Antenna Diversity for Improving Performance of TC 8PSK on Mobile Satellite Communication System

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1. Introduction

In mobile communication such as mobile satellite communication system, because of multipath propagation, the communication channel is modeled as a Rician or Nakagami fading channel. One of the most efficient techniques to reduce fading effect and improve the system performance is space diversity reception [1]. In practical, diversity systems for mobile communication are unlikely to employ more than two branches, since as the number of branches increases the incremental improvement decreases and in addition the system becomes more complex [2]. The most prevalent space diversity combining techniques are maximal ratio combining (MRC), equal gain combining (EGC), and selection combining (SC). Another attractive technique to combat fading is trellis coded modulation (TCM) combined with interleaving techniques [3].

Feminias et.al. in [4] analyzed the performance of TCM schemes with space diversity on Rayleigh fading channels assuming that the interleaving/de-interleaving makes the signal independent on each branch diversity. However, this work does not consider the case of space diversity on correlated fading channel. In mobile satellite communication system, the Rayleigh fading channel may not be good assumption for the satellite channel. Therefore, it is great of interest to consider the the using of antenna diversity for improving the performance of TCM on independent Nakagami fading channel. We also consider the performance of TCM on spatially correlated Nakagami fading channel as comparison.

2. System Model

The block diagram of the system model is depicted in Fig. 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 receiver, there are K branch space diversity systems, the envelope of the received signals on the k-th receiver ($k=1,2,\ldots,K$) can be expressed as

$$r_{k,n} = \rho_{k,n} x_{k,n} + \mu_{k,n} \tag{1}$$

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

The decoder makes an error (pairwise erroro probability), if x' is decoded, given that x is transmitted, where x is not equal to x'. The conditional pairwise error probability (PEP) when the ideal channel state information (CSI) is available can be written as [3]

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

where η represents the set of all n such that x is not equal to x', d^2_n represents the normalized squared Euclidean distance between two modulation signal elements x_n and x'_n, and E_s is the symbol energy. The random variable (rv) R_n represents the signal output of the combiner which depend on the type of space diversity. In our research, we consider the space diversity with two branch diversities.

In SC diversity system, the combiner connects to the receiver having the highest baseband signal to noise ratio (SNR). The selection of the signal with the highest SNR corresponds to demodulated the signal with largest value of $\rho_{k,n}$. The value of R_n on independent Nakagami fading channel can be written as [5]

$$p_R(R_n) = \frac{2\left(\frac{m_1}{\Omega_1}\right)^{m_1}}{\Gamma(m_1).\Gamma(m_2)}.R_n^{2m_1-1}.\exp\left(-\frac{m_1}{\Omega_1}R_n^2\right)\gamma\left(m_2,\frac{m_2}{\Omega_2}R_n^2\right)$$
$$+\frac{2\left(\frac{m_2}{\Omega_2}\right)^{m_2}}{\Gamma(m_1).\Gamma(m_2)}.R_n^{2m_2-1}.\exp\left(-\frac{m_2}{\Omega_2}R_n^2\right)\gamma\left(m_1,\frac{m_1}{\Omega_1}R_n^2\right) \tag{3}$$

where m$_1$ dan m_2 are fading parameter for channel 1 and 2, respectively, Ω_1 and Ω_2 are mean of Nakagami fading for channel 1 and 2 respectively, $\Gamma(\cdot)$ is the Gamma function, $\gamma(\cdot)$ is the incomplete Gamma function. The pdf of R_n on spatially correlated Nakagami fading channel in case $m_1 = m_2 = m$ is given by [5]

$$P_R(R_n) = \frac{2m^m R_n^{2m-1}}{\Gamma(m)\Omega_1^m}\exp\left(-\frac{mR_n^2}{\Omega_1}\right)\Big[1-Q_m\left(\sqrt{2}\,kA_1R_n,\sqrt{2}\,A_2R_n\right)$$
$$+\frac{2m^m R_n^{2m-1}}{\Gamma(m)\Omega_2^m}\exp\left(-\frac{mR_n^2}{\Omega_2}\right)\Big[1-Q_m\left(\sqrt{2}\,kA_2R_n,\sqrt{2}\,A_1R_n\right) \tag{4}$$

where $A_i = \sqrt{m/(\Omega_i(1-k^2))}$, (i = 1,2) and $Q_M(\cdot,\cdot)$ is Nuttal function, and k is the cross correlation between the fading signal.

In the combiner of MRC diversity, K signals are cophased and summed where the weighting coefficients are proportional to the signal voltage to noise ratios. The pdf of R$_n$ with MRC diversity on independent Nakagami fading channel is given by

$$P_R(R_n) = \frac{2R_n^{2\mu-1}\exp\left(-R_n^2\frac{\sigma_1+\sigma_2}{2\sigma_1\sigma_2}\right)}{\Gamma(2\mu)\left(\frac{\sigma_2-\sigma_1}{\sigma_1\sigma_2}\right)^{\mu}\sigma_1^{m_1}\sigma_2^{m_2}}M_{v,\mu-\frac{1}{2}}\left(R_n^2\frac{\sigma_2-\sigma_1}{\sigma_1\sigma_2}\right) \tag{5}$$

where $M_{v,\mu}(.)$ is Whittaker function, $\sigma_i = \frac{\Omega_i}{m_i}$, $\mu = \frac{m_1+m_2}{2}$, and $v = \frac{m_1-m_2}{2}$. The pdf of MRC diversity on spatially correlated Nakagami fading channel is given by

$$p_R(R_n) = \frac{2\sqrt{\pi}\,R_n\exp\left(-\alpha R_n^2\right)}{\Gamma(m)\left(\sigma_1\sigma_2\left(1-k^2\right)\right)^m}\left(\frac{R_n^2}{2\beta}\right)^{m-\frac{1}{2}} I_{m-\frac{1}{2}}\left(\beta R_n^2\right) \tag{6}$$

where $I_v(.)$ is the v-order modified Bessel function of the, α and β are respectively given by

$$\alpha = \frac{(\sigma_1+\sigma_2)/2}{\sigma_1\sigma_2\left(1-k^2\right)}, \qquad \beta = \frac{(\sigma_1-\sigma_2)^2+4\sigma_1\sigma_2k^2}{4\sigma_1^2\sigma_2^2\left(1-k^2\right)^2}.$$

3. Performance Analysis

The average BER for TCM is upper bounded by [3]

$$P_b \le \sum\sum a(x,x')p(x)P(x\rightarrow x') \tag{7}$$

where $a(x,x')$ is the number of bit error that occur when the sequence x is transmitted and the sequence x' is not equal to x is chosen by decoder, $p(x)$ is the a priori probability of transmitting x, C is the set of all coded sequence. $P(x \rightarrow x')$ represents the PEP. The unconditional PEP are obtained by averaging (2) over the pdf of R_n which is given by

$$P(x \rightarrow x') = \int_0^\infty P(x \rightarrow x'|R_n)p(R_n)dR_n \tag{8}$$

The unconditional PEP for TC 8PSK with 2 branch SC and MRC diversityies are obtained by substituting (2) and (3) into (8) for SC on independent fading channel, (2) and (4) into (8) for SC on spatially carrelated Nakagami fading channel, (2) and (5) into (8) for MRC on independent Nakagami fading channel, and (2) and (6) into (8) for MRC on spatially carrelated Nakagami fading channel, respectively. The BER of TC 8PSK with 2 branch SC and MRC diversities on independent and spatially correlated Nakagami fading channels is obtained by substituting (8) into (7).

4. Numerical Results

The BER performance of 4-state of TC 8PSK with diversity on independent Nakagami fading channel are shown in Fig. 2. and 3. for SC and MRC diversities respectively. It is shown from Fig. 2 and 3 that the BER performance of TC 8PSK with 2 branch SC and MRC diversities is improved with increasing m. It is also shown from Fig.2 and 3 that the BER performance of TC 8PSK with 2 branch MRC diversity is better than that of SC diversity.

The BER performances of 4-state TC 8PSK with 2 branch SC and MRC diversities on spatially correlated Nakagami fading channel for different value of the fading correlation parameter k^2 are shown in Figs. 4 and 5 for SC and MRC diversities, respectively. Although the correlation between branches causes SNR losses (relative to $k^2 = 0$), the diversity can lead to achieve diversity gain. It can be observed from Figs. 4 and 5 that the BER of TC 8PSK with 2 branch SC and MRC diversities on spatially correlated Nakagami fading is better than that of TCM without diversity. It can be observed from Figs. 4 and 5 the BER of TC 8PSK with 2 branch SC and MRC diversities is improved with decreasing k^2.

5. Conclusion

We have investigated the using of antenna diversity for improving the performance of TC 8PSK on mobile satellite communication system where the channel is model by Nakagami fading channel. The BER performance of TC 8PSK with 2 branch SC and MRC diversities on independent and spatially correlated Nakagami fading have also analyzed. Although the correlation between branches causes SNR loss (relative to independent fading case) for SC and MRC diversities on spatially correlated Nakagami fading, the antenna diversity can lead to achieve the diversity gain compared to the system without diversity.

References

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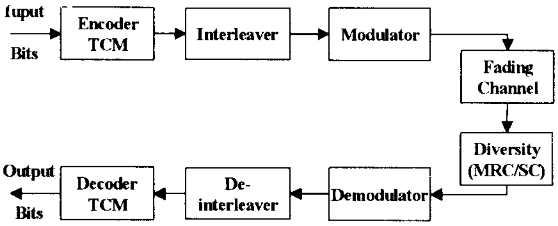

Figure 1. System model

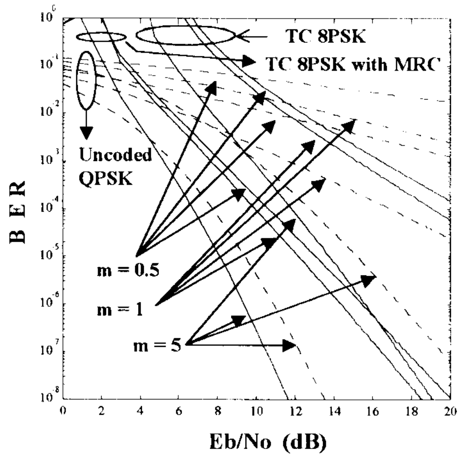

Figure 2. BER of 4-state TC 8PSK with 2 branch MRC diversity on independent Nakagami fading channel for various m

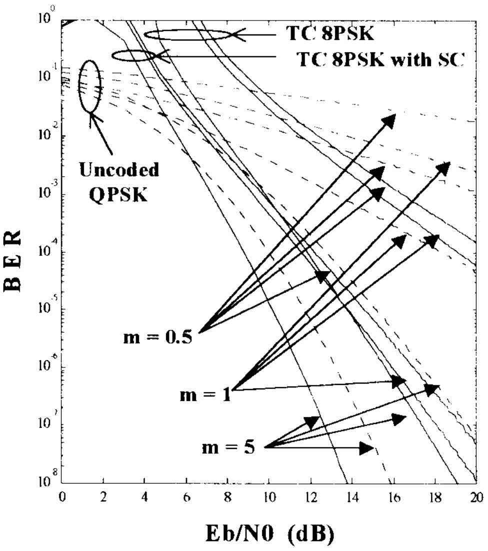

Figure 3. BER of 4-state TC 8PSK with 2 branch SC diversity on independent Nakagami fading channel for various m

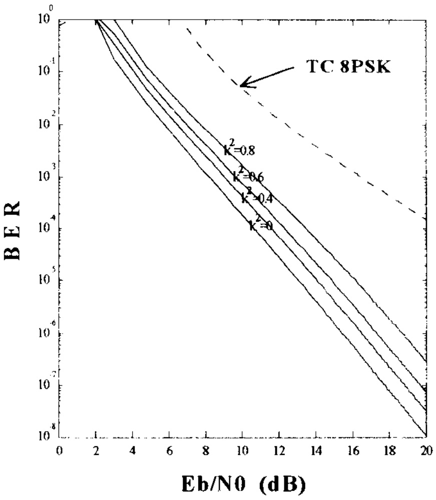

Figure 4. BER of 4-state TC 8PSK with 2 branch MRC diversity on spatially correlated Nakagami fading channel at m = 0.5

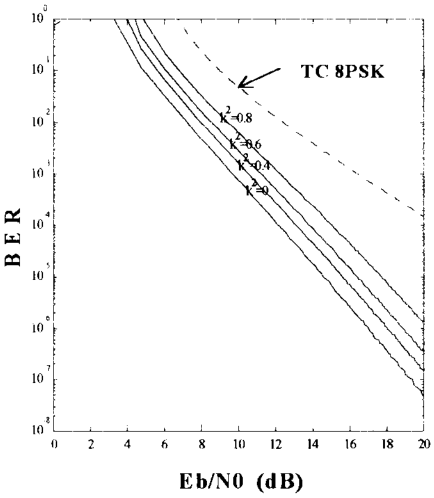

Figure 5. BER of 4-state TC 8PSK with 2 branch SC diversity on spatially correlated Nakagami fading channel at m = 0.5