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Performance evaluation of various MIMO based digital modulation techniques using Minimum mean square error (MMSE) combining

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ABSTRACT

The key challenge faced by cellular and wireless communication is high data rate and high Quality of Service (QOS).To obtain these requirements communication channel needs to be shared in an efficient manner. The only hindrance that prevents the efficient utilisation of communication channels is multipath fading resulting from increased bit error rate of system (BER) at higher signal to noise ratio (SNR) resulting in overall system performance degradation. Various diversity techniques can be used to mitigate the fading effects. The implementation of MIMO technology makes use of multiple antennas both at transmitter as well as receiver thus allowing the transmission of signal through various independent paths, providing the receiver several replicas of the transmitted signal. This increases the probability that accurate information is detected at receiver. In this paper BER vs. SNR is being analyzed for various modulation techniques and the results obtained are compared with each other. The proposed technique makes use of minimum mean square error ratio (MMSE) to provide satisfactory bit error rate (BER) performance as compared to earlier results of Maximum Ratio combining (MRC)

Introduction

The performance of wireless communication systems is mainly governed by the wireless channel environment. As opposed to the typically static and predictable characteristics of a wired channel, the wireless channel is rather dynamic and unpredictable, which makes an exact analysis of the wireless communication system often difficult. In recent years, optimization of the wireless communication system has become critical with the rapid growth of mobile communication services and emerging broadband mobile Internet access services. In fact, the understanding of wireless channels will lay the foundation for the development of high performance and bandwidth-efficient wireless transmission technology. A unique characteristic in a wireless channel is a phenomenon called ‘fading,’ the variation of the signal amplitude over time and frequency. In contrast with the additive noise as the most common source of signal degradation, fading is another source of signal degradation that is characterized as a non-additive signal disturbance in the wireless channel. Fading may either be due to multipath propagation, referred to as multi-path (induced) fading, or to shadowing from obstacles that affect the propagation of a radio wave, referred to as shadow fading. The fading phenomenon in the wireless communication channel was initially modeled for HF (High Frequency, 3_30MHz), UHF (Ultra HF, 300_3000 GHz), and SHF (Super HF, 3_30 GHz) bands in the 1950s and 1960s. Currently, the most popular wireless channel models have been established for 800MHz to 2.5 GHz by extensive channel measurements in the field[1]. These include the ITU-R standard channel models specialized for a single-antenna communication system, typically referred to as a SISO (Single Input Single Output) communication, over some frequency bands. Meanwhile, spatial channel models for a multi-antenna communication system, referred to as the MIMO (Multiple Input Multiple Output) system, have been recently developed by the various research and standardization activities such as IEEE 802,METRA Project, 3GPP/3GPP2, and WINNER Projects, aiming at high-speed wireless transmission and diversity gain In this paper the MMSE algorithm is applied. The MMSE works on minimizing the mean square error between the desired signal and its estimate, there by maximizing the *SINR*. The MMSE algorithm uses certain weights in its operation that require the knowledge of noise-plus-interference statistics. [2][3][4][5]

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Antenna Diversity

Diversity techniques are used to mitigate degradation in the error performance due to unstable wireless fading channels, for example, subject to the multipath fading. Diversity in data transmission is based on the following idea: The probability that multiple statistically independent fading channels simultaneously experience deep fading is very low. There are various ways of realizing diversity gain, including the following ones:

Transmit Diversity

Many schemes are used to obtain transmit diversity in MIMO-OFDM systems, the delay diversity is such a scheme. It is an attractive choice due to its simple implementation, good performance, and no feedback requirement. It is used mainly for downlink transmission. In this approach, delayed versions of a signal are sent at the transmit antennas. The delay process at the transmitter results in a frequency selectivity in the received channel response. Using proper codes and interleaving operation at the transmitter solves this problem without the need for any channel knowledge. Other transmits diversity schemes are the space-time codes. No feedback is required in these approaches, and a linear precoding process is implemented based on channel statistics that requires only minimal feedback. Unlike the delay diversity scheme, in space-time coding the same signal is encoded differently into different streams that are transmitted over multiple antennas. Using the block codes in space-time coding allows for linear decoding at the receiver. The space-time codes can be used with linear precoding (e.g. beam forming) to provide performance gains. In linear precoding, the signal is linearly mapped onto multiple transmit antennas; depending on the channel statistics such as transmit antenna correlation. For our studied MIMO-OFDM system, the used diversity is the space diversity with linear precoding. It is implemented by using multiple antennas or antenna arrays arranged together in space for transmission and/or reception. The antennas are separated in such a way the individual signals are uncorrelated. This type of diversity does not induce any loss in bandwidth efficiency. [6][7][8]

Receive Diversity

In general, several receiving algorithms can be used to achieve the receive diversity. The main two types are: the maximum-ratio-combining (MRC), and the minimum mean square error (MMSE). In MRC algorithm, the received signals are coherently combined in order to maximize *SNR*. Since the MRC algorithm is based on matching the spatial signature of the desired signal, weak interference is attenuated and thus mitigated. However, strong interference such that arising from spatial multiplexing and CCI cannot be suppressed by the MRC. In such a case, the MMSE algorithm can be applied. The MMSE works on minimizing the mean square error between the desired signal and its estimate, there by maximizing the *SINR*. The MMSE algorithm uses certain weights in its operation that require the knowledge of noise-plus-interference statistics. In the case of friendly interferer as in spatial multiplexing, the spatial signature of the interferer is available and can be used in the MMSE weights. Whereas in unfriendly interferer case, second-order statistics as covariance matrices are used to know more about the spatial structure of the interference.

Space-Time Block Code (STBC)

The very first and well-known STBC is the Alamouti code, which is a complex orthogonal space-time code specialized for the case of two transmit antennas [9]. In this section, we first consider the Alamouti space-time coding technique and then, its generalization to the case of three antennas or more [10]

Alamouti Space-Time Code

A complex Orthogonal Space-Time Block Code (OSTBC) for two transmit antennas was developed by Alamouti. The coding matrix is as follows :

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

Where * denotes complex conjugate.It is readily apparent that this is a rate-1 code.It takes two time-slots to transmit two symbols.Using the optimal decoding scheme, the bit error rate (BER) of this STBC is equivalent to 2nR-branch maximum ratio combining (MRC). This is a result of the perfect orthogonality between the symbols after the receive processing.It is the only STBC that can achieve its full diversity gain wihout needing to sacrifice its data rate[4]

As depicted in Figure 1, Alamouti encoded signal is transmitted from the two transmit antennas over two symbol periods. During the first symbol period, two symbols x_1 and x_2 are simultaneously transmitted from the two transmit antennas. During the second symbol period, these symbols are transmitted again, where $-x^*_2$ is transmitted from the first transmit antenna and x^*_1 transmitted from the second transmit antenna.

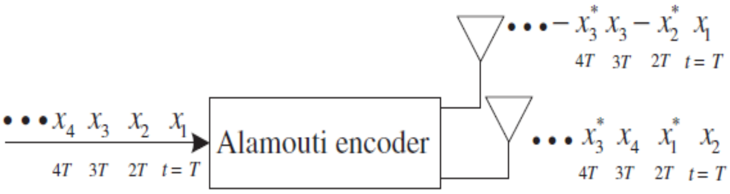

Figure 1. Alamouti Encoder

The scheme is as follows:

1. Consider that we have a transmission sequence, for example $\{x_1 1, x_1 2, x_1 3, \ldots \ldots x_1 n\}$
2. In normal transmission, we will be sending in the first time slot, in the second time slot, and so on.
3. However, Alamouti suggested that we group the symbols into groups of two. In the first time slot send x_1 and,x_2 from the first and second antenna respectively. In the second time slot send $-x_2^*\ and\ \ x_1^*$ respectively from first and second antenna. In the third time slot send $x_3\ and x_4$ respectively from first and second antenna. In the fourth time slot send $-x_4^*\ and\ \ x_3^*$ respectively from first and second antenna. Thus we are grouping two symbols we still need two time slots to send two symbols. Hence, there is no change in data rate.

Proposed Simulation Model

1. Generate random binary sequence of +1’s and -1’s.
2. Group them into pair of two symbols
3. Code it as per the Alamouti Space Time code, multiply the symbols with the channel and then add white Gaussian noise,
4. Equalize the received symbols
5. Perform hard decision decoding and count the bit errors
6. Repeat for multiple values and plot the simulation and theoretical results for various modulation schemes and compare them

Numerical Results

The simulation result for BER vs. SNR for BPSK modulation is shown in figure 2 .From the fig it is seen that theory and simulation curves almost coincide with each other. At higher SNR the simulation slope for BER increases linearly and then gradually falls.

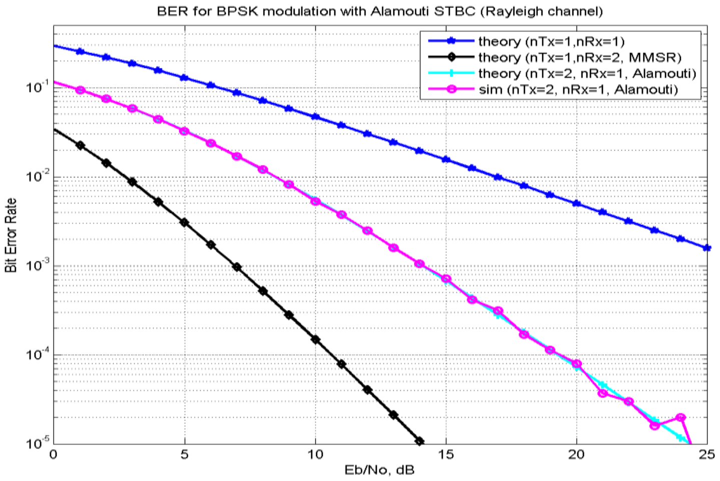

Figure 2. BER vs. SNR for BPSK modulation

Figure 3 shows the simulation result for BER vs. SNR for QPSK modulation. From the figure it is obvious that the slope of simulation curve falls gradually compared to the theoretical value resulting in the decrease in bit error rate. Also at higher SNR the simulation curve shows a greater deviation from theory values.

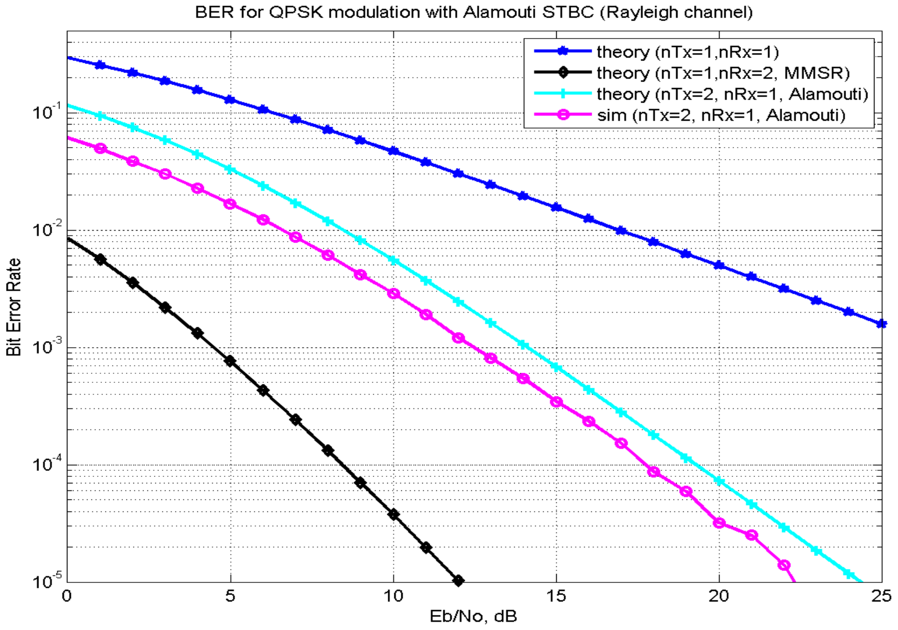

Figure 3. BER vs. SNR for QPSK modulation.

Figure 4 shows the BER vs. SNR results for 16 PSK modulation scheme. From the figure it is seen that simulation curve falls as compared to theory curve. .At SNR of 21db the curve gradually rises almost touching the theoretical value and then falls linearly.

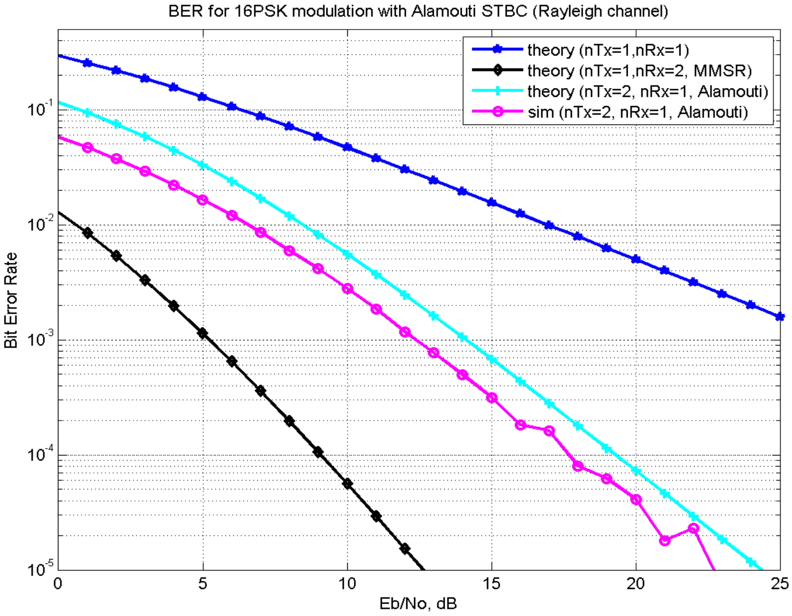

Figure 4.BER vs. SNR for 16 PSK

Figure 5 shows the results for 32 QAM modulation. From the figure it is seen that the simulation curve falls as compared to theory curve resulting in decrease in Bit error rate of the system. At a SNR of 20db.the curve is almost parallel to x axis and then the curve falls with a linearly reaching a minimum value of bit error rate and remains constant there at higher signal –to-noise values.

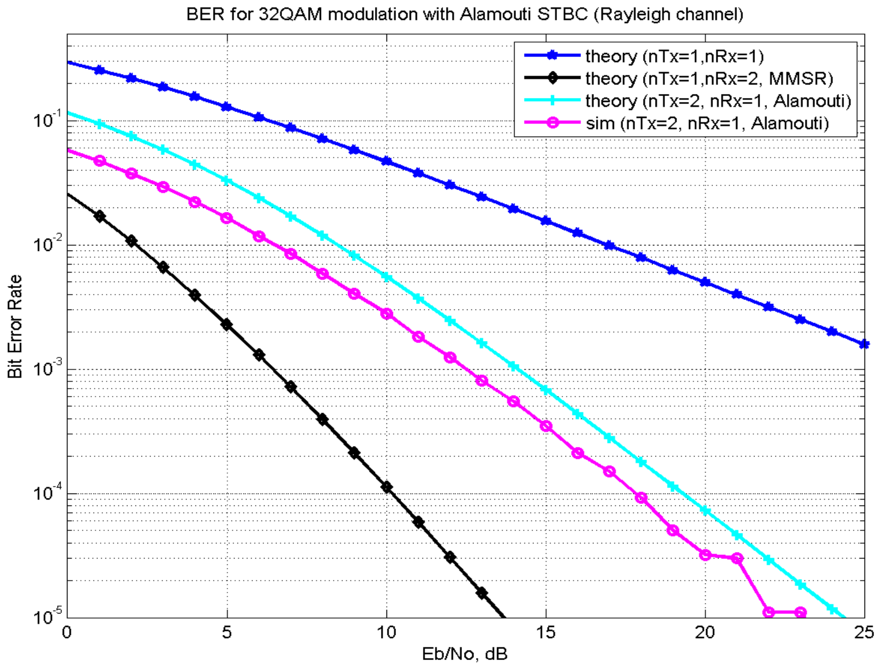

Figure 5. BER vs. SNR for 32 QAM modulation`

Figure 6 shows the BER vs. SNR result for 64 QAM modulation. It is seen from the simulation result that the simulation curve falls as compared to theory curve showing a deviation and decrease in bit error rate of system. At SNR of 18 db the slope tends to fall and at 19 db the slope falls linearly deviating more from theoretical value. At 20 db the slope is almost zero with bit error rate remaining almost constant and then curve falls again linearly and bit error rate reaches a minimum value. At 22db the curve again starts to rise and then again falls at higher signal to noise ratio.

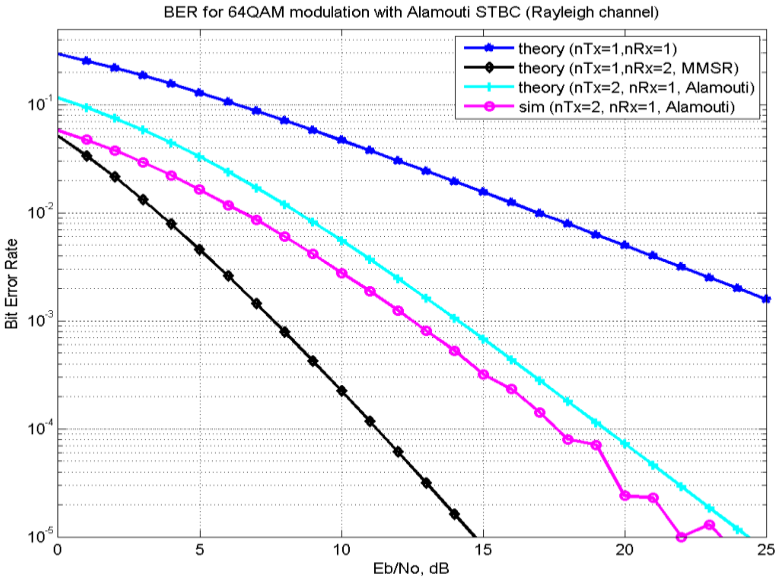

Figure 6. BER vs. SNR for 64 QAM modulation.

Conclusion

Multiple input Multi output is a very promising technique for multicarrier transmission over a wireless link and can become one of the standard choices for high speed data transmission over a communication channel. It has various advantages, but also has one major drawback i.e. Effect of noise within frequency selective fading channel .In this paper we present BER Analysis for MIMO-OFDM System using different Modulation Schemes and comparative study is being done with in phase component to show the better noise reduction parameters.

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