

Performance Evaluation of Orthogonal Space Time Block Codes under Rician Fading Scenario

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Abstract

Multiple Input Multiple Output (MIMO) system has been identified as a new paradigm in wireless communication due to its potential capability to facilitate higher data rates by spatial multiplexing. Space-time block codes (STBC) offer high diversity gain and among which orthogonal STBCs are very attractive due to its relatively simpler design and low decoding complexity. In this paper, an approach has been made to study different types of STBCs employing different numbers of transmitting and receiving antennas under Rician fading situation. In all the cases, the bit error rate has been treated as the figure of merit and its change with SNR are observed due to different parameter variations of the channel distribution as well as different antenna configurations.

Keywords: MIMO system, spatial multiplexing, orthogonal STBC, Rician fading

Introduction

Recent deployment of Multiple Input Multiple Output (MIMO) systems to achieve transmit as well as receive diversity has evolved a new era in wireless communication. To combat the noise effects and other impairments in the channel, MIMO system can be considered as a possible solution as it incorporates spatial multiplexing, that is, the available degrees of freedom of channel is much higher than that of Single Input Single Output (SISO) systems [7].

Space-time block coding (STBC) has been identified as an attractive approach for achieving transmit diversity. Among all the STBCs, Orthogonal STBC (OSTBC) is

observed to be very suitable due to their low decoding complexity. This idea was first imported by Alamouti [1] for two transmit antenna systems and then it was extended for more than two antennas with different code rates [2][3].

In this paper an approach has been made to study the performance of OSTBCs with different code rates by considering Rician fading of the channel. The channel is assumed to be quasi-static and flat faded. Here a codeword is detected by maximum-likelihood decoding and the bit error rates are studied under different code rates [6].

The paper is organized as follows. Section 2 explains the overall system model as well as the theoretical background. Section 3 deals with different simulation results and section 4 concludes the paper.

The System Model

Let us consider a wireless communication system where the transmit base station is equipped with N and the remote station with M antennas. At each time slot t , signals c_{tn} , $n = 1, 2, \dots, N$ are transmitted simultaneously from N antennas. So the received signal r_{tm} at the m^{th} receive antenna is given by

$$r_{tm} = \sum_{n=1}^N \alpha_{nm} c_{tn} + w_{tm} \quad (1)$$

where α_{nm} is the path gain from transmit antenna n to receive antenna m , w_{tm} being independent samples of a Circularly Symmetric Complex Gaussian (CSCG) of zero mean and $N/2\text{SNR}$ variance per real dimension. All α_{nm} are considered to be independent samples of Rician distribution of parameters η and σ , that is

$$\alpha_{nm} \sim \text{Rice}(\eta, \sigma) \quad (2)$$

Assuming perfect channel state information, the decision metric is calculated as

$$\sum_{t=1}^T \sum_{m=1}^M \left| r_{tm} - \sum_{n=1}^N \alpha_{tm} c_{tn} \right|^2 \quad (3)$$

over all codewords, T being the total number of time slots considered. Decision is taken in favour of the codeword for which the above parameter is a minimum.

The bit error probability can be calculated in terms of Marcum's Q function that involves average SNR, code rate and Frobenius norm of the channel matrix. The following figures show the Bit Error Rate (BER) vs. SNR plot for different circumstances. BER falls down with the enhancement of SNR but in different manners giving a clear indication of desirable system designing criteria.

Simulation Results

This section shows different simulation results. The channel realizations are taken

randomly from a Rician distribution and BER performance is studied with distribution parameter variation as well as number of antenna variation.

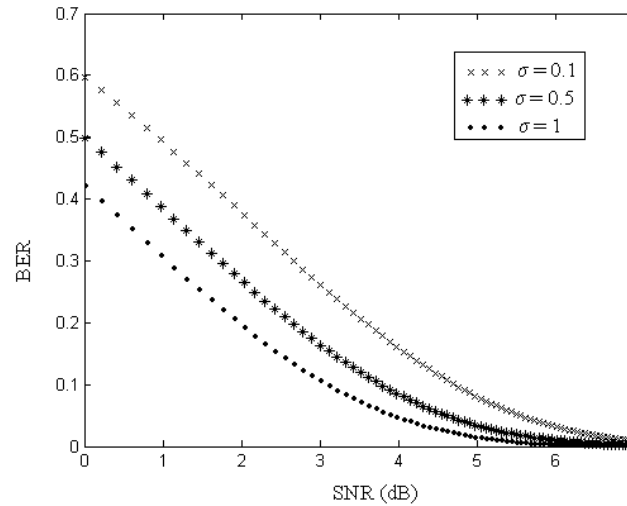


Figure 1: BER vs. SNR plot for various values of σ for a 2×2 MIMO system

Figure 1 shows the BER vs. SNR plot for different σ values for a 2×2 MIMO system considering $\eta = 1$. This indicates clearly that BER performance differs significantly in the low SNR regime for various σ values but they converge at comparatively high SNR regime. So from the design point of view, we may conclude that if σ is low, high SNR zone is suitable. However, BER performance is good for higher σ values both for low as well as high SNR regime.

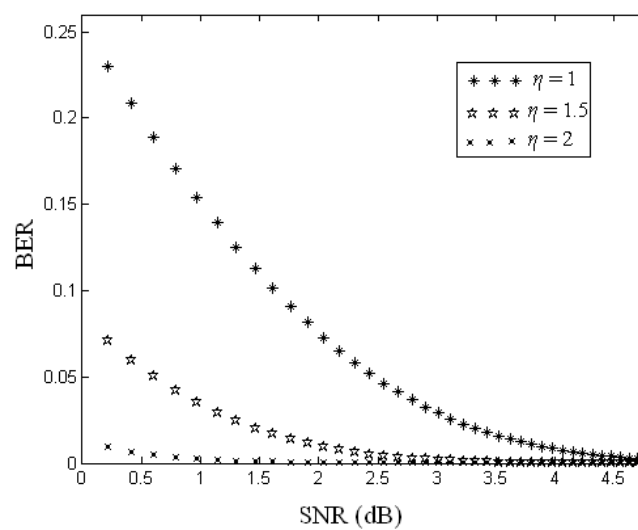


Figure 2: BER vs. SNR plot for various values of η for a 2×2 MIMO system.

Figure 2 shows the BER vs. SNR plot for different values of η for a 2×2 MIMO system considering $\sigma = 1$. Here also we find that BER decays rapidly due to increase in SNR. So a judicious choice of SNR with a specific η value can improve a system performance. As like the previous case, high SNR value gives a good BER performance for all η whereas low SNR regime is suitable only for higher values of η .

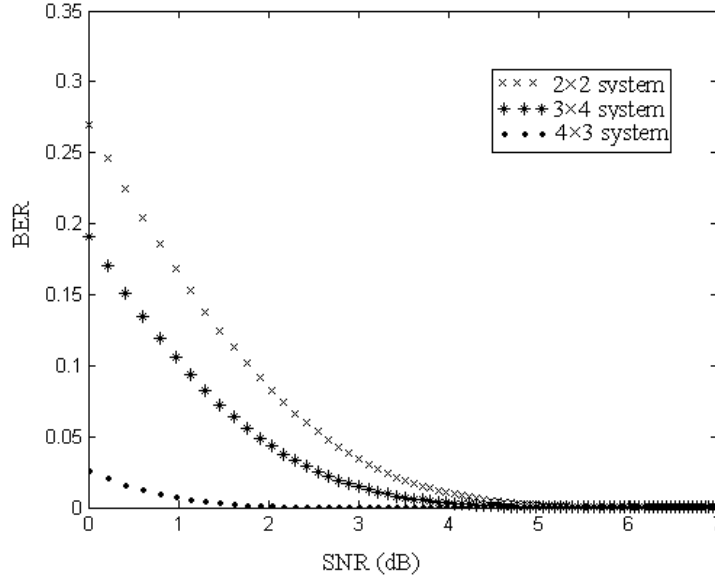


Figure 3: BER vs. SNR (dB) plot for different antenna configurations for the distribution Rice (1, 1)

The BER performance with SNR for different antenna configurations is shown in figure 3. It is found that as the number of transmitting antenna increases, BER improves. The code rates for 3×4 as well as 4×3 are both taken $\frac{3}{4}$, which is the maximum. The code rate for 2×2 system is obviously 1. The BER performances more or less converge at high SNR regime but for the low SNR case, higher number of transmitting antennas is preferable. However depending on the feasibility of number of antennas, the system performance can be optimized.

Conclusion

In this paper, a study of the performance of different OSTBCs under Ricean fading has been observed when transmitted symbols are taken from a complex constellation. The studies may provide a clear indication to a designer of optimizing the system performance. There may be slight variations in results if the distribution parameters considered here are changed or the code rates taken here differ from the practical case but the pattern of the curves are more or less same. One drawback of OSTBCs is that it is not bandwidth efficient, that's why different improved versions of ST codes (for

example, quasi orthogonal STBC) are being proposed. However, due to its less decoding complexity and full diversity, it can be reliably used in wireless communication.

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