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Performance of Diversity Receptions Combined with a Viterbi Equalizer

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INTRODUCTION

This paper describes two reception strategies that combine a Viterbi equalizer with either an antenna pattern diversity (APD) or a space diversity reception to overcome the effect of frequency-selective fading causing severe bit-error-rate (BER) degradation in high-rate digital mobile radio. Taking BPSK as an example, the BER performance improvement attained by the proposed strategies is studied. Specifically, the comparison between an APD reception and a space diversity reception is discussed assuming a simple three-ray multipath propagation model.

OUTLINE OF ANALYSIS

The performance of a Viterbi equalizer greatly depends on the accuracy of the estimated multipath delay profile. A time division multiple access (TDMA) timeslot structure assumed in the analysis is shown in Fig.1. It consists of a 200-bit sequence preceded and followed by 26-bit training sequences. Accordingly, the delay profile is measured twice, i.e., at the head and at the tail of the timeslot, and a linear interpolation is made to obtain an accurate delay profile at any bit location within the timeslot[1]. A training sequence is the same as one of those used in a European GSM system and is

00100 1011 1000 0100 0100 10111

which is obtained by appending five-bit prefix and five-bit suffix cyclically to the 16-bit sequence in the middle[2]. The number of states of a Viterbi algorithm is fixed to be 16. Thus maximum delay time to be equalized is four bit interval. A Gaussian bandpass filter with 3-dB bandwidth normalized by a bit rate being 1.0 is also assumed.

To simplify the calculation, we assumed the number of diversity branches is two. Fig.2 is a block diagram illustrating the system structure proposed in this paper. Each branch has a receiver and a part of Viterbi equalizer. The branch metrics are computed separately at each receiver output using the estimated delay profile at each branch. The sum of these metrics gives the real branch metric of a Viterbi algorithm, since we assumed the additive noises at two diversity branches are subject to mutually independent Gaussian distribution. Then, the Viterbi algorithm is applied to find the maximum likelihood sequence. Bit synchronization or sample timing is determined based on the estimated delay profile of each branch independently.

To compare the BER performance of this branch metric combining method with those of other diversity combining methods, a computer simulation is carried out for three methods, i.e.,

- branch metric combining method (denoted as 'comb' in figures)
- selection diversity reception based on received power of each branch (denoted as 'power')
- ideal selection diversity reception by choosing minimum BER branch (denoted as 'ideal')

The receiving antennas for the space diversity reception are assumed to be omni-directional antennas with 0dB gain. For the APD reception, the receiving antenna system is assumed to consist of a set of two 180°-sectored antennas arranged so as to cover whole azimuthal directions as shown in Fig.3. Its directional gain is 3 dB and front-to-back ratio (F/B) is 10 dB.

A Rayleigh-distributed three-ray multipath model shown in Fig.3 is taken as an example for the analysis. We refer to the first coming wave as a desired (D) wave and delayed signals, delayed by τ_1 and τ_2 second, as undesired (U_1 and U_2) waves, respectively. All of the incoming multipath signals received by the two diversity antennas are subject to mutually independent Rayleigh fading. The incident angles of these waves are assumed to be fixed as illustrated in Fig.3.

SIMULATION RESULTS

Fig.5 and Fig.6 show the variation of BER versus E_b/N_0 for $f_DT = 1/1280$ and $f_DT = 1/640$ respectively, where f_D is a maximum Doppler frequency and T is a bit interval. The word 'dir' in figures indicates the APD reception, and 'omni' represents the space diversity reception using the omni-directional antennas. Assumed delay profiles are illustrated in Fig.4(a). Note that the branch metric combining method is superior to even the ideal selection diversity reception in both the APD and the space diversity reception. Previously, we found the use of a directive antenna is very effective to broaden the transmission bandwidth and improve the BER compared to the omni-directional antenna reception[3]. However, the APD reception is found to be inferior to the space diversity reception using the omni-directional antennas, if combined with a Viterbi equalizer. This is because a Viterbi equalizer utilizes all of the delayed multipath signals as desired signals, and an omni-directional antenna collects all of the incoming multipath signals from every direction, resulting in higher-order path-diversity effect.

Fig.7 shows the variation of BER versus E_b/N_0 for $\tau_2/T = 5.0$. There arises degradation in the BER performances simply because τ_2 is chosen out of the equalizable range of the Viterbi equalizer. Note that the BER of the APD reception proves to be better than that of the space diversity reception. This is because U_2 in the branch 2 of the APD reception is treated as a desired wave, since D and U_1 have 10dB-smaller power than U_2 as illustrated in Fig.4(b).

In the above analysis, we neglected some of the potential effects of a directive antenna. It is well-known that a directive antenna might reduce fading depth and elongate the fading period, by separately receiving multipath components[4]. Both effects improve the performance of a Viterbi equalizer. Therefore the APD reception might show better performance if we take these effects into account.

To investigate the latter effect, we set the fading period of signals received by the directive antenna to be twice as long as that received by the omni-directional antennas, i.e., $f_DT = 1/640$ for the omni-directional antennas and $f_DT = 1/1280$ for the directive antenna. Fig.8 shows that the APD reception gives better BER than the space diversity reception in such a case.

CONCLUDING REMARKS

In this paper, we have compared the performance of an APD and a space diversity reception combined with a Viterbi equalizer. As a result, we found that the BER performance of the space diversity reception using omni-directional antennas is generally better than that of the APD reception in a Rayleigh-distributed multipath propagation channel, due to higher order path-diversity effect. However, it is also demonstrated that there exists a condition that an APD reception shows better performance than a space diversity reception, if we take those effects obtained by a directive antenna into account.

Thus, further performance comparison should be made by finding an appropriate propagation model which reflects the effect of a directive antenna. In addition, we have to take the effect of a co-channel interference into account.

ACKNOWLEDGMENT

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REFERENCES

[1] M.Okada and S.Sampei: "Performance of DDFSE equalizer with interpolation type channel estimator under land mobile frequency selective fading channels," Trans. IEICE Japan, vol.J73-B-II, No.11, pp.727-735, Nov. 1990(in Japanese).

[2] G.D'Aria and V.Zingarelli: "Design and performance of synchronization techniques and Viterbi adaptive equalizers for narrowband TDMA mobile radio," Proc. Third Nordic Seminar on Digital Land Mobile Radio Communication, Copenhagen, 13.5, Sept. 1988.

[3] T.Takeuchi, F.Ikegami and S.Yoshida: "Transmission bandwidth improvement by directive antenna in urban mobile radio communication," Proceedings of the 36th IEEE Vehicular Technology Conference, Dallas, Texas, May 20-22, 1986.

[4] F.Ikegami, T.Takeuchi and S.Yoshida: "Effects of antenna radiation pattern on multipath fading in urban mobile radio," Trans. IECE Japan, vol.J68-B, No.3, pp.403-410, Mar. 1985 (in Japanese).

training sequence	information sequence	training sequence
26 bits	200 bits	26 bits

Fig. 1 A TDMA slot structure.

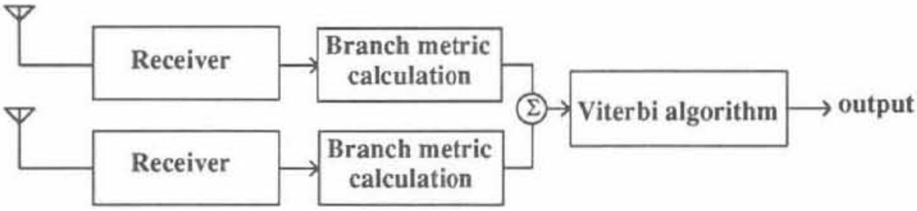


Fig. 2 Block diagram of a receiving system.

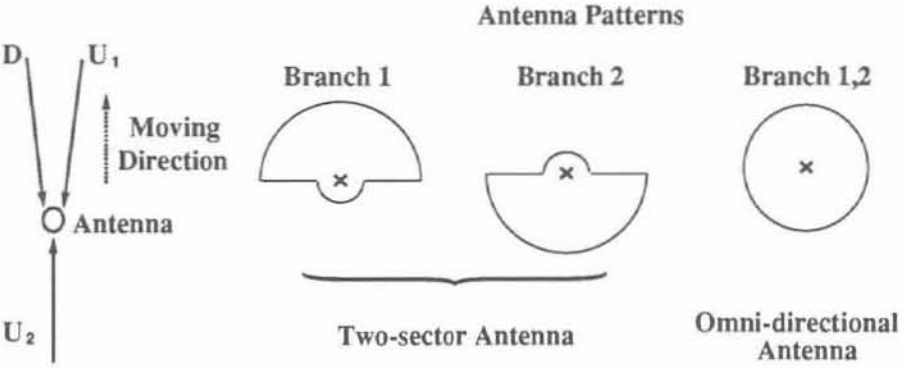
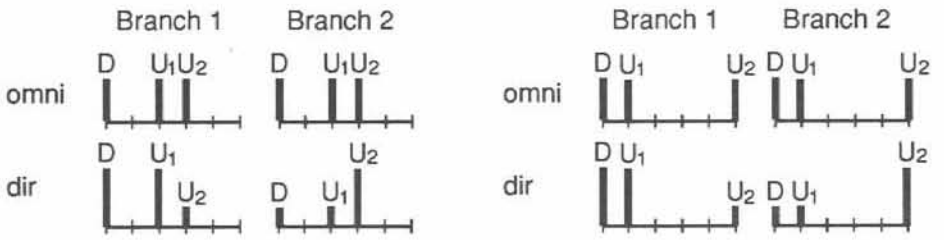


Fig. 3 Antenna configuration and multipath environment.



(a) Delay profiles at Fig.5,6,8.

(b) Delay profiles at FIg.7.

Fig. 4 Assumed multipath delay profile.

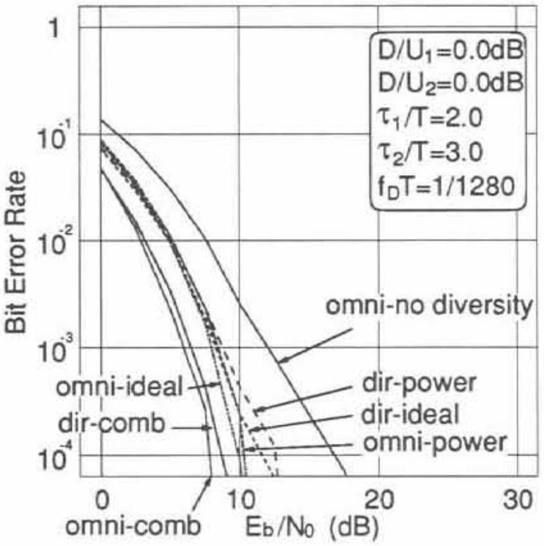


Fig. 5 BER vs. E_b/N_0. ($f_DT = 1/1280$)

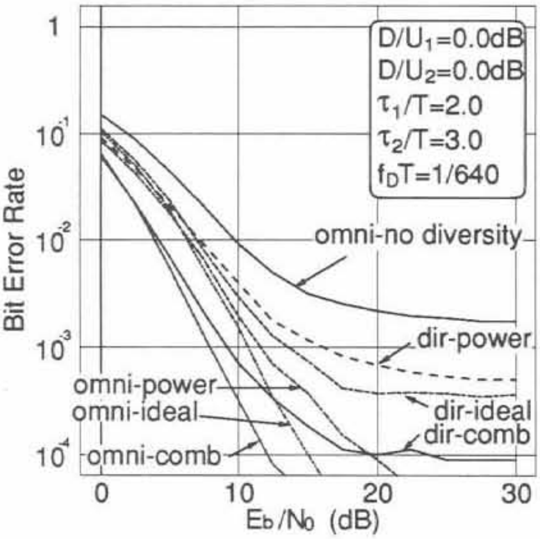


Fig. 6 BER vs. E_b/N_0. ($f_DT = 1/640$)

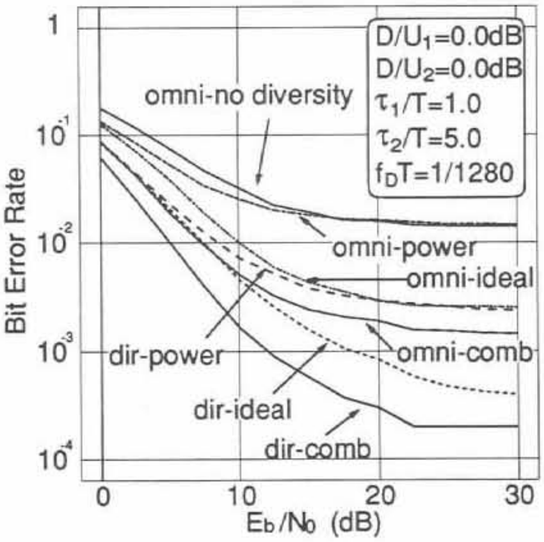


Fig. 7 BER vs. E_b/N_0. ($\tau_2/T = 5.0$)

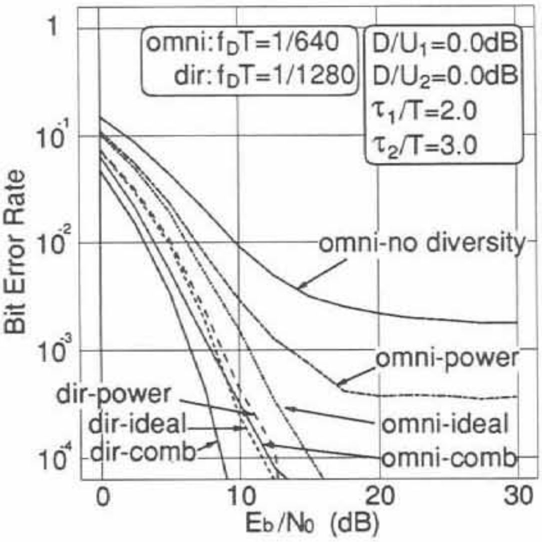


Fig. 8 BER vs. E_b/N_0. (f_DT=1/640 for omni-directional antenna, and f_DT=1/1280 for directive antenna)