Comparative Study of STBC MIMO System in Scattering Environment

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ABSTRACT
At this age of high speed multimedia communication system, MIMO is one of the prime technologies that can achieve the ultimate goal of the 4G. STBC techniques are applied for multiple input multiple output (MIMO) wireless communication system to utilize the inherent spatial diversity in wireless systems. In this paper we presented the performance analysis of STBC coded MIMO system in rich scattering environment and also analyze its performance in different modulation scheme.

Keywords
MIMO, Minimum Mean Square Error (MMSE), Zero Forcing (ZF), Maximum Likelihood (ML).

1. INTRODUCTION
MIMO has multiple (*MT*) transmitting antennas and multiple (*MR*) receive antennas and, finally, MIMO-multiuser (MIMO-MU), which refers to a configuration that comprises a base station with multiple transmit/receive antennas interacting with multiple users, each with one or more antennas [1]. MIMO antenna cam be either at transmitter or receiver or at both. The various configurations can be referred as MISO, SISO, SIMO, MIMO [2] .This system consists of several antenna elements, plus adaptive signal processing, at both transmitter and receiver. It exploits multipath instead of mitigating it [3]. Multiple input multiple output (MIMO) systems have attracted much attention because of high spectrum efficiency. Many different detection techniques are developed to get the diversity gain introduced by MIMO techniques [9]. The effect of multiple antennas might be two fold. In spatial multiplexing mode, the objective is the data rate maximization, by exploiting appropriately the structure of the channel matrix to obtain independent signaling paths that can be used to support independent data streams. Alternatively, in diversity mode the multiple antennas are jointly used in order to effectively mitigate the negative effects of fading, thus improving the overall system reliability [5]. However, the benefits of such systems are obtained at the cost of remarkable implementation complexity [10] [7]. This increases the capacity of the wireless channel [8]. Capacity is expressed as the maximum achievable data rate for an arbitrarily low probability of error [6].

Fading channels are an important element of any wireless propagation environment [4] Multipath fading is a significant problem in communications. In a fading channel, signals experience fades (i.e., they fluctuate in their strength). When the signal power drops significantly, the channel is said to be in a fade. This gives rise to high bit error rates (BER). We resort to diversity to combat fading [11]. This involves providing replicas of the transmitted signal over time, frequency, or space [1]. Multipath propagation has long been regarded as "impairment" because it causes signal fading. To mitigate this problem, diversity techniques were developed.

Here mathematical models for optimal receiver (ML and ML-MMSE joint) are described and flowchart of simulation is depicted in section 2. The simulated results are analyzed in section 3.

2. MATHEMATICAL MODEL

2.1 ML

The ML receiver performs optimum vector decoding and is optimal in the sense of minimizing the error probability. ML receiver is a method that compares the received signals with all possible transmitted signal vector which is modified by channel matrix H and estimates transmit symbol vector x according to the Maximum Likelihood principle , which is shown as:

$$\hat{x} = \arg_{x_k \in \{x_1 x_2 ..... x_n\}} \min \left\| r - H_{x_k} \right\|^2 \qquad \text{------------------------- (1)}$$

Where the minimization is performed over all possible transmit estimated vector symbols Although ML detection offers optimal error performance, it suffers from complexity issues.

2.2 MMSE
The MMSE receiver suppresses both the interference and noise components, whereas the ZF receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence, MMSE is superior to ZF in the presence of noise. Some of the important characteristics of MMSE detector are simple linear receiver, superior performance to ZF and at Low SNR, MMSE becomes matched filter. Also at high SNR, MMSE becomes Zero-Forcing. MMSE receiver gives a solution of:

$$\hat{x} = D.x = \left(\frac{1}{SNR} I_{N_R} + H^H H \right)^{-1} .H^H x$$

------------------------ (2)

At low SNR, MMSE becomes ZF:

$$\left(\frac{1}{SNR} I_{M_R} + H^H H \right)^{-1} H^H \approx \frac{1}{SNR} H^H$$

------------------------ (3)

At high SNR, MMSE becomes ZF:

$$\left(\frac{1}{SNR} I_{M_T} + H^H H \right)^{-1} .H^H \approx \left(H^H H \right)^{-1} H^H$$

------------------ (4)

2.3 ERROR PROBABILITY

The probability density function (PDF) [15] of instantaneous signal to noise ratio (SNR) under Rician fading given by The SNR pdf of a Rician fading channel is given by

$$f_{\gamma}(\gamma) = \frac{(1+K)}{\gamma_S} \exp[-K - \frac{(1+K)\gamma}{\gamma_S}] I_0 (2 \sqrt{\frac{k(1+K)\gamma}{\gamma_S}}), \gamma \geq 0,$$

---- (5)

$\gamma_S(\gamma) = \frac{E_S}{N_0}$ is the average SNR.

Where K= is the Rician factor, I_0 (.) is the zero-order modified Bessel function of the first kind. The Rician factor K can define as the ratio of the LOS component energy to the diffuse (multipath) component energy. If K=0 we get the Rayleigh distribution, whereas the channel approaches the no fading case (AWGN channel) as K increases.

The error probability can be calculated by averaging the conditional probability of error over the pdf of γ, i.e.

$$P(\varepsilon) = \int_0^{\infty} P(\varepsilon \mid \gamma) f_{\gamma}(\gamma) d\lambda$$ ------------------- (6)

Now, the conditional error probability for coherent MPSK is given by

$$P(\varepsilon \mid \gamma) = \frac{1}{\pi} \int_{-\pi/2}^{\pi/2 - \pi/M} \exp\{-\gamma \sin^2 (\frac{\pi}{M}) \sec^2 \theta\} d\theta$$ --- (7)

And for MDPSK modulation the conditional error probability is given by

$$P(\varepsilon \mid \gamma) = \frac{\sin(\pi/M)}{2\pi} \int_{-\pi/2}^{\pi/2} \frac{\exp[-\gamma(1-\cos(\pi/M)\cos\theta)]}{1-\cos(\pi/M)\cos\theta} d\theta$$ ----- (8)

The probability of error for coherent MPSK over Rician fading channel can be calculated, by substituting $P(\varepsilon \mid \gamma)$ and $f_{\gamma}(\gamma)$ as in equation (7) and (5) respectively into equation (6), as given below.

$$P(\varepsilon) = \frac{1}{\pi} \left(\frac{N+K}{\gamma_S} \right)^N \int_{-\pi/2}^{\pi/2 - \pi/M} \frac{\exp\left(- \frac{K \sin^2 \frac{\pi}{M} \sec^2 \theta}{\frac{N+K}{\gamma_S} + \sin^2 \frac{\pi}{M} \sec^2 \theta} \right)}{\left(\frac{N+K}{\gamma_S} + \sin^2 \frac{\pi}{M} \sec^2 \theta \right)^N} d\theta$$

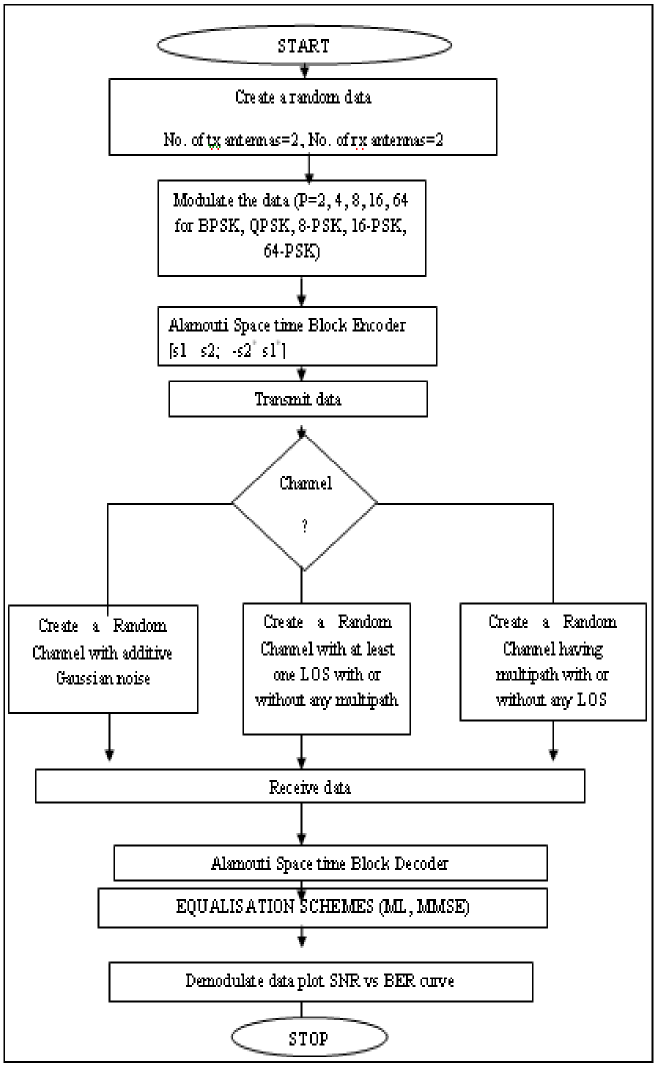
------------------------ (9)

The probability of error for coherent MDPSK over Rician fading channel can be calculated, by substituting $P(\varepsilon \mid \gamma)$ and $f_{\gamma}(\gamma)$ as in equation (8) and (5) respectively into equation (6), as given below

$$P(\varepsilon) = \frac{\sin \frac{\pi}{M}}{2\pi} \left(\frac{N+K}{\gamma_S} \right)^N \int_{-\pi/2}^{\pi/2} \frac{\exp\left(- \frac{K\left(1-\cos \frac{\pi}{M} \cos\theta\right)}{\frac{N+K}{\gamma_S} + 1 - \cos \frac{\pi}{M} \cos\theta} \right)}{\left(1-\cos \frac{\pi}{M} \cos\theta\right)\left(\frac{N+K}{\gamma_S} + 1 - \cos \frac{\pi}{M} \cos\theta \right)^N} d\theta$$

------------------------ (10)

2.4 FLOWCHART



Flow chart1: Flow chart of implementation of 2x2 STBC MIMO system with ML and ML-MMSE receiver

3. SIMULATION RESULT

We have implemented the mathematical model in MATLAB environment. The programming has been done on the basis of the flowchart shown above. Here STBC and equalization schemes ML and MMSE incorporated for better performance in fading channel environment.

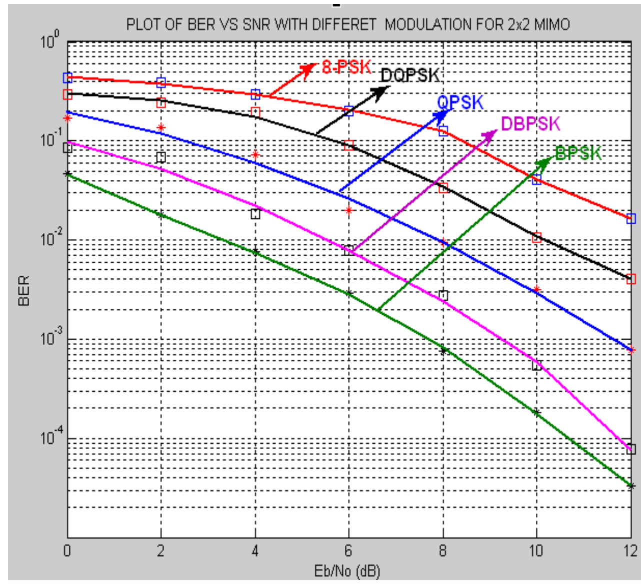


Fig: 1 BER vs SNR curves for 2x2 MIMO system in Rician channel condition with different modulation schemes.

Quantification:-At a particular SNR of 10dB the BER values for BPSK and 8-PSK are 0.0001745 and 0.04066 respectively.

This means that the BER performance of the 2x2 MIMO systems degrades with increase in modulation order. BPSK modulation scheme provides 200 times better performance than that of 8-PSK modulation.

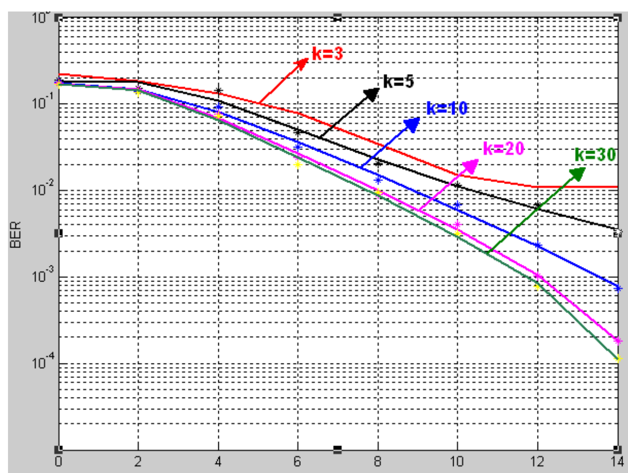


Fig: 2 BER vs SNR curves for 2x2 MIMO system in Rician channel condition with different K.

The Rician K factor is defined as to be the signal power in the dominant component over the scattered. It determines the distribution of the received signal component. Knowledge of the Rician K factor can be useful in determining the bit error rate of the channel. Fig iv shows the plot of the BER as a function of the SNR for the different Rician K factor.

Quantification:-At a particular SNR of 10dB the curves K=30, K=20, K=10, K=5 and K=3 obtain a BER of 0.003, 0.004, 0.006, 0.011, 0.016.

Reason:-This difference in the BER at the same SNR is due to the fact that since K is the ratio of signal power in the dominant component over the scattered so with increasing K value the signal power in the dominant component increases and thus the performance gain improves.

Moreover from the above values we can see that at the same SNR the difference of BER between two consecutive curves starting from K=30 are 0.001, 0.002, 0.005 and 0.006.Thus the successive difference between the curves is increasing.

Another interesting observation from the curve is that with the increasing SNR the spacing of the curves increases. As for example, at a SNR of 6dB the BER value for the curve K=5 is 0.050 while for K=10 is 0.036.whereas the BER values for the same two curves at a SNR of 12dB is at 0.006088 and 0.00225.

Figure 3 depicts the performance comparison curve for the 2x2 MIMO systems in different channel condition. It is clear from the curves that due to the presence of multipath component in Rician and Raleigh channel the system performance is degraded in comparison AWGN condition. Figure 4 represent the comparative study of 2x2 MIMO system with ML and ML-MMSE joint receiver.

4. CONCLUSION

In this paper we have analyzed the 2x2 STBC MIMO systems in scattering environment. MIMO technology is the one way to increase the capacity of the wireless channel without increasing the power or bandwidth. However the complexity of the optimal detector, e.g., ML detector, is exponential with transmission diversity and modulation order which is prohibitive for practical applications.

A large number of low complexity linear MIMO detectors have been studied so far; generally these linear detectors are based on minimum mean-square error (MMSE) and based on Maximum Likelihood (ML) principle. But the performance of this detector can be poor, especially in MIMO systems that use a small number of receiving antenna branches. To improve performance, a so-called vertical Bell laboratories layered space-time (V-BLAST) algorithm needs to be implemented [12] [13]; this performs successive interference cancellations (SIC) in the appropriate order.

5. REFERENCES

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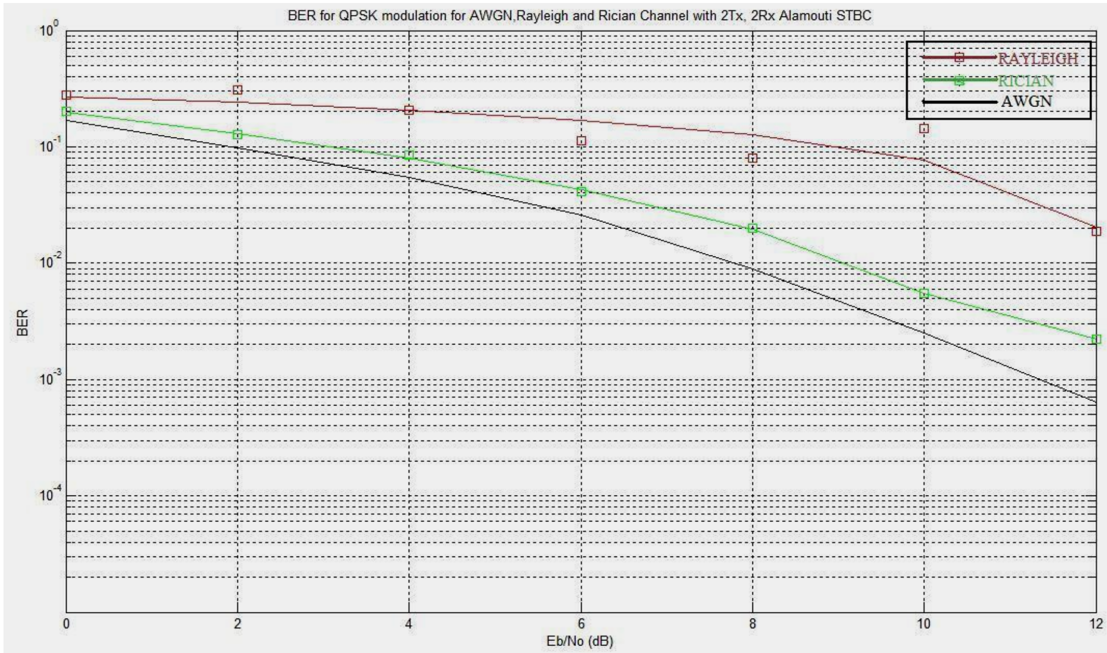

Fig: 3 BER vs SNR curves for 2x2 MIMO systems in Different channel Condition.

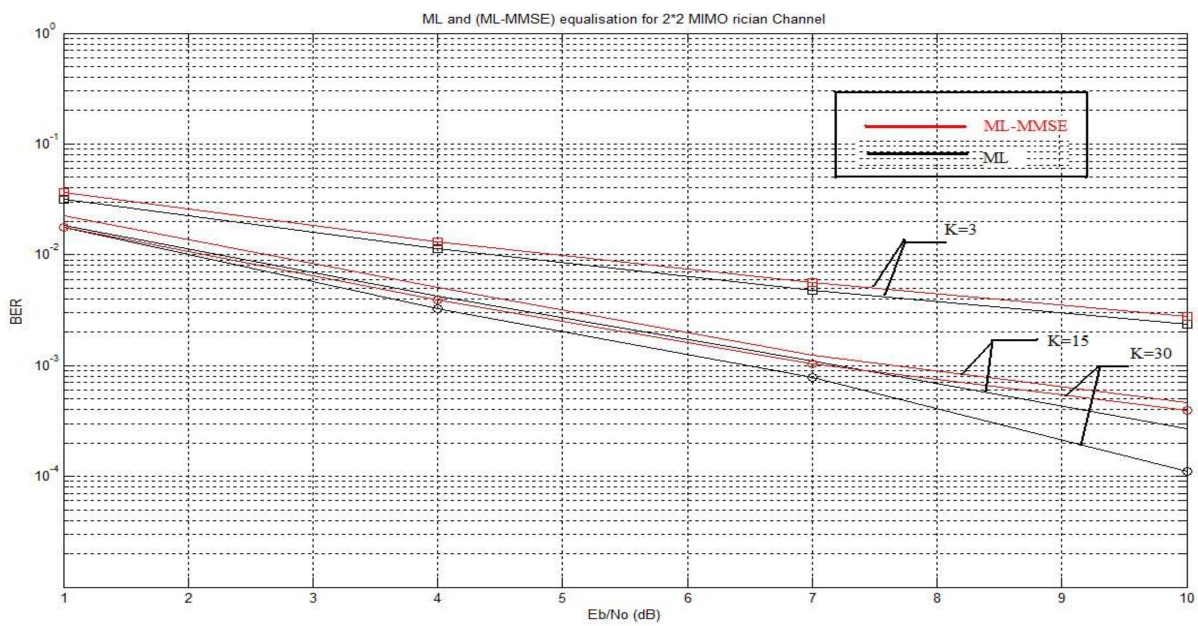

Fig: 4 BER vs SNR curves for 2x2 MIMO systems with ML and ML-MMSE receiver.