Seminar #5

Transmission system (part 2)

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Digital Broadcasting Expert Group (DiBEG)

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

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>Europe</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td>ISDB-T&lt;sub&gt;SB&lt;/sub&gt;</td>
<td>DAB</td>
<td>IBOC</td>
</tr>
<tr>
<td><strong>Carrier modulation</strong></td>
<td>OFDM (DQPSK, QPSK, 16QAM, 64QAM)</td>
<td>OFDM (DQPSK)</td>
<td>OFDM</td>
</tr>
<tr>
<td><strong>Error-correcting code</strong></td>
<td>Reed-solomon + convolutional error correcting</td>
<td>convolutional error correcting</td>
<td>convolutional error correcting</td>
</tr>
<tr>
<td><strong>Multiplex structure</strong></td>
<td>MPEG-2 System</td>
<td>Original System</td>
<td>Original System</td>
</tr>
<tr>
<td><strong>Audio coding</strong></td>
<td>MPEG-2 Audio AAC</td>
<td>MPEG-1 (Layer2)</td>
<td>MPEG-2 Audio AAC</td>
</tr>
</tbody>
</table>
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
Spectrum of 1 segment system and 3 segment system

1 segment system

- 430 kHz
- A layer

3 segment system

- 1290 kHz
- B layer
- A layer
- B layer
Trial Services of DRP

VHF television band assignments

- VHF 6ch
- VHF 7ch
- VHF 8ch

Segment structure

- 8 segments (Normally 13seg.)
- 3seg. broadcasting

Broadcast programs

- 91ch 92ch 93ch 94ch 95ch
- 95ch

Above example is Tokyo station, Osaka's all programs are 1seg. broadcasting.
## Outline of operation -1

<table>
<thead>
<tr>
<th>system</th>
<th>No. assigned segment</th>
<th>Reception style</th>
<th>Transmission parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 segment</td>
<td>1( A layer) (basic segment)</td>
<td>mobile handheld</td>
<td>QPSK 1/2, 2/3 16QAM 1/2</td>
</tr>
<tr>
<td>3 segment</td>
<td>1( A layer) (basic segment)</td>
<td>mobile handheld</td>
<td>QPSK 1/2, 2/3 16QAM 1/2</td>
</tr>
<tr>
<td></td>
<td>2( B layer) (extended segment)</td>
<td></td>
<td>QPSK 1/2, 2/3 16QAM 1/2</td>
</tr>
</tbody>
</table>
# Outline of operation -2

<table>
<thead>
<tr>
<th>System</th>
<th>Data broadcasting</th>
<th>Bi-directional service</th>
<th>CAS (TBD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 segment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A layer</td>
<td>Data broadcasting</td>
<td>TCP/IP (option)</td>
<td>In current license, charged broadcasting is not permitted</td>
</tr>
<tr>
<td></td>
<td>P-profile by BML</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 segment</td>
<td></td>
<td>TCP/IP (option)</td>
<td>RMP is now on discussion</td>
</tr>
<tr>
<td>A layer</td>
<td>Profile for mobile service is now on discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 segment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B layer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Construction of DTSB

- Audio
- Data broadcasting
- Audio coding
- Data coding
- Section
- PES
- Section
- MPEG MUX (TS)
- OFDM frame MUX, transmission coding
- MPEG-TS
- TMCC
- Modulation
- Transmit

Broadcaster (program supplier)

PSI SI CA

DRP
Digital radio/digital TV compatible receiver

- DTTB (UHF)
  13 segment (partial reception operation)

- DTSB (VHF)
  3 segment system

- DTSB (VHF)
  1 segment system

- DTV receiver (VHF+UHF)

- 3 segment receiver (VHF+UHF)

- 1 segment receiver (VHF+UHF)
Trial studio/transmitting station

Each broadcaster → (Tokyo) Shiba Park building → Tokyo tower → Tokyo tower

(Tokyo) Shiba Park building → (Osaka) Twin Tower MID → Mt. Ikoma → Mt. Ikoma

CH91 → Master room → Transmitter room → antenna

CH92

CH93

CH98

Master room

Transmitter room

Tokyo (fiber)

Osaka (STL)
Details of ISDB-T<sub>SB</sub> 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) Pixela will deliver mid of this year
DRP prototype receiver (1 segment)
PDA type prototype receiver (KDDI/TFM/Vitec)
Pixela PC card type receiver
PC card type receiver (test product)
### <Digital radio trial broadcasting>
#### Channel construction

**Tokyo**

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

*Apr. 1st 2004*
<Digital radio trial broadcasting>
Channel construction

Osaka

<table>
<thead>
<tr>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
<th>98</th>
</tr>
</thead>
</table>

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) 

Apr. 1st 2004
<table>
<thead>
<tr>
<th>Time</th>
<th>MAIN</th>
<th>SUB 1</th>
<th>SUB 2</th>
<th>SUB 3</th>
<th>DATA (NHK)</th>
<th>DATA (VICS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00</td>
<td>サウンドパサージュ</td>
<td></td>
<td></td>
<td></td>
<td>見えるニュース</td>
<td>道路交通情報</td>
</tr>
<tr>
<td>13:00</td>
<td>サウンドパサージュ</td>
<td>ニュースダイジェスト</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:00</td>
<td>新基礎英語1</td>
<td>新基礎英語2</td>
<td>選べるニュースダイジェスト(A)</td>
<td>選べるニュースダイジェスト(B)</td>
<td>選べるニュースダイジェスト(C)</td>
<td></td>
</tr>
<tr>
<td>20:00</td>
<td>新基礎英語2</td>
<td>新基礎英語3</td>
<td>新基礎英語3</td>
<td>フランス語講座</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20:15</td>
<td>英会話レッツスピーク</td>
<td>ハングル語講座</td>
<td>スペイン語講座</td>
<td>ドイツ語講座</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20:30</td>
<td>英語リスニング入門</td>
<td>中国語講座</td>
<td>イタリア語講座</td>
<td>ロシア語講座</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Time table of Digital Radio 98 The Voice

<table>
<thead>
<tr>
<th>Time</th>
<th>音声1+静止画 ロゴ</th>
<th>音声2 or 簡易動画</th>
<th>音声2 or 音声3</th>
<th>データ放送</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>It’s 笑 Time No. 1</td>
<td>Music Stream</td>
<td>This is The Voice 98</td>
<td>くるくる</td>
</tr>
<tr>
<td>11:00</td>
<td>It’s 笑 Time No. 2</td>
<td>Music Stream</td>
<td>This is The Voice 98</td>
<td>くるくる</td>
</tr>
<tr>
<td>12:00</td>
<td>ヘルスセンター 98-1</td>
<td>This is The Voice 98</td>
<td>くるくる</td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>ヘルスセンター 98-2</td>
<td>This is The Voice 98</td>
<td>くるくる</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>またたび アワー No. 1</td>
<td>Music Stream</td>
<td>This is The Voice 98</td>
<td>くるくる</td>
</tr>
</tbody>
</table>
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, prototype 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


• 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

Sawara Stn.
SFN

Tokyo

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)

- Mode 3, 64QAM, 5/6, 13 Seg.
- Mode 2, DQPSK, 1/2, 1 Seg.
- Mode 2, 64QAM, 7/8 12 Seg.
Comparison of Time Interleave
(Phase1: Mobile reception)

Correct Reception Time Rates (%)

Mode 2, DQPSK, 1/2, 13 seg.

- With Time Interleaving
- Without Time Interleaving

Measured Field Strength (dBμ V/m)

99%
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 $\mu$V. In the central area of town, there were rare cases of freeze the pictures.

- **DQPSK-2/3**: field strength was about 45dB $\mu$V. Sometimes the picture froze at the central area of town and shadow area.

- **DQPSK-3/4**: field strength was about 50dB $\mu$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 $\mu$V. Same to DQPSK-3/4
2.2 Result of comparison test conducted by ABERT/SET of Brazil

Original published in Portuguese.
Translated in English
# Laboratory Tests Basic Configurations

<table>
<thead>
<tr>
<th>PAYLOAD (Mbps)</th>
<th>ATSC</th>
<th>DVB-2K*</th>
<th>DVB-8K**</th>
<th>ISDB-4K***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configurations</td>
<td>1</td>
<td>Many</td>
<td>Lots</td>
<td></td>
</tr>
</tbody>
</table>

* 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**

![Graph showing carrier to noise ratio as a function of the carrier to echo ratio.](image)

- **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)

Successful Reception Percentage -
Cumulative function - Criteria: Margin - F(50,90) >0 and Errors< 5

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) Differences of Transmitter Composition

Transmitter composition is quite different.

(a) Analog High Power Transmitter block-diagram

(b) Digital High Power Transmitter block-diagram

(note) TS: transport stream
(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 TV, 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.
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.

![Graph showing BER vs. C/N(dB) for different distortion levels](image-url)

- **High distortion**
- **Low distortion**
- **Linear**

[DiBEG Digital Broadcasting Experts Group]
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)
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.
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)
      - **Coupling loop interference**
      - Merit: low cost
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

Transmitting Antenna

Receiving Antenna
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)

![Graph showing the degradation of equivalent C/N (dB) against coupling loop D/U (dB). The graph compares 'Without canceller' and 'With canceller' conditions. There is a significant improvement with the canceller, indicated by a 20dB difference.](image)
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 multipath 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: $\tau_{GI}$ (for example $\tau_{GI} = 126$ usec)
- Long delay multipath over guard interval $\tau_x > \tau_{GI}$
- If $D > 37.8$ km, $t_2 > 126$ usec, there is possibility to be $\tau_x > \tau_{GI}$

Development of long delay multipath equalizer is important.
Receiver improvement
Principle of long delay multipath 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:
- O : DATA
- ● : SP
Performance of long delay multipath equalizer

Useful symbol duration (Tu) : 1008usec
Guard interval (GI = Tu/8) : 126usec

Mode | 3
GI   | 1/8
Mod  | 64QAM
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
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

Derived from the frequency response, based on the received Scattered Pilot (SP) signal of OFDM

Block diagram of diversity reception system
Results of lab test on 4-branch diversity reception system

GSM Typical urban area model
Mode3 GI=1/8
64QAM 3/4 I=2
18.255 Mbps

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

Number of branches improved:
- 35 km/h
- 20 dB improved
Field trial in Tokyo (suburban area)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>UHF 19ch 509 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx power</td>
<td>30 W (45dBm)</td>
</tr>
<tr>
<td>Polarization</td>
<td>Horizontal</td>
</tr>
</tbody>
</table>

Experimental station

TX antenna

Measured route

1000 m
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

- **Electric field strength [dBuV/m]**
- **Percentage of success on receiving [%]**

**Mode3 GI=1/8**
64QAM 3/4 I=2

**Number of used branches**
- 1
- 2
- 3
- 4
**Effectiveness of diversity reception**

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

<table>
<thead>
<tr>
<th>Number of branch</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{min}}$ at CRR of 50 %</td>
<td>61</td>
<td>50</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>$E_{\text{min}}$ at CRR of 90 %</td>
<td>65</td>
<td>55</td>
<td>50</td>
<td>48</td>
</tr>
</tbody>
</table>

$E_{\text{min}}$: Minimum usable field strength [dB$\mu$V/m]
CRR: Correct Reception Rate

- At CRR of 90 %,
  $E_{\text{min}}$ of 17dB can be reduced by using 4-branch diversity reception.
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
Transmitting station (Tokyo tower)

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

<table>
<thead>
<tr>
<th>Channel</th>
<th>UHF 27ch (557MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission power</td>
<td>300 W</td>
</tr>
<tr>
<td>ERP (Effective radiation power)</td>
<td>570 W</td>
</tr>
<tr>
<td>Antenna height</td>
<td>267 m</td>
</tr>
<tr>
<td>Polarization</td>
<td>Horizontal</td>
</tr>
</tbody>
</table>
Transmission parameters and receiving scenery

Transmission parameters of NHK Digital GTV

<table>
<thead>
<tr>
<th>Mode</th>
<th>3 (5617 carriers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI (Guard Interval)</td>
<td>1/8 (126usec)</td>
</tr>
<tr>
<td>Hierarchical transmission</td>
<td>2 layers</td>
</tr>
<tr>
<td>Number of segments</td>
<td>A: 1, B: 12</td>
</tr>
<tr>
<td>Carrier modulation</td>
<td>QPSK, 64QA M</td>
</tr>
<tr>
<td>FEC coding rate</td>
<td>1/2, 3/4</td>
</tr>
<tr>
<td>Time interleaving</td>
<td>215ms, 215ms</td>
</tr>
</tbody>
</table>

Receiving scenery

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