BER Performance Analysis of Alamouti Coding Technique in Rayleigh Fading Channel

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Abstract: ***For several years, wireless communication is facing major problem of scarce bandwidth availablity and with exponential growth of this area, many new technologies are used to improve communication performance and overcome the bandwidth limitation in wireless communication environment, such as temporal dispersion, multipath propagation, and frequency dispersion. space-time coding (STC) is a breakthrough technology, which transmits and receives information with more reliability and at higher data rates by using multiple antennas at both sides. Multiple antenna (MIMO) systems with significantly reduced complexity and (STBC) space time block coding, for communication over fading channels (Rayleigh channel is used in this paper) using multiple transmit antennas have been used. We have tested the performance of Alamouti coding technique for the Rayleigh channel. The signals on the transmitter (Tx) antennas at one end and the receiver (Rx) antennas at the other end are "combined" in such a way that the BER (quality) or the data rate (bits/sec) of the communication are improved. The simulation results are used to compare and analyze the performance.***

Keywords: STBC, MIMO, Wireless, Fading Channel, Alamouti.

1. Introduction

The space-time coding is a technique that provides both space and time diversity. Alamouti [1] followed by Tarokh et al [2] presented research papers in which a linear block code was designed for multi antenna system.

It provides a reliable wireless communication in fading channels such as Rayleigh fading channel.[6],[10] In Alamouti linear block code two transmit and arbitrary no of receiver antennas were used, which could achieve maximum diversity, which is possible due to orthogonal design. For decoding maximum likelyhood decoding is used. Tarokh et al [2] paper proposed orthogonal space time block code for the transmitter diversity [3].

The aim of this paper is to compare BER (bit error rate) with various SNR (signal to noise ratio) for 1 transmitter-1 receiver (SISO), 2 transmitter-1 receiver (MISO) and 2 transmitters – 2 receivers (MIMO) and compare the results.
Design of different types of STC codes was done for achieving maximum diversity and full rate. But the condition of having multiple receiver antennas is very difficult to achieve. Alternate scheme [3], [4], [5] were provided. It was shown that code rate cannot be greater than one. But the biggest drawback with these codes are that during decoding, they do not perform well, when number of receiver antennas are less than transmitter antennas.

Method for increasing the spectral efficiency of Alamouti code has been presented [6], [7]. But such a scheme does not contribute significant improvement in efficiency for more than two transmit antennas.

In this paper we have proposed a technique to improve the spectral efficiency of STBC for two transmit antennas retaining maximum diversity, full rate (which is equal to one) and simple (ML) maximum likelihood decoding characteristics of original code. This paper focuses on design of efficient code for two transmit antennas scenario, same idea can be used to design higher order MIMO system.

2. Channel Under Consideration

2.1 Rayleigh Fading Channel

In mobile radio channels, the Rayleigh distribution is used to describe the time varying nature of the received envelope of a signal which is flat fading, or the envelope of an individual multipath component[6],[11]. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. The Rayleigh distribution has a probability density function which shown in Fig 1 and given by

$$P(r) = \begin{cases} \frac{r}{\sigma} e^{\frac{-r^2}{2\sigma^2}}, 0 < r < \infty \\ 0, r < 0 \end{cases}$$

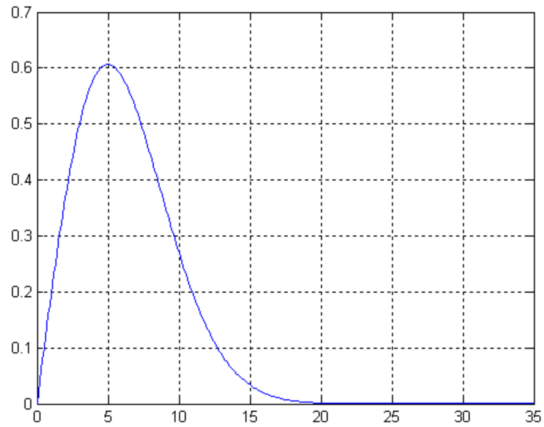


Figure 1: Rayleigh distribution

And the amount of fading is equal to 1 and typically agrees very well with experimental data for mobile systems where no LOS path exists between the transmitter and receiver antennas. It also applies to the propagation of reflected and refracted paths through the troposphere and ionosphere [9].

3. Channel Capacity

In MIMO system as multiple antennas are used thus space diversity increases [6],[10], some of the simulated comparison results of 1-Tx – 1-Rx, 2-Tx – 2-Rx, 3-Tx – 3-Rx are shown.

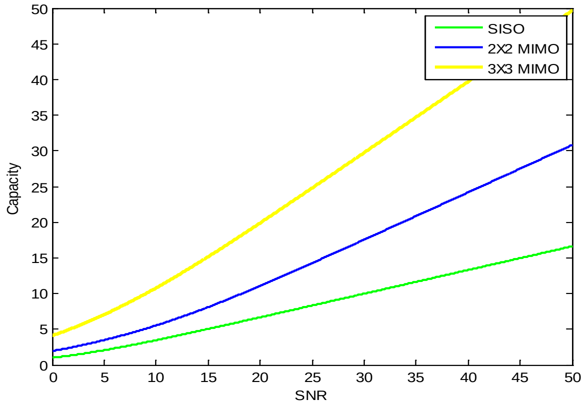
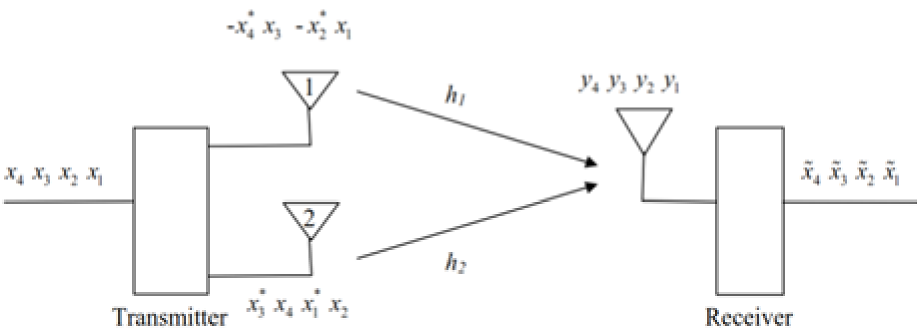


Figure 2: Channel capacity diagram



2×1 System.

Figure 3

In this scheme we use two antennas for transmitting and one for receiving as shown in Figure 3. The diversity gain is two times than SISO system as two channels are available. The scheme is to transmit two symbols, x_1 and $x_2$by the following procedure:

x_1 and x_2 are simultaneously transmitted during the first time interval using antenna 1 and antenna 2 respectively and then the symbols $-x_2^*$ and x_1^* are simultaneously transmitted during the second time interval. Thus, the transmitted signal expressed as a matrix

$$\mathrm{X}=\begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix}$$

where the (*) indicates complex conjugation operation. This process is then continuously repeated to transmit the next two symbols and so on. Four symbols x_1, x_2, $x_3$and x_4 would be transmitted during four time intervals. It is the characteristic of this scheme that two symbols form a block and they are simultaneously encoded and decoded as a block only. Referring to Figure 3, the received signals $\boldsymbol{y_1}$ and$\boldsymbol{y_2}$ are the combination of the signals from antennas 1 and 2, plus additive noise [8]:

$$\mathrm{y_1} = \mathrm{h_1 x_1} + \mathrm{h_2 x_2} + \mathrm{n_1}$$

$$\mathrm{y_2} = -\mathrm{h_1 x_2^*} + \mathrm{h_2 x_1^*} + \mathrm{n_2}$$

where $\mathrm{n_1}$ and $\mathrm{n_2}$ represent the additive noise and $\mathrm{h_1}$ and $\mathrm{h_2}$ are complex numbers, representing the channel gain. It is assumed that the channel is flat and memoryless, thus inducing a magnitude and phase change in the transmitted signal, without inducing a time delay. We further assume that the receiver has perfect Channel State Information (CSI) i.e., the receiver can measure and determine h_1 and h_2 . The receiver then computes estimates of $x1$ and $x2$, denoted $\widetilde{x_1}$ *and* $\widetilde{x_2}$, by processing $\boldsymbol{y_1}$ and $\boldsymbol{y_2}$ as follows

$$\widetilde{x_1} = \boldsymbol{h_1^* y_1} + \boldsymbol{h_2 y_2^*}$$

$$\widetilde{x_2} = \boldsymbol{h_2^* y_1} - \boldsymbol{h_1 y_2^*}$$

Substituting the values of $\boldsymbol{y_1}$ and $\boldsymbol{y_2}$ in this equation:

$$\widetilde{x_1} = h_1^* y_1 + h_2 y_2^*$$
$$= (|h_1|^2 + |h_2|^2)\, x_1 + h_1^* n_1 + h_2 n_2^*$$

Thus on the basis of this result we can comment that with space diversity channel capacity also increases.

4. Alamouti and Higher Order Schemes

A MIMO system using two antenna at the transmitting side and one or more antenna at the receiving side was first presented by Alamouti [1]. we use basic concepts of the Alamouti scheme and then use these concepts to introduce scheme of higher order and achieve higher communication rates (lower SNR). The code is validated by simulation results.

5. 2×1 Scheme

$$\widetilde{x_2} = h_2^* y_1 - h_1 y_2^*$$
$$= (|h_1|^2 + |h_2|^2)\, x_2 + h_2^* n_1 - h_1 n_2^*$$

Matrix representation

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{h_1} & \boldsymbol{h_2} \\ \boldsymbol{h_2^*} & \boldsymbol{-h_1^*} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \mathrm{H} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

H matrix has an orthogonal design

The simulated result for 2X1 is as shown in the following figure

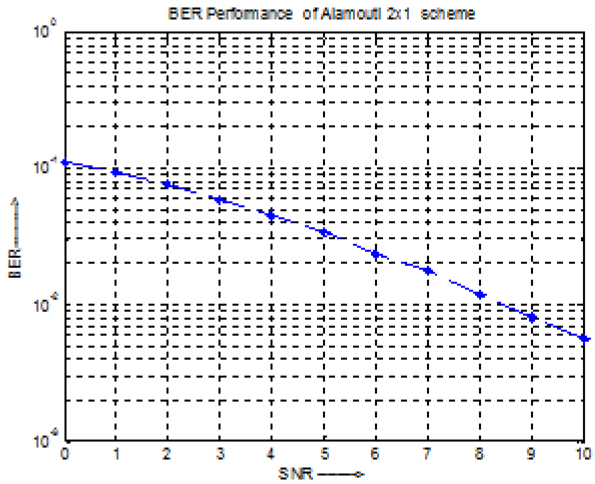


Figure 4

6. 2x2 scheme

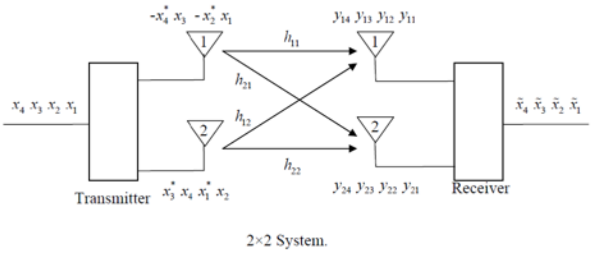


Figure 5

The diversity gain is double that of the 2×1 scheme since there are four different paths. The transmitting side is the same as the 2×1 scheme. Antenna 1 transmits $\boldsymbol{x_1}$ and antenna 2 transmits $\boldsymbol{x_2}$during the first time interval. In the second time interval, $-\boldsymbol{x_2^*}$ and $\boldsymbol{x_1^*}$ are transmitted by antennas 1 and 2, respectively. Two antennas are on the receiver side. First reception of antenna 1 present on the receiving side is $\boldsymbol{y_{11}}$, is the combination of two signals transmitted during the first time interval, and its second reception, $\boldsymbol{y_{12}}$, is the combination of the two signals transmitted during the second time interval, and so on. The received signals can be written as

$$\mathrm{y}_{11} = \mathrm{h}_{11}\mathrm{x}_1 + \mathrm{h}_{12}\mathrm{x}_2 + \mathrm{n}_1$$

$$\mathrm{y}_{12} = -\mathrm{h}_{11}\mathrm{x}_2^* + \mathrm{h}_{12}\mathrm{x}_1^* + \mathrm{n}_2$$
$$\mathrm{y}_{21} = \mathrm{h}_{21}\mathrm{x}_1 + \mathrm{h}_{22}\mathrm{x}_2 + \mathrm{n}_3$$
$$\mathrm{y}_{22} = -\mathrm{h}_{21}\mathrm{x}_2^* + \mathrm{h}_{22}\mathrm{x}_1^* + \mathrm{n}_4$$

The mathematical reduction for 2X2 is same as that for 2X1 scheme. The simulated result for 2X2 is as shown in the following figure

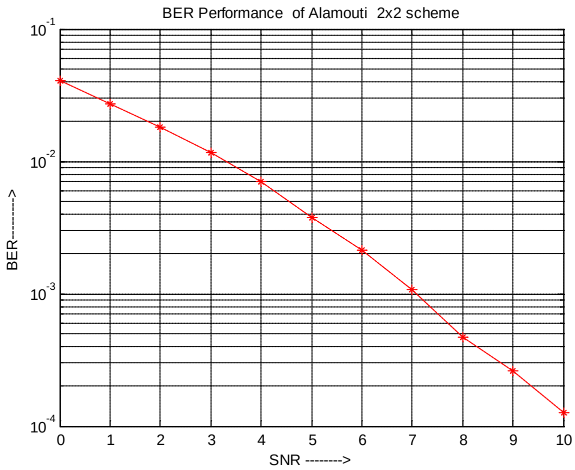


Figure 6

Comparative study can be made between 2X1 and 2X2 from the following result.

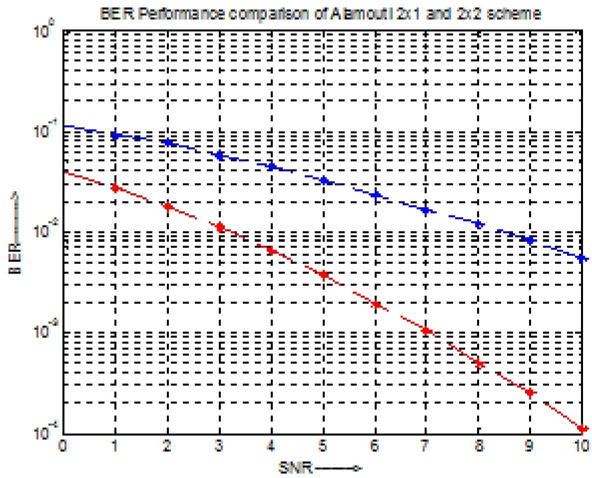


Figure 7

On the basis of this comparative result, we can comment that BER significantly reduces with higher number of transmitter and receiver.

7. Conclusion

The work shows that the combination of STBC and MISO and MIMO provides improved error performance in fading channels with certain modulation schemes. With BPSK, such a combination of 1-Tx – 1-Rx, 2-Tx – 2-Rx, 3-Tx – 3-Rx, provides improvements in BER values for SNR ranges of 0 dB to +10 dB. Results obtained thus prove that spatial diversity significantly improves the error performance in terms of BER in wireless fading channels. We also conclude that 2X2 MIMO system is better than 2X1 MIMO system in terms of lower value of BER at same value of SNR.

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