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Diversity Reception on Mobile Terminal under Slow Fading Environment

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1. Introduction

In recent years, television broadcasting can be received on mobile terminals in Japan since terrestrial digital television broadcasting (ISDB-T) has been initiated. In case of mobile reception, however, reception quality becomes worth because of fluctuation of received signal due to fading as shown in Fig.1 [1]. In general, burst error due to deep fading could be dispersed by time interleaving and relieved by forward error correction. However, duration of the burst error becomes long in case of slow fading and the errors can not be corrected sufficiently, especially in case of handy terminals [2].

As a counter measure for the above problem, we consider the utilization of diversity reception technique in this paper. For the diversity reception, plural antennas should be mounted on a terminal. But, it seems that enough element space could not be kept because the wave length in UHF band which utilized in ISDB-T is relatively long compared with the size of the handy terminals [3]. Moreover, scheme of the diversity switching and threshold of switching obviously affects on the effectiveness of the diversity reception.

In this paper, effectiveness of several schemes of diversity reception in slow fading environment is compared and the optimal threshold is discussed. Furthermore, effect of Doppler shift and correlation between branches on bit error rate (BER) performance is described.

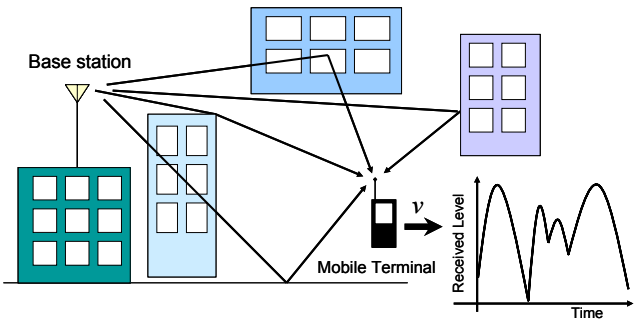

Figure 1: Mobile radio Environment

2. Switching Method for Diversity Reception

Following four diversity schemes are considered in this paper and behaviour of each scheme is shown in Fig. 2.

- Selection Combining (SC): Always the branch which has larger received power than the others is selected as shown in Fig. 2(a).
- Switch and Examine (SE): Continuously switch while the received power of both branches are below the threshold as shown in Fig. 2(b).
- Modified Switch and Examine (Modified SE): Continuously switch as the same with the SE, but stay several symbols after the switching as shown in Fig. 2(c). Three symbols for stay were adopted in the computer simulation in following section.
- Switch and Stay (SS): Switch the branch and stay until the selected branch becomes below the threshold as shown in Fig. 2(d).

Since the received signal levels of both antennas should be monitored in SC, two receivers are required in SC. On the other hand, only one receiver is required in case of SE, Modified SE and SS, because the signal level of only the selected antenna is compared with the threshold level.

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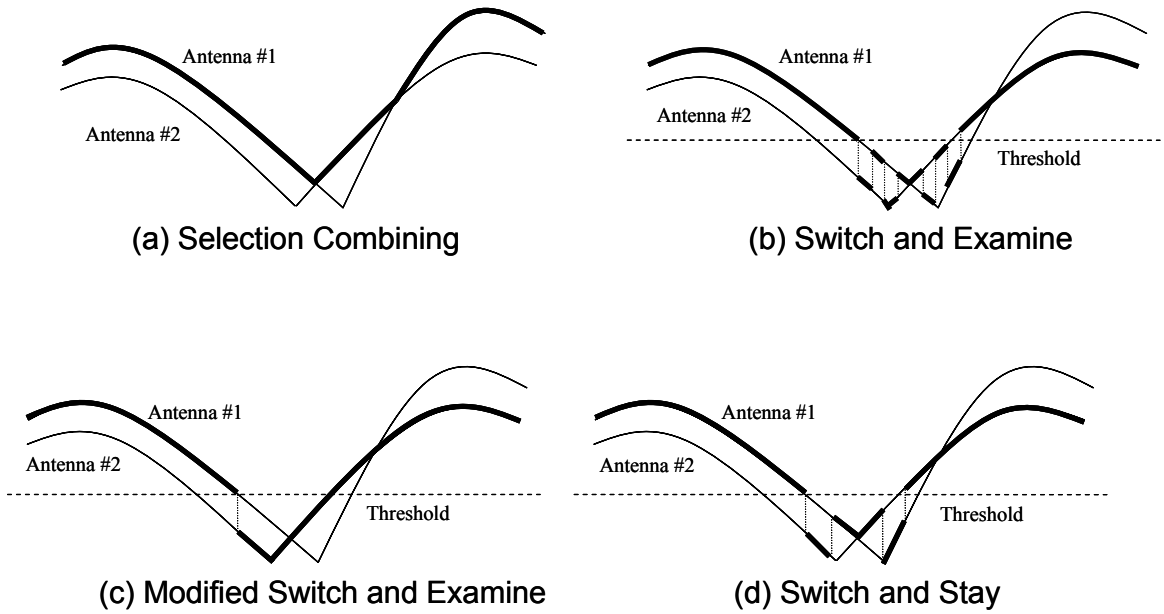

Figure 2: Schemes of Switching Diversity

3. Effect of Switching Method on BER Performance

3.1 Condition in Simulation

The BER performance of the respective switching scheme has been evaluated through computer simulation. The condition in the simulation is indicated in Table 1. The symbol length of 1 [msec] is correspond to that of the terrestrial television broadcasting in Japan. It is assumed that two waves arrive at receiving point with Rayleigh fading and the delay time of the second wave is 2 μsec. It is also assumed that the normalized Doppler frequency and number of branches on the mobile terminal is 10^{-5} and 2, respectively. These parameters are typical condition on handy terminal in urban area.

Table 1 : Conditions of Computer Simulation

Symbol length	1 [msec]
Modulation	DQPSK
Propagation Model	Rayleigh fading
Number of waves	2 waves
Delay of 2nd wave	2 [μsec]
Doppler frequency (f_dT)	10^{-5}
Number of branches	2
Branch Correlation	0

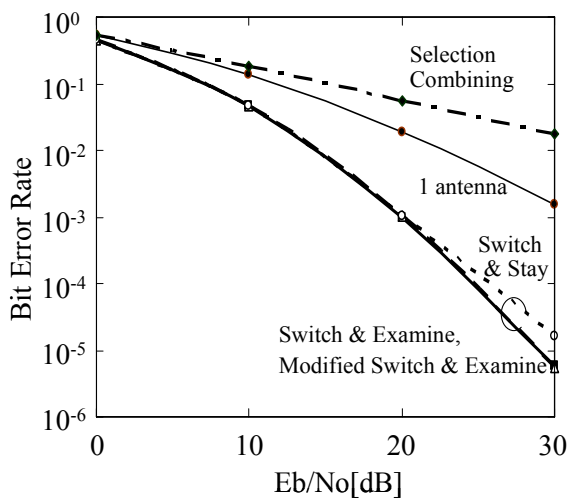

Figure 3: BER Performance with Switching

3.2 Difference of BER Performance between Switching Method

Figure 3 shows the relationship between the average E_b/N_0 and the BER. The parameter in the figure is the switching schemes. For comparison, the BER performance with single antenna is also indicated in the figure. We can see that SE and Modified SE have the best performance and the SC is the worst which is inferior to the case of single antenna. This is because that symbol length is very long as 1 [msec] and the SC switches most frequently. The wasteful switching leads the discontinuous phase during one symbol and it causes bit errors in a demodulator.

4. Effect of Threshold on BER Performance

The threshold level of the switching is obviously affects the BER performance. However, we can not decide the threshold level based on the signal level because the signal level extremely fluctuates in mobile environment. On the other side, the thermal noise level at an output of receiving antenna is usually constant. Thus, it is reasonable to decide the threshold level based on the thermal noise level.

Figure 4 shows the BER performance as a function of the threshold level of switching. The horizontal axis shows the threshold level compared with the noise level. For example, the value of 10 dB on the horizontal axis means that the threshold level has been set at 10 dB above the noise level. The parameter in the figure is the average E_b/N_0. The dotted line in Fig. 4 indicates the optimum threshold to obtain the smallest BER for respective average E_b/N_0. As we can find from Fig. 4 that the optimum threshold revel depend on the average E_b/N_0.

Figure 5 shows relationship between the E_b/N_0 and BER when the threshold revel is fixed and the optimum threshold is adopted. For comparison, the BER performance with single antenna is also indicated in the figure. As we can see, setting the optimum threshold is effective to improve the BER performance.

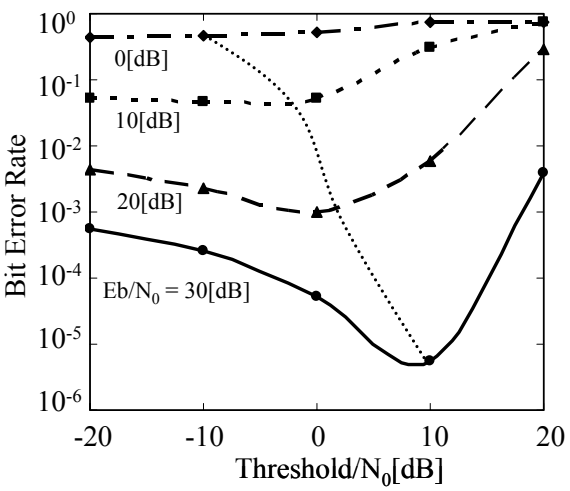

Figure 4: Effect of Threshold

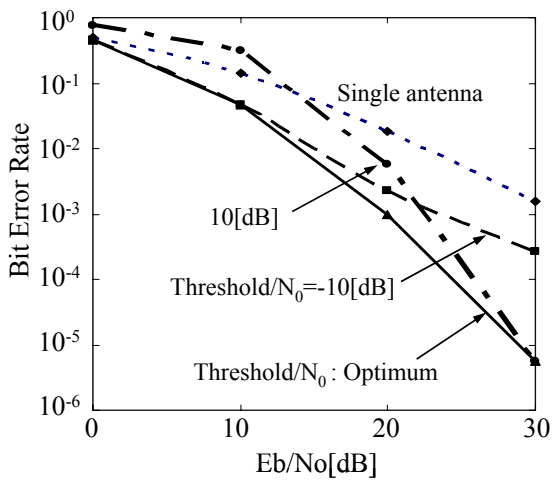

Figure5: Effect of Optimum Threshold

Figure 6 shows the variation of BER performance as a function of Doppler frequency. The BER with optimum threshold is shown by solid lines and that with fixed threshold is shown by broken lines. As we can see in Fig.6, low BER can be obtained as a matter of course when the Doppler frequency is very slow. And the BER is further improved by adopting the optimum threshold, especially in case of slow fading.

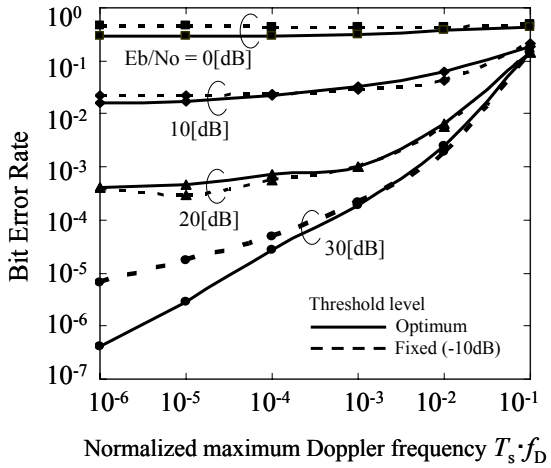

Figure 6: Effect of Doppler frequency

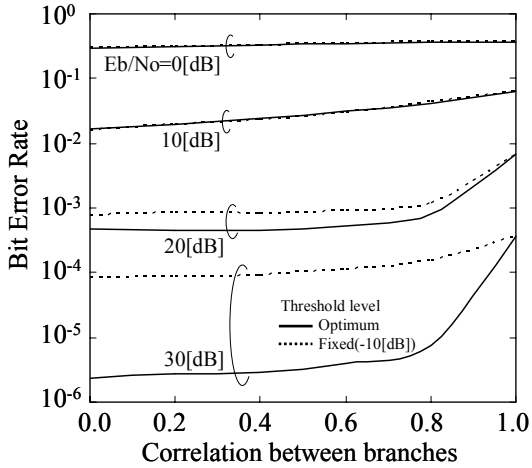

Figure 7: Effect of Correlation coefficient

5. Effect of Correlation between Branches on BER Performance

In the case of handy terminals, the correlation between received signal revel of respective antennas tend to be large because the element space cannot be kept enough compared with the wavelength, especially in UHF band.

Figure 7 shows the relationship between the correlation coefficients of two branches and BER. The BER when the correlation equal to 1.0 is correspond to that when single antenna is used and no diversity scheme is applied. It is found from the figure that the BER performance is greatly improved compared with the single antenna case when the correlation is below 0.8. The results suggest that the diversity effect on the handy terminal can be obtained by decreasing the correlation through improving the shape or radiation patterns of antenna elements.

6. Conclusion

In this paper, effectiveness of several schemes of diversity reception in slow fading environment was evaluated.

At first, BER performance of the respective diversity scheme was compared and the optimal threshold was discussed. As the results, it was found that "Switch and Examine method" had the best performance in the evaluated schemes.

Next, it was discussed the effect of the threshold level of switching on the BER performance. Then, it was found that the optimum threshold revel depends on the average E_b/N_0 and the BER was improved by adopting the optimum threshold, especially in case of slow fading.

Finally, it was discussed the effect of correlation coefficients between two branches on BER performance. It was found that BER performance was greatly improved compared with the case of single antenna case when the correlation was less than approximately 0.8. The results suggest that the diversity effect on the handy terminal can be obtained by decreasing the correlation through improving the shape of antenna elements.

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