

## **Experimental Results of Diversity Reception for Terrestrial Digital Broadcasting**

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### **Abstract**

Terrestrial digital broadcasting services in Japan will start in 2003, and conventional analog broadcasting will be terminated in 2011. However, it has been reported that the mobile reception quality for the terrestrial digital broadcasting is significantly reduced for high bit rate transmissions such as high definition television broadcasting. In this study, the reception quality of terrestrial digital broadcasting when the directional pattern of the mobile terminal is controlled has been experimentally investigated

using an experimental radio wave. As a result, it is confirmed that the reception probabilities by controlling the directional pattern are significantly improved compared to an omnidirectional antenna. Especially, it is found that the improvement in the reception probability is greatly increased as the electric field strength decreased. Thus, it is expected that the directional pattern control is an effective method for improving the reception quality and expanding the service area of the terrestrial digital broadcasting.

**Keywords**

Maximum ratio combining, Mobile reception, Terrestrial, Digital broadcast

## 1. Introduction

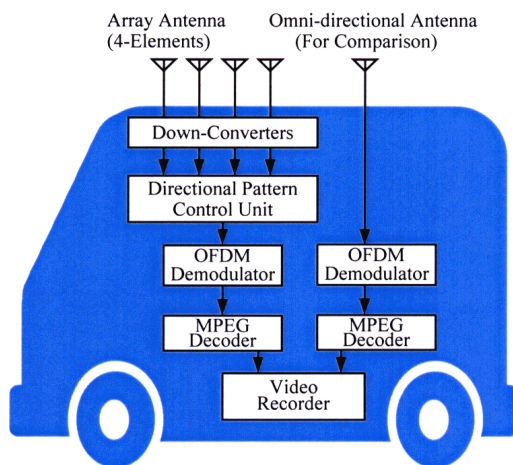
Terrestrial digital broadcasting services in Japan will start in 2003, and conventional analog broadcasting will be terminated in 2011. However, it has been reported that the mobile reception quality for the terrestrial digital broadcasting is significantly reduced for high bit rate transmissions such as high definition television broadcasting<sup>1)</sup>. To improve the reception quality, several techniques such as diversity reception techniques and adaptive arrays have been studied<sup>2-5)</sup>. These studies showed that the diversity techniques and adaptive arrays are effective methods for improving the reception quality of terrestrial digital broadcasting. However, these results are based on computer simulations and indoor experiments.

In this study, the effects of the diversity reception for improving the mobile reception quality of the terrestrial digital broadcasting have been experimentally investigated using an experimental radio wave. In **section 2**, an outline of the experiments such as the setup and conditions of the experiments is presented. The results of the experiments and discussion are provided in **section 3**.

## 2. Outline of experiments

### 2.1 Experimental setup

**Figure 1** shows the outline of the experimental setup. OFDM (Orthogonal Frequency Division Multiplexing) signals received by the antenna elements



**Fig. 1** Setup of mobile terminal.

are down-converted and then input into the directional pattern control unit. In this unit, the signals are weighted and combined together based on the maximum ratio combining (MRC) method. The combined OFDM signal is input to an OFDM demodulator, and then the signal is demodulated into MPEG2 transport stream packets. The transport stream packets are decoded into an NTSC video signal and audio signals. The decoded signals are then recorded. For comparison, video and audio signals using an omni-directional antenna were simultaneously recorded.

### 2.2 Condition of experiments

In the experiments, an experimental radio wave for the terrestrial broadcasting transmitted from the Higashiyama Tower in Nagoya City is utilized. The height of the transmitter is approximately 130 meters. The transmission parameters of the experimental wave are shown in **Table 1**. The other conditions of the experiments are shown in **Table 2** and photos of the experimental setup are shown in **Fig. 2**.

A 1-box type car was used for the experiments and cross-dipole antennas are used in both cases along with the diversity reception and the omni-directional antenna. The array antenna is composed of four cross-dipole antennas. The maximum gain of the

**Table 1** Transmission parameters.

Mode	2
Guard interval	1/32(16 $\mu$ sec)
Time interleave	4
Modulation of sub-carriers	64 QAM
Code rate	1/2

**Table 2** Experimental conditions.

Transmission point	Higashiyama Tower (Nagoya City)
Transmission power	1 kW (ERP = 1.5 kW)
Center frequency	485.15 MHz (UHF 15 ch)
Antenna elements for mobile terminal	Cross dipole antenna (Maximum gain 0 dBd) (Fluctuation in horizontal plane <2 dB)
Number of antenna elements	4
Element space	60cm (1 $\lambda$ ), square array
Antenna height	Approximately 2.5 m from ground

elements are 0 dBd and a gain fluctuation of the antennas in the horizontal plane is less than 2 dB. The antennas were mounted on the roof of the experimental car.

### 2.3 Course for experiments

The experiments were conducted using the three courses shown in **Fig. 3**. The "S" symbol in the figures indicates the starting point of each course and the experiments were conducted by traveling in the direction of the arrows shown in the figures. The features of each course are as follows.

Course 1: This course includes the downtown area of Nagoya City and the Nagoya Expressway. The distance from the Higashiyama Tower to this course is about 5 - 12km. The first half of the course is in the urban and residential area. The latter is the expressway in the downtown area of Nagoya city. There are few line-of-sight paths on the expressway. This course has

been used as the standard course for the Tokai digital terrestrial broadcasting experiment conference<sup>6)</sup>.

Courses 2 and 3: These courses are located east of Nagoya City. The distance from the Higashiyama Tower to these courses is about 13 - 17km. These courses are in suburban area and parts of these courses include hills, therefore there are few line-of-sight paths. The area is at the edge of the service area for fixed reception from the Higashiyama Tower<sup>6)</sup>.

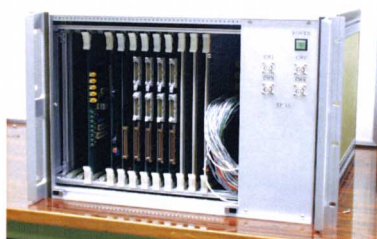
The measured electric field strength on the courses is shown in **Fig. 4** as a reference. The electric field strength are measured every 100 msec with a cross-dipole antenna which is the same antenna used in the experiments. The values in Fig. 4 are median values for every 10 seconds. The horizontal axes of the figures are the time from the start of each course. Moreover, the average values of each entire course are also indicated in the figures.



(a) Experimental car

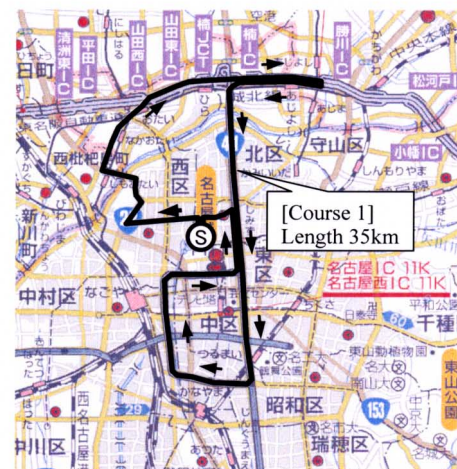


(b) Inside of experimental car



(c) Directional pattern control unit

**Fig. 2** Setup of experiments.



(a) Course 1



(b) Course 2 and Course 3

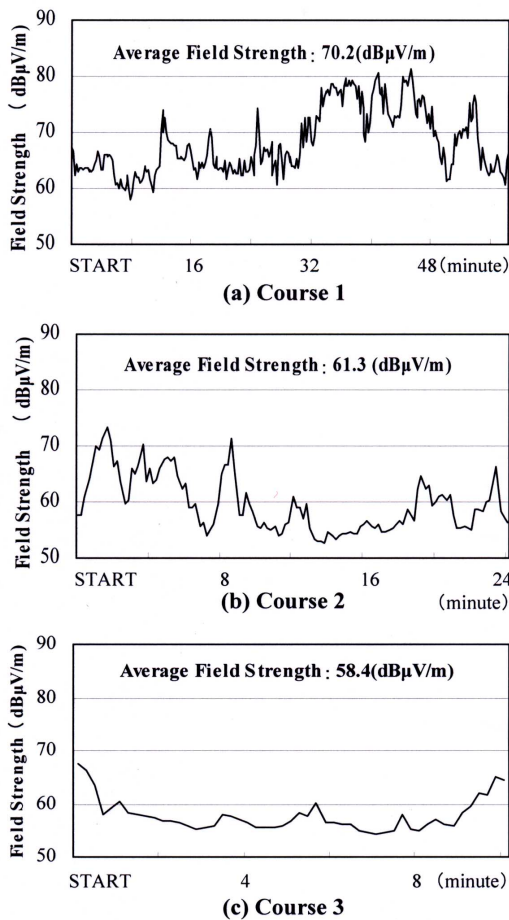
**Fig. 3** Experimental courses.

### 3. Results and Discussion

**Figure 5** shows the results of the experiments. The vertical axes of the figures are the reception probability\*, while the horizontal axes are the same as those in Fig. 4. The white marks indicate the reception probability when the MRC method has been applied and the black marks indicate the reception probability when the omni-directional antenna is used as a comparison. Fig. 5(a), Fig. 5(b) and Fig. 5(c) are the results for Course 1, Course 2 and Course 3, respectively. It can be seen that the reception probability for Course 2 and Course 3, where the electric field strengths are relatively weak, have been significantly improved.

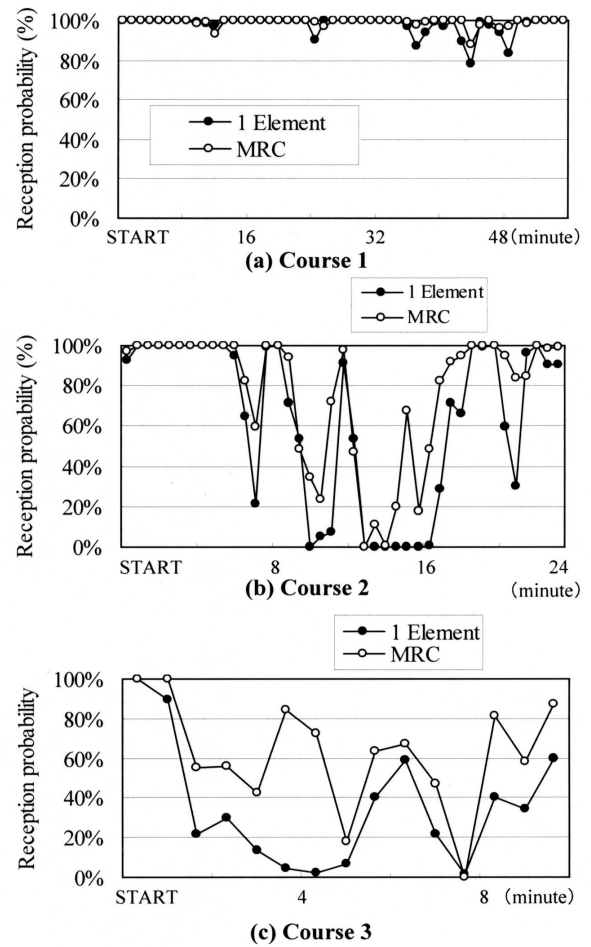
The results of the experiments are summarized in

\*We have defined the reception probability as the rate of the time of successfully receiving a video image without block noise for only the traveling time and not the stopping time.



**Fig. 4** Field strength on Courses.

**Table 3.** It is found from the table that the improvement in the reception probability is increased as the electric field strength decreased. Especially in Course 3, the reception probability has been significantly improved from 34.9 % to 62.2 % by applying the MRC method compared to using the omni-directional antenna. At the edge of the service area, it is thought that the reception quality degrades due to a decrease in the electric field strength. Thus,



**Fig. 5** Reception probability.

**Table 3** Experimental results.

	Average field Strength	Reception Probability (%)		Improvement Probability (%)
		1 Element	MRC	
Course 1	70.2 dBμV/m	97.9	99.2	1.3
Course 2	61.3 dBμV/m	63.2	79.6	13.7
Course 3	58.4 dBμV/m	34.9	62.2	27.3

it is expected that the directional pattern control is an effective method for improving the reception quality and expanding the service area of the terrestrial digital broadcasting.

#### 4. Conclusion

The reception quality of the terrestrial digital broadcasting when the directional pattern of the mobile terminal is controlled has been experimentally investigated using an experimental radio wave. As a result, it was confirmed that the reception probabilities by controlling the directional pattern were significantly improved compared to using an omni-directional antenna. Especially, it was found that the improvement in the reception probability increased as the electric field strength decreased.

At the edge of the service area, it is thought that the reception qualities are degraded due to the decrease in the electric field strength. Thus, it is expected that the directional pattern control is an effective method for improving the reception quality and expanding the service area of the terrestrial digital broadcasting.

For a future study, a performance evaluation is planned when conformal antennas and flush mount antennas are used.

#### Acknowledgments

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#### References

- 1) Takada, M., Kimura, S. and Moriyama, S. : "Mobile reception performance for digital broadcasting system ISDB-T", J. of ITE, **54-11**(2000), 1590-1597
- 2) Hamazumi, H., Ito, Y. and Miyazawa, H. : "Performance of frequency domain sub-band diversity combination technique for wide-band mobile radio reception -An application to OFDM (Orthogonal Frequency Division Multiplexing) reception -", IEICE Trans. B-II, **J80-B-II-6**, (1997), 466-474
- 3) Seki, T. and Sugimoto, M. : "Performance of diversity reception for digital terrestrial television broadcasting", ITE Tech. Rep., **25-34**(2001), 1-6
- 4) Itami, M., Teramoto, T., Shima, T., Ohta H. and Itoh, K. : "Reception characteristics of OFDM signals using array antennas", J. of ITE, **53-11**(2000), 1566-

1574

- 5) Fujimoto, M., Nishikawa, K., Shibata, T., Kikuma, N. and Inagaki, N. : "A Novel Adaptive Array using Frequency Characteristics of Multi-carrier Signals", IEICE Trans. Commun., **E83-B-2**(2000), 371-379
- 6) Utilization reports, 3rd edition, Tokai digital terrestrial broadcasting experiment conf., (2001)  
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