

Effect of Element Patterns on Diversity Reception

Fumihiro TERADA, Mitoshi FUJIMOTO and Toshikazu HORI
 Graduate School of Engineering, University of Fukui
 3-9-1 Bunkyo, Fukui, 910-8507 Japan
 E-mail: terada@wireless.fuis.fukui-u.ac.jp

1. Introduction

Land mobile propagation channels become a multipath propagation due to reflection, diffraction, and scattering caused by the topography around mobile stations. The strength of the reception signal changes according to the time and place, and the reception performance deteriorates when mobile terminals move in such a multipath propagation environment. The diversity reception technique is used as a countermeasure to fading, and the correlation coefficient is used to evaluate the diversity effect. The diversity effect can generally be estimated from the signal correlation between branches. However, this evaluation procedure takes a significant amount of time to estimate the diversity effect using computer simulation since it considers not only the antenna characteristics but also the propagation characteristics. We can obtain an estimate more efficiently if the diversity effect can be estimated from the antenna characteristics of the respective branches [1].

In this paper, the effects of the antenna element spacing and distortion of the directional patterns on the diversity reception are considered in a basic study to estimate the diversity effect from the antenna characteristics. First, the effect of the antenna element spacing on the diversity reception is considered. Next, the effects of the fluctuation width and variation period of the directional patterns on the diversity reception are considered.

2. Estimation Method for Diversity Effect and Modeling of Element Patterns

2.1 Estimation Method for Diversity Gain

Figure 1 is a flow chart to estimate the diversity gain. First, the shapes of the terminals and antennas are modeled. Next, to obtain the antenna characteristics, the antennas are analyzed using the method of moment. Then the received levels are obtained from the fading variation when the antennas are moved in the propagation environment, and the bit error rate (BER) is obtained.

The diversity gain can generally be estimated from the signal correlation between the branches. However, it spends much time for the evaluation because a lot of computational resources are required for analyzing the propagation channel. We

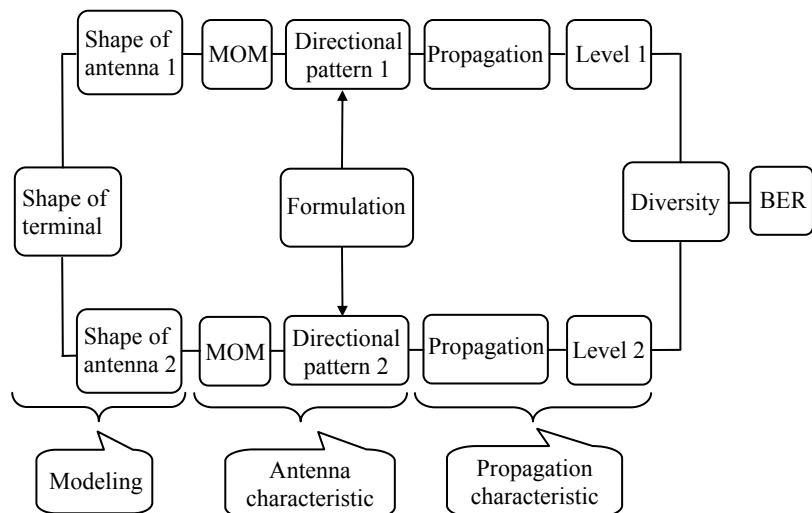


Figure 1: Flow Chart for Estimating Diversity Gain

because a lot of computational resources are required for analyzing the propagation channel. We

can estimate the diversity gain more easily if we can estimate it from the antenna characteristics of the respective branches. The effects of the antenna element spacing and the distortion of the element patterns on the diversity gain are considered in a basic study to estimate the diversity gain from antenna characteristics of the respective branches.

2.2 Modeling of Element Patterns

In this paper, the directional patterns of the antenna elements in the flow chart in Fig. 1 are expressed by the following formula.

$$D(\theta) = 1 + A \cdot \cos(B\theta + \theta_0) \quad (1)$$

Here, A is the fluctuation width of the amplitude, B is the variation period, and θ_0 is the rotation of the directional patterns. The distortion of the element pattern is given by changing fluctuation width A and variation period B . Moreover, the correlation, ρ , between two directional patterns is varied by changing the rotation of the directional patterns. The purpose of this study is to clarify the relation between the diversity gain and the parameters of directional patterns such as A , B , and θ_0 .

2.3 Simulation Conditions

Table 1 gives the simulation conditions. Under the assumption of MODE3 in ISDB-T [2], the symbol length is set to 1 [ms]. However, to simplify the synchronous processing, DQPSK is used as the modulation method. We assume that ten waves arrive at the receiving point to establish a fading environment in the simulation. The ten waves arrive with the same amplitude but random phase, and the maximum Doppler frequency is 1 [Hz]. The Switch and Examine method is used as the switching method for diversity reception [3]. The threshold level, i.e., the switching level of the antenna, is set to the average noise power of the receiver (Threshold/ N_0 = 0 [dB]). The effects of the antenna element spacing and distortion of the element patterns on the diversity effect are evaluated based on the diversity gain. The diversity gain in this paper is defined as follows.

Table 1: Simulation Conditions

Modulation method	DQPSK
Effective symbol length	1 [ms]
Maximum Doppler frequency	1 [Hz]
Antenna switch reception method	Switch and Examine
Threshold level (Threshold/ N_0)	0 [dB]
Incoming wave	10 waves (random)

$$Diversity\ gain[dB] = \frac{E_b / N_0 @ BER = 10^{-2} (Omni - directional\ antenna)}{E_b / N_0 @ BER = 10^{-2} (Diversity\ reception)}$$

3. Effect of Element Spacing

The effect of the antenna element spacing on the diversity reception is considered when the ranges of fluctuation width A and variation period B are changed. The simulation is performed based on the conditions given in Table 1. Figure 2 shows the results of the simulation.

Figure 2 shows the relationship between the antenna element spacing and the diversity gain. The parameters are the fluctuation width and the variation period. The rotation angle, θ_0 , is 0 [deg]. In other words, the two antenna elements have exactly the same directional pattern. Thus, the correlation, ρ , of the element directional patterns of the two antennas is one. The large values for fluctuation width A and variation period B mean that the element directional patterns are more distorted.

Figure 2 shows that the diversity gain becomes large when the antenna element spacing becomes large regardless of the shapes of the element patterns. These results clearly show that the antenna element spacing influences the diversity gain. Moreover, the diversity gain hardly changes when the antenna element spacing increases to more than a quarter of wavelength.

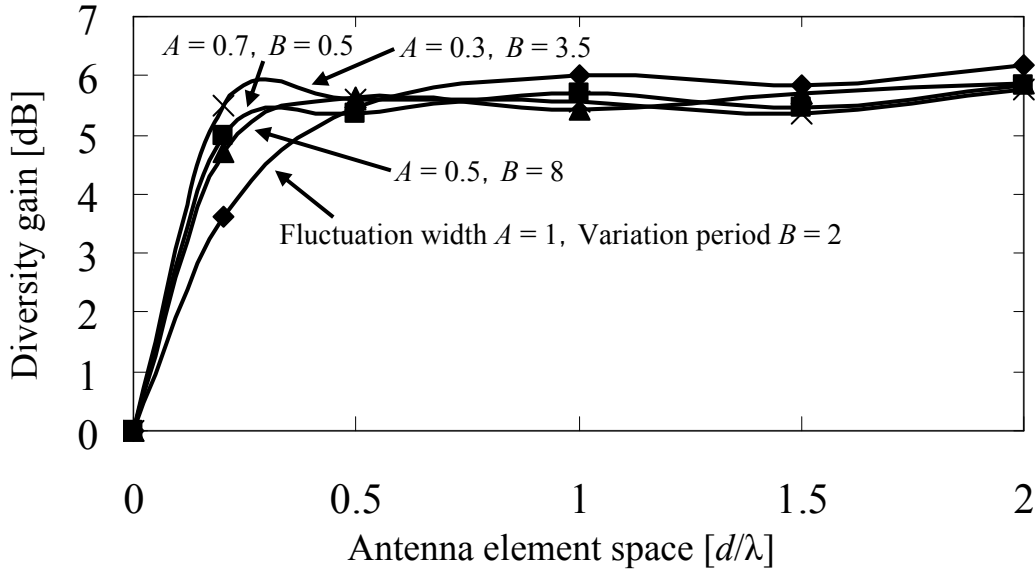


Figure 2: Relationship Between Antenna Element Spacing and Diversity Gain

4. Effect of Distortion of the Antenna Directional Patterns

The effect of the distortion of the element patterns on the diversity gain is considered by changing the ranges of fluctuation width A and variation period B . A simulation is performed based on the conditions given in Table 1. Figure 3 shows the results of the simulation.

Figure 3 shows the effects of fluctuation width A and variation period B on the diversity gain when the antenna element spacing, d , is $0.02 [\lambda]$. Here, the correlation, ρ , of the element directional patterns is changed by changing θ_0 and rotating the element directional patterns. The degree of brightness in the figure indicates the level of the diversity gain.

4.1 Effect of Fluctuation Width A

The effect of fluctuation width A on the diversity effect is evaluated. Figure 3 shows that the diversity gain becomes large when fluctuation width A becomes large, regardless of the rotation of the directional patterns. In particular, it is shown that fluctuation width A significantly influences the diversity effect when variation period B is large. This is because the diversity gain changes greatly when variation period B is large. Since the antenna element directional patterns approach an Omni-directional pattern when variation period B is small, the effect of fluctuation width A becomes small when variation period B is small. Moreover, we find that fluctuation width A significantly influences the diversity gain when the rotation of the directional patterns is large.

4.2 Effect of Variation Period B

Next, we focus on the effect of variation period B on the diversity effect. We can find in Fig. 3 that the diversity gain becomes large when the variation period B becomes large, regardless of the amplitude of fluctuation width A . Furthermore, the diversity gain hardly changes when variation period B becomes greater than 1. The diversity gain changes most when variation period B is set to 0.3 to 1. Thus, variation period B does not affect the diversity effect when variation period B is greater than 1. Variation period B significantly influences the diversity effect when it is set 0.3 to 1.

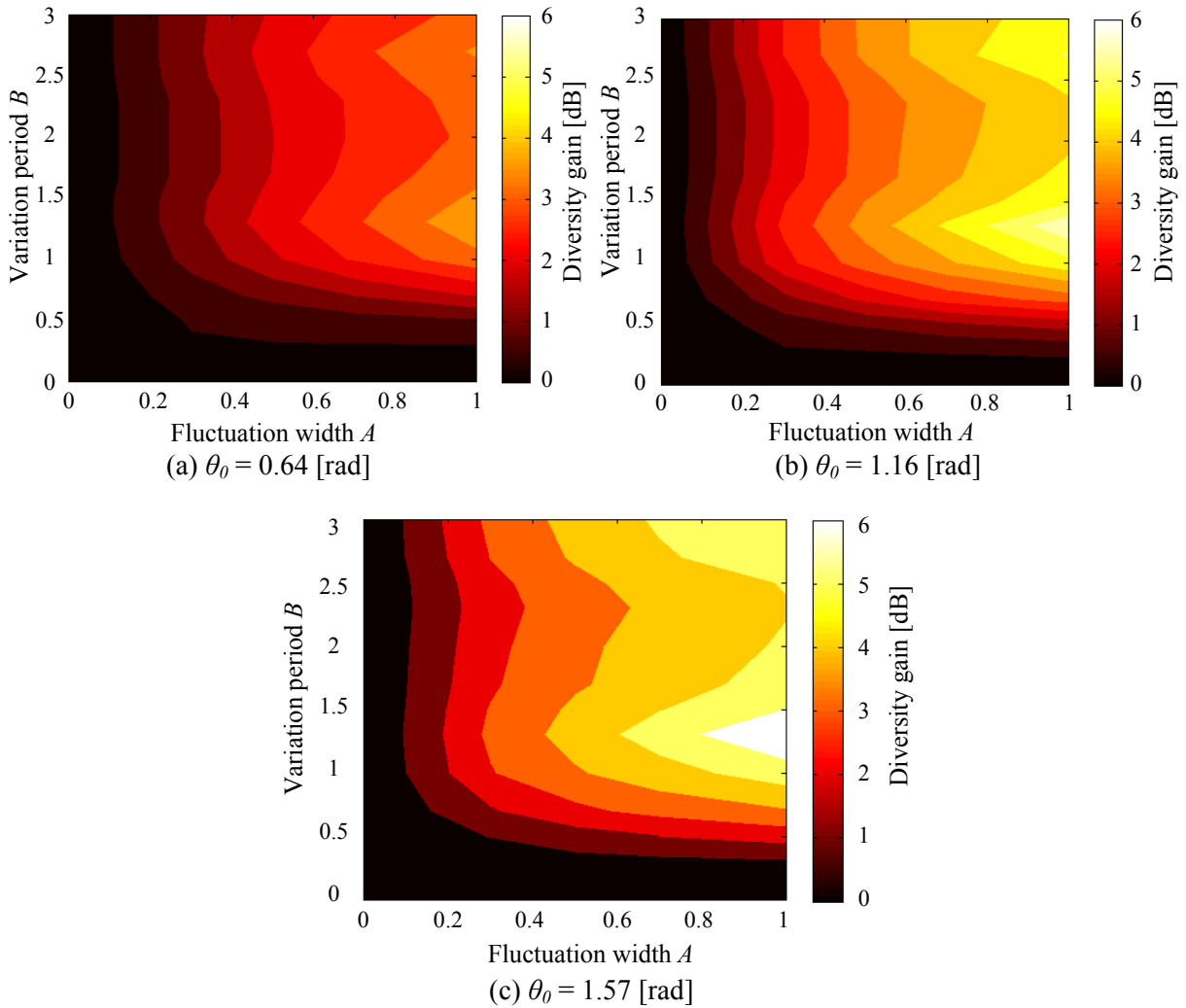


Figure 3: Effects of the Fluctuation Width A and Variation Period B on Diversity Gain

5. Conclusion

The effects of the antenna element spacing and distortion of the antenna element directional patterns on the diversity reception were clarified in a basic study to estimate the diversity gain from antenna characteristics of the respective branches. The results based on this consideration showed that the antenna element spacing influences the diversity effect, regardless of the shapes of the antenna element directional patterns. Moreover, we showed that fluctuation width A significantly influences the diversity effect when variation period B is large. We also showed that variation period B has no influence on the diversity effect when it is greater than 1 and that it has a large influence on the diversity effect when it is set to 0.3 to 1.

References

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