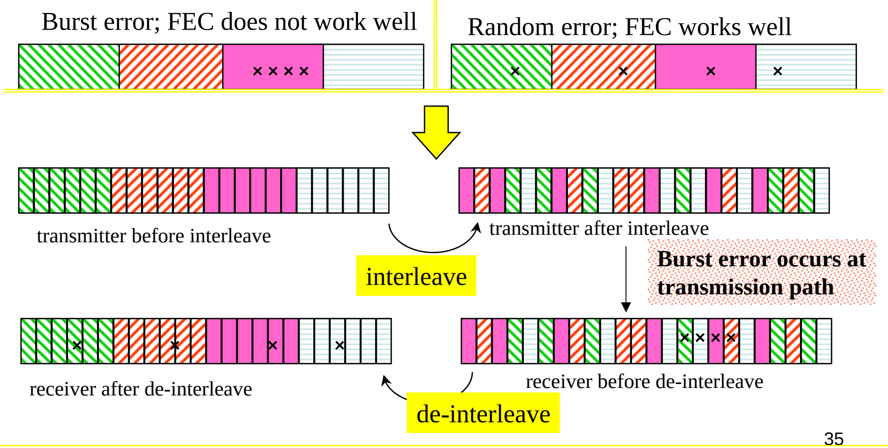
Example of input C/N vs BER characteristics

Mode;1 GI=1/8, 64QAM, I=0, RS;OFF

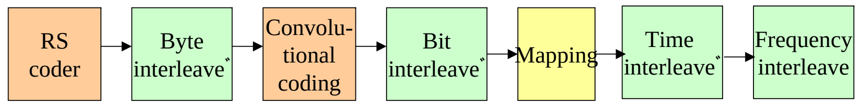


Effect of interleave

Interleave is one of important technology in transmission system.
Error correction system is most effective when the characteristics of noise is random.
The purpose of interleave is to randomize the burst error occurred in transmission path



Kind of interleave and these effect



Byte interleave
Byte interleave is located between outer coder and inner coder. Randomize the burst error of Viterbi decoder output

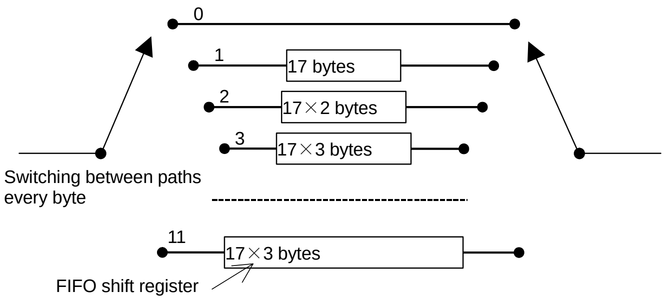
Bit interleave
Bit interleave is located between convolutional coding and mapping. Randomize the symbol error before Viterbi decoding

Time interleave
Time interleave is located at the output of maping(modulation). And randomize the burst error of time domain which is mainly caused by impulse noise, fading of mobile reception, etc.

Frequency interleave
Frequency interleave is located at the output of time interleave. Randomize the burst error of frequency domain which is mainly caused by multi-path , carrier interference, etc.

Byte interleave

The 204-byte transmission TSP, which is error-protected by means of RS code and energy-dispersed, undergoes convolutional byte interleaving. Interleaving must be 12 bytes in depth. Note, however, that the byte next to the synchronization byte must pass through a reference path that causes no delay.



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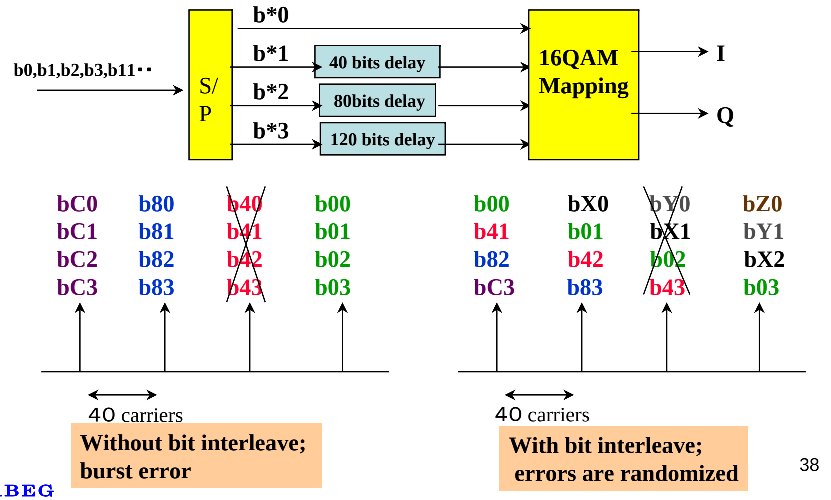
Bit interleave

(B31, clause 3.9.3)

Bit interleave circuit is different according to carrier modulation. Following diagram is a example of 16QAM.



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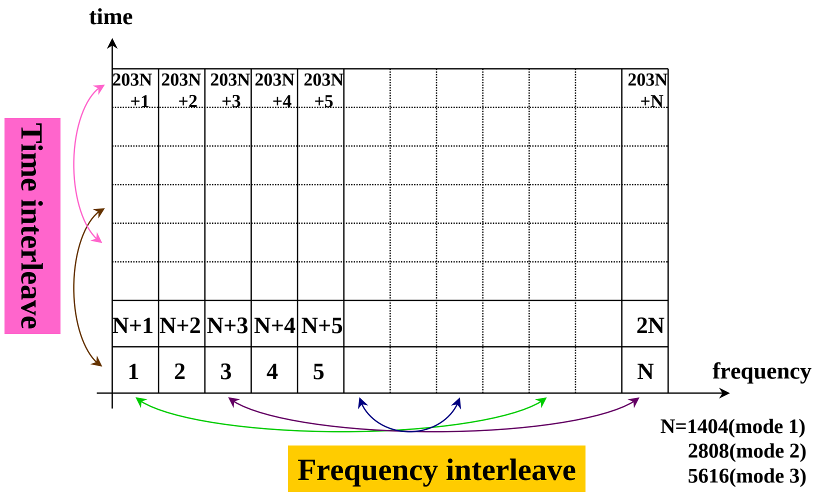
Relation between OFDM frame and interleave



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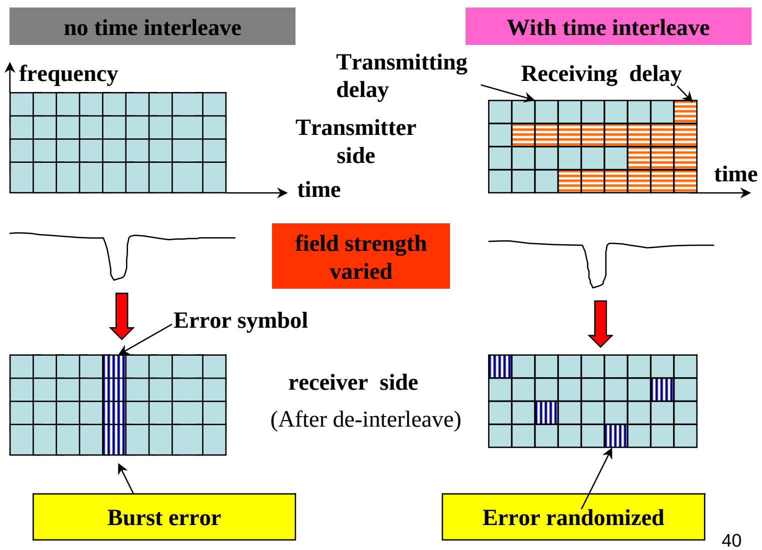
Effect of time interleave



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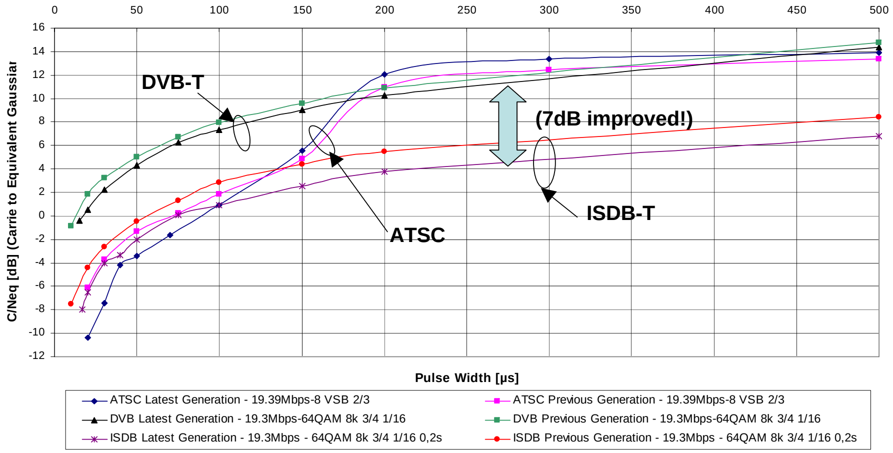
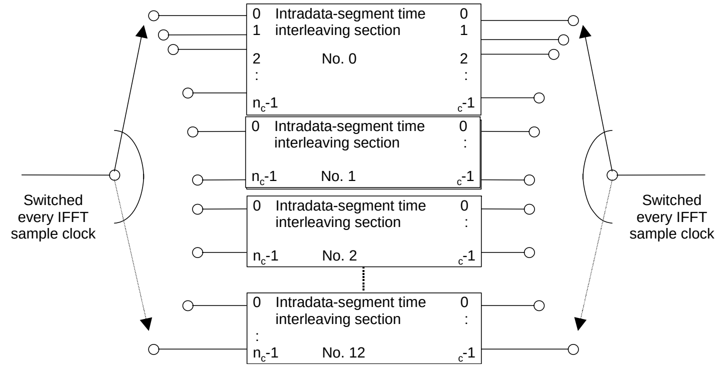
3-2. What is the merit of Time- Interleave? (2/2)

•How much improved by using Time- Interleave

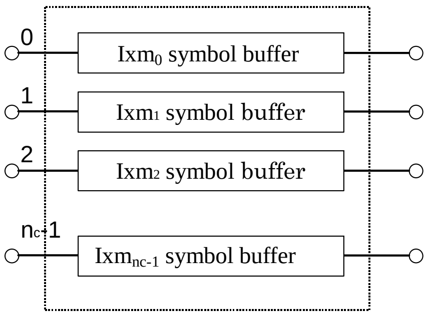
Following graph shows degradation by impulse noise, which is dedicated by Mackenzie Presbyterian University measured in Autumn , 2005



7dB improved ➡ Transmitter power reduced to 1/5 !!



Time interleaver blockdiagram(B31, 3.11.1)



Provided that mi = (i × 5) mod 96

nc is 96, 192, and 384 in modes 1, 2, and 3, respectively.

Fig. 3-23: Configuration of the Intra-segment Time Interleaving Section

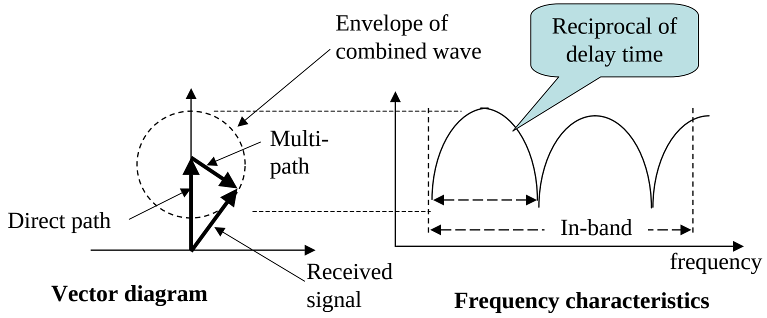
Table 3-12: Time Interleaving Lengths and Delay Adjustment Values

Mode 1			Mode 2			Mode 3		
Length (I)	Number of delay-adjustment symbols	Number of delayed frames in transmission and reception	Length (I)	Number of delay-adjustment symbols	Number of delayed frames in transmission and reception	Length (I)	Number of delay-adjustment symbols	Number of delayed frames in transmission and reception
0	0	0	0	0	0	0	0	0
4	28	2	2	14	1	1	109	1
8	56	4	4	28	2	2	14	1
16	112	8	8	56	4	4	28	2

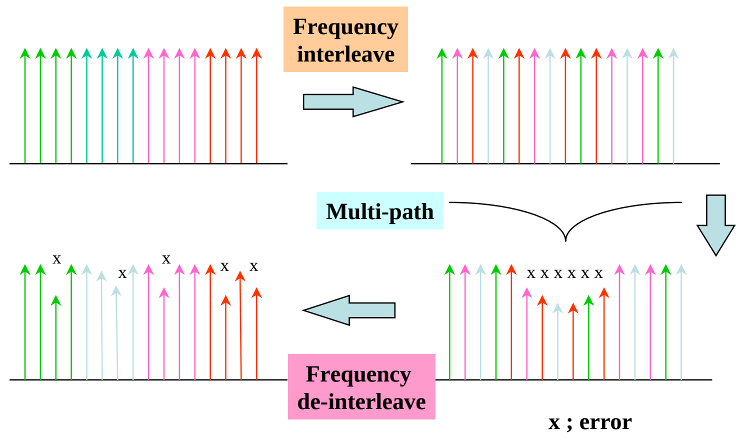
(Notification)

Frequency characteristics distortion caused by multi-path

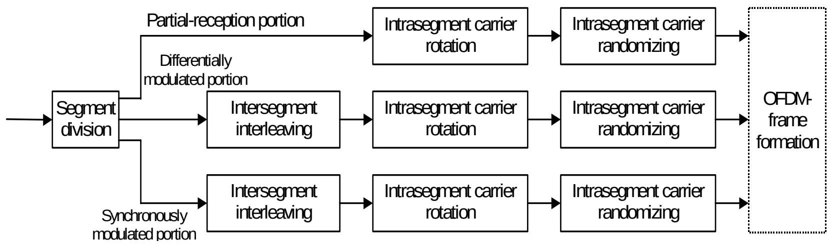
This drawing shows the effect of multi-path. As shown, received signal level is varied in frequency domain.



Effect of frequency interleave



As shown above, function of frequency interleave is to disperse the error caused by multi-path



Configuration of frequency interleaving section

The input signal must be 2 bits per symbol and QPSK-mapped to output multi-bit I- and Q-axes data. To conduct mapping, the 120-bit delay element shown in Fig. 3-14 is inserted into the mapping input for bit interleaving.
Figs. 3-14 and 3-15 show the system diagram and mapping constellation, respectively.

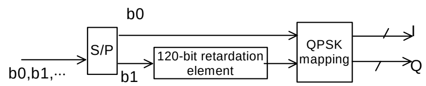


Fig. 3-14: QP 120-bit delay element System Diagram

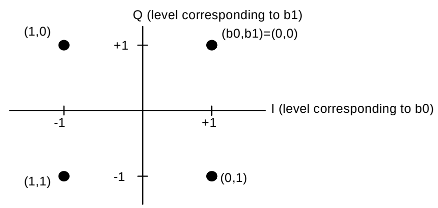


Fig. 3-15: QPSK Constellation

Mapping

The input signal must be 4 bits per symbol and 16QAM-mapped to output multi-bit I- and Q-axes data. To conduct mapping, the delay elements shown in Fig. 3-16 are inserted into b1 to b3 for bit interleaving.
Figs. 3-16 and 3-17 show the system diagram and mapping constellation, respectively.

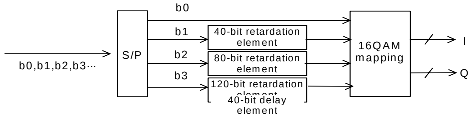


Fig. 3-16: 16QAM System Diagram

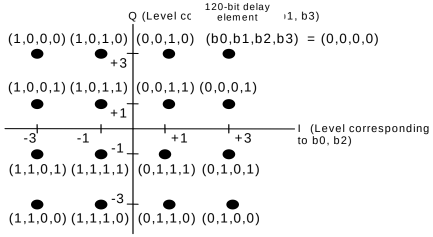


Fig. 3-17: 16QAM Constellation

Mapping

DiBEG

Required C/N (dB) (note)

Modulation	Coding rate 1/2	2/3	3/4	5/6	7/8
QPSK	4.9	6.6	7.5	8.5	9.1
DQPSK	6.2	7.7	8.7	9.6	10.4
16QAM	11.5	13.5	14.6	15.6	16.2
64QAM	16.5	18.7	20.1	21.3	22.0

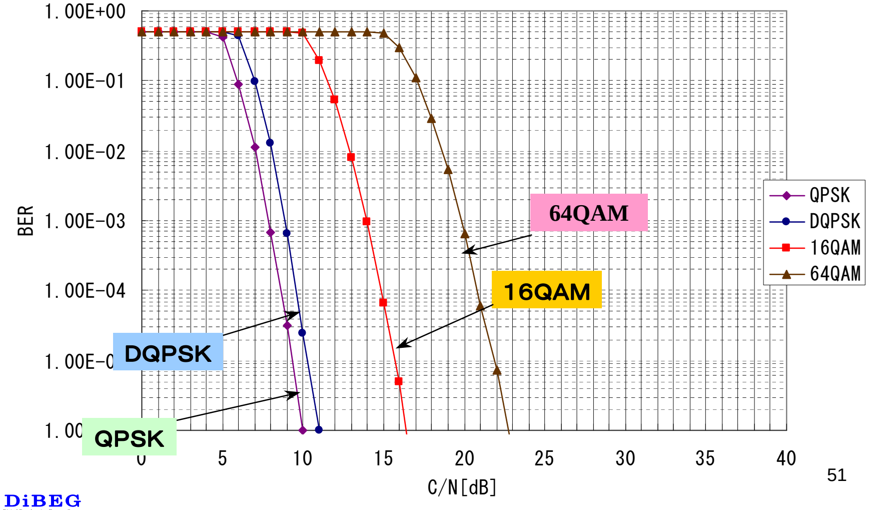
(note) after Viterbi decoding, BER is as much as $2*10^{-4}$

Note: these data are simulation data at early stage, but recently, receiver LSI shows more good data.

DiBEG

Input C/N vs BER characteristics

Mode; 1, GI=1/8 FEC=3/4, RS=OFF



DiBEG

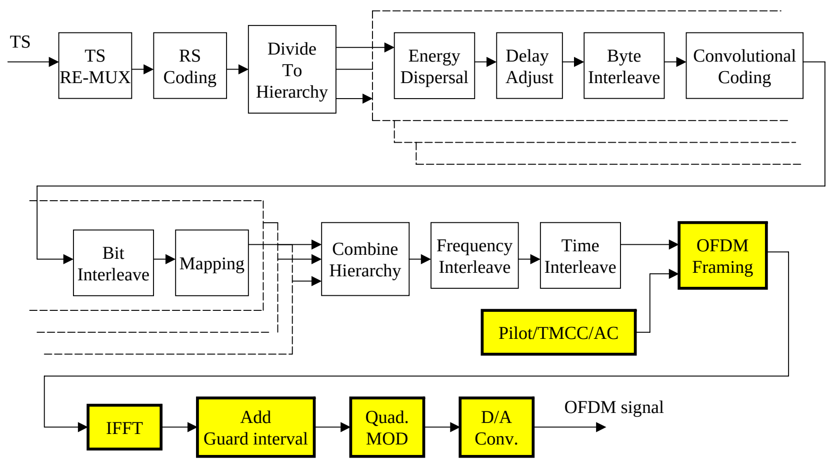
4. OFDM modulation

(1) IFFT
(2) Pilot signal
(3) AC
(4) TMCC
(5) Guard interval
(6) Quad. Modulation and RF format

Relating clause of ARIB standard; B31 clause 3.12 – clause 3.15

DiBEG

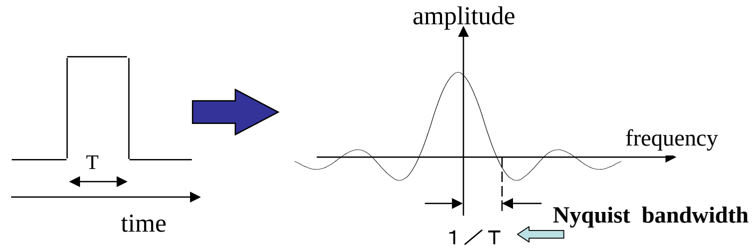
Blockdiagram of ISDB-T Transmission coding



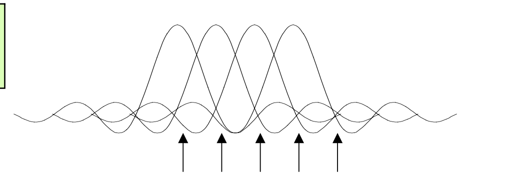
These functions are presented in this section

Nyquist separation and orthogonal FDM

Fourier transform and inverse FFT

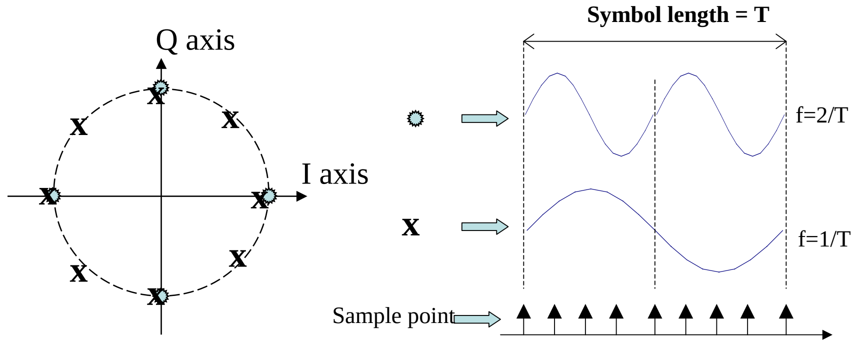


Orthogonal division multiplex



At the adjacent carrier position ,all other carrier energy is zero.

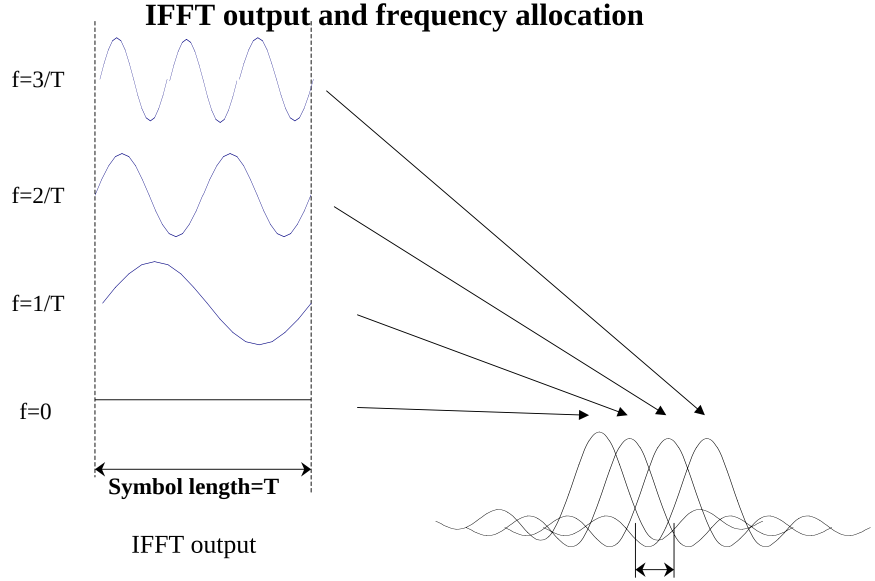
OFDM signal generation by IFFT



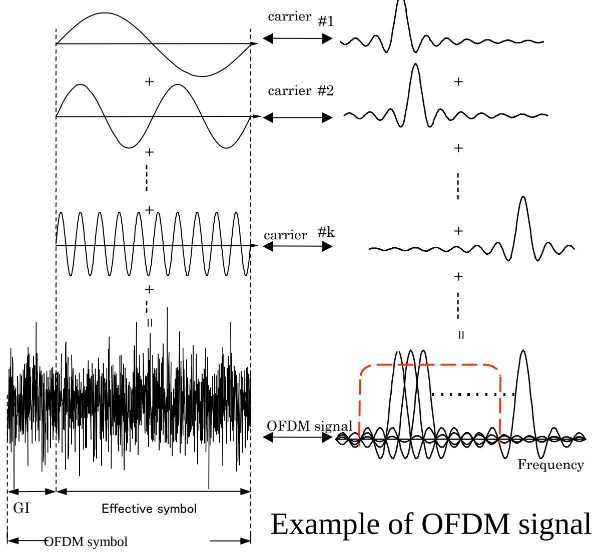
X; Sample point to generate sine wave of f=1/T cycle

Sample point to generate sine wave of f=2/T cycle

IFFT output and frequency allocation



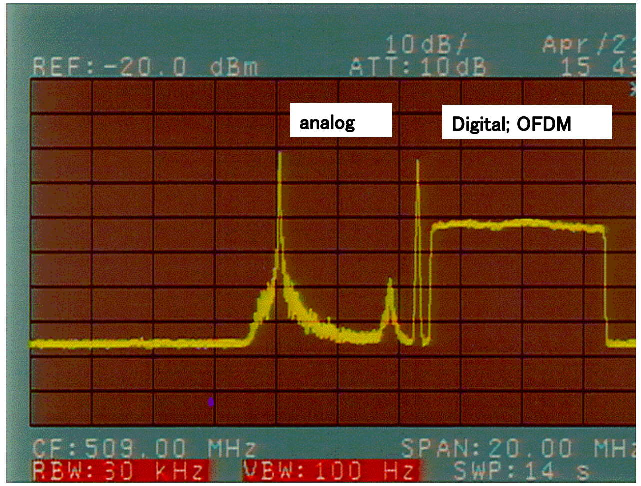
Freq. separation=1/T



Example of OFDM signal waveform

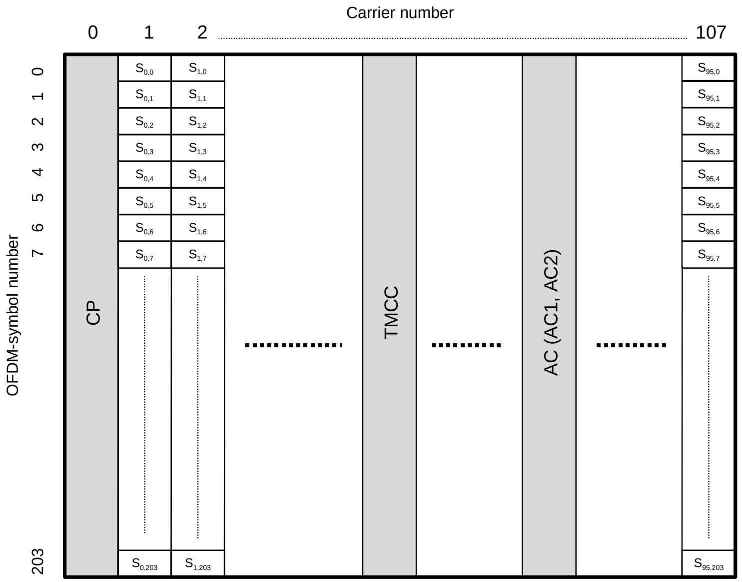
DiBEG

TV signal spectrum



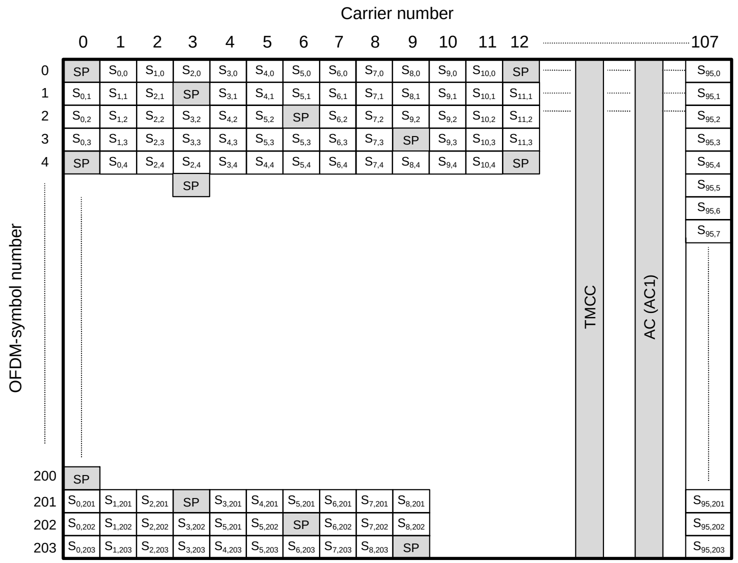
DiBEG

OFDM frame structure (DQPSK, mode 1)



DiBEG

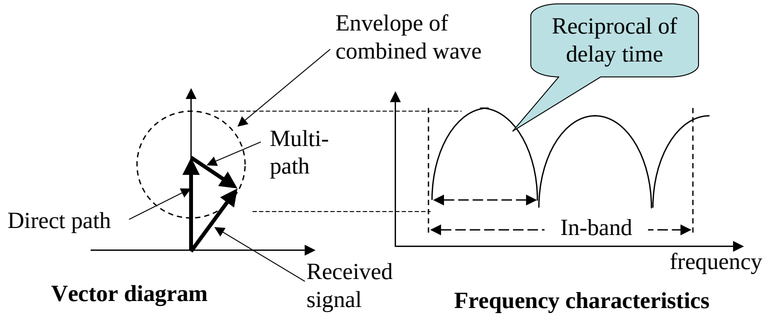
OFDM frame structure (QPSK, 16QAM, 64QAM, mode 1)



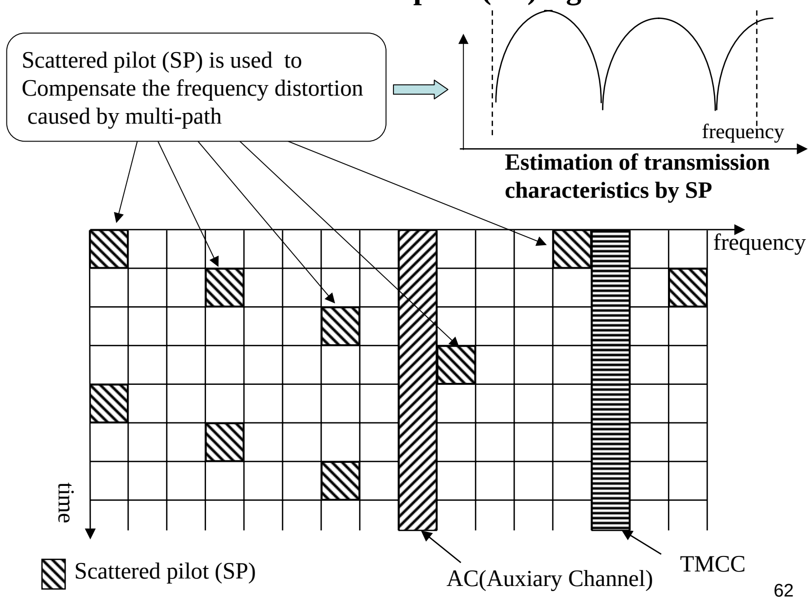
DiBEG

Frequency characteristics distortion caused by multi-path

This drawing shows the effect of multi-path. As shown, received signal level is varied in frequency domain.



Effect of scattered pilot (SP) signal



Example of AC, TMCC (mode 1, QPSK,16QAM, 64QAM)

(a) AC and TMCC Carrier Arrangements in Mode 1

Segment No.	11	9	7	5	3	1	0	2	4	6	8	10	12
AC1_ 1	10	53	61	11	20	74	35	76	4	40	8	7	98
AC1_ 2	28	83	100	101	40	100	79	97	89	89	64	89	101
TMCC 1	70	25	17	86	44	47	49	31	83	61	85	101	23

What is AC?

AC; (Auxiliary Channel)
AC is a channel designed to convey additional information on modulating signal-transmission control.
AC's additional information is transmitted by modulating the pilot carrier of a type similar to CP through DBPSK. The reference for differential modulation is provided at the first frame symbol, and takes the signal point that corresponds to the Wi value stipulated in Section 3.13.1.

- Details of AC is specified in ARIB STD-B31 reference
- Recently, new utilization of AC has been proposed, that is, the transmission network management information can be carried to relay station by using AC. Details will be explained in seminar #9

In DVB-T system, CP is inserted for carrier synchronization instead of AC, but CP cannot carry any information. This is the feature of AC

TMCC; transmission management and configuration control signal

The TMCC signal is used to convey information on how the receiver is to perform demodulation of information such as the hierarchical configuration and the OFDM-segment transmission parameters.

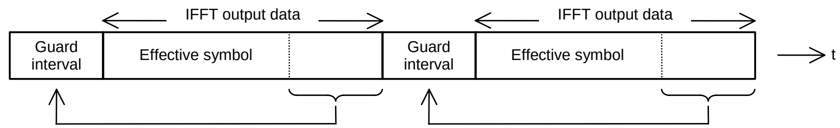
Table 3-20: Bit Assignment

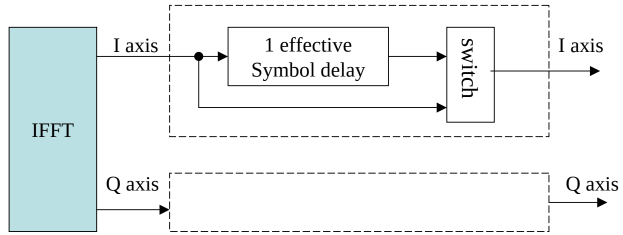
B_0	Reference for differential demodulation
$B_1 - B_{16}$	Synchronizing signal (w0 = 0011010111101110, w1 = 1100101000010001)
$B_{17} - B_{19}$	Segment type identification (differential: 111;synchronous: 000)
$B_{20} - B_{121}$	TMCC information (102 bits)
$B_{122} - B_{203}$	Parity bit

See details of TMCC information in 3.15.6 of ARIB STD-B31

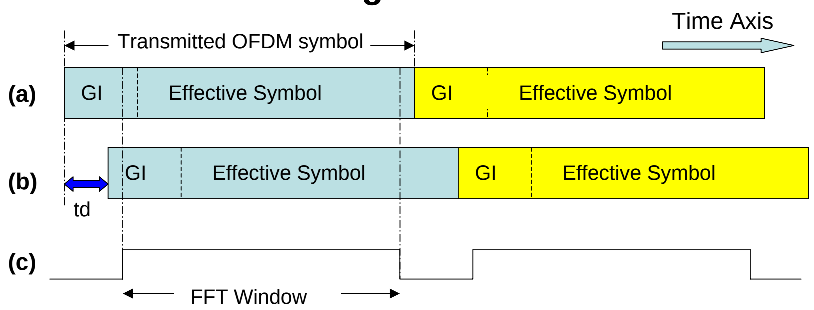
Guard interval

A guard interval, the latter part of the IFFT (Inverse Fast Fourier Transform) data output for the specified duration, is added without any modification to the beginning of the effective symbol. This operation is shown in Fig. 3-33.





Effect of guard interval



(a) : Direct wave from transmitter, (b) : reflected wave (multi-path wave)

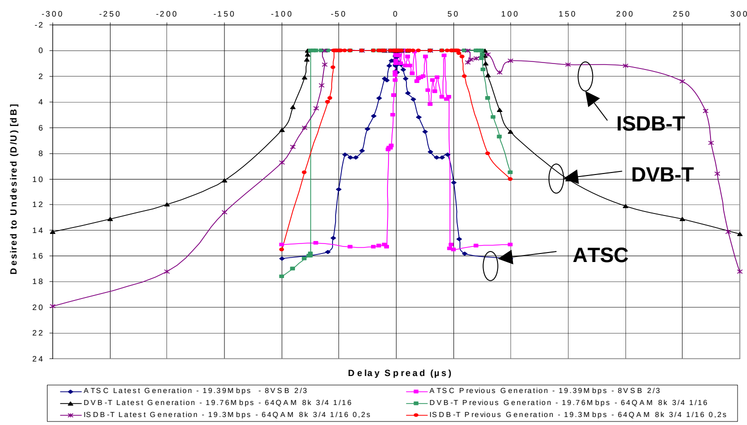
GI: Guard Interval , td: delay time of multi-path, (c) FFT window of receiver

FFT window of receiver cuts a signal with Ts (effective symbol) length, this signal is fed to FFT to demodulate OFDM signal. If FFT window can be set within the interval of "transmitted OFDM symbol", Inter Symbol Interference (ICI) is not occurred.
As a result, if multi-path delay time is no longer than GI, multi-path interference is almost compensated.

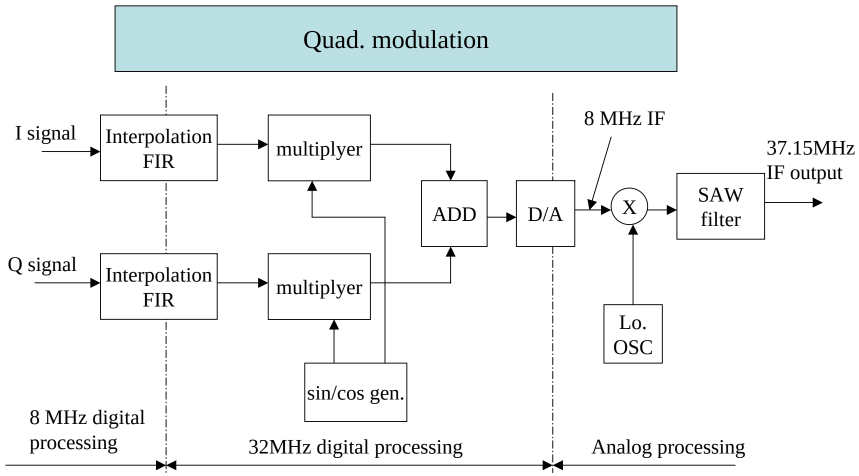
Performances under multi-path condition

•Performances of each DTTB systems

Following graph shows degradation by single multi-path, which is dedicated by Mackenzie Presbyterian University measured in Autumn , 2005



As shown above, within guard interval length (+/- 63 us), ISDB-T work well almost 0dB D/U ratio. In addition, newest ISDB-T demodulator LSI adopt adaptive compensation technology, so, widen the low D/U area up to 250us



(1) interpolation/FIR; convert from 8MHz sampling to 32 MHz sampling

(2) Quad. Mod.; multiply I and Q data and add, 32 MHz digital signal process. The output is 8MHz OFDM signal with 32MHz sampling

(3) Analog circuit; up convert to 37.15 MHz IF and SAW filter.

5. ISDB-T$_{SB}$ transmission system

1. Outline of ISDB-T$_{SB}$ transmission system
2. Consecutive transmission system
3. Example of consecutive transmitter station

Relating clause of ARIB standard; B31 clause 3.12 – clause 3.15

1. ISDB-T$_{SB}$ transmission system

(1) What is ISDB-T$_{SB}$

ISDB-TSB transmission system is unique in ISDB-T family. This transmission system has been standardized for narrow band ISDB-T transmission system, which is focused to audio and data service, therefore, called ISDB-TSB.

(2) Commonality with ISDB-T

(a) Same segment transmission construction. But ,considering narrow band reception, only 1 segment and 3 segment transmission systems are standardized

(b) Adopt same transmission parameters as ISDB-T.

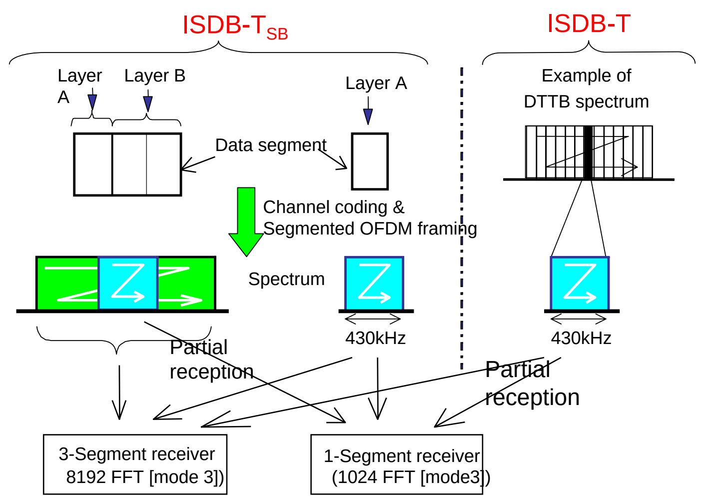
(c) Commonality of 1 segment receiver with ISDB-T partial reception

(3) Efficient use of frequency resource

(a) Consecutive transmission system. This system is unique for ISDB-TSB, this transmission system is to transmit plural channel without guard band

(b) To achieve consecutive transmission, phase compensation technology at transmitter side is adopted

ISDB-T$_{SB}$ transmission and partial reception



Transmission parameters

Mode	1	2	3
Segment(s)	1 or 3		
Bandwidth	430kHz or 1.3MHz		
Carrier spacing	3.97kHz	1.98kHz	0.99kHz
Total carriers	109 / 325	217 / 649	433 / 1297
Data carriers	96 / 288	192 / 576	384 / 1152
TMCC,AC,CP, SP carriers	13 / 37	25 / 73	49 / 145
Modulation	QPSK, 16QAM, 64QAM, DQPSK		

Transmission parameters (continued)

Mode	1	2	3
Symbol duration	252µs	504µs	1.008ms
Guard interval	1/4 ～ 1/32 of symbol duration		
Symbols/frame	204		
Frame duration	53～64ms	106～129ms	212～257ms
Inner code	Convolutional code (1/2, 2/3, 3/4, 5/6, 7/8)		
Outer code	(204,188) RS code		
Interleaving	Time and Frequency		

Example of information bit-rate(TS rate)

	1segment	3segment	note
QPSK, r=1/2,Tg=1/4	280kbps	0.84Mbps	**Minimum rate**
QPSK, r=1/ 2,Tg=1/16	330kbps	0.99Mbps	
QPSK, r=2/3,Tg=1/16	440kbps	1.32Mbps	
16QAM, r=1/2.Tg=1/16	660kbps	1.98Mbps	
64QAM,r=7/8,Tg=1/32	1.87Mbps	5.20Mbps	**Maximum rate**
Bandwidth	430kbps	1.3Mbps	

The information bit rates do not depend on transmission mode1,2 or 3, They depend on modulation ,coding rate and guard interval

Spectrum utilization (1)

Broadcasting frequency bands are looked upon as a sequence of segments,which have a bandwidth of one fourteenth of a TV channel.

BST-OFDM scheme provides followings.

-DTV uses 13 segments, remaining one ; guard band,

-DSB uses 1 or 3 segments

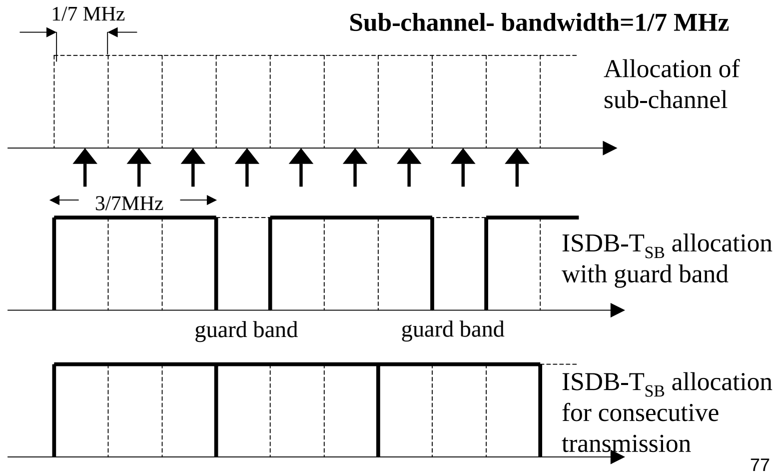
-1-segment reception of 13 segment-TV signal by DSB receiver

-Consecutive-segment transmission without guard bands

-systematic frequency re-packing towards total digital age

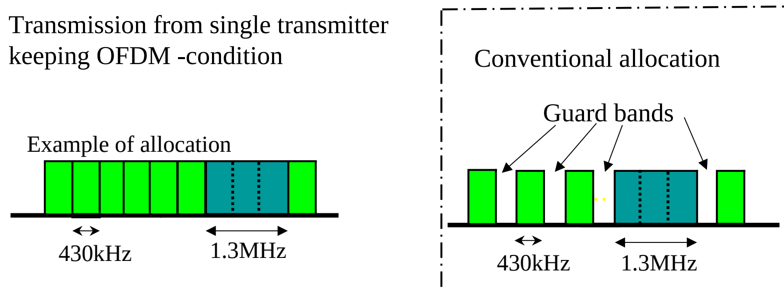
Frequency allocation of consecutive transmission

Concept of sub-channel



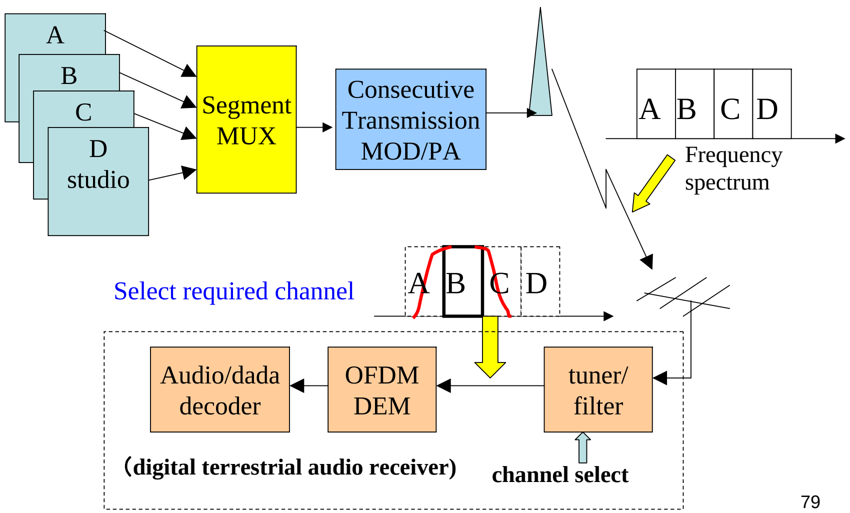
Spectrum utilization (2)

Consecutive-segment Transmission of DSB channels

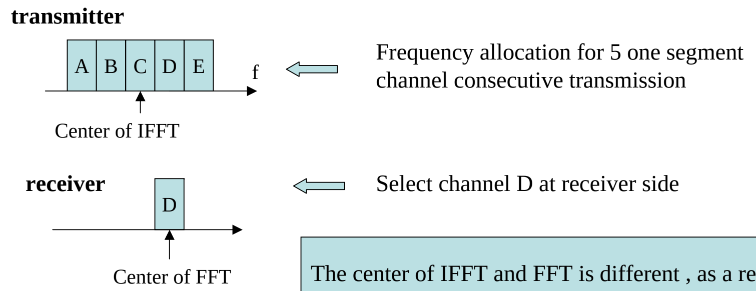


Frequency utilization efficiency will be improved up to 150%.

Image of consecutive transmission and reception

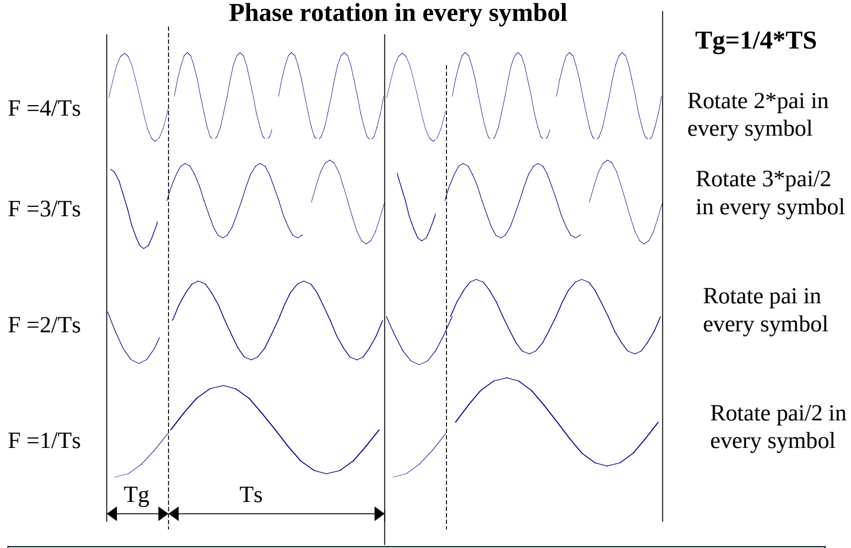


Why is the phase compensation of segment necessary for consecutive transmission ?



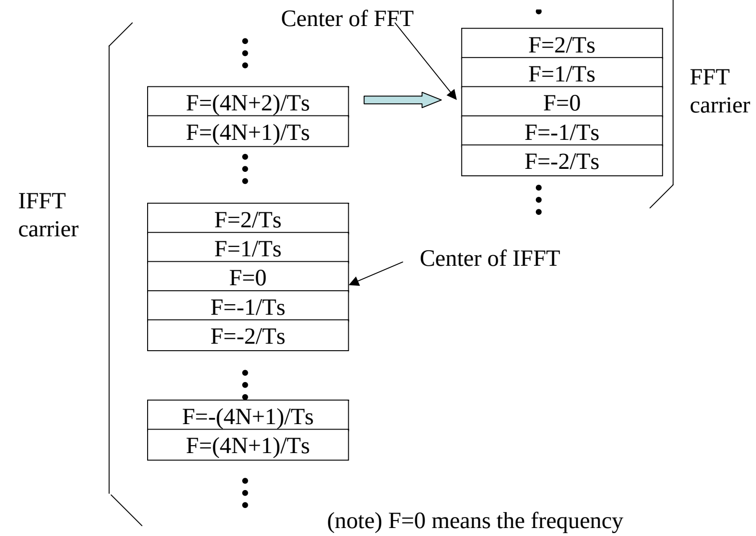
The center of IFFT and FFT is different , as a result, each carrier of received OFDM signal rotate during Guard interval period. (see next page)
This phase rotation is compensated at the trans-mitter side.

Phase rotation in every symbol



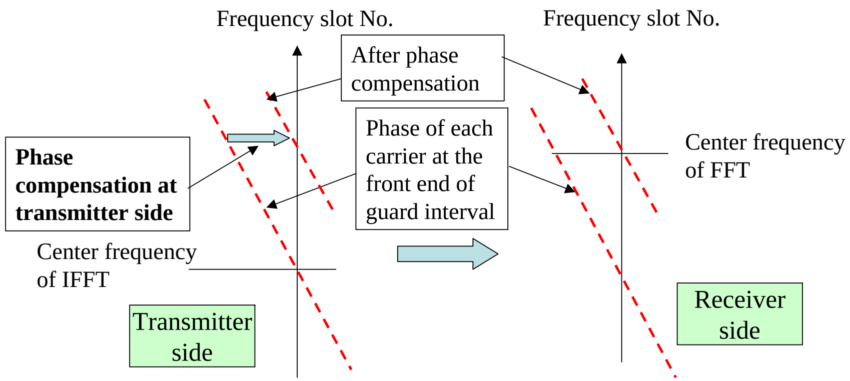
During guard interval (Tg) period, phase rotation (=2*N*pai*Tg/TS) occurs.
Consequently, each carrier seems to rotate in every symbol period.

Relationship between IFFT and FFT for consecutive transmission



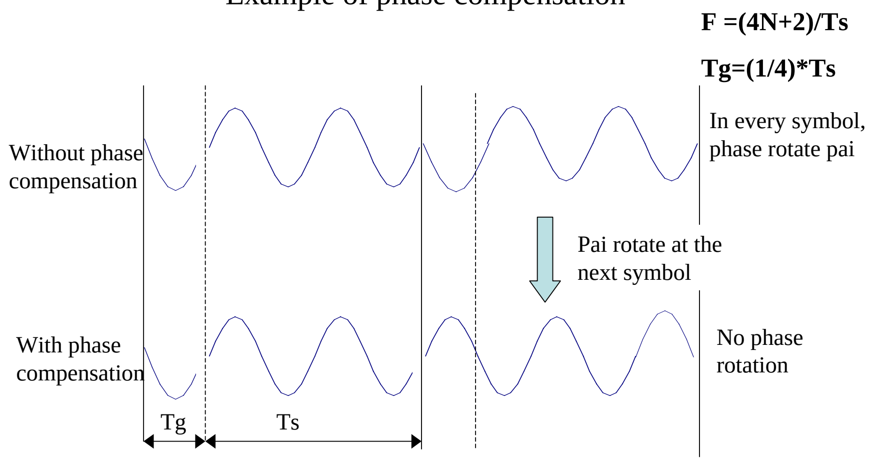
(note) F=0 means the frequency which is the center of FFT and IFFT

Phase of Each carrier in consecutive transmission



In case of consecutive transmission, center frequency of IFFT and FFT is different. Therefore, during guard interval, each carrier phase rotate according to above figure. To avoid such phase rotation at receiver FFT, phase compensation is done at transmitter side.

Example of phase compensation



In this example, center frequency of FFT is equal to F=(4N+2)/Ts of IFFT. Therefore, if Tg is equal to (1/4)*Ts, at the front end of every symbol rotate pai.

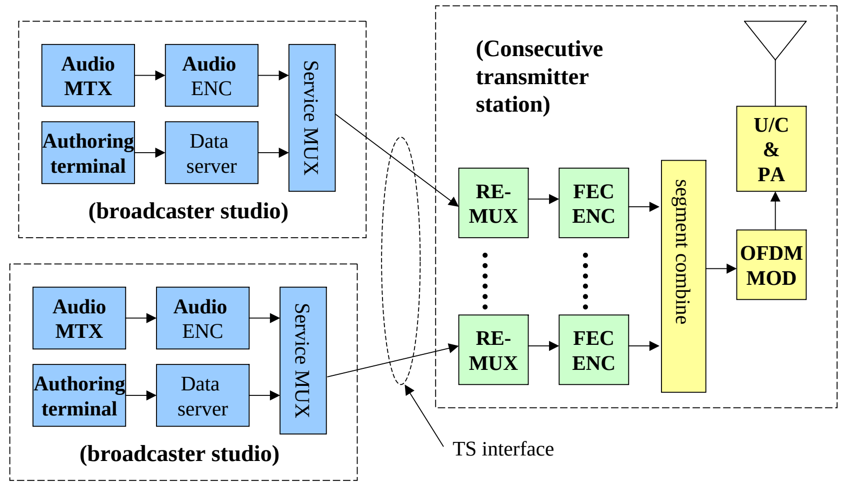
Phase compensation in every symbol

Upper adjusent channel format

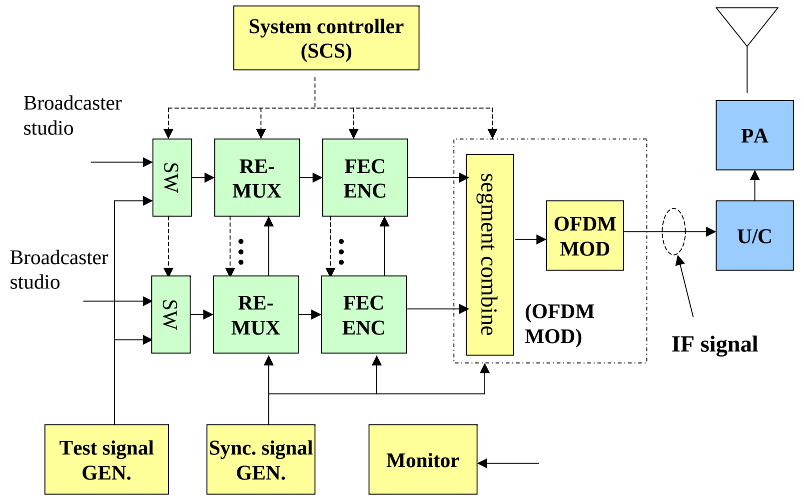
	GI	1 segment mode 1	1 segment mode 2	1 segment mode 3	3 segment mode 1	3 segment mode 2	3 segment mode 3
1	1/32	-3/8	-3/4	-1/2	-6/8	-2/4	0
	1/16	-3/4	-1/2	0	-2/4	0	0
	1/8	-1/2	0	0	0	0	0
	1/4	0	0	0	0	0	0
3	1/32	-6/8	-2/4	0	-1/8	-1/4	-1/2
	1/16	-2/4	0	0	-1/4	-1/2	0
	1/8	0	0	0	-1/2	0	0
	1/4	0	0	0	0	0	0

Number of segment pf received channel

ISDB-TSB studio & transmitter system for consecutive transmission system



Details of ISDB-T_{SB} transmitter block diagram



After RE-MUX , frame and clock of each channel are synchronized

END of Seminar #3

Thank you for your attention