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Comparison of BER Performance & Capacity Analysis of MIMO System with STBC & MRC to improve Link Performance in Fading Environment

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Abstract

MIMO (Multiple-input Multiple-output) systems are used in wireless communications to ensure high reliability, high data-rate & high capacity transmission. STBCs (Space-Time Block Coding) used in MIMO systems for increasing diversity gain. In MIMO system, high-data rates are obtained through Spatial multiplexing which also helps in combatting the effect of multipath fading. For SIMO (Single-input Multiple-output) schemes, MRC receiver is used to handle same information signal over two or more fading channel. In this paper, we investigate the Ergodic Capacity of different MIMO & SIMO systems & comparison of Bit Error Rate performance of un-coded coherent BPSK employing Alamouti STBC as transmit diversity & MRC (Maximal Ratio combining) as receiving diversity in Rayleigh fading channel.

Keywords: *MIMO, STBC, MRC, MATLAB, Ergodic Capacity, BER, Rayleigh fading.*

1. Introduction

The demand for high data rates & capacity in wireless networks has grown in a literally explosive manner. Multiple antenna schemes play an important role in providing reliable & high-data rates in next generation wireless communication system. Better transmission over fading channel environment is possible by using diversity techniques with the use of multiple transmitters & receiving antennas & it can be achieved by using Space-Time Block Coding.

STBC has been implemented in cellular systems as well as in optical wireless networks. STBC can achieve transmit diversity & coding gain over wireless networks without sacrificing bandwidth. Alamouti proposed a transmitting scheme for two antennas which acquires full diversity gain with a simple maximum likelihood decoding algorithm[1], after which Tarokh formalized & extended this concept by showing orthogonal designs providing full rate only for two antennas [2]. Thus, STBC as primary MIMO scheme [3] which uses multiple antennas at both the transmitter & receiver sides is well known for its ability to resist the influence of wireless fading channel & for providing high capacity & better system performance than single link systems in wireless communications. Proper antenna selection highly impacts on costing & complexity by selecting single or multiple antennas & thus improves bit error performance of the system [4,5].In this paper, MIMO system performance of BPSK for transmit diversity (Alamouti STBC) & receive diversity (MRC) has been shown in Rayleigh fading channel & Capacity of various systems has been shown.

The rest of this article is organized as follows. In Section 2 presents MIMO system performance for BPSK modulation of MRC & Alamouti STBC in fading channel is shown. Section 3 demonstrates Simulation results are followed by the conclusion in section 4 on the basis of our observations.

2. System Model

Figure 1 shows a block diagram of prime components of MIMO system.

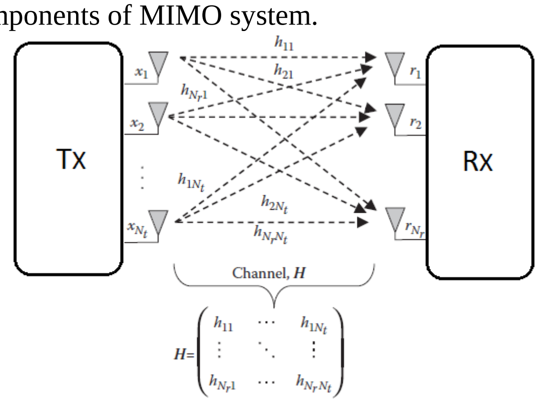


Fig.1 Block diagram of MIMO system model [3].

Where N_t is number of transmitting antennas & N_r is the number of receiving antennas & H is the channel matrix which represents the channel gain between transmitting & receiving antenna.

2.1 Space-Time Block Coding (STBC)

STBC [8] is one of the techniques which is used for transmission of multiple copies of information to antennas to improve the reliability of system, thus providing high data rates & increasing the capacity of the system.

2.1.1 Alamouti STBC 2x1 System (2-Transmitting antennas & 1-Receive antenna)

Alamouti space-time coding scheme generating the code word S given in equation (1) is used to encode data symbols.

$$\begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \qquad (1)\ [7]$$

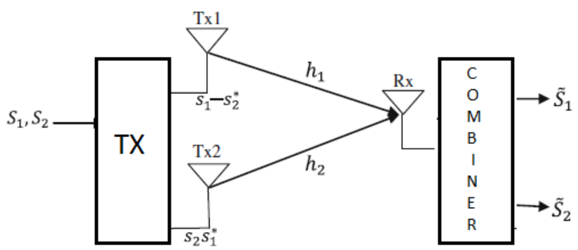


Fig.2 Alamouti STBC scheme 2x1 System [7].

Accordingly, Signals S_1 & S_2 are transmitted from antenna 1 & 2 during first time slot & in next time slot, antenna 1 & 2 transmits – S_2*& S_1*.

The BER [7] for Alamouti STBC 2x1 antenna with BPSK modulation can be written as

$$BER_{MRC(1X2)} = P_{MRC}^2\,[1 + 2(1 - P_{MRC})]$$

Where

$$P_{Alamouti} = \frac{1}{2} - \frac{1}{2}\left(1 + \frac{2}{\frac{E_b}{N_0}}\right)^{-\frac{1}{2}} \qquad (3)$$

2.1.2 Alamouti STBC 2x2 System (2-Transmitting antennas & 2-Receive antenna)

Alamouti scheme with 2-transmit & 2-receive antenna is expressed in the Fig 3.

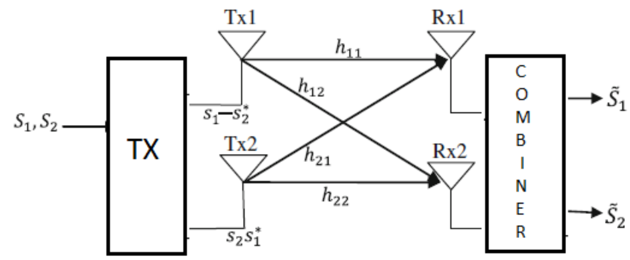


Fig.3 Alamouti STBC scheme 2x2 System [7].

The BER [7] for Alamouti STBC 2x2 antennas with BPSK modulation can be written as Eq(3):

$$BER_{Alamouti(2X2)} = P_{Alamouti}^4\,[1 + 4(1 - P_{Alamouti}) + 10(1 - P_{Alamouti})^2 + 20(1 - P_{Alamouti})^3 \qquad (3)$$

2.2 Maximal Ratio Combining (MRC)

MRC scheme is used to combine the signals from multiple diversity branches. Basically, it amplifies the strong signal branch while it attenuates the weak signal. The received signal is the product of transmitted signal vector & the channel with additive noise.

The BER [7] for MRC for one transmitting & two receiving antennas with BPSK modulation can be depicted as Eq (4):

$$BER_{MRC(1X2)} = P_{MRC}^2\,[1 + 2(1 - P_{MRC})]$$

Where

$$P_{MRC} = \frac{1}{2} - \frac{1}{2}\left(1 + \frac{2}{\frac{E_b}{N_0}}\right)^{-\frac{1}{2}} \qquad (4)$$

Also, the BER [7] for MRC for one transmitting & four receiving antennas with BPSK modulation can be depicted as Eq (5):

$$BER_{MRC(1X4)} = P_{MRC}^4\,[1 + 4(1 - P_{MRC}) + 10(1 - P_{MRC})^2 + 20(1 - P_{MRC})^3 \qquad (5)$$

MIMO systems combined with MRC receivers can acquire the highest available spatial diversity order.

2.3 Channel capacity of random MIMO Channels:

MIMO channel capacity can be given by its time average [6]. We should consider the following statistical notion of the MIMO channel capacity from (Eq.6):

$$C_{erg} = E\left[log_2\, det\left\{I_{NR} + \frac{SNR}{N_T}\, \lambda i\right\}\right]$$

(Eq.6) [6]

Where, E is the energy of the N_T transmitted signals, and I_{NR} is power distribution among transmitters is Identity matrix & λi (where i= 1, 2,…, n(rank of matrix)) are Eigen values obtained from Eigen decomposition of HH^T .

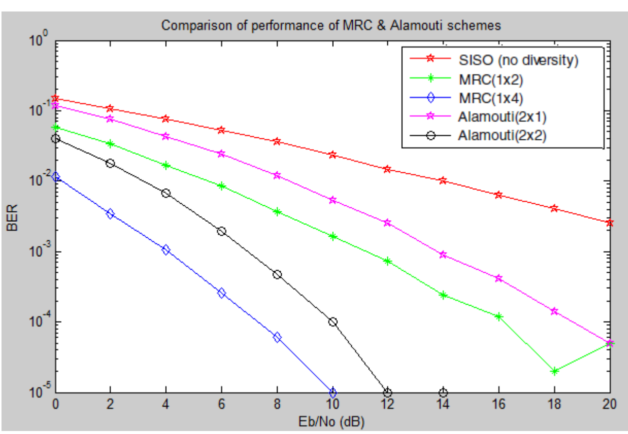
This is known as Ergodic channel capacity.

MIMO channel capacity improves with increasing the number of transmitting & receiving antennas.

3. Simulated Results:

In this section, the Bit error rate analysis of MIMO system performance of BPSK for transmit diversity (Alamouti STBC) & receive diversity (MRC) is shown in Rayleigh fading channel.

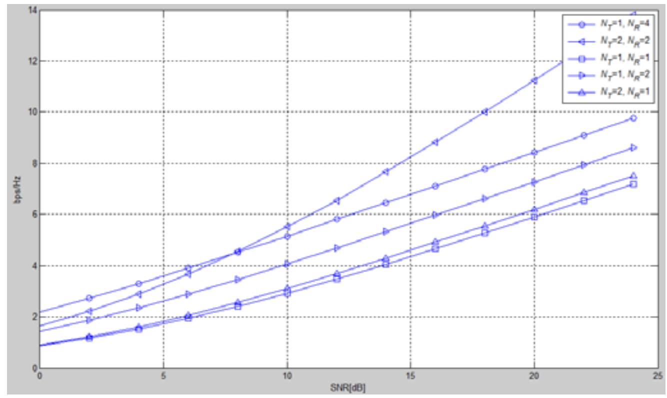
Graph 1.shows the BER values as a function of varying E_b /N_0 for the MIMO Scheme.



Graph.1: Measured BER for various transmit & receive diversity schemes over Rayleigh fading channel using BPSK.

In this, the performance of 1x4 MRC is 2-dB times better than 2x2 Alamouti STBC. Also, the performance of 2x1 Alamouti STBC is 2-dB worse as compares to 1X2 MRC.

Graph 2.plots the Ergodic Capacity of a various MIMO & SIMO schemes:



Graph.2: Measured Ergodic capacity v/s SNR plot for various transmit & receive diversity schemes.

Here, 2X2 MIMO shows the highest capacity as compared to other schemes as channel capacity increases with number of transmitting & receiving antennas.

4. Conclusions

In this paper, we studied and analyzed the system capacity & bit error rate performance for various transmit & receiving diversities operating under Rayleigh fading. The closed-form expressions for the BER & the Ergodic capacity are depicted to investigate the impact of these schemes on the particular system. The 2-dB penalty is due to the assumption that each transmit antenna in the Alamouti STBC radiates half the energy in order to ensure the same total radiated power as with one transmit antenna of the MRC. Also, the capacity of the system enhances as we increase the number of transmitting & receiving antennas which also enhances the data rate & reliability of the system.

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