Bit Error Rate Performance of MIMO Channels for various Modulation Schemes using Maximum Likelihood Detection Technique

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ABSTRACT
In the present paper performance analysis and a comparative study is reported for channels using receive diversity (1X2) , transmit diversity (2X1) and transmit-receive diversity(2X 2) with maximum Likelihood detection technique. The channel is assumed to be flat Rayleigh fading channel and noise samples are independent with zero mean complex Gaussian random variable. The Alamouti Space Time Block codes with modulation techniques BPSK, QPSK 8-PSK and 16-QAM are used to obtain the bit error rate performance under different SNR scenarios. The results reported in this paper suggest substantial improvement in the system performance by incorporating multiple input multiple output techniques in order to improve the link quality.

Keywords
Channel state information (CSI), Phase Shift Keying (PSK), Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), Space Time Block codes (STBC) Quadrature Amplitude Modulation (QAM)

1. INTRODUCTION
Multiple Input Multiple Output (MIMO) technology holds the promise of higher data rates with increased spectral efficiency. All commercial wireless systems operate in high multipath environments and it is the benefit of multipath that provides the performance improvement when using multiple antenna configurations [1]. Diversity is often used in wireless channels to combat multipath fading effect. The main idea behind “diversity” is to provide different replicas of the transmitted signal to the receiver [2]. If these different replicas fade independently, it is less probable to have all copies of the transmitted signal in deep fade simultaneously and the receiver can reliably decode the transmitted signal. The replica of the transmitted signal can be sent through different means, MIMO utilizes Antenna diversity to combat fading by combining signals from two or more independently faded channels.[3].In the present paper We have used Alamouti Space Time Coding (STC) that sends the same user data to both transmit antennas, but at different times, for improving the probability of successfully recovering the desired data. The STC process effectively encodes the data in both space and time.[4,5] The greatest advantage obtained in using Alamouti scheme is that provides maximum diversity of 2m (m is no. of receiving antennas) without CSI at the transmitter and a very simple maximum likelihood decoding system at the receiver.

2. SPATIAL DIVERSITY
Diversity is usually employed to reduce the depth and duration of the fades experienced by a receiver in a local area, which are due to motion. Diversity techniques are often employed at both base station and mobile receivers. The most common diversity technique is called spatial diversity [6] , whereby multiple antennas are strategically spaced and connected to a common receiving system. Other diversity techniques include antenna polarization diversity, frequency diversity, time diversity and multi path diversity.

Depending on which end of the wireless link is equipped with multiple antennas, we may identify three different forms of space diversity:

1. Receive diversity, which involves the use of a single transmit antenna and multiple receive antennas. Also known as single input, multiple output (SIMO) schemes.

2. Transmit diversity, which involves the use of multiple transmit antennas and a single receive antenna. Also known as multiple input, single output (MISO) schemes.

3. Diversity on both transmit and receive, which combines the use of multiple antennas at both the transmitter and receiver. Also known as multiple inputs, multiple output (MIMO) scheme.[7-9]

Diversity technique does not improve the system data rate but rather improves the signal quality.

3. SYSTEM MODEL

A simplified block diagram using Alamouti STC is shown in Figure 1. The scheme can be broken down in to three functional parts:

1. Transmit chain (sequence) for encoding information symbols at the transmitter.
2. signal combination algorithm at the receiver
3. Maximum likelihood Detection

The data input is first modulated using any of the M-ary modulation schemes. The encoded symbols are then sent to Alamouti STBC encoder. In this system, two different symbols are simultaneously transmitted from the two antennas during any symbol period. During the first time period, the first symbol in the sequence, s_1, is transmitted from the upper antenna 1 while the second symbol, s_2, is simultaneously transmitted from the lower antenna 2. During the next symbol time the signal $-s_2^*$ is transmitted from the upper antenna and the signal s_1^* is transmitted from lower antenna[10].

	Tx 0	**Tx 1**
Time t	S_1	S_2
Time t+T	$-s_2^*$	s_1^*

Table 1 : The encoding and transmission sequence for alamouti STBC scheme

The received signals, r_0 ,r_1, r_2 and r_3 as a function of the transmitted signals and channels coefficients can be represented as[10,11]

$$r_o = r_o(t) = h_1S_1 + h_2S_2 + n_0 \quad (1)$$

$$r_1 = r_1(t) = -h_1S_2^* + h_2S_1^* + n_1 \quad (2)$$

$$r_2 = r_1(t + T) = h_3S_1 + h_4S_2 + n_2 \quad (3)$$

$$r_3 = r_1(t + T) = -h_3S_1^* + h_4S_0^* + n_3 \quad (4)$$

where n1, n2, n3 and n4 are complex random variable representing receiver thermal noise and interference. The combiner builds the following two signals that are sent to the maximum likelihood detector(MLD).

MLD utilizes decision regions formed by digital modulation scheme for hard threshold decoding. Depending on where the combined symbol is in signal space, it is hard decoded to the closest signal constellation [12].

$$S_1 = h_1^*r_0 + h_2^*r_0 + h_3^*r_2 + h_4^*r_3 \quad (5)$$

$$S_2 = h_2^*r_1 - h_1^*r_2 + h_4^*r_3 - h_3^*r_4 \quad (6)$$

In order to recover the actual transmitted symbols, s_1 and s_1, the receiver requires knowledge of the channel coefficients, h_1 ,h_2, h_3 and,h_4. These channel coefficients are often estimated at the receiver by measuring known signals embedded in the transmitted waveforms.

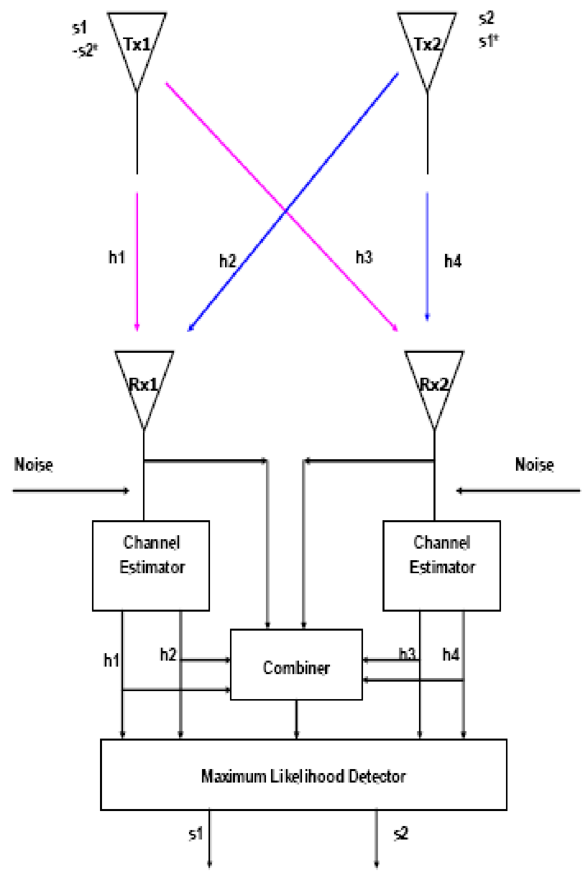

Fig. 1 : Simplified Alamouti Space Time Coding (STC) block diagram for 2X2 MIMO [10]

Note that ( )* is the complex conjugate operation

4. RESULTS & DISCUSSIONS

In this section Diversity performance gains are analyzed through BER versus SNR curves plotted on logarithmic vertical scale. In the simulation, the channel is assumed to be a Rayleigh flat fading channel and the noise samples are independent samples of a zero mean complex Gaussian random variable. The transmission employs different modulation schemes i.e. BPSK, QPSK, 8-PSK and 16-QAM for all schemes. Maximum likelihood detection Technique is used at receiver for detection of signal. The SNR of the channel was varied from 0dB to 20 dB with BER measured at 1dB increments.

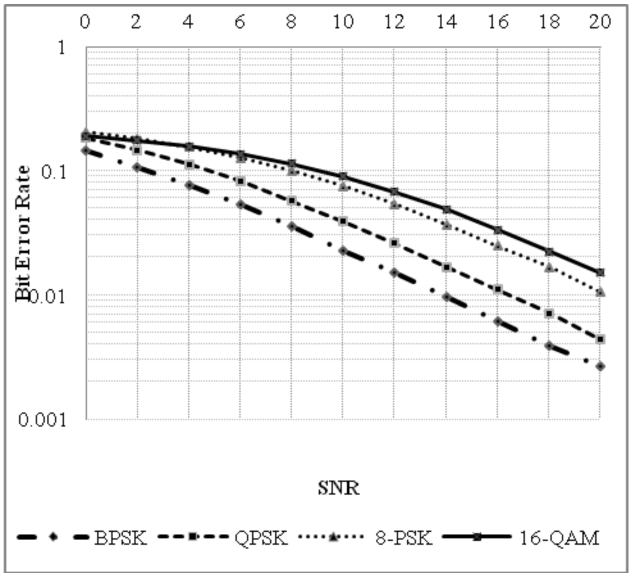

Fig 2.1 : BER vs SNR plot for various modulation scheme for 1x1 (SISO channel)

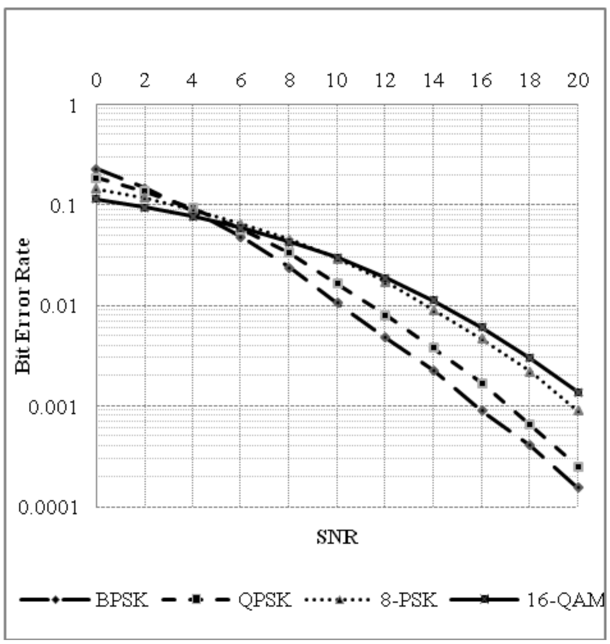

Fig 2.2 : BER v/s SNR plot for various modulation scheme for 2x1 STBC

Fig 2.1 reveals that BER for all systems decrease monotonically with increase in SNR. Normally the Bit Error Rate is measured by the distance between two nearest possible signal points in the signal space diagram (constellation diagram) as the distance between two points decreases the possibility of error increases. Hence distance should be as large as Possible. So, probability of BER increases as M increases. It is observed that M-ary QAM outperforms the corresponding M-ary PSK in probability of BER for M>8 with slightly decrease in average performance.

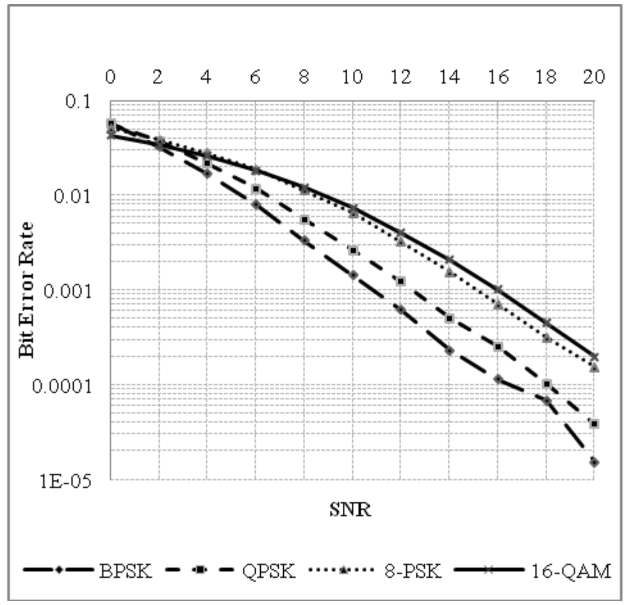

Fig.2.3 : shows the performance curve for Single Input Single Output 1X2 STBC scheme.

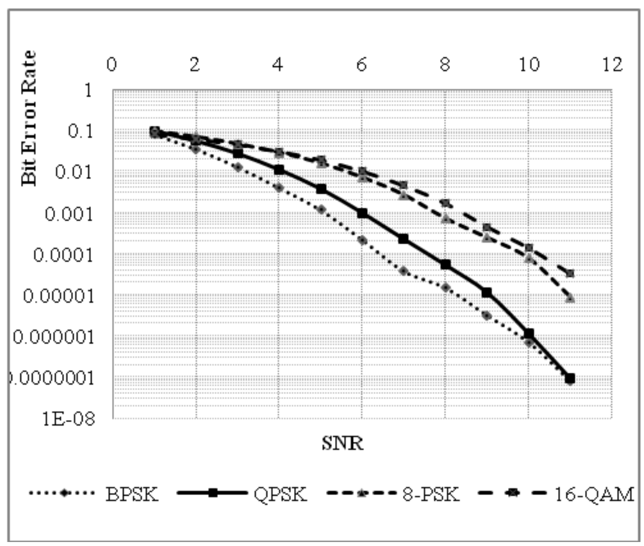

Fig 4.4 : BER vs SNR plot for various modulation scheme for 2x2 STBC

Figure 2.2 and 2.3 illustrates the variation of BER with increasing SNR for 2X1 (two transmitting and one receive antenna) and 1X2 (one transmit antenna and two receive antenna), the performance curve shows significant improvement in BER for given value of SNR as compared to no Diversity 1X1 Scheme 2X1 suffers 2db penalty in performance as compared to 1X2 Scheme.

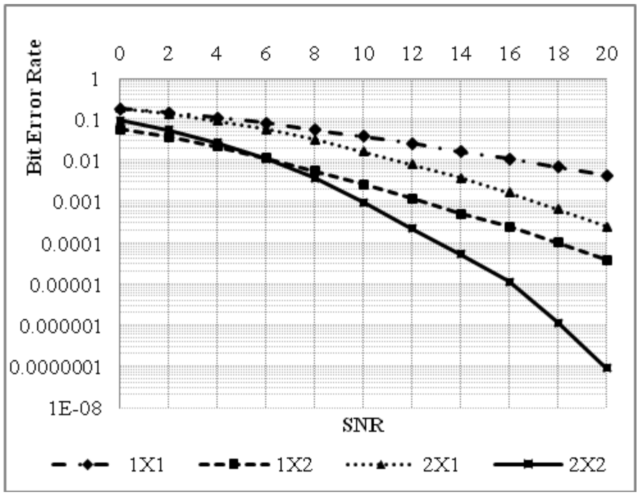

Fig 2.5: BER v/s SNR plot for various diversity schemes for QPSK

As we can see from above performance curves that MIMO is better than MISO and SIMO. The roll-off is steeper as the diversity order increases. From Fig. 2.1,the value of BER is 10^{-1}at the SNR value of 12dB whereas the value of BER is 10^{-2} and 10^{-5} in Fig 2.2 and 2.4 for same SNR in QPSK. One interesting point observed from figure 2.5 is that performance of 1X2 is comparable with 2X2 for lower value for SNR (below 7 dB) but MIMO outperforms other schemes as SNR increases, It also results in diversity order of 4.

5. CONCLUSIONS

We have investigated the error probability of various space Diversity systems using Alamouti STBC with variation in modulation schemes. We conclude that 16 QAM offers more flexibility and reliability considering bandwidth efficiency and noise sensitivity and Data rate. It can be concluded that implementation of 2X2 scheme improves the reliability by a very good margin compared to SISO. Alamouti scheme provides maximum diversity of 2m where m is the no. of receiving antennas without CSI at the transmitter and a very simple maximum likelihood decoding system at the receiver. This scheme is a prospective contender for improving link quality with no bandwidth expansion (as redundancy is in space, not in time or frequency) for future wireless broadband systems.

6. ACKNOWLEDGEMENT

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