Research Report

Results of Experiments Investigating Diversity Reception with a Mobile Terminal for ISDB-T HDTV

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Abstract

In Japan, Terrestrial Integrated Service Digital Broadcasting (ISDB-T) began in December 2003. Generally speaking, reception quality with mobile terminals is poor in the case of high bit rate transmissions such as HDTV. As part of this study, we developed a diversity reception system and investigated, through field experiments, the effects of diversity techniques on a mobile terminal designed for ISDB-T HDTV services. The results of our experiments show that the reception quality with the newly developed system is significantly improved for mobile applications. It was found that, by using diversity techniques, we could receive HDTV on a mobile terminal across a larger area.

Keywords: Diversity reception, Maximal ratio combining(MRC), Mobile communications, Terrestrial digital broadcasting, HDTV

1. Introduction

Terrestrial Integrated Service Digital Broadcasting (ISDB-T) was introduced in Japan in December 2003. Band Segmented Transmission (BST-) OFDM was adopted for ISDB-T to provide a range of services simultaneously, such as High-Definition TV (HDTV) and multimedia services. BST-OFDM consists of thirteen frequency blocks, called "segments," and allows the use of up to three different modulation schemes and coding rates on different segments according to the service requirements and receiving conditions. For fixed reception, a directional antenna is usually used, which has a high gain and a narrow beam width, and which is set up ten meters above the ground. Therefore, high data rate services such as HDTV can be accessed across a wide area. In mobile reception, on the other hand, an omni-directional antenna is usually used, which has low gain and is set up no more than a few meters from the ground, resulting in a decrease in the signal-to-noise (S/N) ratio and an increase in the multipath effects. Moreover, mobile reception conditions change continuously according to changes in the receiving position. As a result, it is difficult to receive HDTV in a mobile environment.[1)] Diversity reception techniques are useful for improving the reception quality for mobile reception.[2)] Post Fast Fourier Transform (post-FFT) diversity techniques have been investigated mainly for OFDM systems.[3, 4)] Okada et al. investigated a pre-FFT diversity technique, which offers the advantage of reduced computational complexity, because only one FFT processing unit is necessary for the pre-FFT diversity reception system.[5)] We have developed a pre-FFT diversity reception system for ISDB-T to verify HDTV service availability in mobile environments. Also, the performance of the developed system was evaluated through field experiments.

In this paper, **Section 2** describes the diversity reception system that we developed. **Section 3** presents an outline of the field experiments including the setup and conditions. **Section 4** presents the results of our experiments and a discussion.

2. Developed reception system

We adopted (pre-FFT) maximal ratio combining (MRC) as the diversity technique. **Figure 1** is a schematic of the developed diversity reception system.

OFDM signals received by the antenna elements are down-converted and then input into the A/D converter. In this system, the received OFDM signals are weighted and then combined based on the MRC method. The weighting factors were calculated from the correlation between the received and combined signals. The combined OFDM signal is input to an OFDM demodulator. This system is constructed as a diversity receiver that is an addition to a typical OFDM demodulator.

3. Field experiments

3. 1 Conditions

The effects of diversity techniques on improving the mobile reception quality of terrestrial digital broadcasts were investigated by means of experiments using a test signal. The transmission parameters of the test signal for the terrestrial digital broadcasts are listed in **Table 1**. An outline and photos of the experimental setup are shown in **Figs. 2** and **3**. For comparison, video and audio signals for

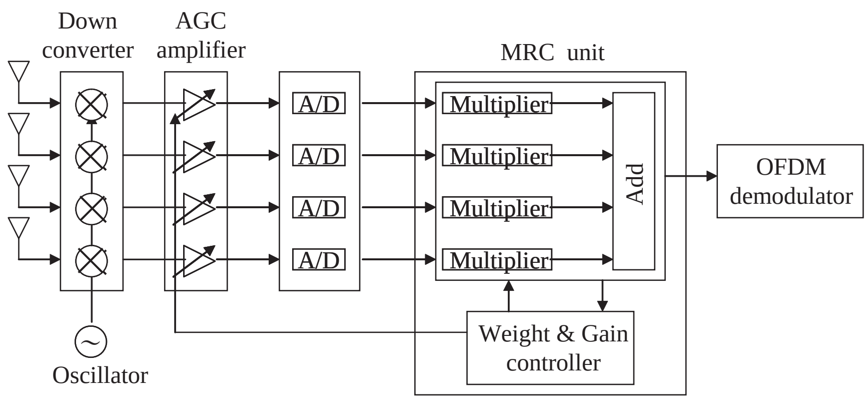


Fig. 1 Block diagram of the receiver system.

both the diversity and omni-directional antenna were also recorded.

A van was used for the experiments. The diversity branch was composed of four antennas. Four glass-printed antennas were used for the diversity reception, while crossed-dipole antennas were used for the omni-directional antenna.

3. 2 Courses

Two routes were used as shown in **Fig. 4**. The 'S' in the figure indicates the start point of each route. The experiments were conducted by traveling in the directions indicated by the arrows. The features of the two routes were as follows:

Course A: This course was through an urban area in the center of Nagoya. The distance from the test signal transmitter to the van was about 4 to 5 km. There were few line-of-sight paths because of the city's tall buildings.

Course B: This course was in a suburban area located west of Nagoya. The distance from the test signal transmitter to the van was about 10 to 35 km. There were few line-of-sight paths.

The measured electric field strength on the routes is shown in **Fig. 5** as a reference. The electric field

Fig. 3 Antenna and experimental vehicle.

Table 1 Transmission parameters.

Mode	3 (8k FFT)
Guard interval	1/8 (126 μ sec)
Modulation of sub-carriers	64 QAM
Coding rate	3/4
Data rate	16.4 Mbps
Center frequency	485.15 MHz

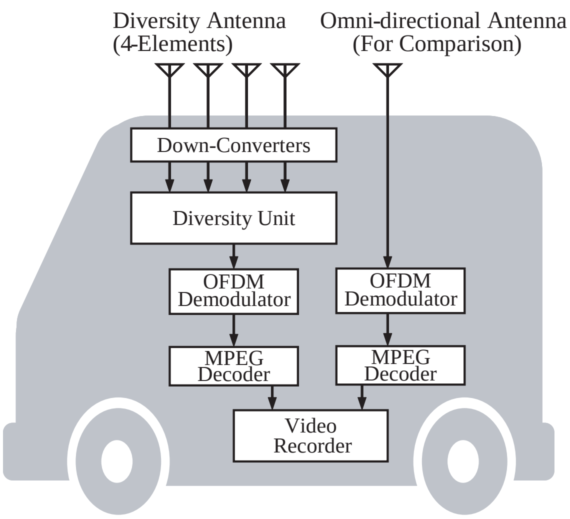


Fig. 2 Outline of experimental setup.

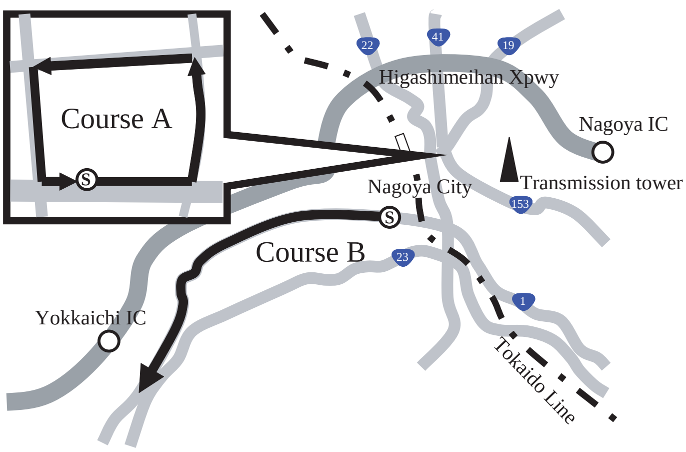


Fig. 4 Experimental courses.

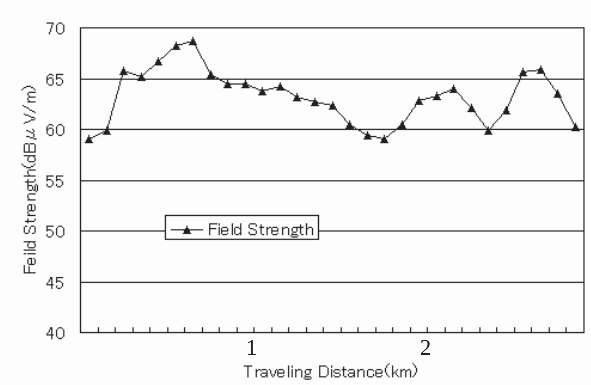
strength was measured every 100 ms using a crossed-dipole antenna which was the same antenna as that used in the experiments. The values shown in Fig. 5 are median values for every 10 s. The horizontal axes of the figures indicate the distance traveled from the start of each course.

4. Results and discussion

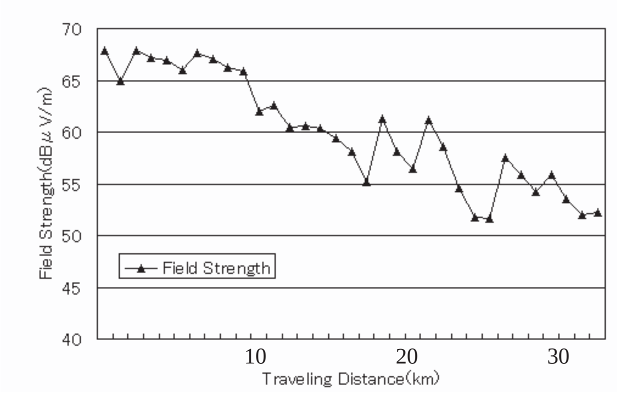
Figure 6 shows the results of the experiments. The vertical axes of the figures are the reception probability*, while the horizontal axes are the same as those in Fig. 5. The white marks indicate the reception probability when the MRC method was applied, while the black marks indicate the reception probability when a crossed dipole antenna was used. Figs. 6(a) and (b) show the results for Courses A and B, respectively.

For Course A, the diversity reception was perfect. With the crossed-dipole antenna, even though the electric field strength was strong, reception errors sometimes occurred. We assumed that this was a result of multi-path signals bouncing off the

* We have defined the reception probability as the ratio of the time that video images were received successfully, without block noises, only while the van is in motion, and excluding those signals received while the vehicle was stopped at traffic lights etc.

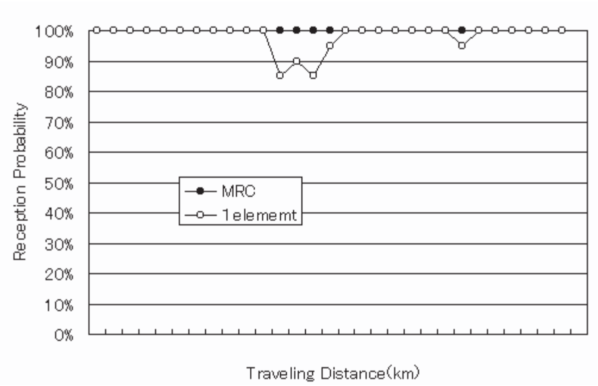


(a) Course A

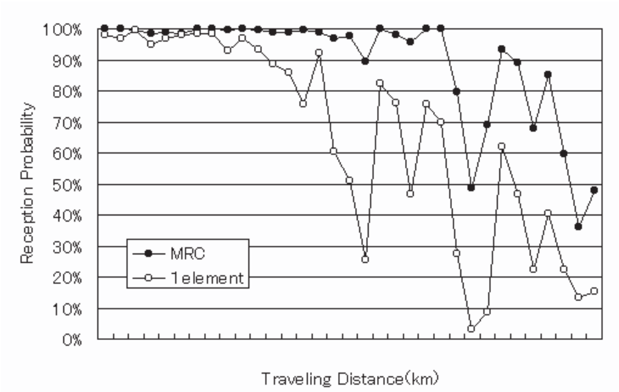


(b) Course B

Fig. 5 Field strength.



(a) Course A



(b) Course B

Fig. 6 Reception probability.

buildings. Therefore, we believe that the diversity technique reduces the multi-path effect. It can be seen that the reception probability for Course B, for which the electric field strengths were relatively weak, was significantly improved through the use of the diversity technique. It was found that the diversity technique produced an improvement in the S/N ratio.

We believe that, by using diversity techniques, we can receive HDTV on mobile terminals across a relative large area.

Moreover, **Fig. 7** shows the relationship between the reception probability and the measured electric field strength. An estimation of the perception for the reception probability has not been done, although the experiments pointed to the following:

Over 99%: perfect reception
About 95%: watchable with some pixelization
Under 90%: unwatchable, pixelization and screen freezing

The electric field strength satisfying above reception probability was obtained from Fig. 7, and is shown in **Table 2**. It was found that using the diversity technique provided an improvement of over 6 dB relative to a single antenna element.

5. Conclusion

The mobile reception quality of terrestrial digital broadcasting with a diversity technique (pre-FFT MRC) was investigated through experiments. It was found that the diversity technique produced an improvement in the S/N ratio and a reduction in the influence of the multi-path signals. Consequently, the reception probabilities with the diversity technique were significantly better than when using a single antenna. It was mentioned that, by using diversity techniques, we could receive HDTV on a mobile terminal across a larger area.

Moreover, the lower bound of the electric field strength for receiving HDTV on mobile terminals was calculated. And, it was found that the use of diversity techniques produced an improvement of about 6 dB for the lower bound of the electric field strength.

Future studies will consider further improvement of the reception system. Also, a compact reception system will be constructed.

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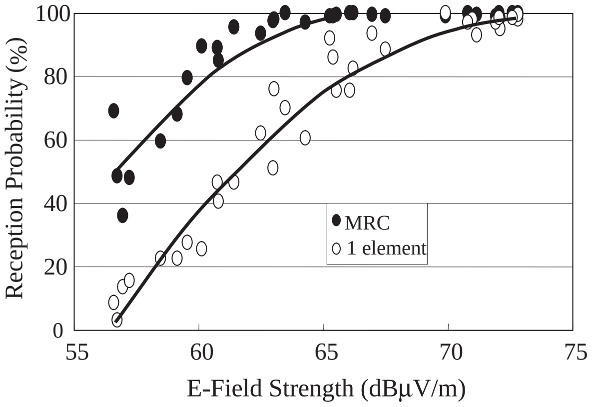

Fig. 7 Relation between the reception probability and the electric field strength.

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Table 2 Improvement by using diversity technique.

Reception Probability	Field Strength (dB μV/m)		Improvement (dB)
	Diversity	One element	
99 %	67.0	73.0	6.0
95 %	63.5	70.5	7.0
90 %	62.0	68.5	6.5

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