ISDB-T seminar in Brazil

Seminar #5

Transmission system (part 2)

30th March, 2005

Digital Broadcasting Expert Group (DiBEG)

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Contents

1.Digital Terrestrial Sound Broadcasting

In this section, outline of digital terrestrial sound broadcasting described below are introduced. Most of document is dedicated by DRP(Digital Radio Promotion Association).

-outline and feature of digital terrestrial sound broadcasting

-infrastructure of broadcaster

-current state of receiver

-channel allocation and program time table

Digital Terrestrial Sound Broadcasting (DTSB)

Status

- report of technical requirement for Digital Terrestrial Sound Broadcasting (DTSB) published in 1999
- ARIB STD-B29 "Transmitting system of DTSB and ARIB STD-B30 "Receiver for DTSB" established in 2001
- enforcement of revised radio raw for DTSB in 2002
- Test licences for DTSB awarded to DRP in 2003
- Experimental DTSB services started at 10th Oct. 2003 in Tokyo and Osaka

Digital Terrestrial Sound Broadcasting System

Comparison of DTSB system

	Japan	Europe	USA
System	ISDB-T_{SB}	DAB	IBOC
Carrier modulation	OFDM (DQPSK,QPSK, 16QAM,64QAM)	OFDM (DQPSK)	OFDM
Error-correcting code	Reed-solomon + convolutional error correcting	convolutional error correcting	convolutional error correcting
Multiplex structure	MPEG-2 System	Original System	Original System
Audio coding	MPEG-2 Audio AAC	MPEG-1(Layer2)	MPEG-2 Audio AAC

Promotion of the Digital Terrestrial Sound Broadcasting (DTSB) in Japan

1 Purpose

The Digital Radio Promotion Association (DRP) was established in October 2001 to promote the Digital Terrestrial Sound Broadcasting (DTSB) in Japan.

2 Activities

- Carry out the experimental DTSB services (started at 10 October 2003 in Tokyo and Osaka)
- Develop new application for DTSB
- Research of the demand for DTSB
- Promote the DTSB receivers

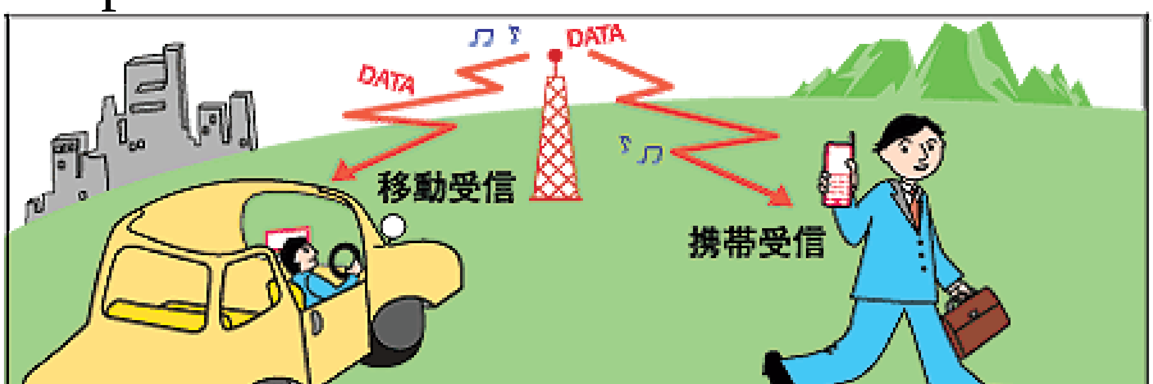
3 Members

DRP has 76 members (Sound Broadcasters, manufacturers etc)

Feature of digital terrestrial sound broadcasting

Digital Terrestrial Sound Broadcasting(DTSB) is the new broadcasting service, which provide high quality audio(CD quality), still picture and simple motion picture. Through these media, many convenient service such as traffic information, live information service are available.

In addition above, not only indoor but mobile and handheld reception is possible.

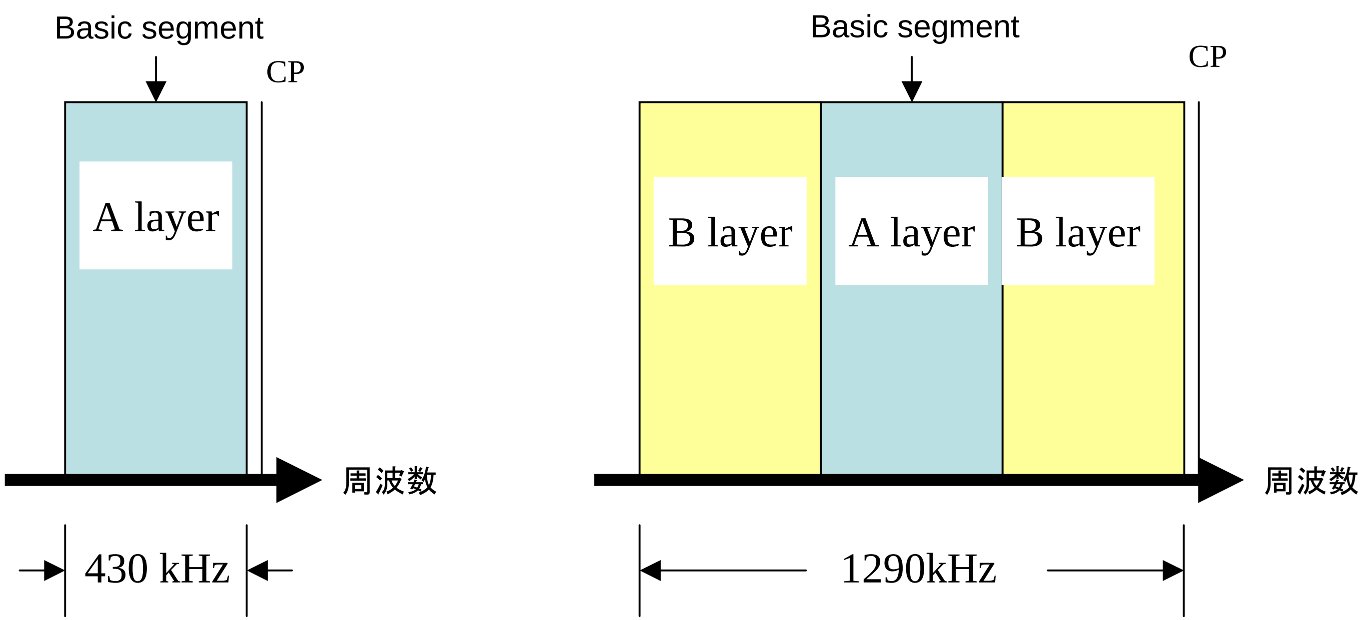


Merit of digital radio

1. high quality audio(CD quality)
2. Variety of broadcasting service
3. more service
4. high quality handheld reception
5. bi-directional service

Digital terrestrial broadcasting

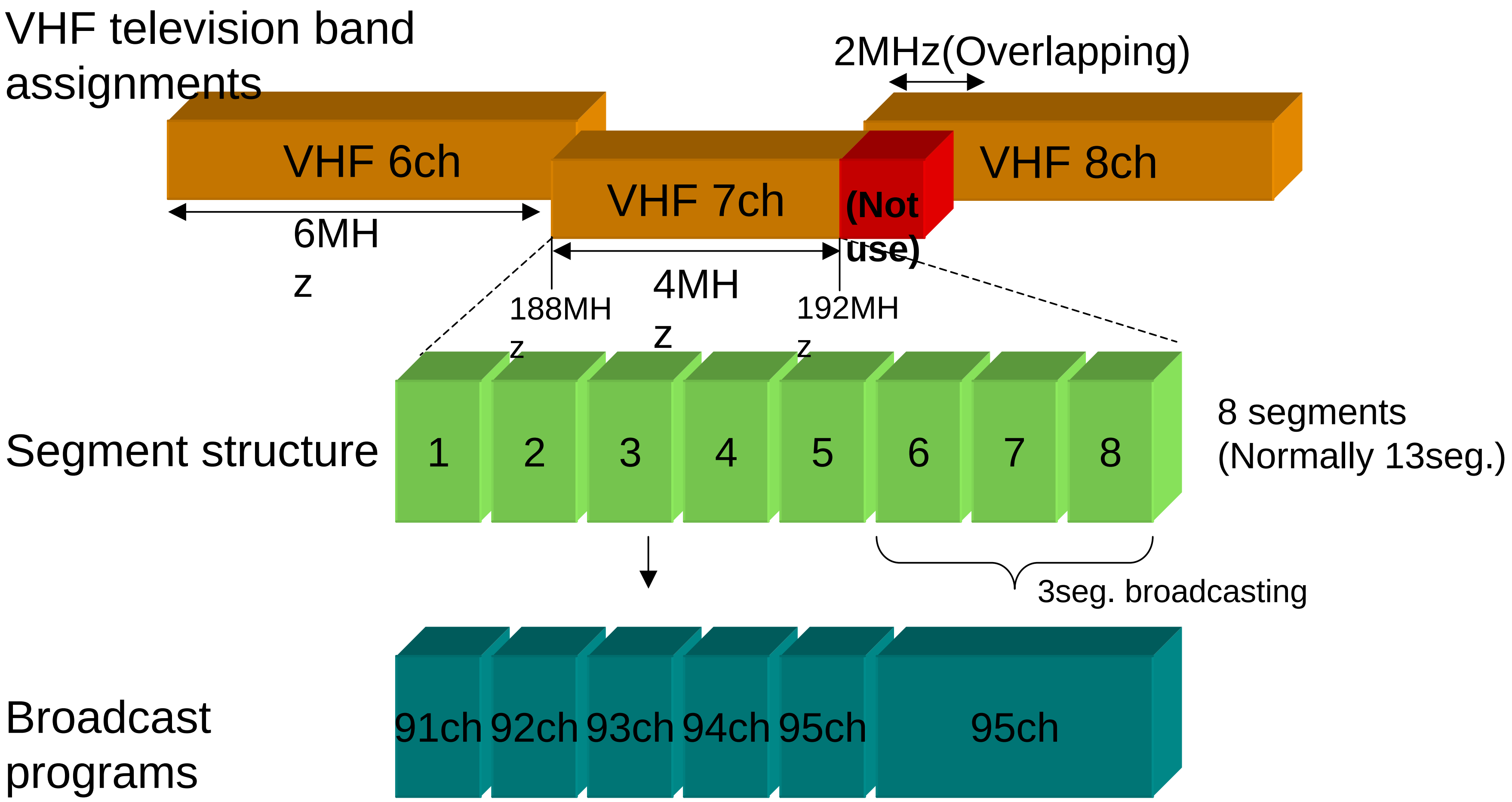
Spectrum of 1 segment system and 3 segment system



1 segment system

3 segment system

Trial Services of DRP



Above example is Tokyo station , Osaka's all programs are 1seg. broadcasting.

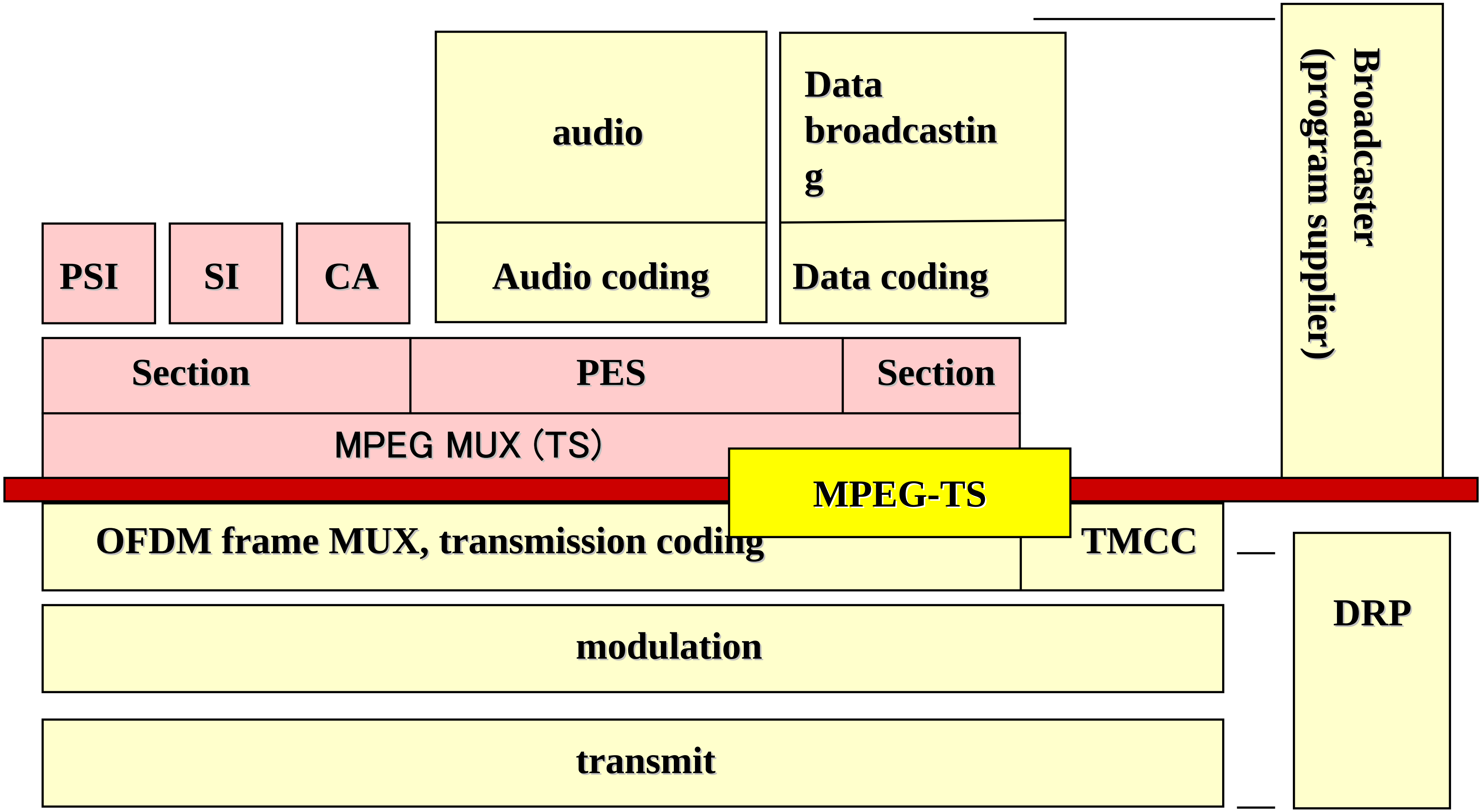
Outline of operation -1

system	No. assigned segment	Reception style	Transmission parameter
1 segment	1(A layer) (basic segment)	mobile handheld	QPSK 1/2, 2/3 16QAM 1/2
3 segment	1(A layer) (basic segment)	mobile handheld	QPSK 1/2, 2/3 16QAM 1/2
	2(B layer) (extended segment)		QPSK 1/2, 2/3 16QAM 1/2

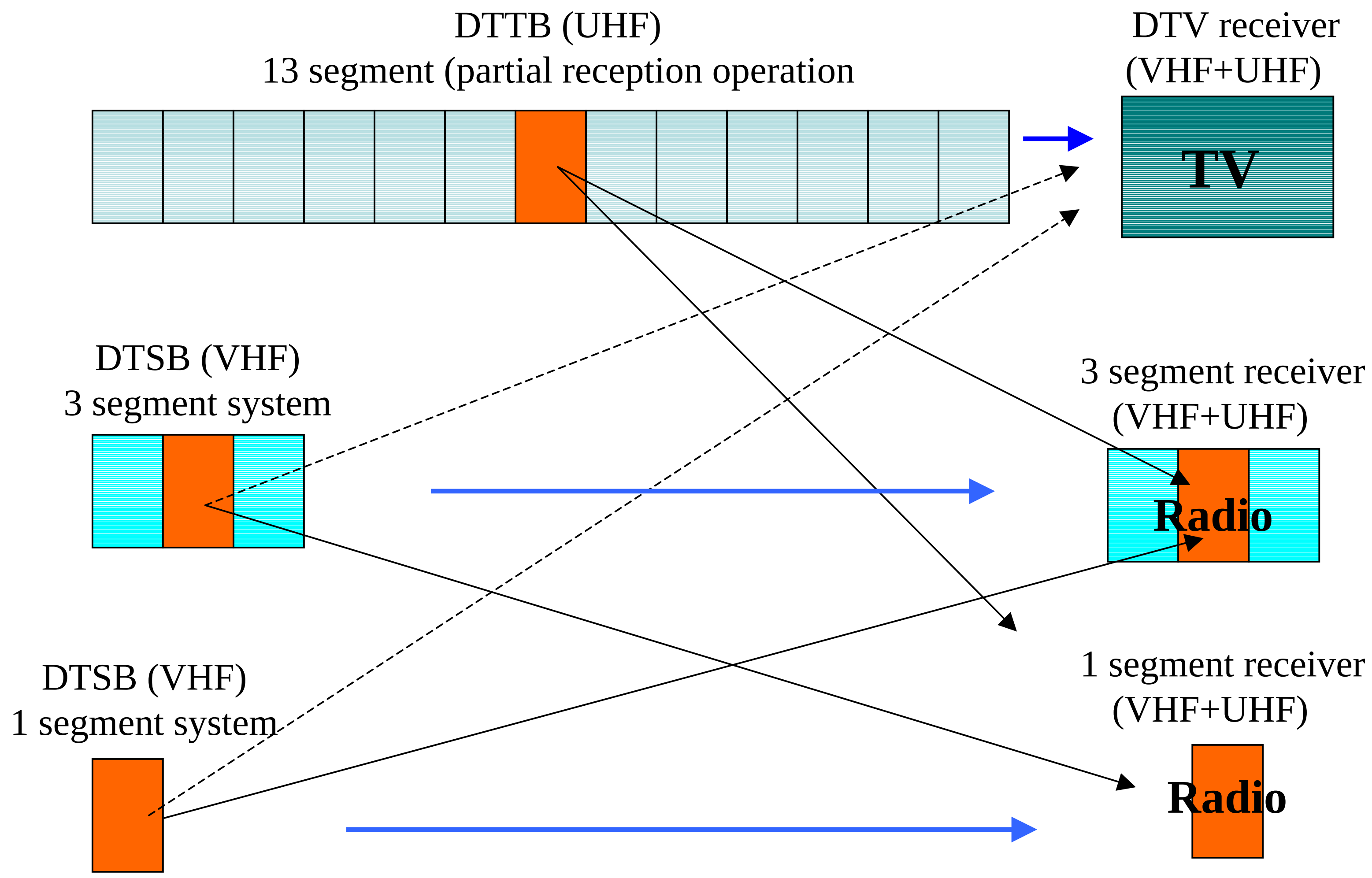
Outline of operation -2

system	Data broadcasting	Bi-directional service	CAS (TBD)
1 segment A layer	P-profile by BML Profile for mobile service is now on discussion	TCP/IP (option)	In current license, charged broadcasting is not permitted RMP is now on discussion
3 segment A layer		TCP/IP (option)	
3 segment B layer			

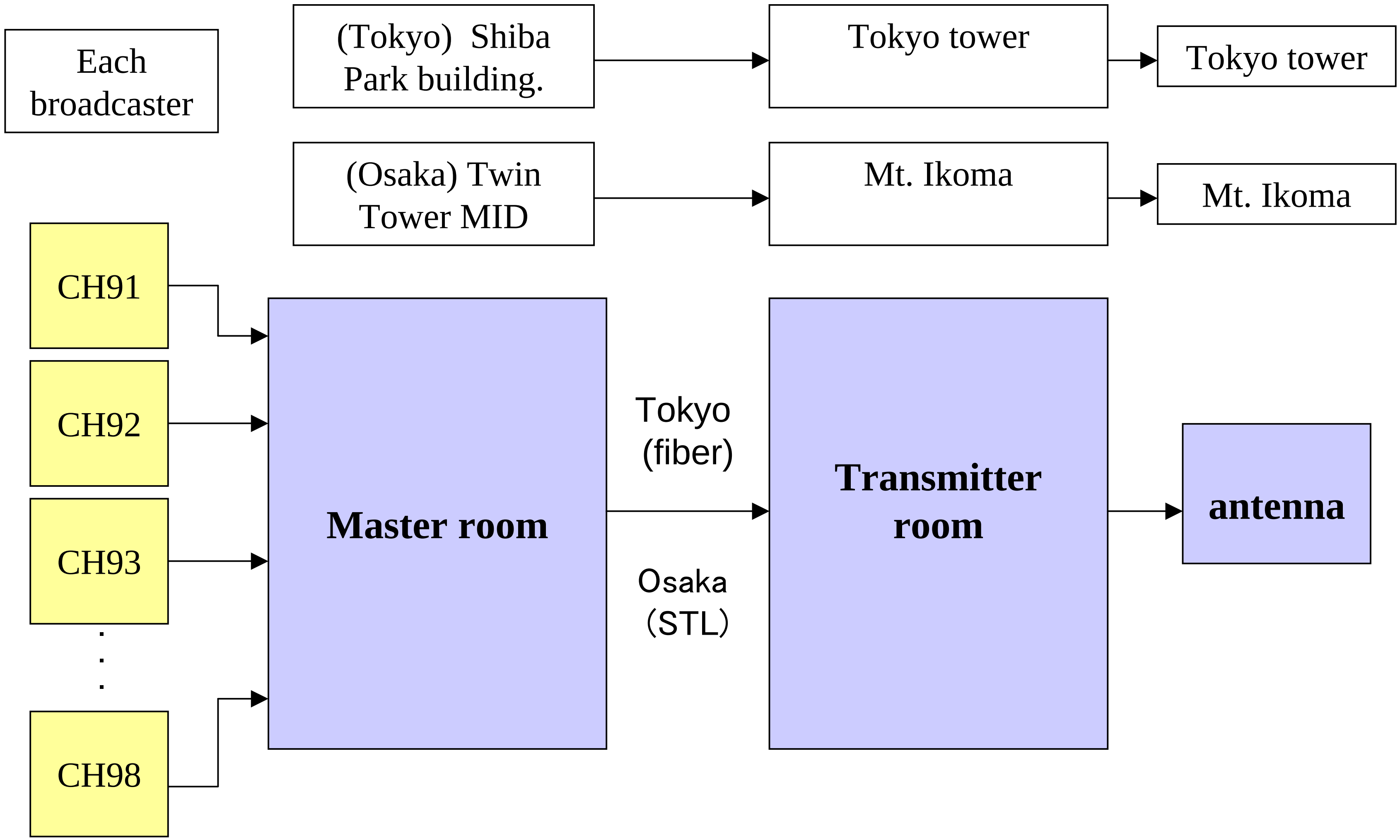
Construction of DTSB



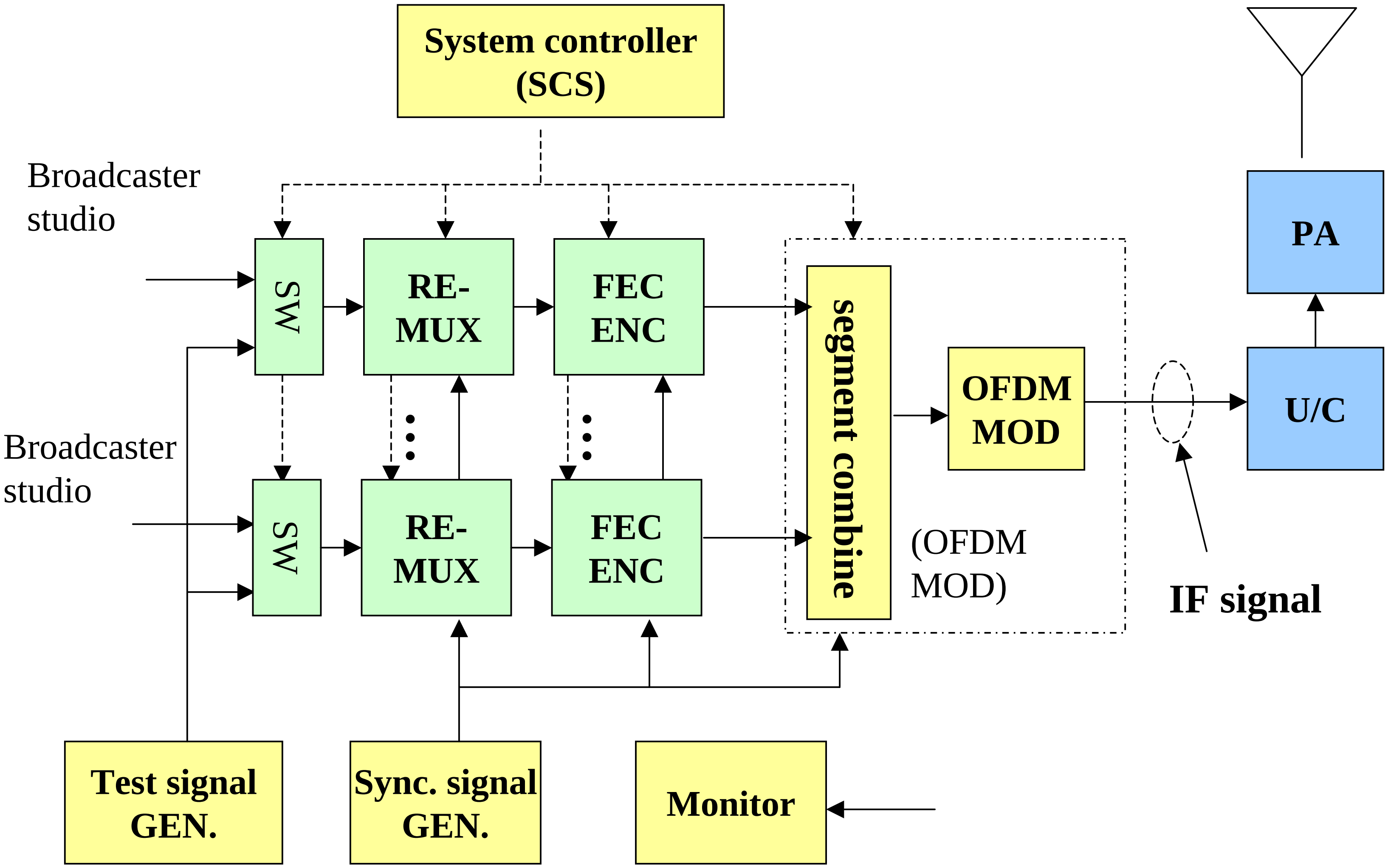
Digital radio/digital TV compatible receiver



Trial studio/transmitting station



Details of ISDB-T$_{SB}$ transmitter block diagram

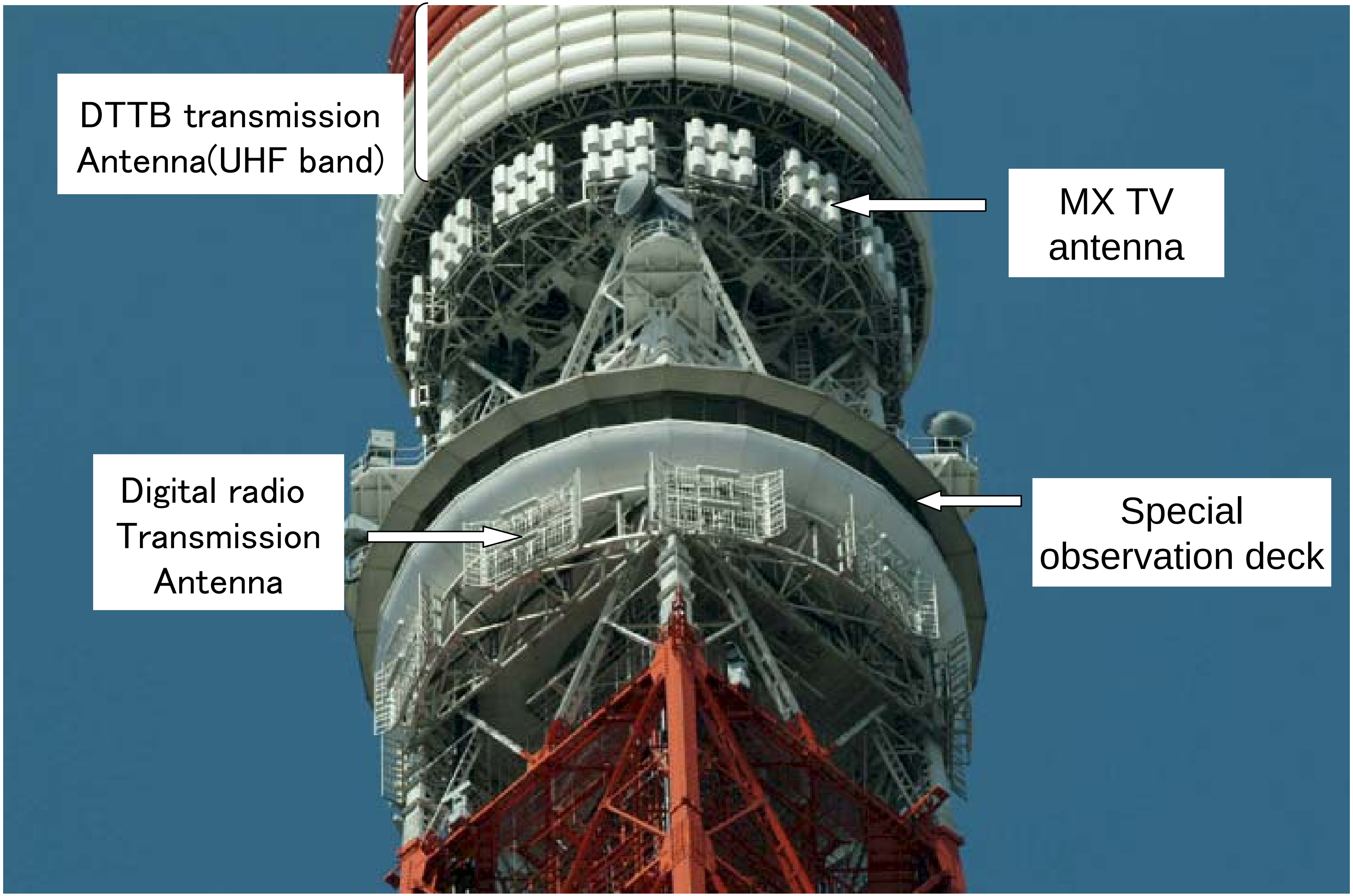


After RE-MUX , frame and clock of each channel are synchronized

DRP Tokyo master rack room

DRP Tokyo digital radio transmitter room

Antenna


DTTB transmission
Antenna(UHF band)
MX TV
antenna
Digital radio
Transmission
Antenna
Special
observation deck

Current state of receiver

(1) DRP prototype receiver(1 segment)

(2) PDA type prototype receiver (KDDI/TFM/Vitec)

(3) PC card type receiver for test product（Pixela Co.）(note)

(note)Pixela will deliver mid of this year

DRP prototype receiver(1 segment)

DRP

PDA type prototype receiver (KDDI/TFM/Vitec)

DRP

Pixela PC card type receiver

PC card type receiver (test product)

DRP

<Digital radio trial broadcasting> Channel construction

Tokyo

Apr. 1st 2004

91 NHK VICS	92 DR@ TOKYO92	93 DigiQ+ N93	94 DAZ94	95 D95	98 Digital Radio 98 The Voice
NHK VICS	FM Yokohama TBS radio & comunications BAYFM Radio NIKKEII	NACK5 QR TV asahi (B member)	J-WAVE Mega-port Radio NIPPON	Ito-chu SONY	TOKYO FM NIPPON broadcasting JFNC (B member)

<Digital radio trial broadcasting>
Channel construction

Osaka

Apr. 1st 2004

91	92	93	94	95	96	97	98

Asahi broadcasting, Ito-chu, fm osaka, α-STATION

FM802, Radio Osaka, Kansai TV, KBS kyoto

VICS, NHK, MBS, Yomiuri TV

Kiss-FM KOBE(B member), Promenade (B member), Radio Kansai (B member) ）

Example of time table(91CH, NHK/VICS)

	MAIN	SUB 1	SUB 2	SUB 3	DATA NHK	DATA VICS
11:00	サウンドパサージュ				見えるニュース	道路交通情報
13:00	サウンドパサージュ	ニュースダイジェスト				
15:00		選べるニュースダイジェスト（A）	選べるニュースダイジェスト（B）	選べるニュースダイジェスト（C）		
20:00	新基礎英語1	新基礎英語2	新基礎英語3	フランス語講座		
20:15	英会話レッツスピーク	ハングル語講座	スペイン語講座	ドイツ語講座		
20:30	英語リスニング入門	中国語講座	イタリア語講座	ロシア語講座		

Time table of Digital Radio 98 The Voice

	音声1+静止画 ロゴ	音声2 or 簡易動画	音声2 or 音声3	データ放送
10:00	It's 笑 Time No. 1	Music Stream	This is The Voice 98	くるくる
11:00	It's 笑 Time No. 2	Music Stream	This is The Voice 98	くるくる
12:00	ヘルスセンター 98−1		This is The Voice 98	くるくる
13:00	ヘルスセンター 98−2		This is The Voice 98	くるくる
14:00	またたび アワー No. 1	Music Stream	This is The Voice 98	くるくる

Example of DTSB service

2. Transmission performance of ISDB-T

2.1 Fundamental performance of ISDB-T

2.2 Test result in Brazil

2.3 Protection ratio

1.1 Fundamental performance of ISDB-T

ISDB-T system was standardized at 1998. At same time , proto type ISDB-T MODEM had been developed and was used to test the ISDB-T transmission performance. The experimental test results shown in this section were test result of ISDB-T initial stage.

From 1998, many of new technologies has been proposed and introduced. Several of these technologies are introduced in next section.

(note) At present, many new technologies has been developed and commercialized, therefore, present ISDB-T system has more high performance. The test result introduced in this section are just reference, not present ability.

(1)Results of Transmission Tests

The experimental test result, introduced here, was tested from 1998, in Tokyo Pilot Test.

Practical Experiments

- **Digital Terrestrial Broadcasting Experiments**

Nov. 1998 - : Launched the Digital Terrestrial Broadcasting Pilot Experiment, "Tokyo Pilot Project"

- **Preparation of Open Facilities for R&D on Digital Broadcasting**

Fiscal 1998 - : Preparation of 10 facilities for practical broadcasting services

Outline of Tokyo Pilot Project

*Date of inception; October 2, 1998

*Membership: 73 associations (as of the end April 2000)

*Experiments to be conducted by the Tokyo Pilot Project

Phase 1 (from November 1998 to March 1999)

Video transmission experiments in multi-channel, HDTV and mobile reception experiments, and so on.

Phase 2 (from April 1999 to March 2000)

Experiments in new multimedia broadcasting services of data broadcasting, EPG service, and so on.

Phase 3 (from April 2000)

Under consideration about themes of experiments for Phase 3.

Experimental Broadcasting in Japan

for System finalization of ISDB-T

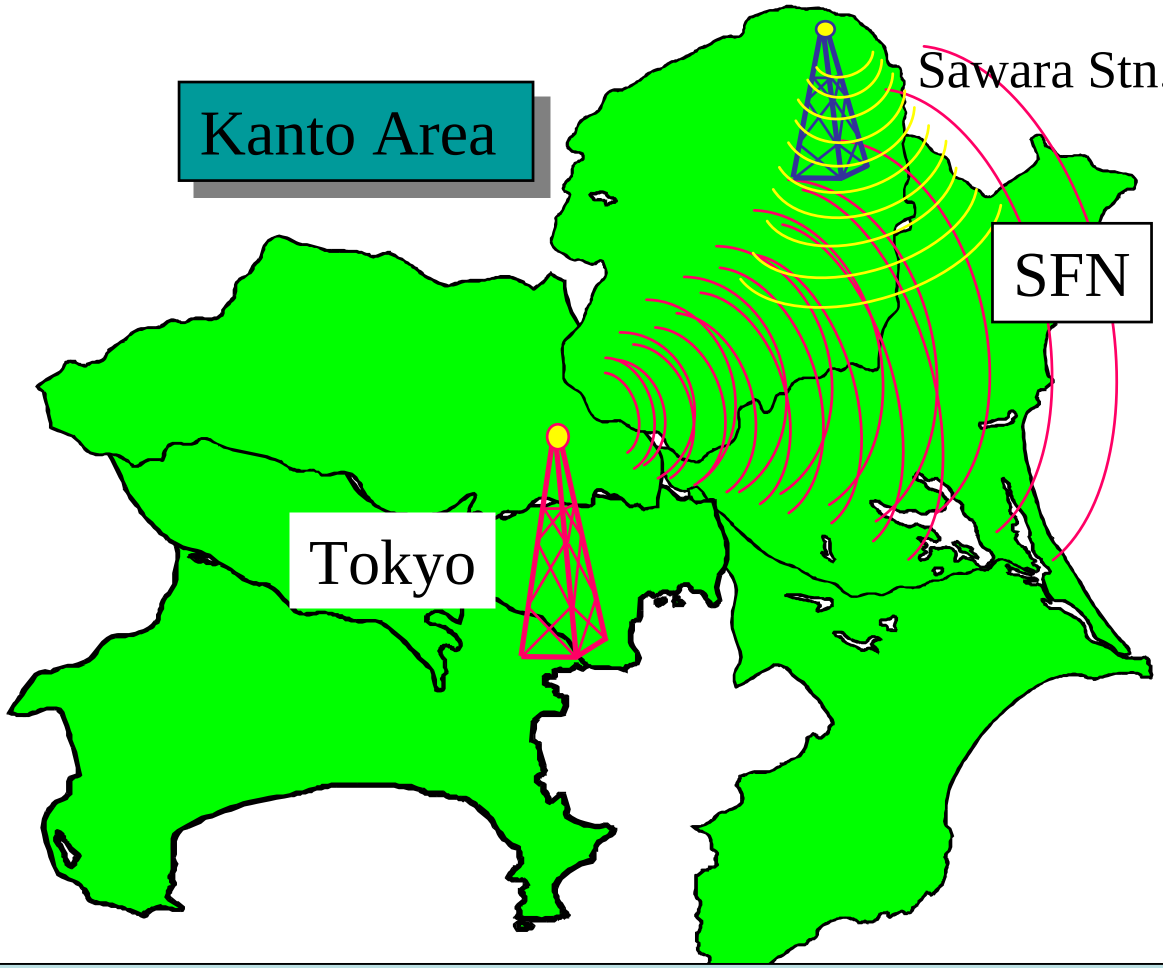
Transmitting started since Oct.'98

Tokyo Tower

Height 210m
CH UHF-15
Power 500W

Existing Analog TV

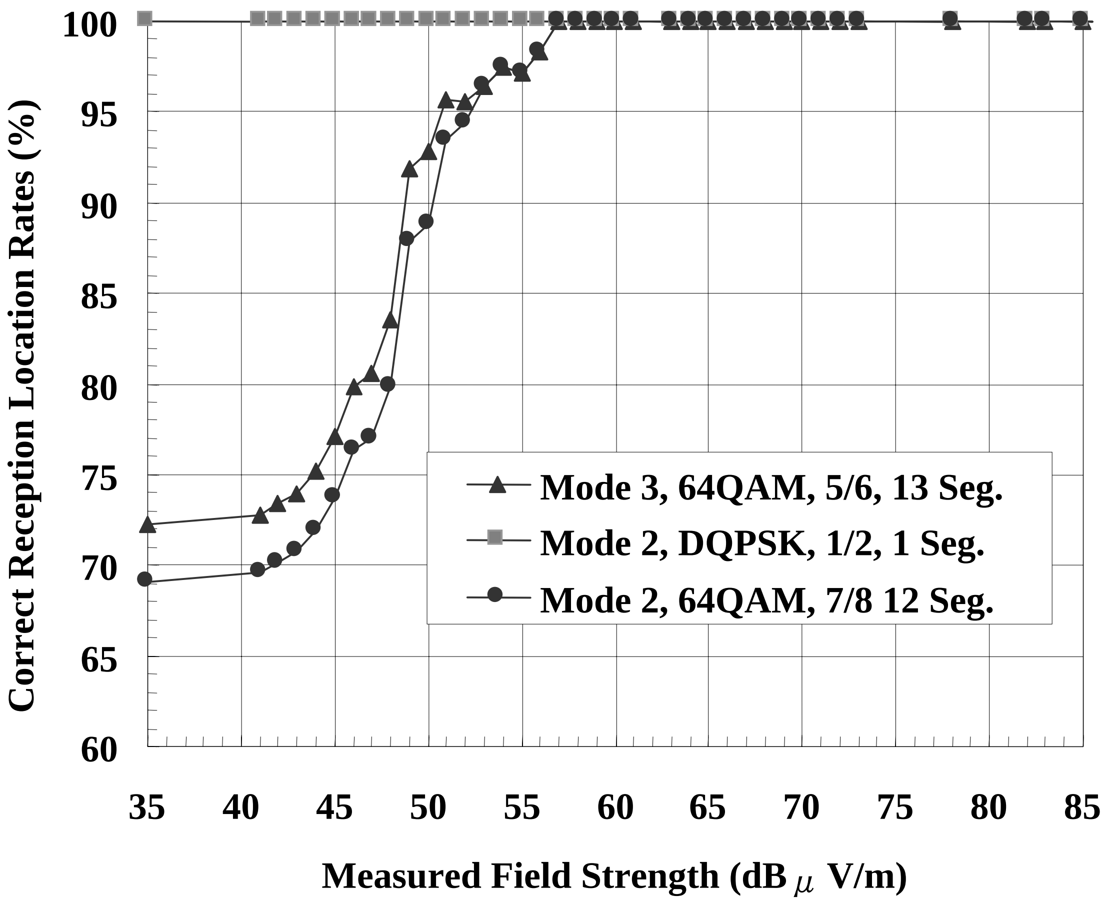
Ch-14 10kW
Ch-16 50kW



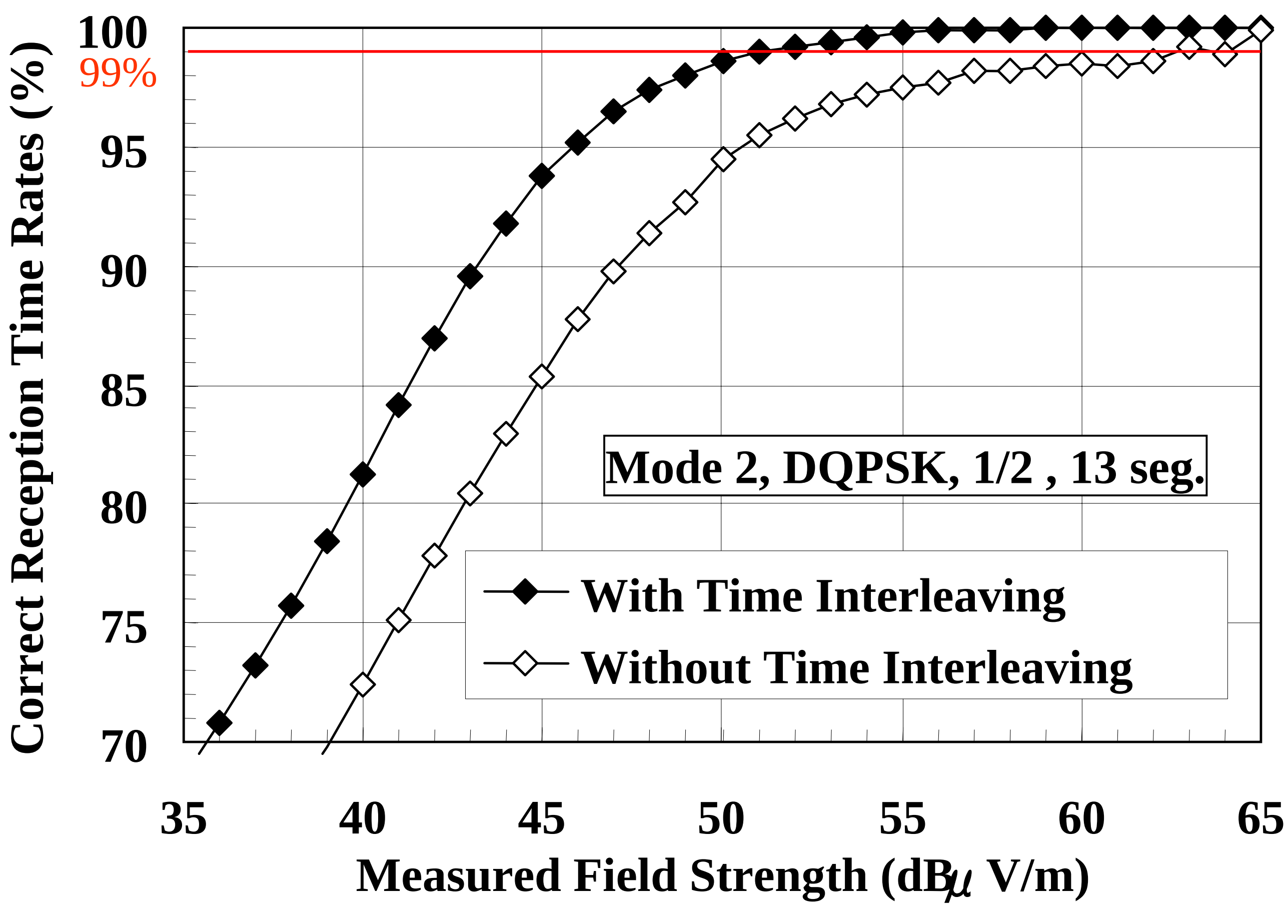
Field Trial

*Stationary reception,*Mobile reception,* Wide-area mobile reception

Correct Reception rate (Phase1: Stationary reception)



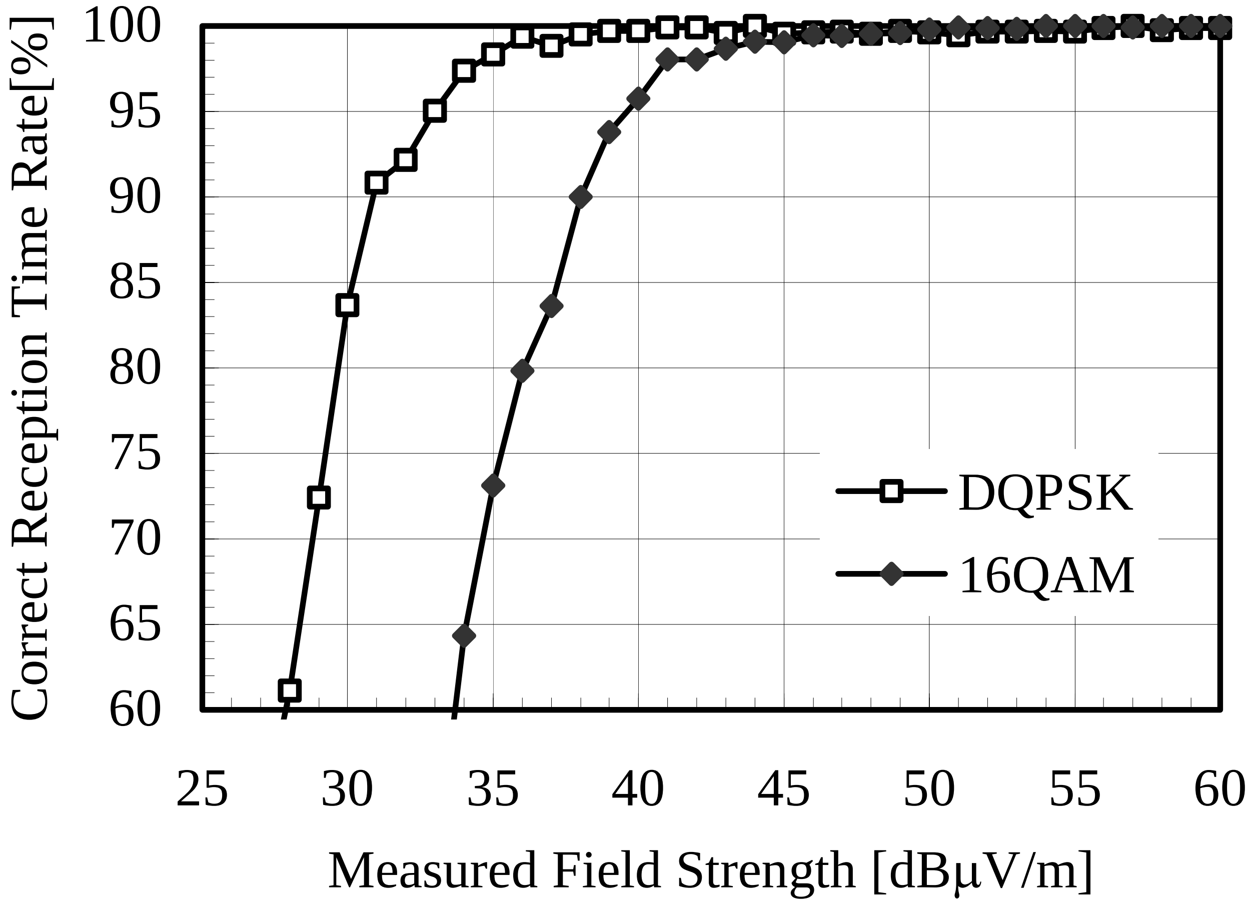
Comparison of Time Interleave (Phase1: Mobile reception)



Mobile Receiving

Digital Analog

Correct reception time-rates (Phase1: Wide-area mobile reception)



Results of Experiments for Mobile Reception

- DQPSK-1/2: possible field strength was 40dB μ V.
  In the central area of town, there ware rare case of freeze the pictures.
- DQPSK-2/3: field strength was about 45dB μ V.
  Sometimes the picture froze at the central area of town and shadow area.
- DQPSK-3/4：field strength was about 50dB μ V.
  In the central area of town, it could not receive. In the suburbs or good location, it could receive mostly.
- 16QAM-1/2：freeze began at about 50dB μ V.
  Same to DQPSK-3/4

2.2 Result of comparison test conduced by ABERT/SET of Brazil

Original published in Portuguese.

Translated in English

Laboratory Tests Basic Configurations

	ATSC	DVB-2K*	DVB-8K**	ISDB-4K***
PAYLOAD (Mbps)	19.39	19.75	18.09	19.33
Configurations	1	Many		Lots

* 2K, FEC ¾, GI 1/16 (18,67us)

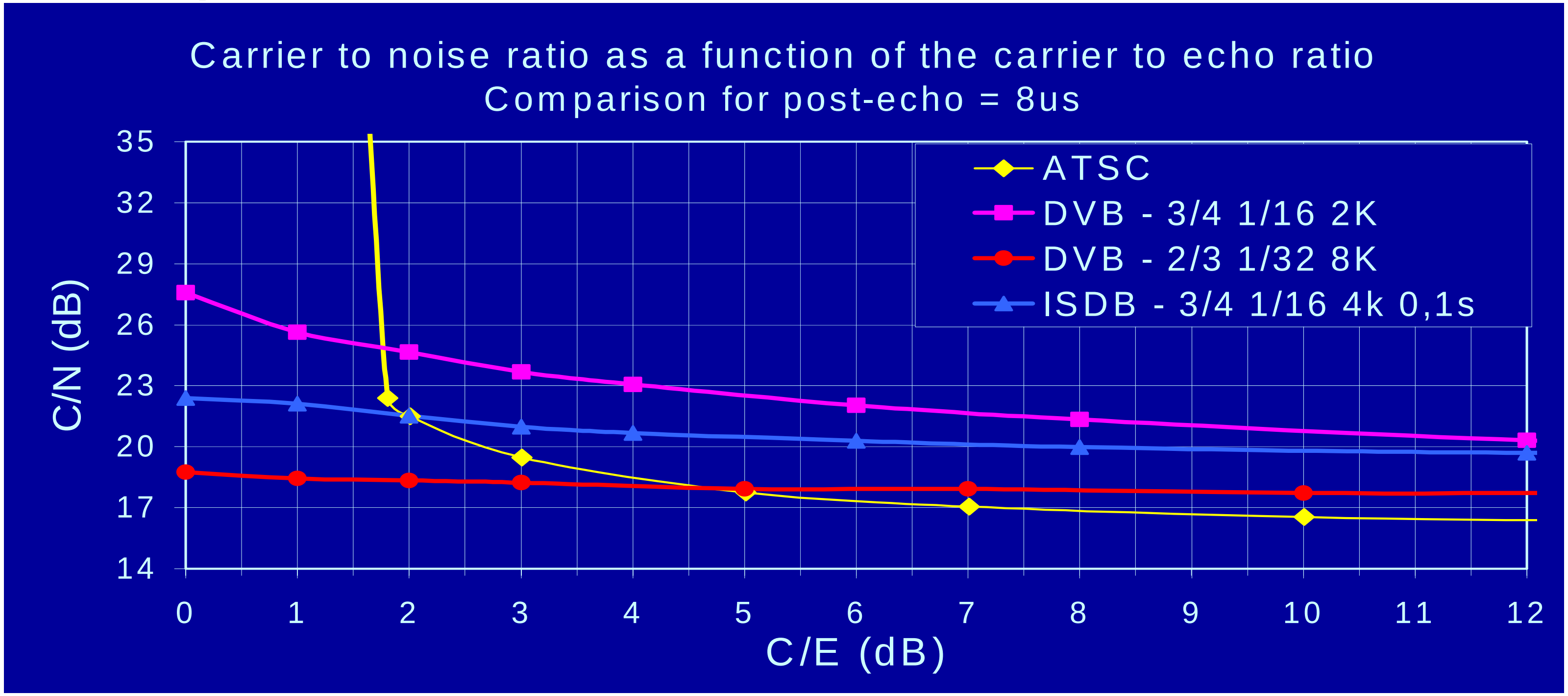
** 8K, FEC 2/3, GI 1/32 (37,33us)

*** 4K, FEC ¾, GI 1/16 (31,5us), 0,1s Time Interleaving

Original published by ABERT/SET in Portuguese. Translated and revised by NHK

Laboratory Tests - Results

- Multi-path

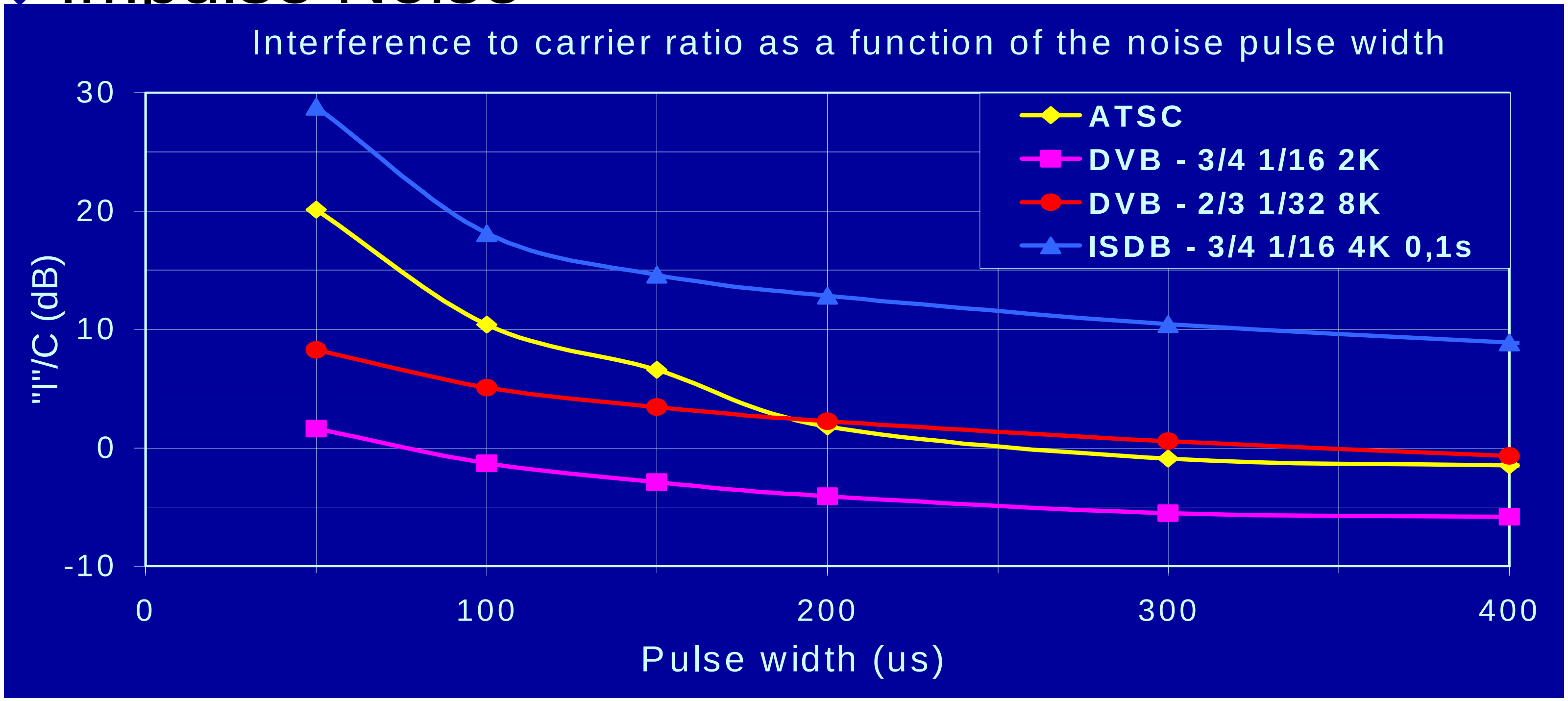


- DVB 8K Best Result
- OFDM results are function of FEC and Receiver implementation

Original published by ABERT/SET in Portuguese. Translated and revised by NHK

Laboratory Tests - Results

- Impulse Noise

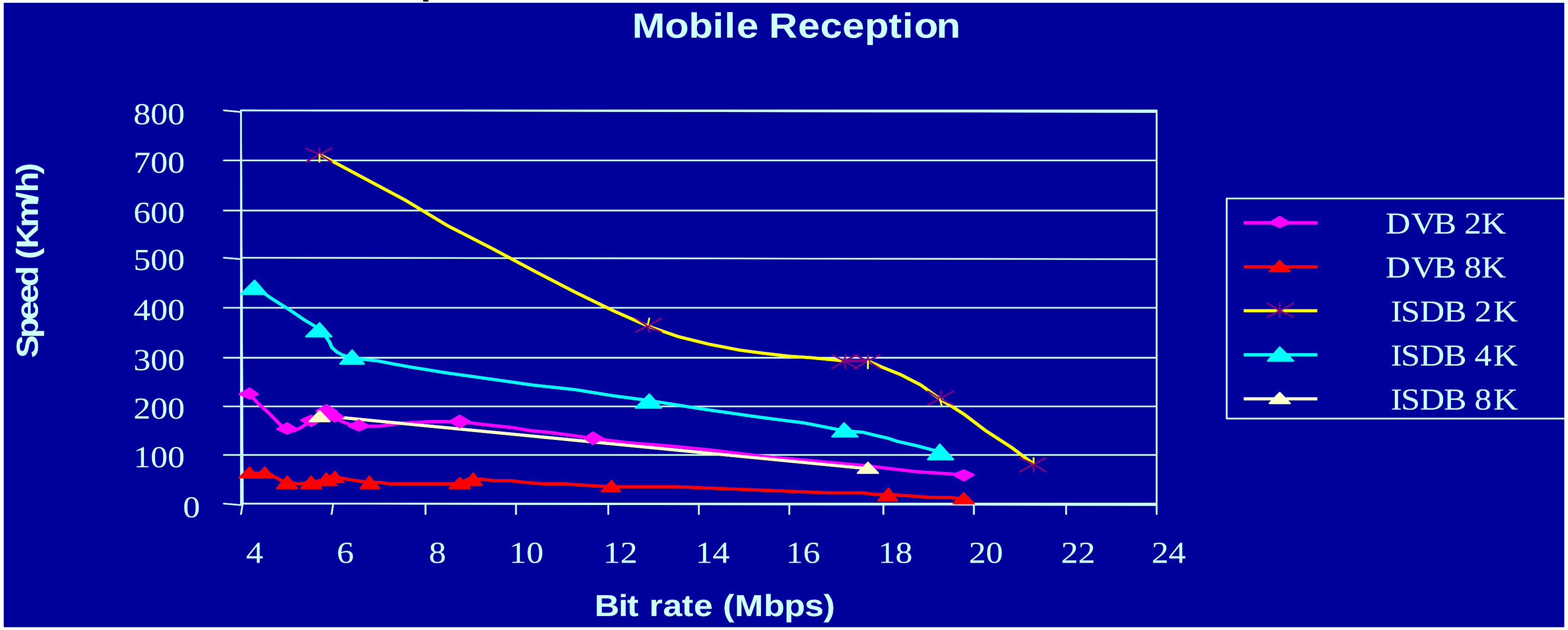


- ISDB – Best Results (Time Interleaving)
- DVB 8K Better than DVB 2K (5dB)

Original published by ABERT/SET in Portuguese. Translated and revised by NHK

Laboratory Tests - Results

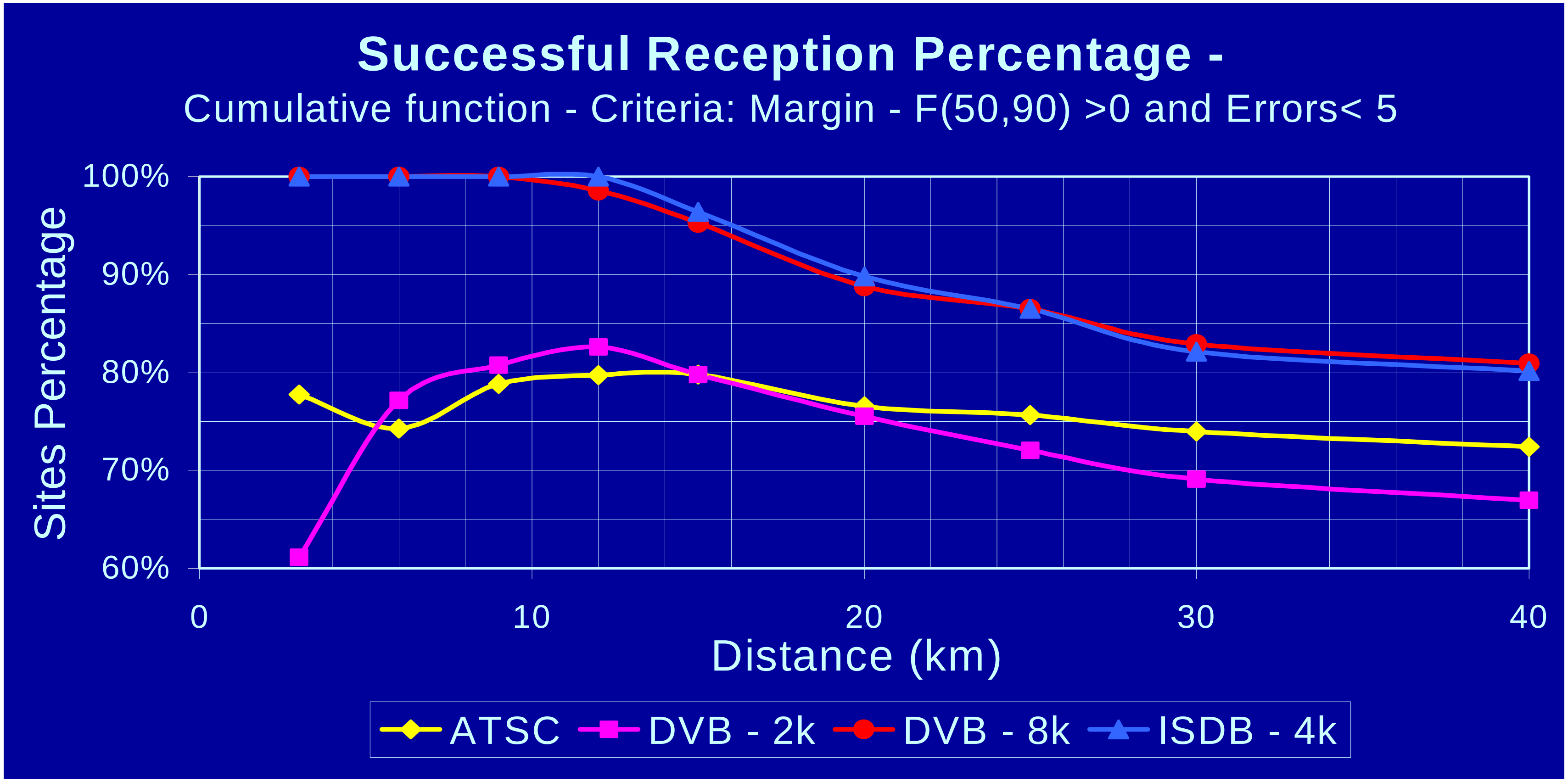
- Mobile Reception Simulation



- ATSC did not work at 1.8 Km/h
- Number of carriers is a key factor
- ISDB 4K has similar performance to the DVB 2K
- DVB 8K only portable Rx.

Original published by ABERT/SET in Portuguese. Translated and revised by NHK

Field Test – Results Coverage



- DVB 8k similar to ISDB 4k
- ATSC similar to DVB 2k (inadequate)
- ISDB 4k Higher Payload (+1.2 Mbps)

UK used DVB-2K at first
(Added by NHK)

Original published by ABERT/SET in Portuguese. Translated and revised by NHK

2.3 Protection ratio

(see for detail data “”Protection ratio experiment and result”)

Protection ratio is very important factor for channel planning.

In Japan, also protection ratio was examined in early stage of digitalization, in 1998.

The detail data is attached on DiBEG homepage.

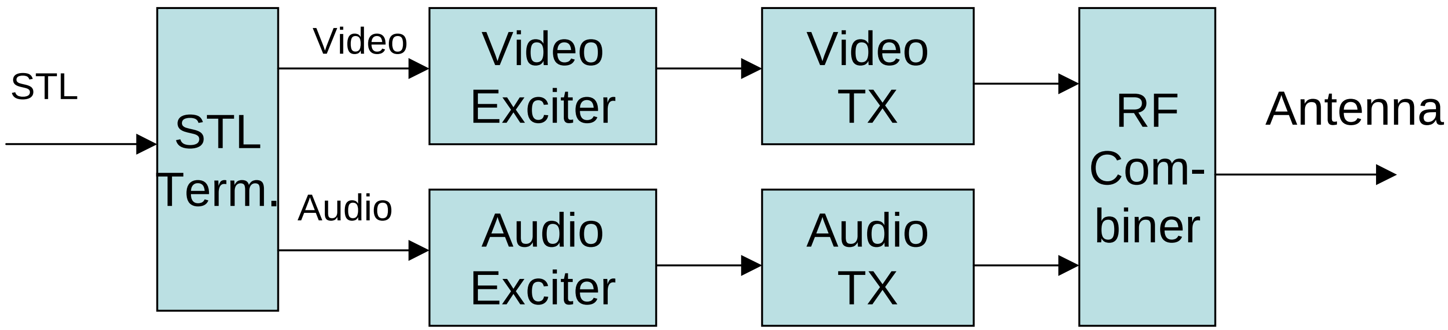
I will explain technical details of these data.

3. Key technology for improvement of ISDB-T transmission characteristics (transmitter and micro-wave relay)

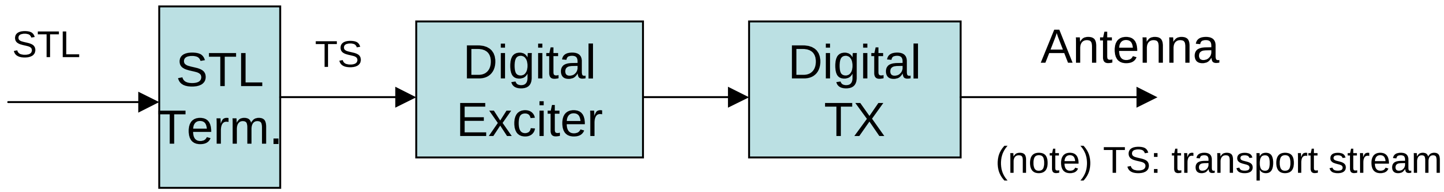
1. Comparison of Analog system and Digital System(1/)

（1）Differences of Transmitter Composition

Transmitter composition is quite different.



(a) Analog High Power Transmitter block-diagram



(b) Digital High Power Transmitter block-diagram

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(2) Differences of Specification

(a) Required transmitting Power

minimum required signal field strength of digital system is about 1/10 of analog system.(In Japan, 70dBuV/m for analog T V, 60dBuv/m for digital TV)

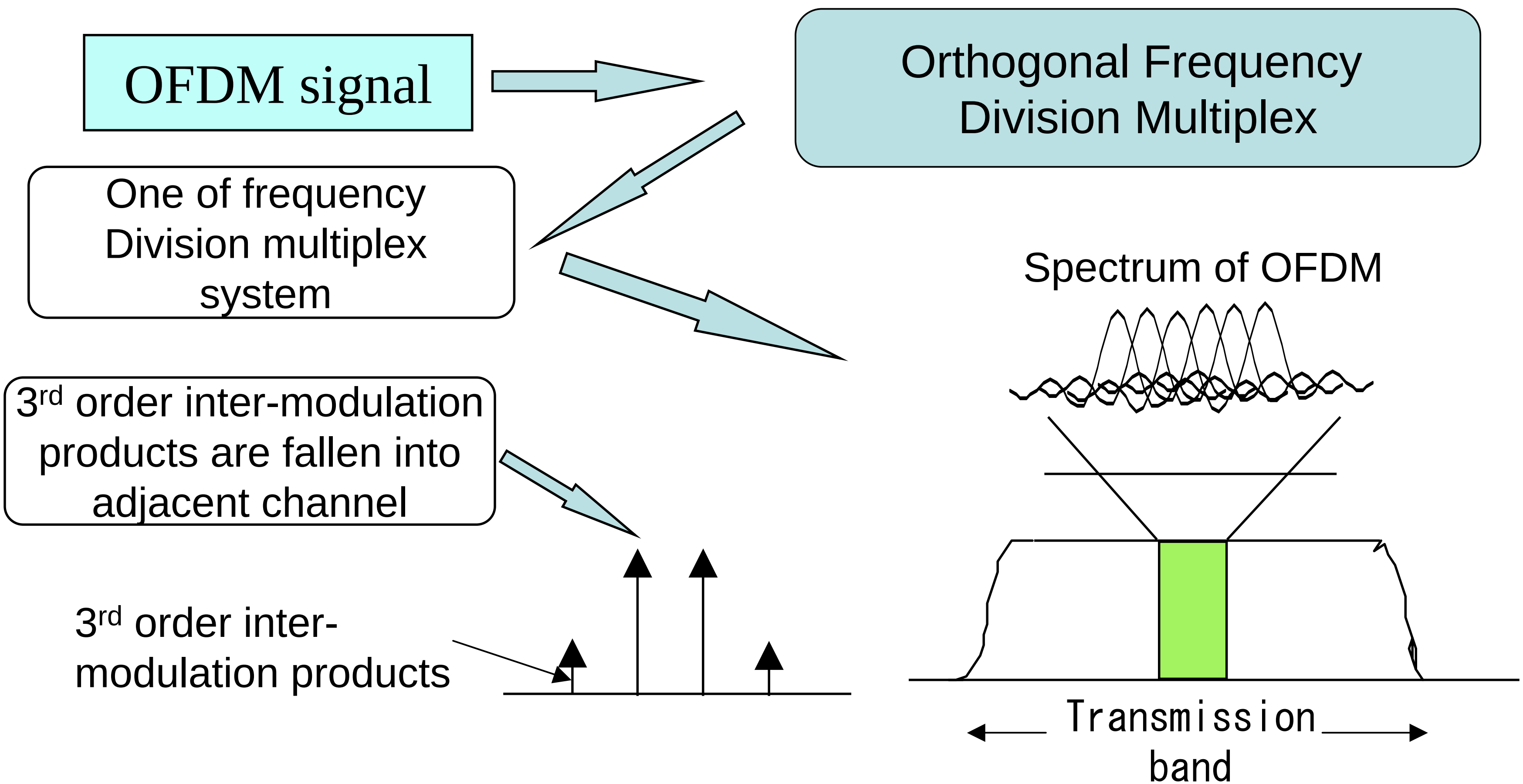
Tokyo area key station:	Analog system; 50kW VHF
	Digital system ; 10kW UHF

(b) Frequency difference

Frequency difference is critical for digital SFN network system

(c) Non-linear distortion

In digital system Non-linear distortion of transmitter causes the inter-modulation products, and these products are fallen into the adjacent sub-channels. Therefore signal quality is degraded by the Inter-carrier interference.



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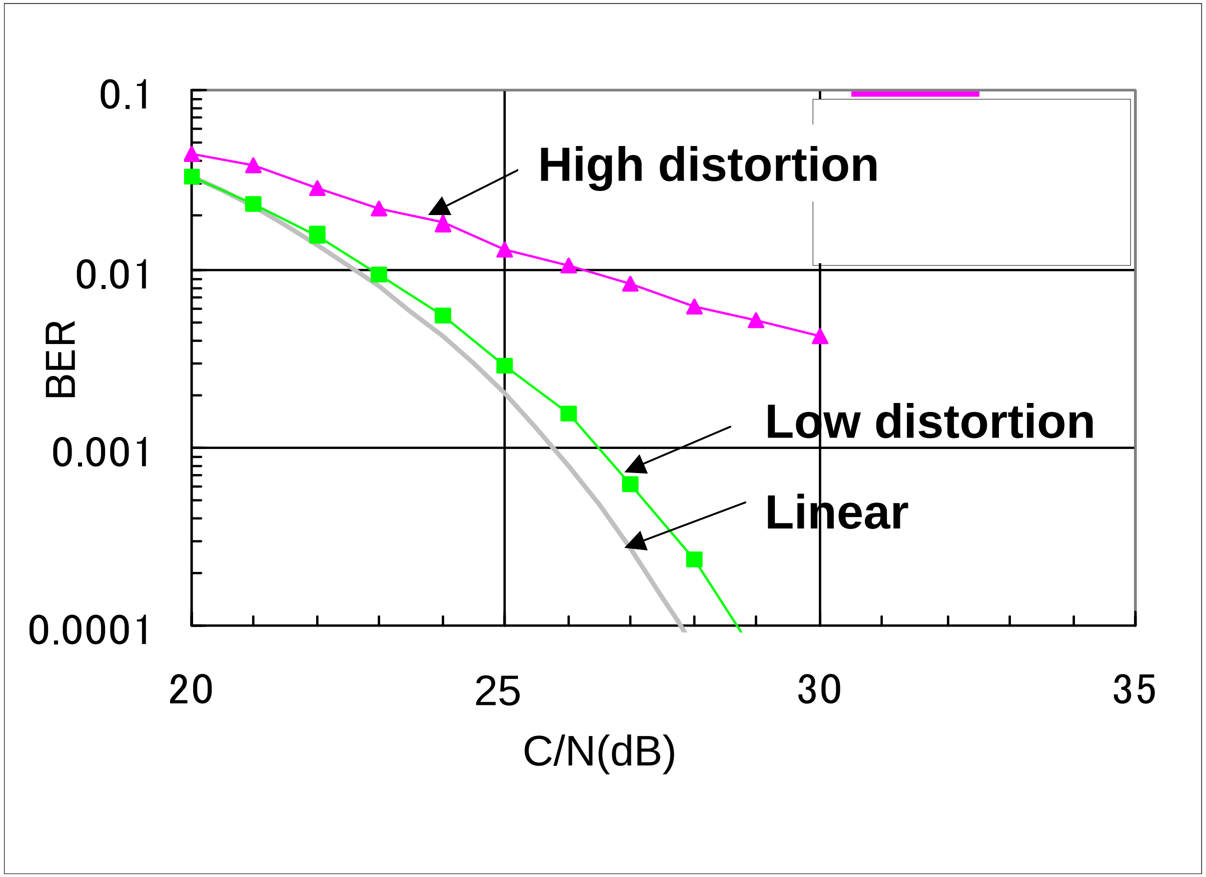
Signal degradation caused by non-linear distortion

Inter-modulation products are fallen into adjacent sub-channels. These products behave as thermal noise, therefore BER characteristics are degraded.



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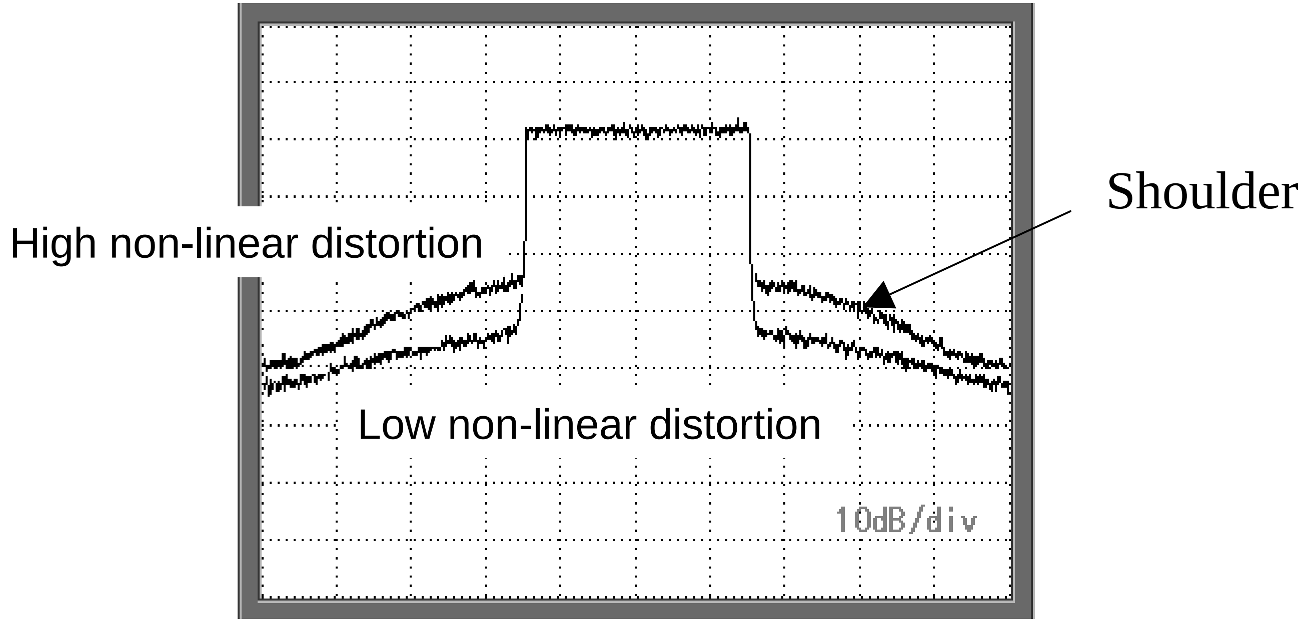
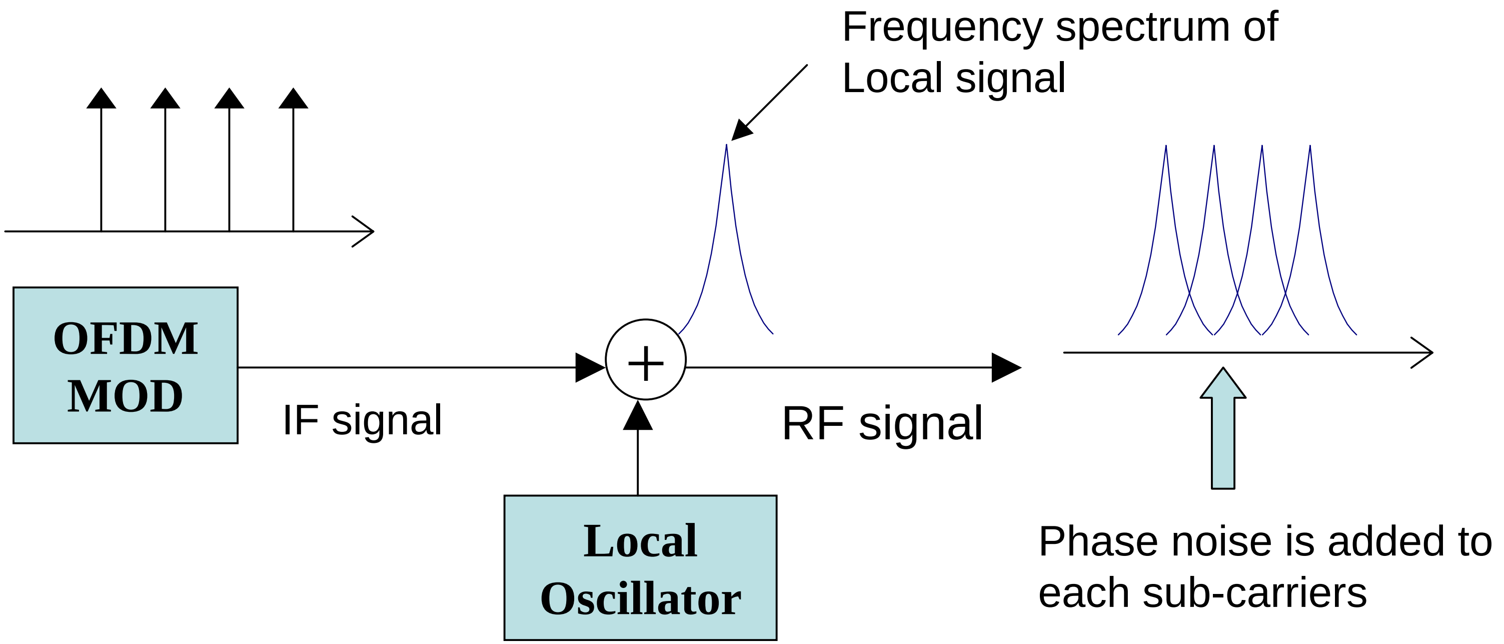
An example of output spectrum



The 3rd-order inter-modulation products appeared on the outside of signal bandwidth. These products are coaled “Shoulder”, and used for measurement parameter of transmitter

(d) Phase Noise

The phase noise is mainly generated from local oscillator, and is added to each sub-carriers of OFDM signal(See below)



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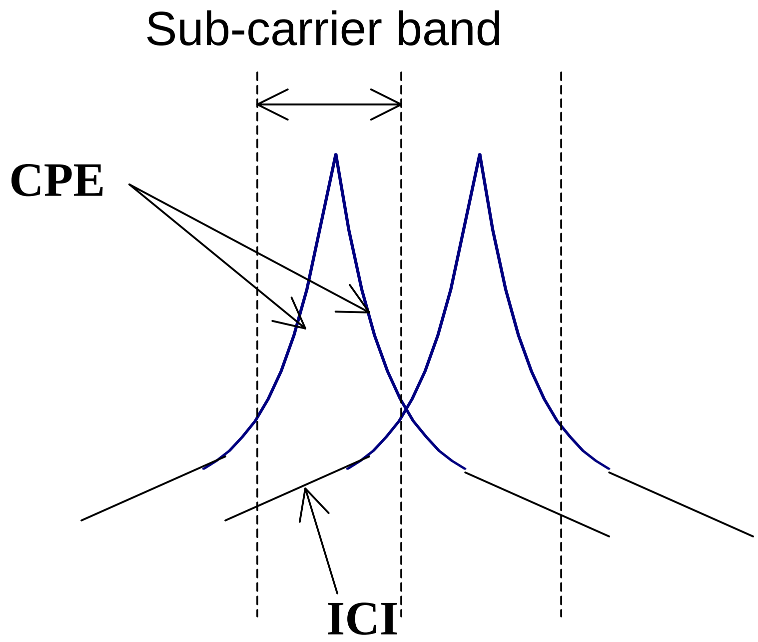
The Influences of Phase Noise



CPE: **Common Phase Error. The in-band components of Phase Noise. This causes circular shift of signal constellation. As a result, causes the C/N degradation.**

ICI: **Inter-Carrier Interference. The out-band components of Phase Noise. This components behave as a thermal noise. As a result, causes the C/N degradation.**

4. Key technology for improvement of ISDB-T transmission characteristics (Broadcast relay station and reception)

In this section, we introduce the key technologies for broadcast relay station and reception.

The whole pages of this section are dedicated by NHK laboratory.

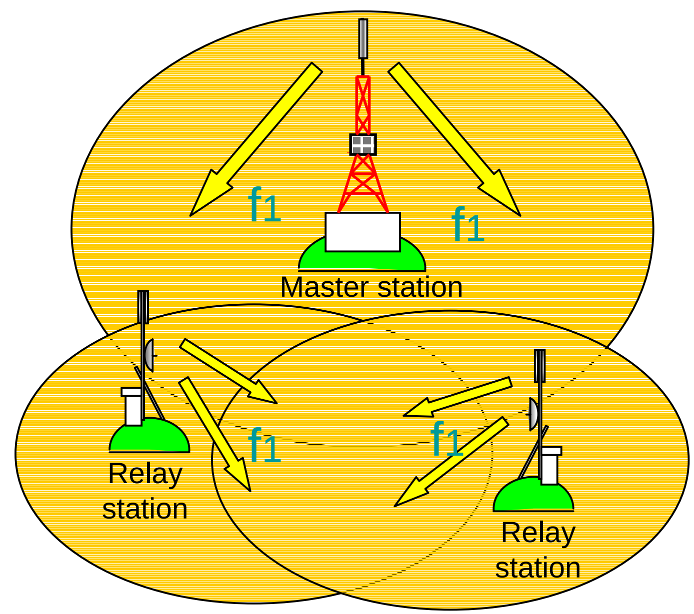
1. R&D relate to DTTB transmission technologies

- Transmitter side
  - Coupling loop interference canceller at broadcast-wave relay station for single frequency network
- Receiver side
  - Fixed reception
    - Long delay multipath equalizer
  - Mobile reception
    - HDTV mobile reception
  - Handheld/portable reception
    - Study on prediction of service area

Countrywide transmitter networks

- To cover the service area all over the country, Broadcasters have to construct relay stations.
- DTTB has an ability of constructing SFN.
- There are 3 delivery methods of DTTB signal from master station to relay station.
  - Microwave Link
    - ➢ More frequency bands (limited frequency band)
  - Optical Fiber
    - ➢ Construction and running cost (expensive)
  - Broadcast-wave relay system (On air relay from master station)
    - ➢ <u>Coupling loop interference</u>

      Merit : low cost



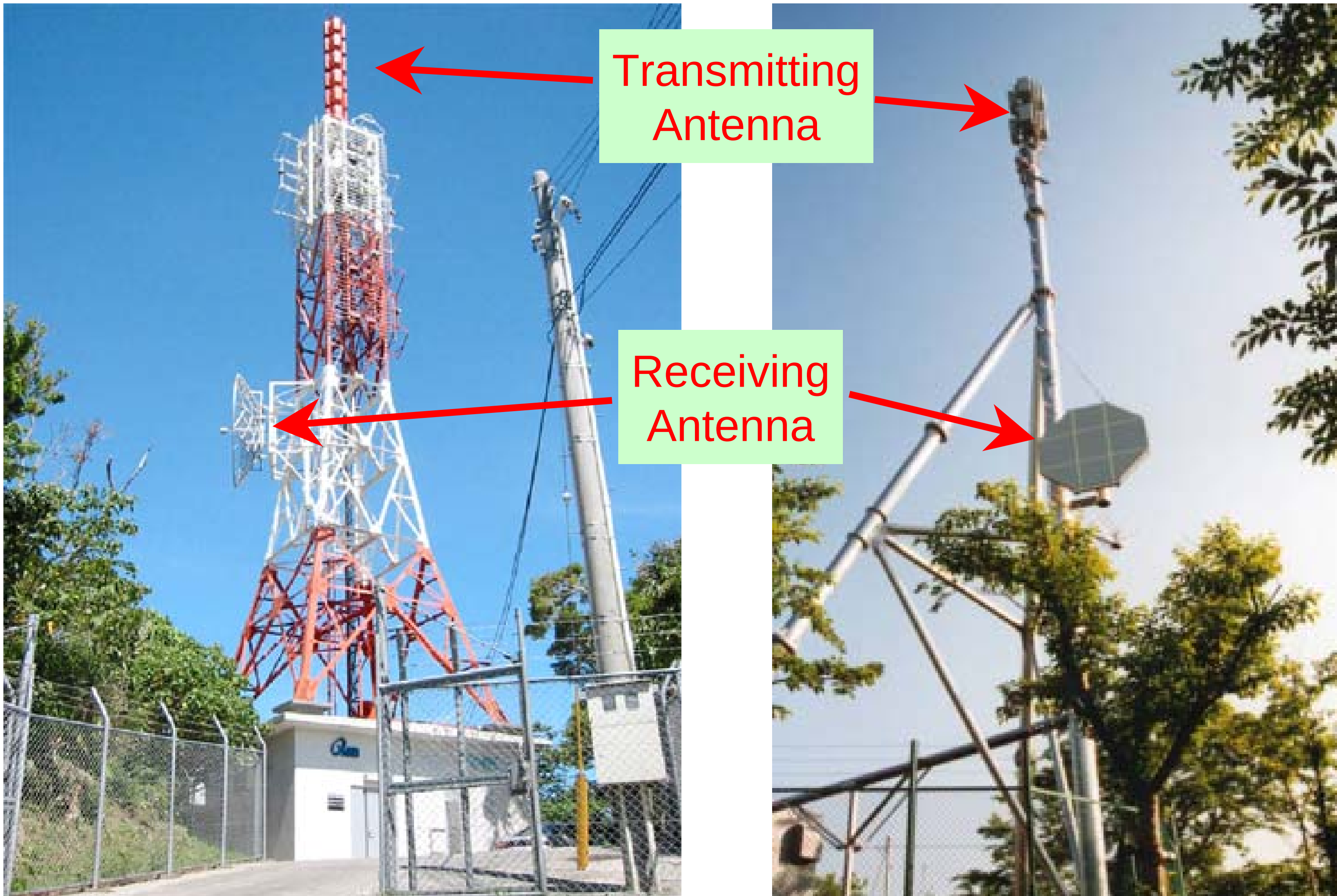
SFN : Single Frequency Networks

CLI canceller for broadcast-wave relay system

-Toward the construction of countrywide digital terrestrial broadcasting networks -

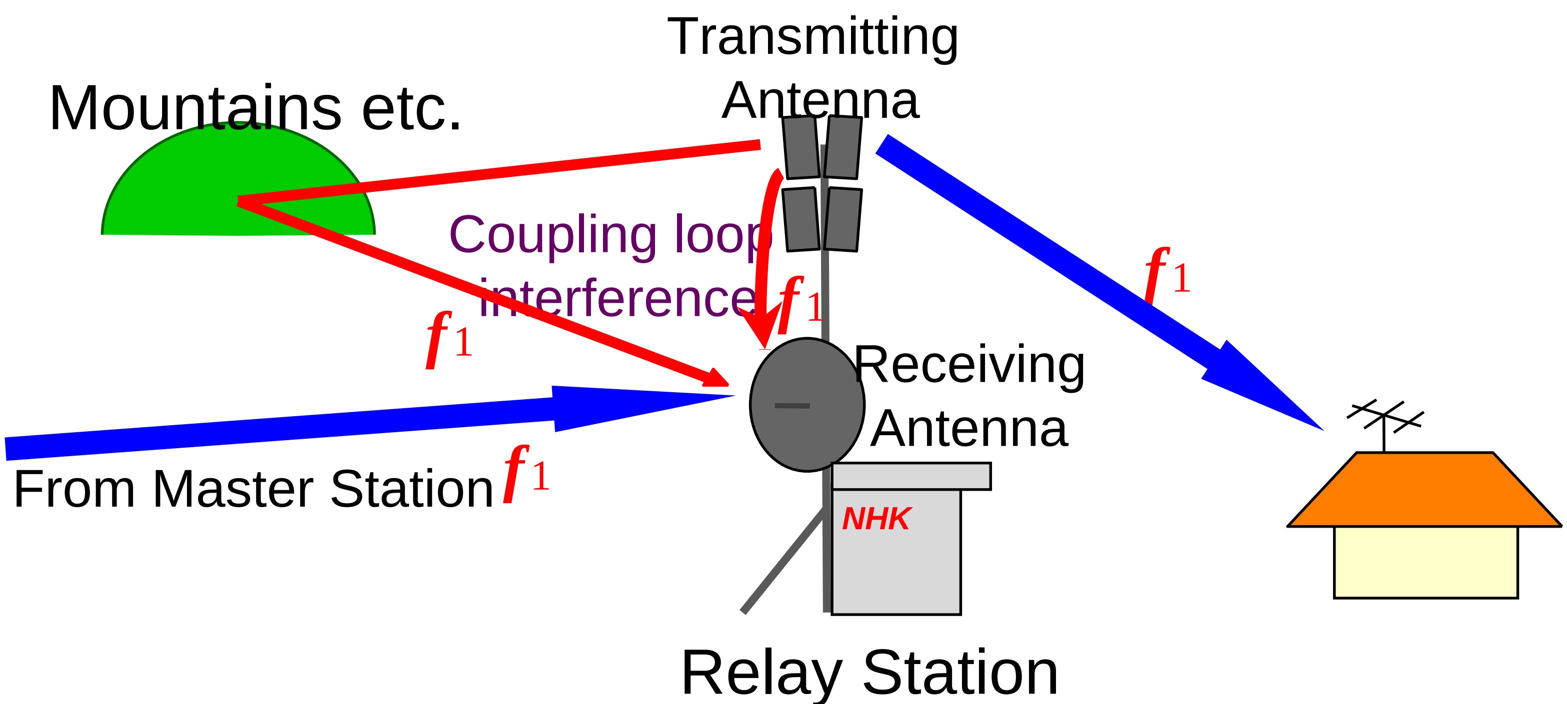
- Constructing stable and cost-effective relay networks is important.
- Broadcast-wave relay system is the most cost-effective signal delivery system.
- Remaining problem was stability. But we developed Coupling loop interference (CLI) canceller.
- CLI cancellers can eliminate distortion when signals are relayed in a single frequency network (SFN).

Broadcast-wave relay stations

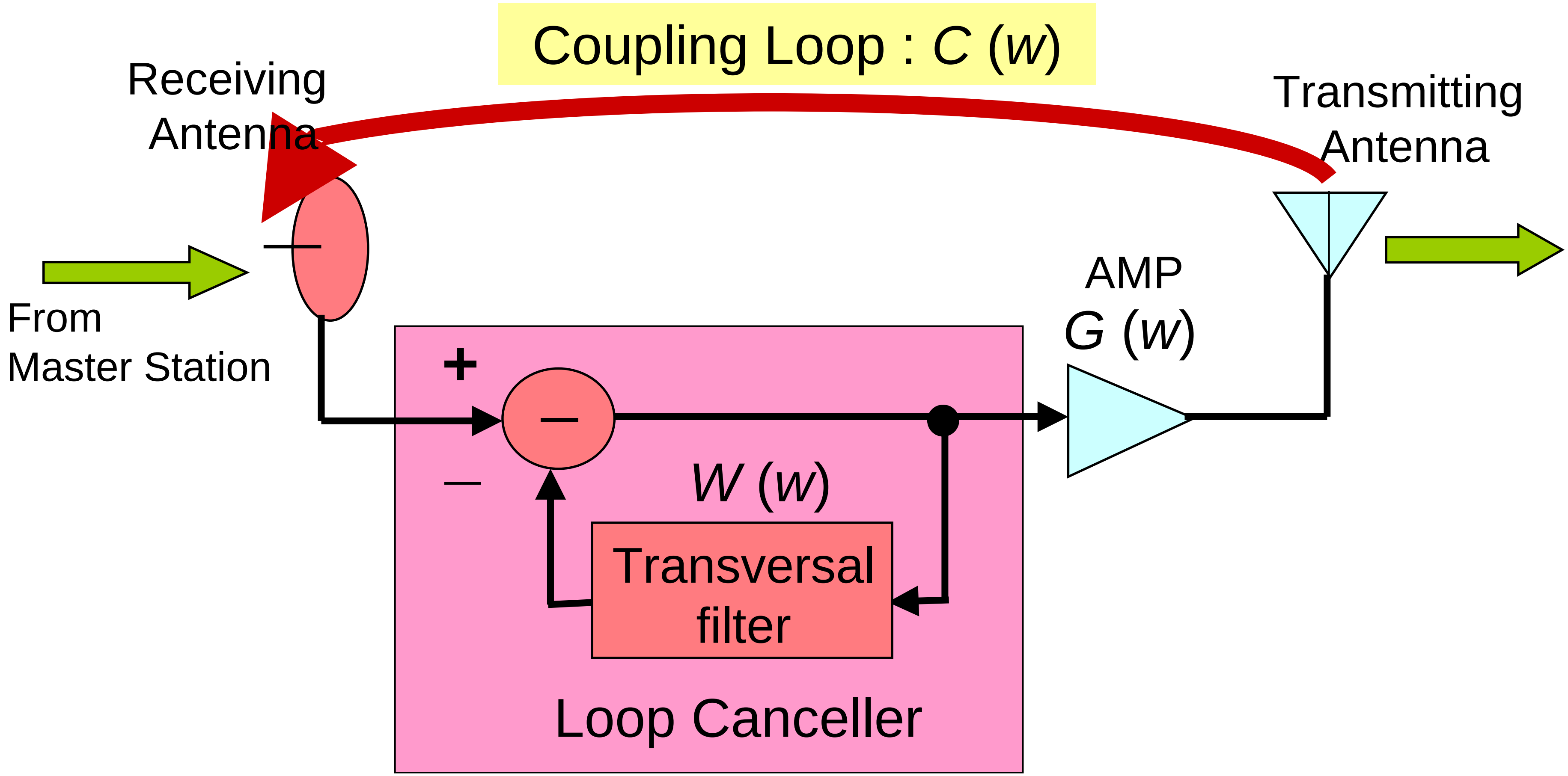


What is CLI (coupling loop interference) ?

- Frequency of transmitting signal is the same as frequency of receiving signal.
- If the output of transmitting signal comes to the input receiving antenna, receiving signal is interfered. This is CLI.
- It is generally said that more than 90dB isolation is needed between transmitting antenna and receiving antenna.

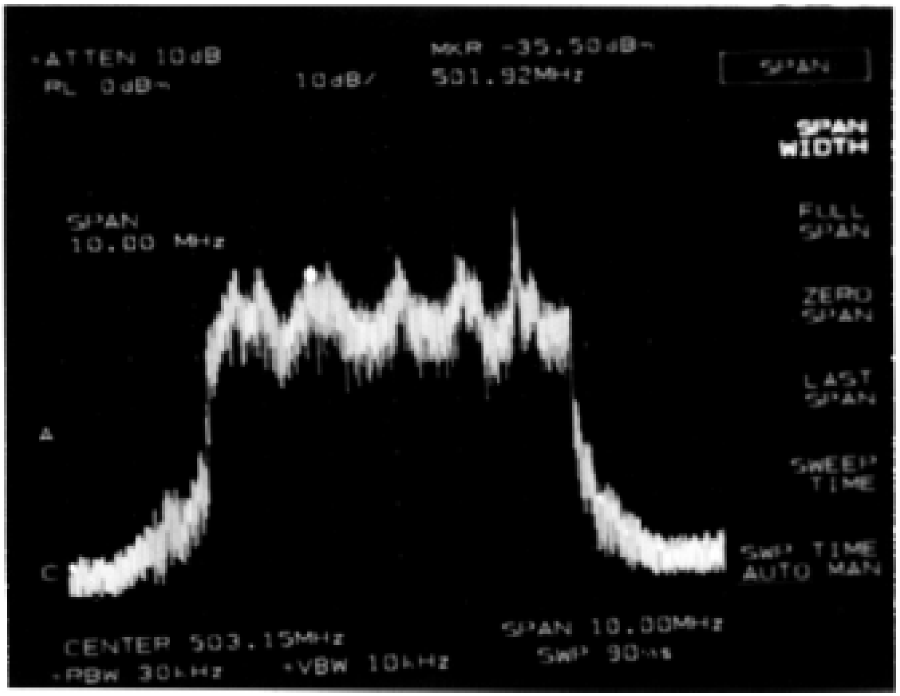


Principle of CLI canceller

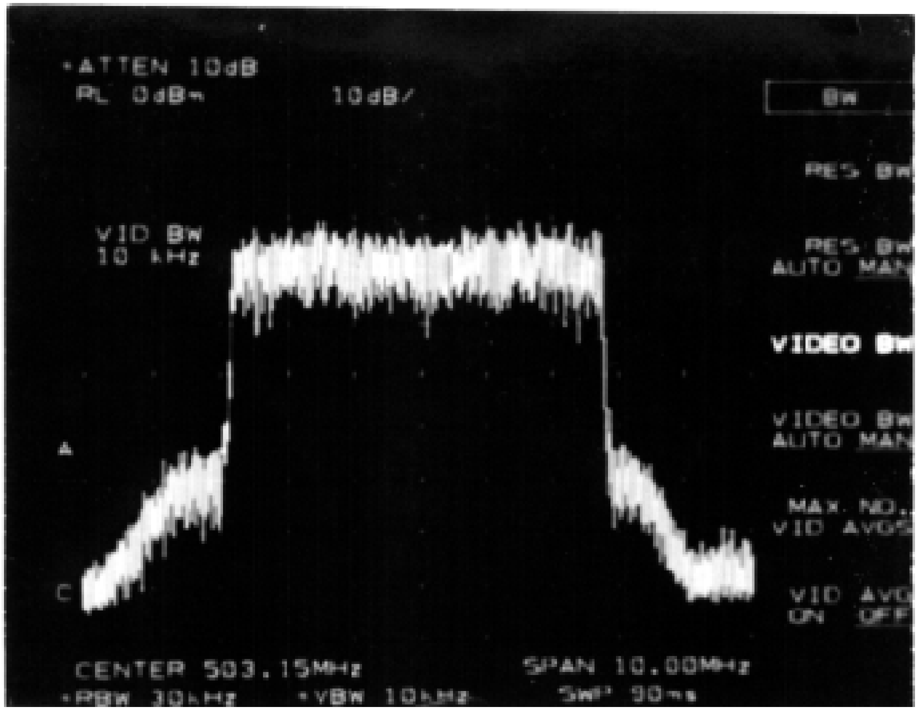


Condition for canceling : $W(w) = G(w)\,C(w)$

Effect of CLI canceller

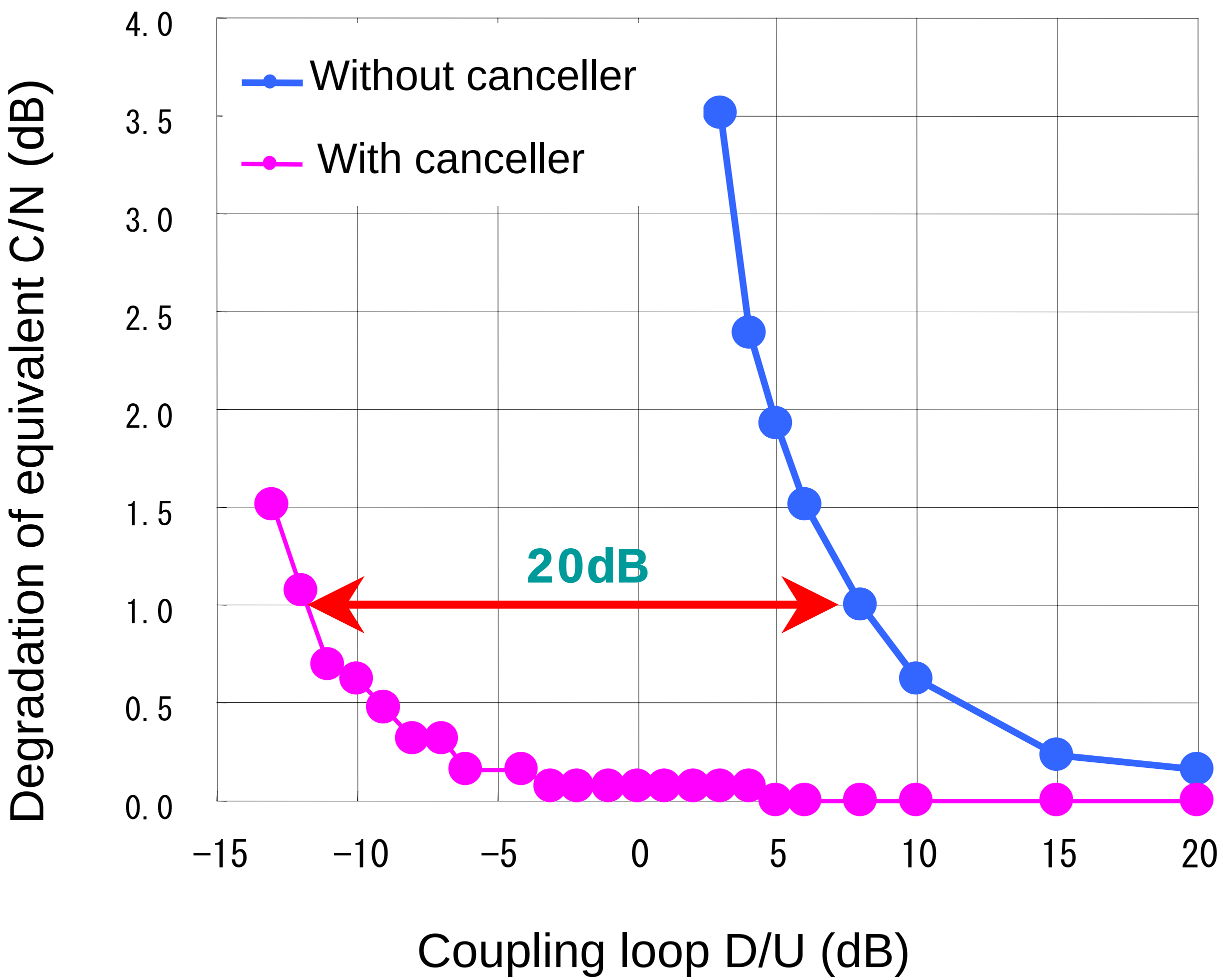


Transmission signal
without CLI canceller



Transmission signal
with CLI canceller

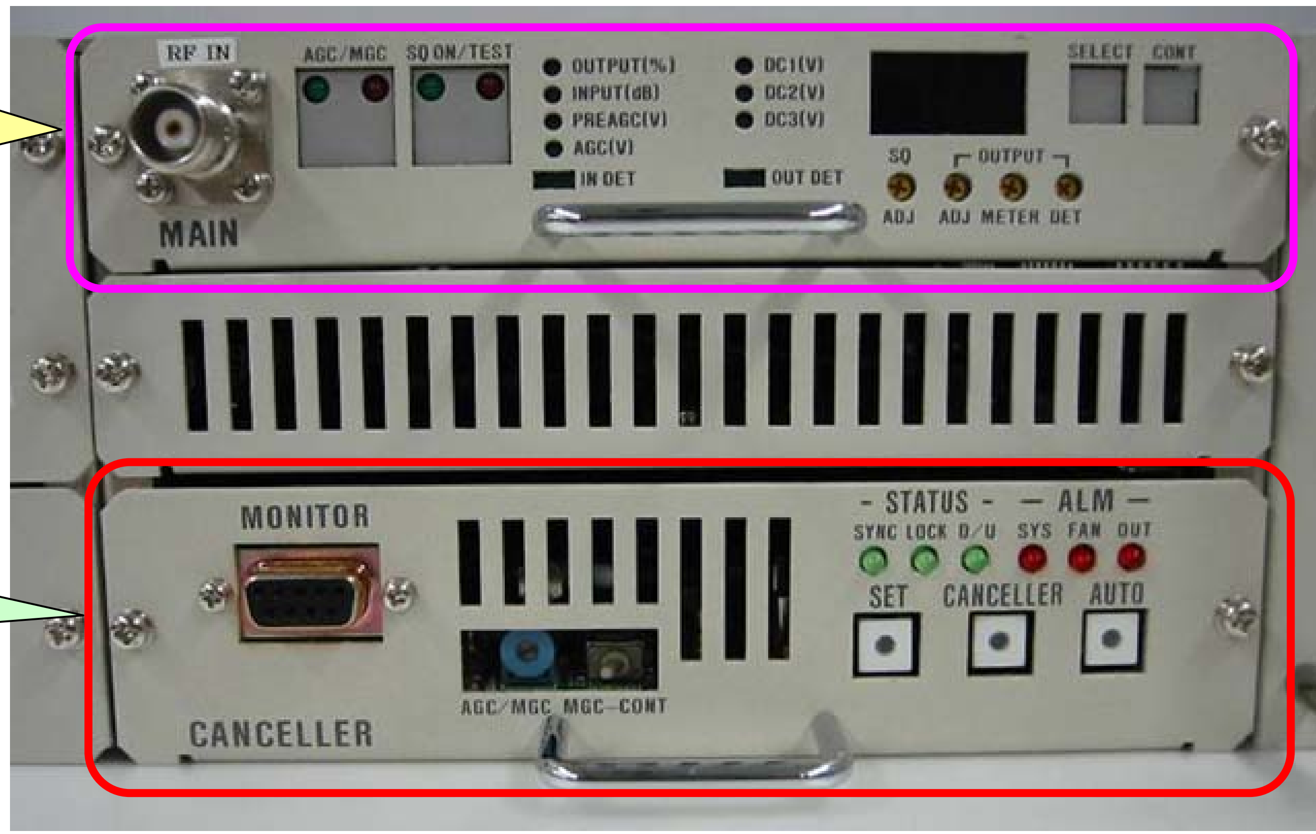
Performance of CLI canceller (Experimental data)



Equipment of CLI canceller (small type)

RF/IF, IF/RF freq. transform

Loop canceller



1. R&D relate to DTTB transmission technologies

- Transmitter side
  - Coupling loop interference canceller at broadcast-wave relay station for single frequency network
- Receiver side
  - Fixed reception
    - Long delay multipath equalizer
  - Mobile reception
    - HDTV mobile reception
  - Handheld/portable reception
    - Study on prediction of service area

Merits / demerits of SFN

- Merit of SFN
  - Frequency effective use (Frequency is limited)
- Demerits of SFN
  - CLI at broadcast-wave relay station
    - solve by CLI canceller
  - Appearance of long delay multipath
    - solve by guard interval of OFDM

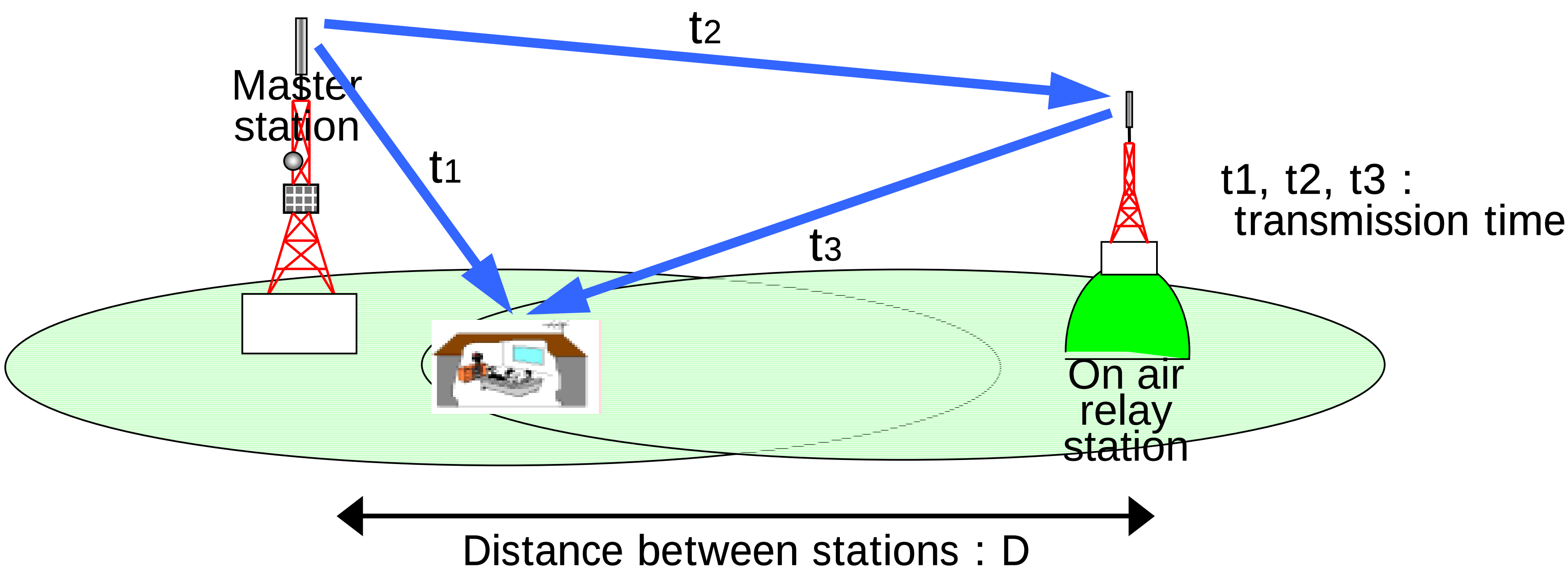
How about long delay multipath over guard interval

→ Long delay mutipath equalizer

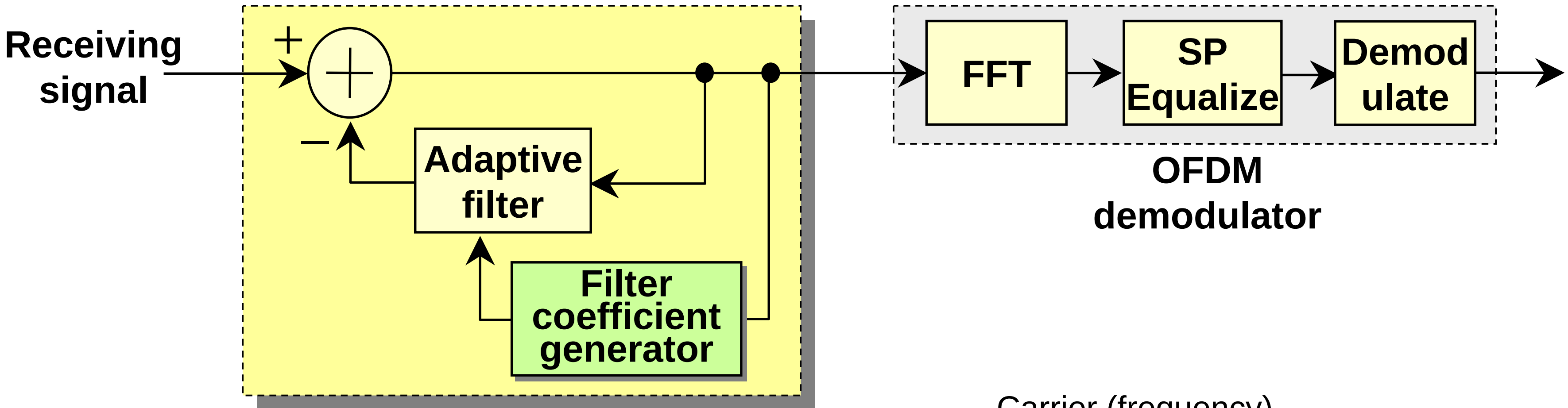
Long delay multipath situation

- Transmission time of desired signal : t_1
- Transmission time of delayed (undesired) signal : t_2+t_3
- Delay time of undesired signal $\tau_x = (t_2+t_3) - t_1$
- Guard Interval : τ_{GI} (for example τ_{GI} = 126 usec)
- Long delay multipath over guard interval $\tau_x > \tau_{GI}$
- IF D>37.8km, t_2>126usec, there is possibility to be $\tau_x > \tau_{GI}$

⇒ Development of long delay multipath equalizer is important.

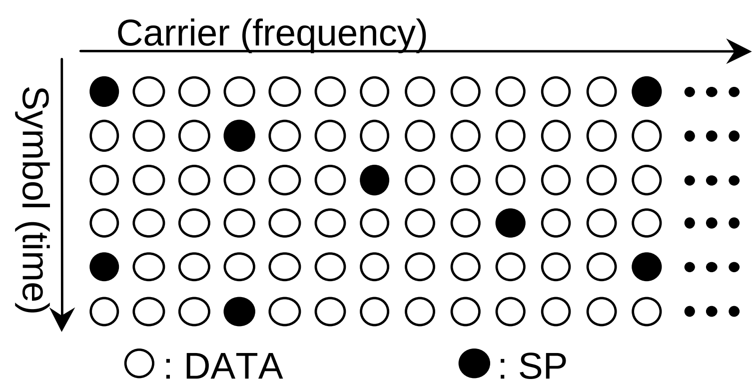


Receiver improvement
Principle of long delay mutipath equalizer



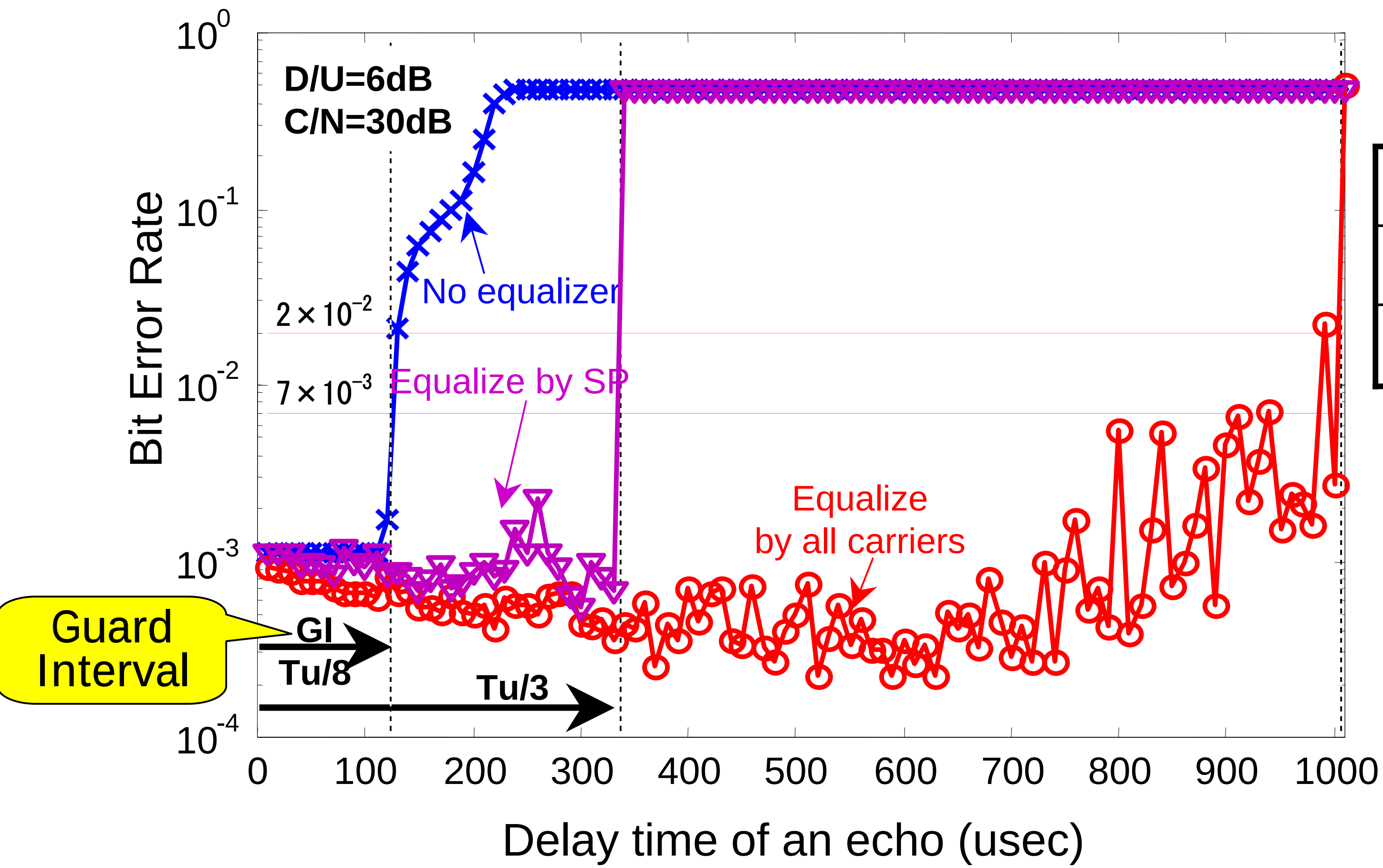
Equalizer adapted with long echo over guard interval
(Equalizer in time domain)

Update of filter coefficient ;
- SP : 4 symbol interval
- All carrier : 1 symbol



Distribution of Scattered Pilot symbol

Performance of long delay multipath equalizer



Mode	3
GI	1/8
Mod	64QAM

Useful symbol duration (Tu) : 1008usec

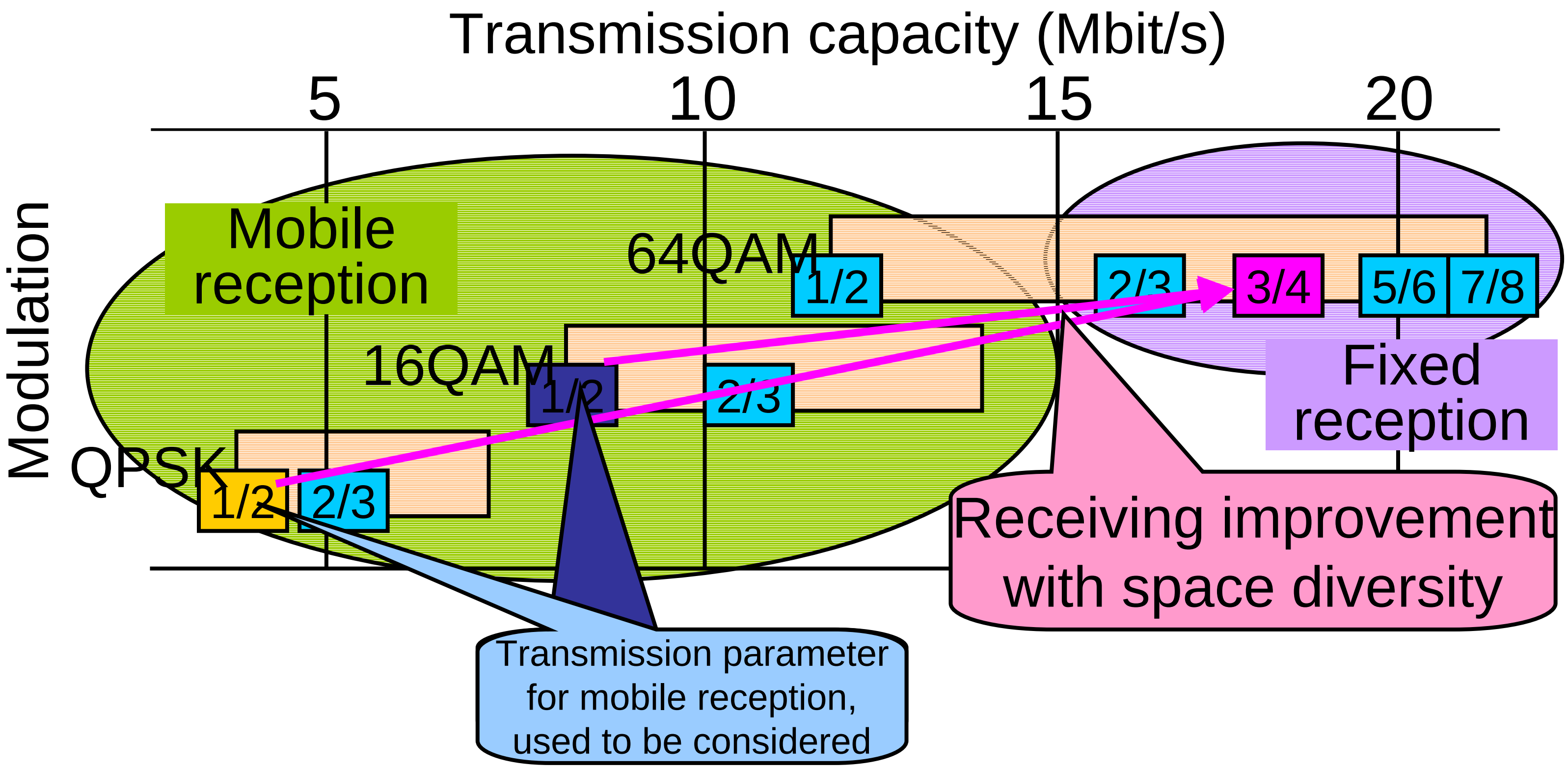
Guard interval (GI = Tu/8) : 126usec

Equipment
of long delay multipath equalizer

1. R&D relate to DTTB transmission technologies

- Transmitter side
  - Coupling loop interference canceller at broadcast-wave relay station for single frequency network
- Receiver side
  - Fixed reception
    - Long delay multipath equalizer
  - Mobile reception
    - HDTV mobile reception
  - Handheld/portable reception
    - Study on prediction of service area

HDTV mobile reception
- background -



DTTB replaces analog TV. Analog TV is mainly for fixed reception service.
So, in Japan, main service of DTTB is decided to be HDTV.
DTTB has ability to transmit STDV service for mobile reception using QPSK or 16QAM, however, there is no TV channel to be assigned for mobile reception.

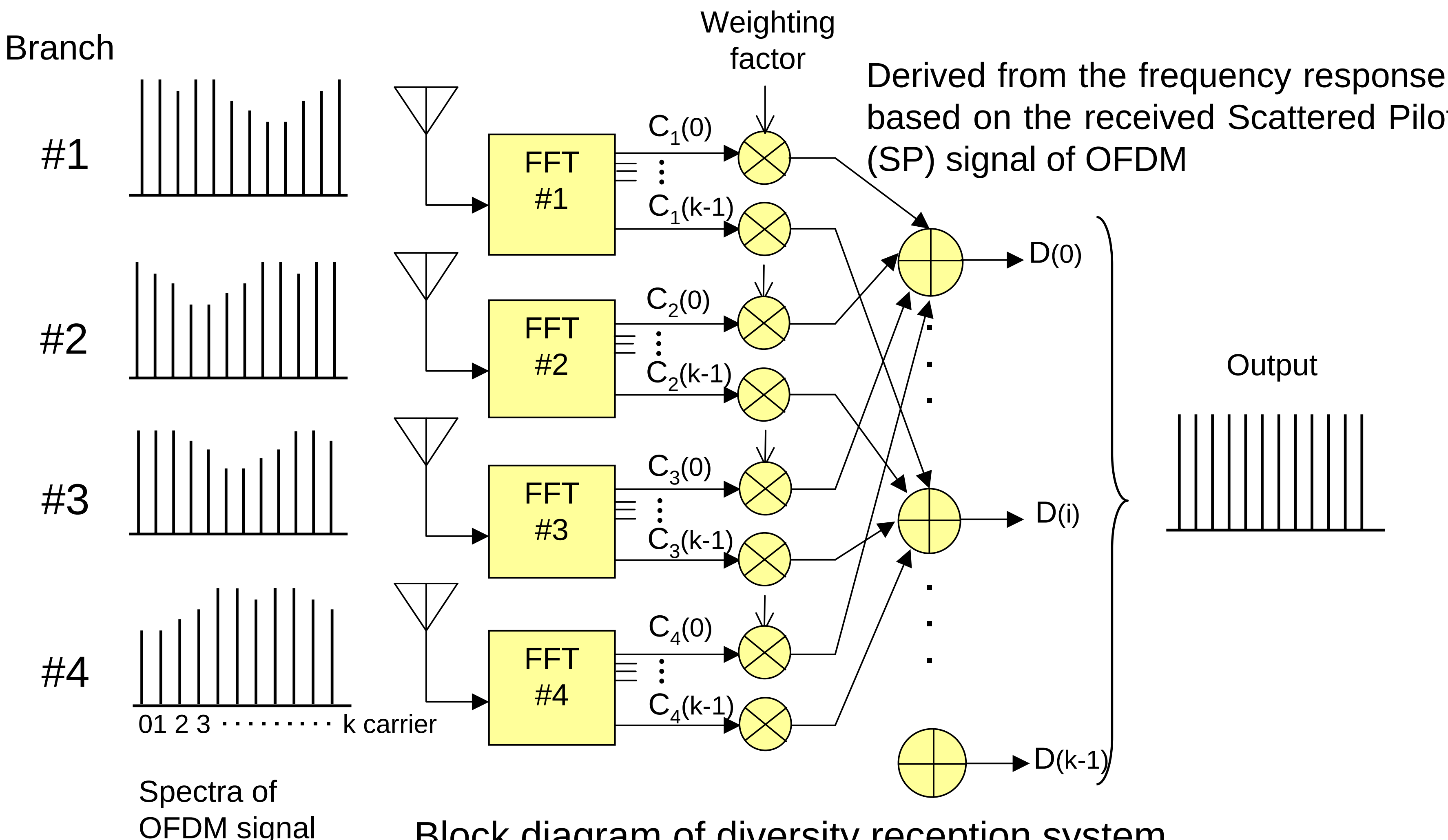
⇒ It is hopeful that HDTV service for fixed reception can be received by mobile.

HDTV mobile reception system

4-branch space diversity

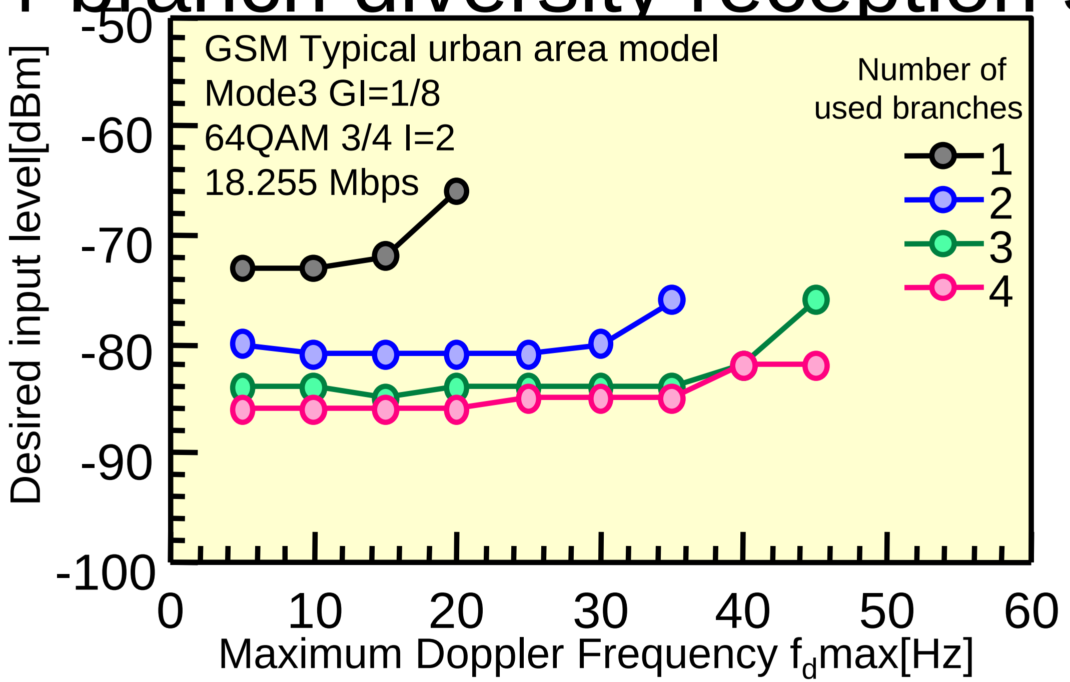
- HDTV mobile reception system
  - Signal : 6MHz BW 64QAM-OFDM (ISDB-T)
  - Application : HDTV (18.3 Mbps) in a mobile car
  - Diversity : 4-branch space diversity
- Implementation and performance evaluation
  - Laboratory test
    - Maximum Doppler frequency in fading environment
  - Field trial in Tokyo suburban area

Principle of 4-branch space diversity for OFDM signal under mobile reception



Block diagram of diversity reception system

Results of lab test on 4-branch diversity reception system



Number of Branch	$f_d$max	Velocity@19ch ($v = f_d\text{max} \times \lambda$)	Velocity@62ch ($v = f_d\text{max} \times \lambda$)	Desired input level (@ $f_d$max =20Hz)
1	20Hz	42 km/h	28 km/h	-66 dBm
2	35Hz	74 km/h	49 km/h	-81 dBm
3	45Hz	95 km/h	63 km/h	-84 dBm
4	45Hz	95 km/h	63 km/h	-86 dBm

35km/h improved

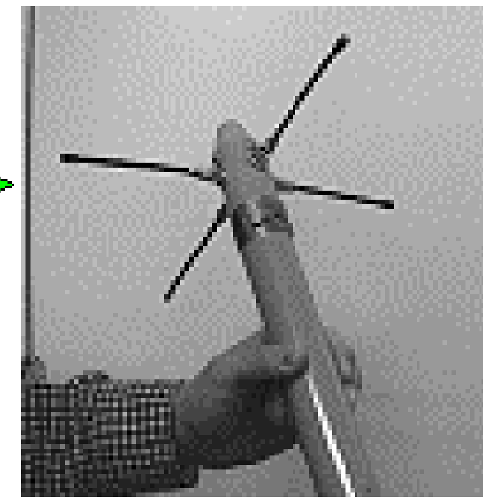
20dB improved

Field trial in Tokyo (suburban area)

Frequency	UHF 19ch 509 MHz
Tx power	30 W (45dBm)
Polarization	Horizontal

TX antenna

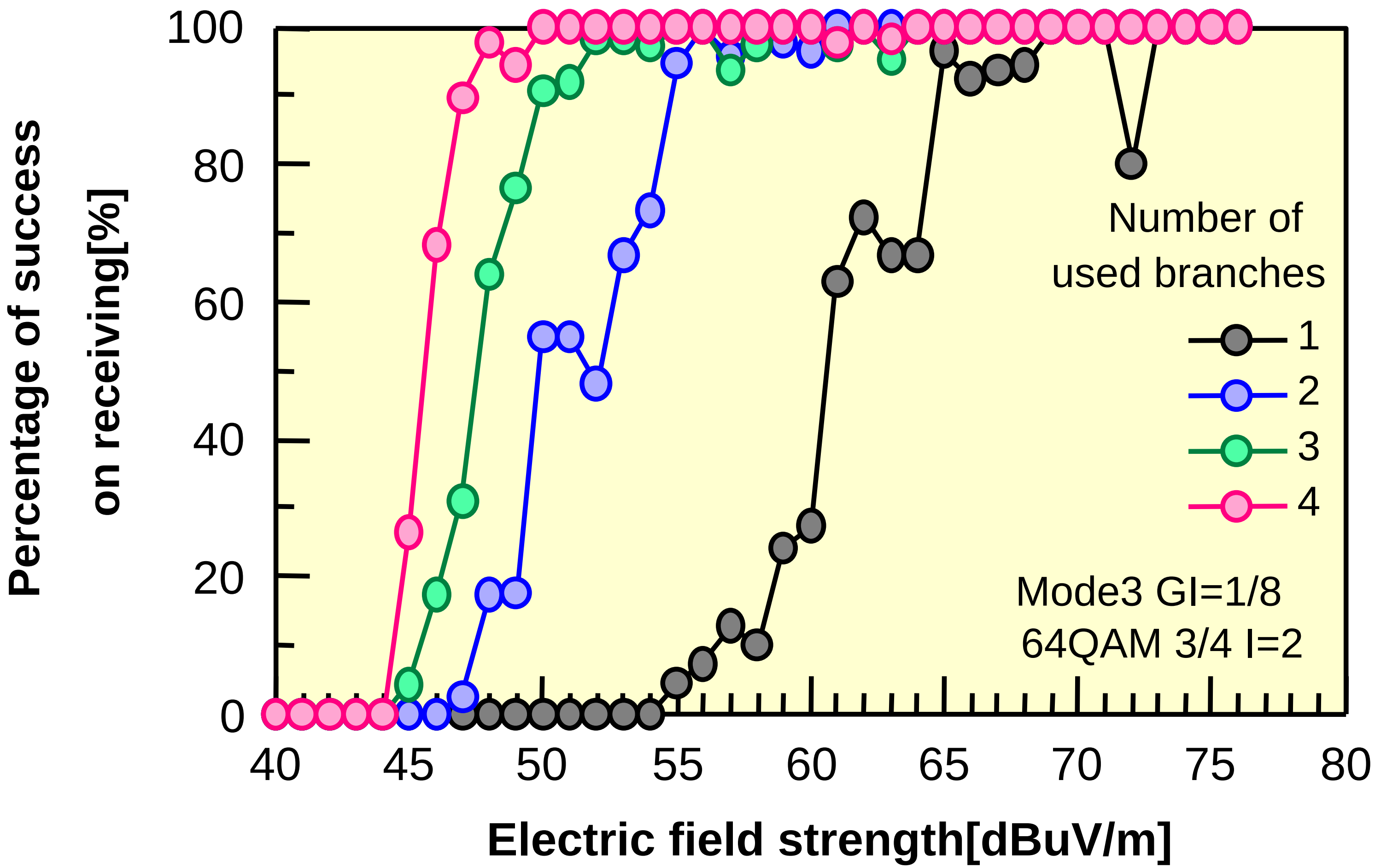
Receiving antennas
for DTTB mobile reception



Cross dipole antenna
Gain = 0 dB

4 antennas are mounted on the car roof.
Height is 2 m above the ground.

Results of field experiment



Effectiveness of diversity reception

Required field strength
for 50 % and 90 % correct reception rate.

Number of branch	1	2	3	4
E_{min} at CRR of 50 %	61	50	48	46
E_{min} at CRR of 90 %	65	55	50	48

E_{min} : Minimum usable field strength [dBμV/m]
CRR: Correct Reception Rate

✓At CRR of 90 %,
E_{min} of 17dB can be reduced
by using 4-branch diversity reception.

1. **R&D** relate to **DTTB** transmission technologies

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Transmitting station (Tokyo tower)

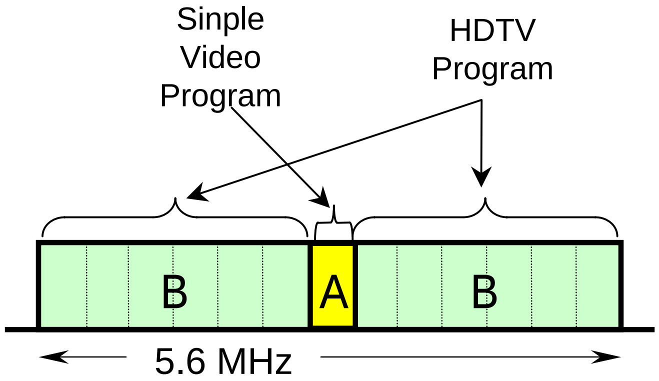
Tokyo tower digital transmitter
1st stage (NHK Digital GTV)

Channel	UHF 27ch (557MHz)
Transmission power	300 W
ERP (Effective radiation power)	570 W
Antenna height	267 m
Polarization	Horizontal

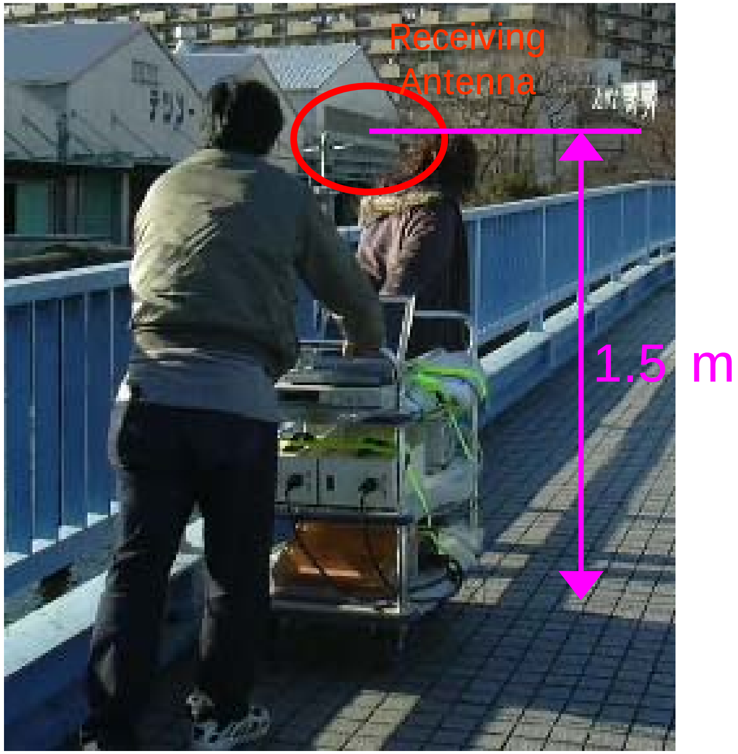
Transmission parameters and receiving scenery

Transmission parameters of NHK Digital GTV

Mode	3 (5617 carriers)	
GI (Guard Interval)	1/8 (126usec)	
Hierarchical transmission	2 layers	
	A	B
Number of segments	1	12
Carrier modulation	QPSK	64QAM
FEC coding rate	1/2	3/4
Time interleaving	215ms	215ms



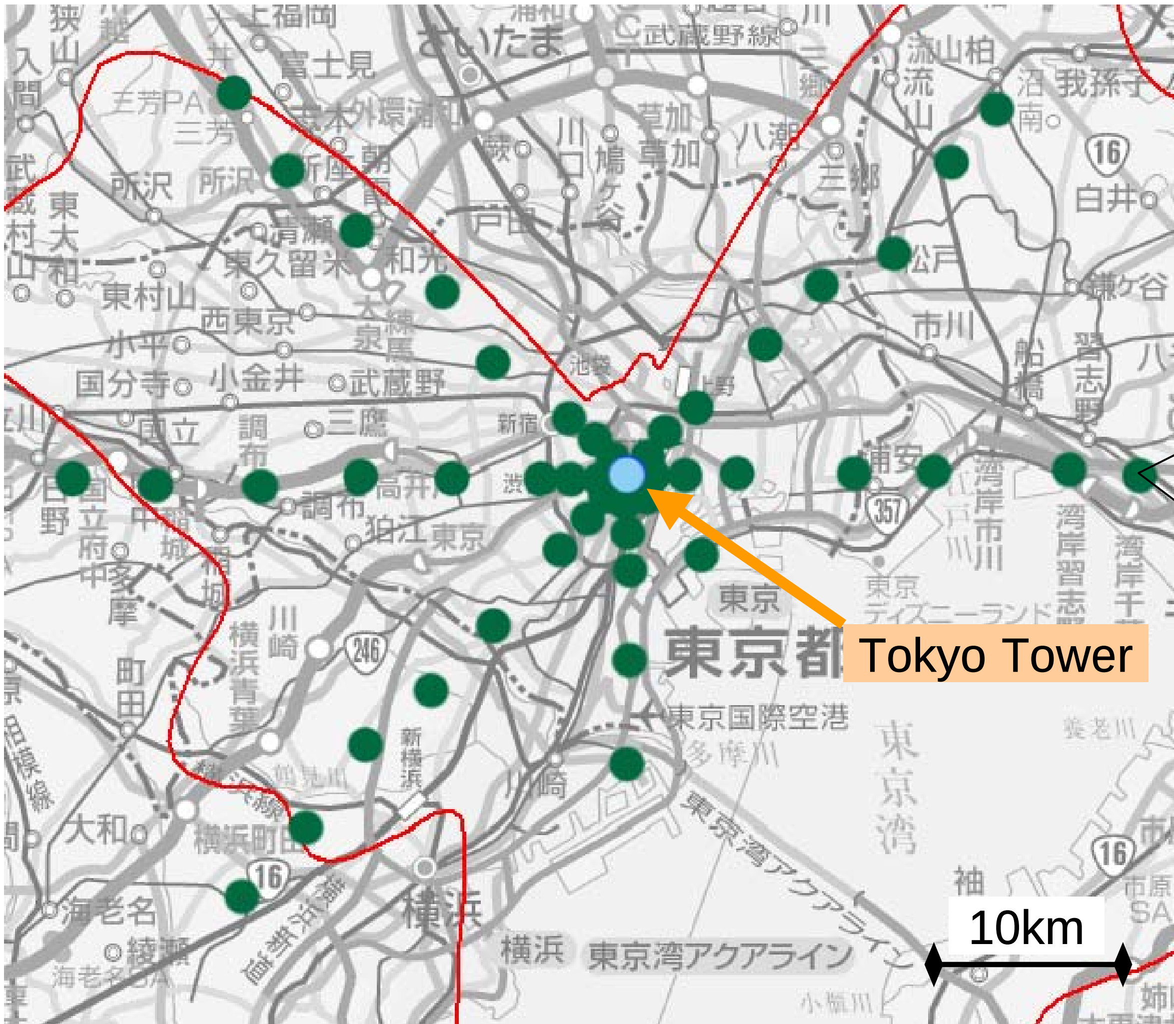
Receiving scenery



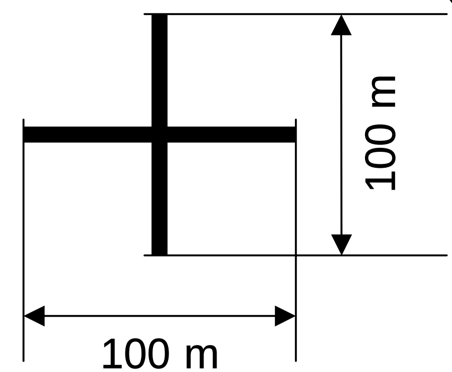
Receiving antenna height : 1.5m
Receiving antenna : Cross dipole antenna

NHK

Measured sites for handheld reception



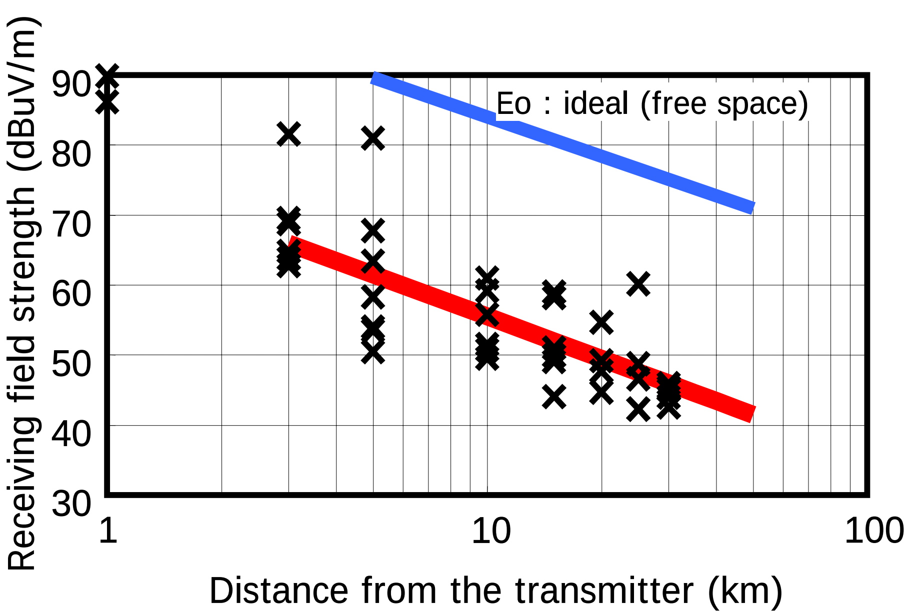
- 7 directions (spokewise)
- 1,3,5,10,15,20,25,30 km

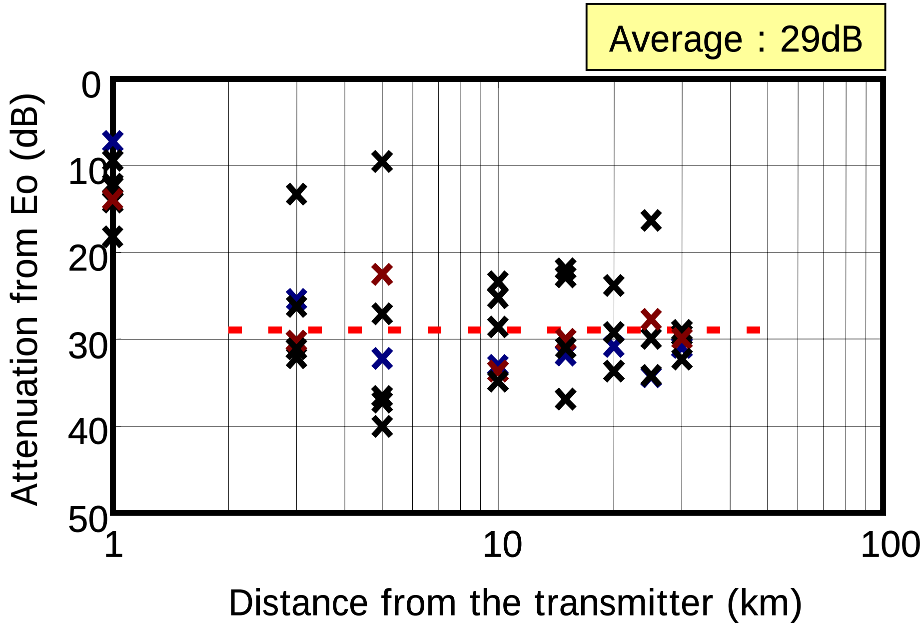


100 samples / one way

Representative value : medium

Distribution of measured field strength





Average attenuation from Eo (free space electric field strength) = 29dB

END of seminar #5

Thank you for your attention !