Performance of TC 8PSK With Combination of Transmit-SC and Receive MRC on Nakagami Fading Channel

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1. Introduction

In mobile communication system, because of multipath propagation, the communication channel is modeled as a Rayleigh fading channel. One of the most efficient techniques to reduce fading effect and improve the system performance is space diversity reception, in which several signals received on different antennas are combined [1]. The most prevalent space diversity combining techniques are maximal ratio combining (MRC), equal gain combining (EGC), and selection combining (SC).

Bit error rate (BER) performance of trellis coded (TC) 8PSK with taking space diversity into consideration has been reported in [2]-[4]. Feminias et.al. in [2] and Saud in [3] analyzed the performance of TCM schemes with space diversity reception on Rayleigh fading channels assuming that the interleaving/de-interleaving makes the signal independent on each branch diversity. We had analyzed the BER performance of TC 8 phase shift keying (8PSK) with 2 branch SC and MRC diversities on independent and spatially correlated Nakagami fading channels [4]. In these researches the antenna diversities are fitted at the receiver.

It has been known that the systems using multiple antennas at both transmitter and the receiver have been used for improving the spectral efficiency or the reliability of wireless communications over fading channels. Steven et.al in [5] analyzed the performance of uncoded binary PSK (BPSK) with a combination of SC at the transmitter and MRC at the receiver on Rayleigh fading channel. On the other hand, Suzuki [6] shows that the Nakagami fading model fits some urban multipath channel data better than Rayleigh, Rician, or log normal distribution. distribution It has been know that trellis coded modulation (TCM) combined with interleaving techniques is attractive technique to combat fading [7]. Therefore, it is great interest to analyze the performance of TC MPSK with a combination of SC at the transmitter and MRC at the receiver on Nakagami fading channel.

2. System Model

The block diagram of the system model is depicted in Figure 1. Input bits representing data are passed through trellis encoder. The output signal is interleaved so as to break the correlation caused by the fading channel. Therefore, the fading characteristic among time sample is uncorrelated by an ideal interleaving. The interleaved symbols are mapped according to the mapping by set partitioning rules onto MPSK signal set. We denote a coded sequence of transmitted signal of length N by $x = \{x_1,\ldots,x_N\}$, where $n = 1,2,\ldots,N$, are vector representations of the transmitted signals. At the receiver, the received signals which is faded and corrupted by AWGN are decoded by a maximum likelihood sequence estimator (MLSE) using the Viterbi algorithm. At the transmitter there are K branch SC antennas and L branch MRC antennas at the receiver, we label as SC/MRC. At the receiver, the envelope of the received signals on the k-th receiver ($k=1,2,\ldots,L$) can be expressed as

$$r_{kl,n} = \rho_{kl,n} x_{k,n} + \mu_{kl,n}$$

where $\mu_{kl,n}$ is the additive white Gaussian noise (AWGN) and $\rho_{kl,n}$ is the fading amplitude in the k-th branch receiver antenna from transmitter antenna l.

The decoder makes an error (pairwise erroro probability), if x' is decoded, give3n that x is transmitted, where x' ≠ x. The conditional pairwise error probability (PEP) when the ideal channel state information (CSI) is available can be written as [7]

$$P(x \to x' | \rho_N) \le \frac{1}{2} \prod_{n \in \eta} \exp\left(-\frac{E_S}{4N_0} \rho_n^2 d_n^2 \right)$$

where η represents the set of all ***n*** such that $\boldsymbol{x \neq x'}$, $\boldsymbol{d^2_n}$ represents the normalized squared Euclidean distance between two modulation signal elements x_n and $\boldsymbol{x'_n}$, and E_s is the symbol energy. The random variable (***rv***) $\boldsymbol{\rho_n}$ represents the signal output of the combiner that depends on the type of space diversity.

In our research, we consider case of K branches SC diversity at the transmitter and L branches MRC diversity at the receiver. In the combiner of MRC diversity, L signals are cophased and summed where the weighting coefficients are proportional to the signal voltage to noise ratios. The probability density function (pdf) of $\boldsymbol{\rho_n}$ with MRC diversity on Nakagami fading channel is given by

$$f_R(\rho_n) = \frac{2m^{mL} \left(\rho_n^2\right)^{mL-1}}{\Gamma(mL)} \exp(-m\rho_n^2)$$

The cumulative distribution function (cdf) F($\boldsymbol{\rho_n}$) is given by

$$F_R(\rho_n) = 1 - \frac{\Gamma(mL, 2mL))}{\Gamma(mL)}$$

In SC diversity, the combiner connects to the branch having the highest baseband signal-to-noise ratio (SNR), the selection of the signal with the highest SNR corresponds to the signal with largest value of $\boldsymbol{\rho_n}$ that can be expressed as

$$f_\rho(\rho_n) = KF(\rho_n)^{K-1} f_\rho(\rho_n)$$

3. Performance Analysis

The average BER for TCM is upper bounded by [7]

$$P_b \le \sum \sum a(x,x') p(x) P(x \to x')$$

where a(x,x') is the number of bit error that occur when the sequence x is transmitted and the sequence x' ≠ x is chosen by decoder, p(x) is the a priori probability of transmitting x, C is the set of all coded sequence. P(x→x') represents the pairwise error probability

(PEP), i.e. the probability that decoder chooses x' when x was transmitted. In the following we consider to BER performance of TC 8PSK with SC/MRC diversity. The unconditional PEP is given by

$$P(x \rightarrow x') = \int_0^\infty P(x \rightarrow x' | \rho_n) f_\rho(\rho_n) d\rho_n$$

4. Numerical Results

The BER performance of 4-state of TC 8PSK with SC/MRC on independent Nakagami fading channel at m = 2 and the number of branches MRC diversity, L = 3 with variation of number of branches SC diversity is shown in Figure 2. It is shown from Fig. 2., that the BER performance of system improves as the number of branches SC diversity increases. This is because as the number branches of SC diversity increases the signal with largest SNR is possible to get in the system.

Figure 3 shows the BER performance of TC 8PSK with SC/MRC diversity at m = 2 and K + L = 7. It is shown from Figure 3, that the BER performance increases as the number of branches MRC diversity increase. Figure 4. shows BER performance comparison between TC 8PSK with SC/MRC diversity and TC 8PSK with MRC diversity on Nakagami fading channel at m = 2. It is that the BER performance of system with MRC diversity better than that of system with SC/MRC.

5. Conclusion

We have investigated the using of SC diversity at transmitter and MRC diversity at the receiver for improving the performance of TC 8PSK on Nakagami fading channel. The BER performance of TC 8PSK with SC/MRC diversity on Nakagami fading have also analyzed. It shown that the BER performance of TC 8PSK with SC/MRC improves by increasing the number of branches SC and MRC diversities. It is also shown that the BER performance of system with MRC is better than that of system with SC/MRC.

References

[1]. W.C. Ed. Jakes, Jr., Microwave Mobile Communications, New York: Wiley, 1974.

[2]. G. Feminas and R. Agusti, “Analysis of predetection diversity TCM-MPSK and postdetection diversity TCM-MDPSK systems on Rayleigh fading channel”, IEEE Trans. Vehicl. Technol., vol.VT-41, no. 2, pp. 199-210, May 1992.

[3]. Saud and Thomas F, “Performance analysis of coherent TCM with diversities reception in slow Rayleigh fading”, IEEE Trans. Vehicl. Technol. Vol. VT-48, no. 1. pp. 198-212, Jan. 1999.

[4]. G. Wibisono, “*Performance of TC MPSK with diversity on mobile satellite communication system*”, *Journal Technology*, Edisi No. 2, Tahun XIV, June 2000, pp. 133 – 140.

[5]. S. Theon, L.V. der Perre, B. Gyselinckx, and M. Engels, “Performance of analysis of combined transmit-SC/Receive-MRC”, IEEE Trans. On Commun., vol. COM-49, no. 1, pp. 5-8, Jan. 2001.

[6]. H. Suzuki, “A statistical model for urban multipath propagation,” IEEE Trans. Commun., vol.COM-25, no.7, pp. 673-680, Jul 1977.

[7]. D. Divsalar and M.K. Simon, "The design of trellis coded MPSK for fading channels: performance criteria," IEEE Trans. Commun., vol.COM-36, no.9., pp.1004-1012, Sep. 1988.

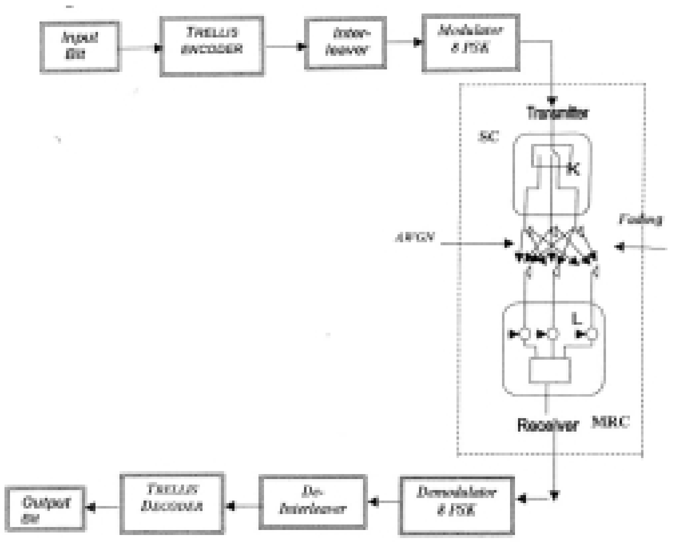

Figure 1. System model

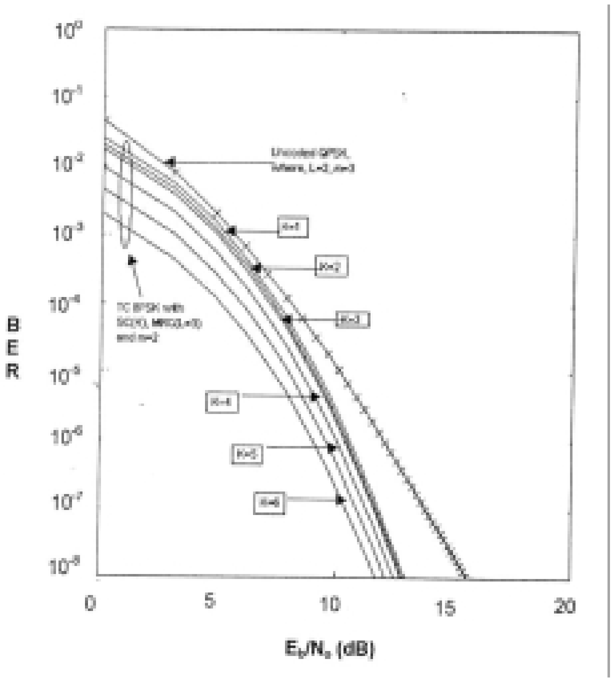

Figure 2. BER performance of TC 8PSK with SC/MRC on Nakagami fading channel at m = 2 and L = 3

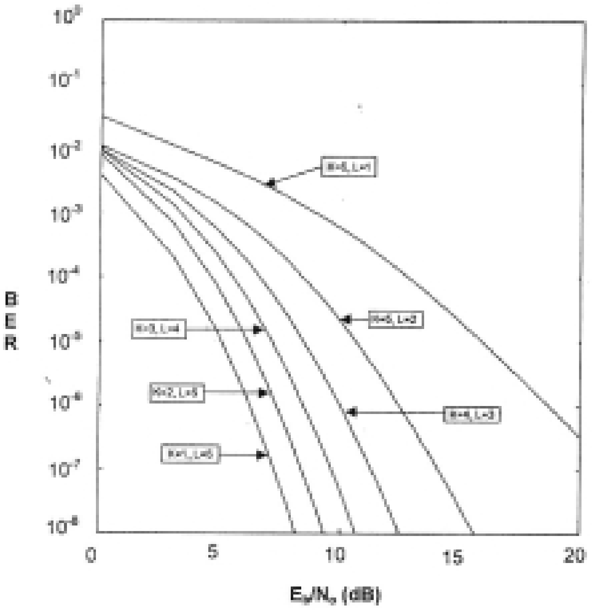

Figure 3. BER performance of TC 8PSK with SC/MRC diversity on Nakagami fading channel at m = 2 and L + K = 7

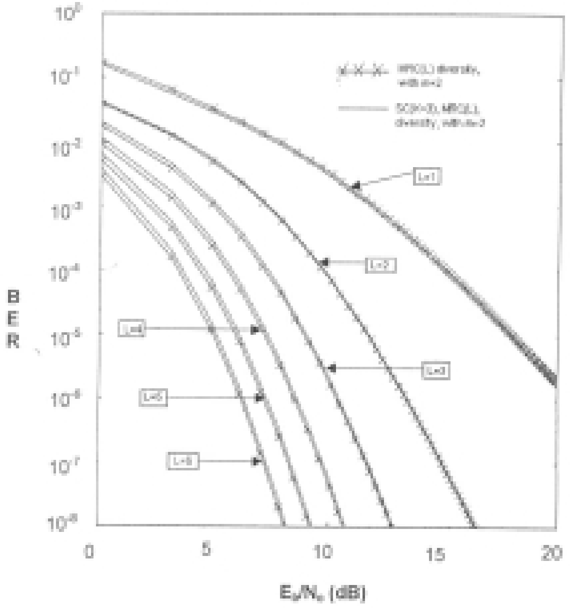

Figure 4. Performance comparison of BER between TC 8PSK with SC/MRC diversity and TC 8PSK with MRC diversity on Nakagami fading channel at m = 2