Research Report

Experimental Results of Diversity Reception for Terrestrial Digital Broadcasting

Mitoshi Fujimoto, Junji Imai, Nobuo Itoh

指向性制御による地上ディジタル放送移動受信品質の改善

藤元美俊，今井純志，伊藤修朗

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 omni-directional 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

要　旨

地上波を用いたディジタルTV放送は2003年に本放送が開始され，2011年にはアナログ放送からディジタル放送に全面的に移行する予定である。しかし，自動車などの移動体で地上ディジタル放送を受信する場合，受信映像が途切れるなど受信品質が大きく劣化することが明らかとなっている。

本論文では，指向性制御技術による受信品質改善効果について，地上ディジタル放送の試験電波を利用して実験的に検討した結果を述べる。実験の結果，指向性を電波環境に適応して制御することにより，アンテナ1素子で受信した場合に比べ受信品質を大きく改善できることが分かった。特に，電界強度の弱い地域において受信品質改善効果が大きいことから，指向性制御技術は受信エリア拡大に大きく寄与できるものと期待できる。

キーワード　最大比合成，移動受信，地上ディジタル放送

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[1]. To improve the reception quality, several techniques such as diversity reception techniques and adaptive arrays have been studied[2-5]. 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 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.

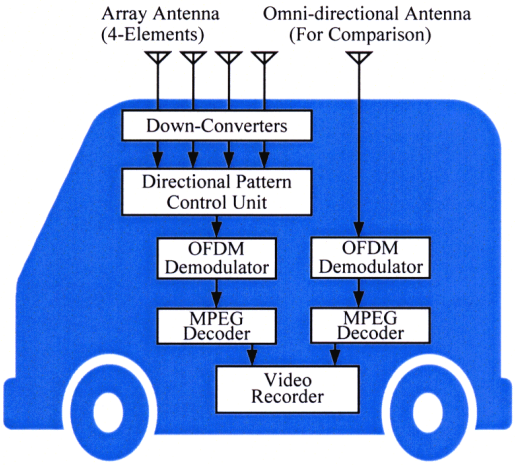


Fig. 1 Setup of mobile terminal.

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 μsec)
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 (1λ), 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 [6].

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 [6].

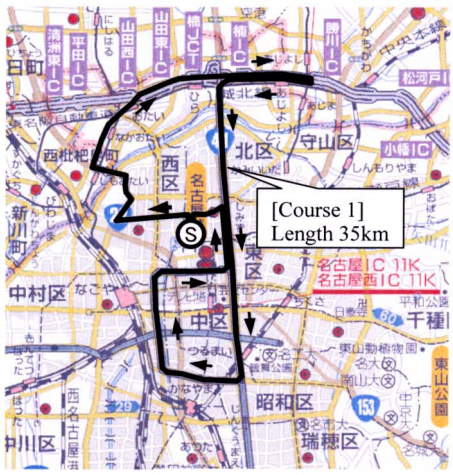
The measured electric field strength on the courses is shown in **Fig. 4** as a reference. The electric field strength are measured every 100 msec with a cross-dipole antenna which is the same antenna used in the experiments. The values in Fig. 4 are median values for every 10 seconds. The horizontal 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 **Table 3**. It is found from the table that the imprevement 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,

*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.

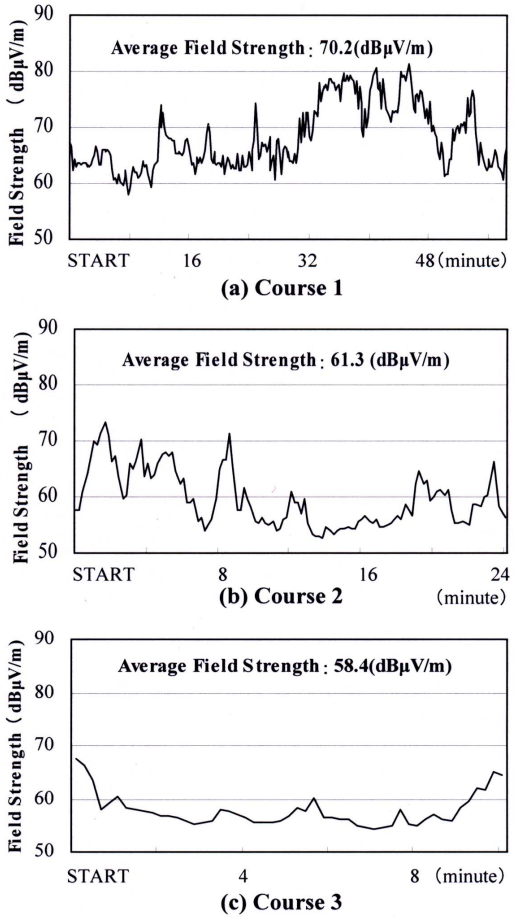


Fig. 4 Field strength on Courses.

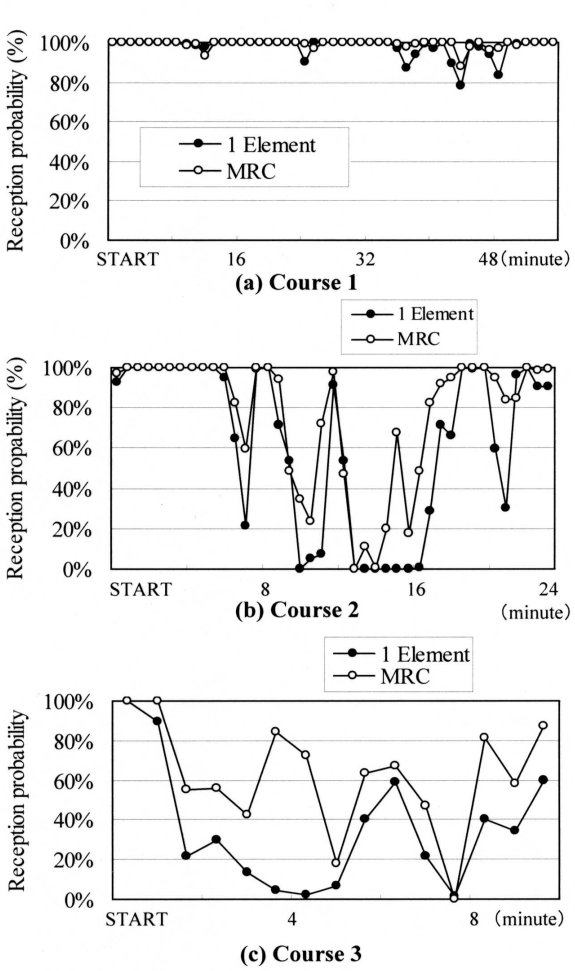


Fig. 5 Reception probability.

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

The authors wish to acknowledge the members of the Tokai Digital Broadcasting Experiment Conference for their support of this study.

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)

(Report received on March 21, 2002)

Mitoshi Fujimoto 藤元美俊
Year of birth : 1964
Division : Research-Domain 21
Research fields : Mobile communication
Academic degree : Dr. Engng.
Academic society : The Inst. of Electron. Inf. and Commun. Eng.
Awards : Young engineer award, IEEE AP-S Tokyo chapter, 1992

Junji Imai 今井純志
Year of birth : 1975
Division : Research-Domain 21
Research fields : Mobile communication
Academic society : The Inst. of Electron. Inf. and Commun. Eng., The Operations Res. Soc. of Jpn.

Nobuo Itoh 伊藤修朗
Year of birth : 1957
Division : Research-Domain 21
Research fields : Signal processing
Academic degree : Dr. Engng.
Academic society : The Inst. of Electron. Inf. and Commun. Eng., The Inst. of Image Inf. and Television Eng.