Comparison of BER Performance Analysis of MIMO-OFDM for Different Modulation Schemes using MRRC Technique

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Abstract-Wireless communication systems need tremendously high data rates and high transmission reliability in order to meet the hastily increasing demand for multimedia applications such as high quality audio and video. OFDM is a widespread and one of the most promising modulation techniques. Recently, there has been a lot of interest to use OFDM in combination with a MIMO transceiver system, named MIMO OFDM system which is used to increase the diversity gain and system capacity. The BER performance of the MIMO-OFDM for various modulation techniques i.e., BPSK, QPSK, 16-PSK,8-PSK ,64-PSK and QAM using AWGN (Additive White Gaussian Noise) and Rayleigh channel is evaluated. The receiver diversity technique used is Maximum ratio receiver combining technique (MRRC). By multicarrier modulation , we can achieve advantages like high data rate, higher reliability, inter symbol interference (ISI) reduction, and better performance in multipath fading.

Keywords--*AWGN, Cyclic prefix , MIMO, MRRC, OFDM, QAM, PSK, Rayleigh Fading*

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1. INTRODUCTION

One of the major challenges facing in modern communications is to satisfy the ever increasing demand of high speed reliable communications with the constraints of extremely limited frequency spectrum and limited power. Wireless communications systems require very high capacity to fulfill the demand of high data rates. These systems must achieve the desired reliability within the limits of power and frequency spectrum availability, often in severe channel environments. Wireless communication systems with multiple transmit and multiple receive antennas can provide high capacity at low probability of bit error with extremely low power, even in densely populated urban areas. In recent years, orthogonal frequency division multiplexing (OFDM) has been widely used in communications systems to operate in frequency selective channels .Communication systems with a MIMO-OFDM combination can significantly improve capacity and reliability by exploiting the robustness of OFDM to fading.

1.1. Methodology

Our proposed work is Performance analysis of MIMO-OFDM for different modulation schemes under different channel models.

The main objective of proposed technique is to evaluate the performance of MIMO-OFDM for different modulation schemes under different channels.

The first step to achieve the objective is to study the fundamentals of OFDM systems then, the OFDM technique is applied to a multiple-input multiple-output (MIMO) system. Multicarrier modulation is implemented with different M-array values of PSK (Phase shift keying) and QAM (Quadrature amplitude Modulation).The design is simulated both in an additive white Gaussian noise (AWGN) channel and then with a multipath faded channel with AWGN i.e., Rayleigh channel. The receiver design was based on the maximal ratio receiver combining (MRRC) technique with the assumption of perfect knowledge of channel state information (CSI) at the receiver end. The performance is calculated in terms of Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) using MATLAB.

The rest of the paper has been organized as follows: In section II, MIMO–OFDM system model, and in section III channel models, Digital modulation and MRRC have been described. In section IV, simulation results are analyzed and finally, conclusion.

2. MIMO-OFDM

2.1(a) OFDM System Model: Figure 1 represents the block diagram of OFDM system [5], consist of transmitter and receiver. The data bits inserted are firstly mapped using different modulation techniques and it is converted from serial to parallel through convertor. Now N subcarriers are present and each sub-carrier consists of data symbol. These N subcarriers are generated by inverse fast Fourier transform (IFFT) block. The output of IFFT block is written as

$$f(n) = \sum_{k=0}^{N-1} F(k) \exp\left(\frac{j2\pi kn}{N}\right) \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Cyclic Prefix (CP) is added to the output of the IFFT block in order to mitigate the Inter symbol interference. After adding CP, the signal is sent to parallel to serial convertor and then, this signal is sent to either Rayleigh channel or AWGN channel.

At the receiver, the data is converted to parallel by using serial to parallel convertor and cyclic prefix is removed. After removing the CP, the received samples are sent to a Fast Fourier transform (FFT) block to demultiplex the multi-carrier signals. The output of FFT block is given as

$$F(k) = \sum_{n=0}^{N-1} f(n) \exp\left(\frac{-j2\pi kn}{N}\right), \ldots\ldots\ldots\ldots\ldots (2)$$
$$0 \le k \le N-1$$

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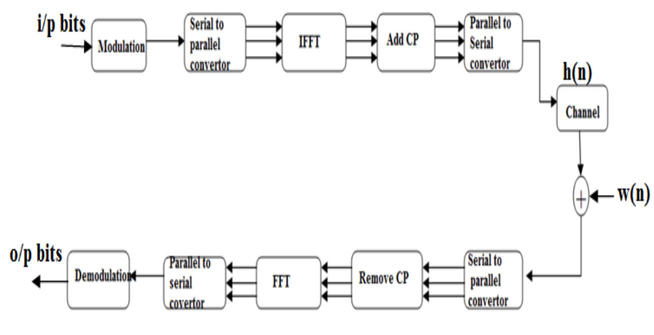


Fig.1: Block Diagram of OFDM System

2.1(b) Multiple Input Multiple Output (MIMO) Systems

Multiple-antenna technique[8] can be divided into three categories, Spatial Diversity , Spatial Multiplexing and Adaptive Antenna System. In radio communications MIMO means multiple antennas both on transmitter and receiver side of a specific radio link. Multiple antennas can be used to reduce the error rate as well as to improve the quality and capacity of wireless transmission. The technique used in this paper is spatial multiplexing technique where different data bits are transmitted on the radio link by different antennas on the same frequency within the same time interval. MIMO transmission can be characterized by the time variant channel matrix.

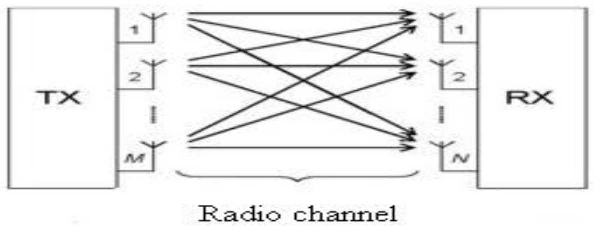


Fig.2: MIMO System along M transmit antennas and N receive antennas

Let us assume a MIMO system with M transmit antennas and N receive antennas as shown in figure 2, then a matrix of dimension N ∗ M with complex transfer factors H_{ij}, , can easily express the channel behavior.

$$\begin{bmatrix} H_{1,1} & \cdots & H_{1,M} \\ \vdots & \ddots & \vdots \\ H_{N,1} & \cdots & H_{N,M} \end{bmatrix} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Here H is the channel matrix and it is also known as the channel transfer function.

2.1(c) MIMO - OFDM

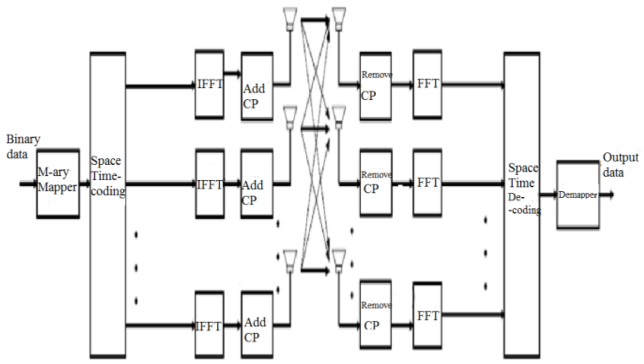


Fig 3: Block diagram of MIMO-OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is used for high data rate in wireless communications. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transceiver to increase the diversity gain and the system capacity.

3. CHANNEL MODELS

3.1(a) AWGN Channel: Additive white Gaussian noise (AWGN) channel is a commonly used channel model for analyzing modulation schemes [1]. In AWGN channel a white Gaussian noise is added to the signal that passes through it. Fading does not exist for this channel. The mathematical expression of received signal is:

$$r(t) = s(t) + n(t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Where s(t) is transmitted signal and n(t) is additive white Gaussian noise .

3.1(b) Rayleigh Channel: Rayleigh fading model [1] assume that the signal that has passed through such a channel will distorted according to a Rayleigh distribution .The effects of multipath causes constructive and destructive interference. This causes Rayleigh fading. Rayleigh fading is most applicable when there is a non line of sight communication between the transmitter and receiver .The received signal can be given as :

$$R(n)=\sum h(n,\tau)s(n-m)+w(n) \dots\dots\dots\dots\dots\dots (5)$$

Where w(n) is AWGN and $h(n)$ is channel impulse response .

The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function is given by:

$$P(z)=\frac{z}{\sigma^2 (e^{-\frac{z}{2\sigma^2}})}, z \geq 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

Where σ^2 is the time-average power of the received signal and eq. (7) is called a Rayleigh random variable.

3.2 Digital Modulation

Digital modulation[8] schemes transform digital signals into waveform that are compatible with the nature of the communications channel. One category uses a constant amplitude carrier and the other carries the information in phase or frequency variations (FSK, PSK).A major transition from the simple amplitude modulation (AM) and frequency modulation (FM) to digital techniques such as Quadrature Phase Shift Keying (QPSK), Frequency Shift Keying (FSK), and Quadrate Amplitude Modulation (QAM). PSK and QAM are advantageous in terms of bandwidth compared to other modulation schemes.

3.3 Maximum ratio receiver combining:

To eliminate the effect of multipath fading, antenna diversity is commonly used technique [12]. MRRC is a receiver diversity technique, which uses the multiple antenna at the receiver and performs combining or selection to improve the quality of received signal.

The received signals with added noise is $r_1=s_1h_1+n_1$and $r_2=s_2h_2+n_2$ Where n_1 & n_2 are awgn noise .The two branch MRRC combiner combines the received signal as follow:

$$\tilde{s} = h_1^* r_1 + h_2^* r_2$$
$$= h_1^*(h_1 s_1 + n_1) + h_2^*(h_2 s_1 + n_2)$$
$$= (\propto_1^2 + \propto_2^2) s_1 + h_1^* n_1 + h_2^* n_2$$

After combining the signal, maximum likelihood decision rule is used at receiver to choose the signal which symbol was actually transmitted. Finally the maximum likelihood detector will produce the signal $s_1$which is maximum likelihood estimate of s_1. Let h_0 , h_1 ,h_2 ,and h_3 be the channel between two transmit and two receive antennas. The received signals at time t and t+T are r_0, r_1 ,r_2 and r_3 are given as

$$r_0 = h_0 s_0 + h_1 s_1 + n_o$$
$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$
$$r_2 = h_2 s_0 + h_3 s_1 + n_2$$
$$r_3 = -h_2 s_1^* + h_3 s_0^* + n_3$$

The combiner gives the following two signals

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^* \quad (8)$$
$$\tilde{s}_1 = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \quad (9)$$

These combined signals are then sent to the maximum likelihood decoder which for signal s_o uses the decision criteria expressed in following equations for PSK signals. Choose $\tilde{s}_i$ iff

$$d^2(\tilde{s}_0, \tilde{s}_i) \le d^2(\tilde{s}_0, \tilde{s}_k), \forall i \ne k \quad (10)$$

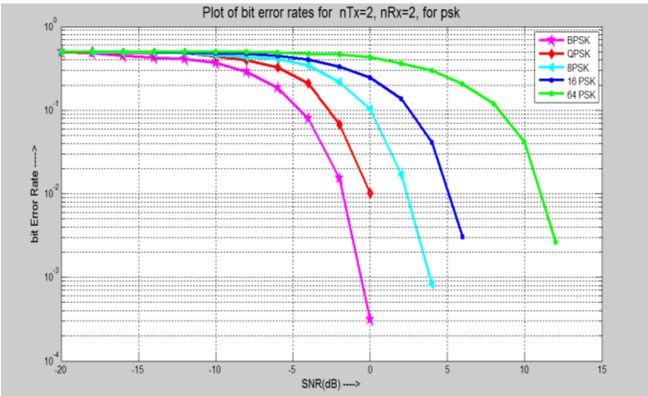
Each receiver antenna receives a superposition of faded symbols. The ML decoder would select the signal which has minimum Eucleadian distance.

4. Result Analysis

List of Simulation parameters :

Parameters	Specifications
Modulation	PSK (M=2,4,8,16,64),QAM
Channel model	Rayleigh, AWGN
No. of Tx, No. Of Rx	2,2
CP length	16
FFT length	64

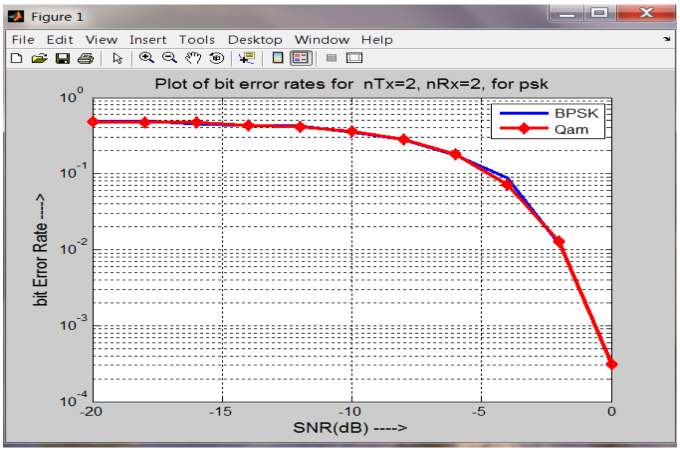
Table-1: Simulation Parameters for MIMO OFDM



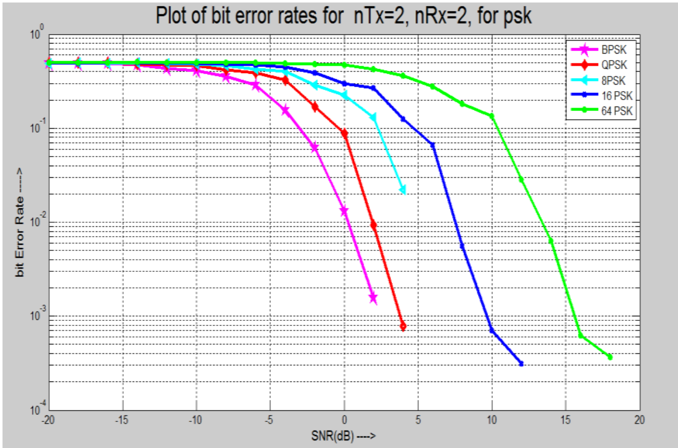
Simulation result (a): Performance analysis of MIMO-OFDM different modulation schemes of PSK in AWGN channel

Modulation scheme	SNR(dB)	Bit error rate(BER)
BPSK	2dB	0.0003
QPSK	2dB	0.0102
8-PSK	2dB	0.0170
16-PSK	2dB	0.1365
64-PSK	2dB	0.3620

Table-2: Comparison of different M-array values of PSK in MIMO-OFDM under AWGN Channel.



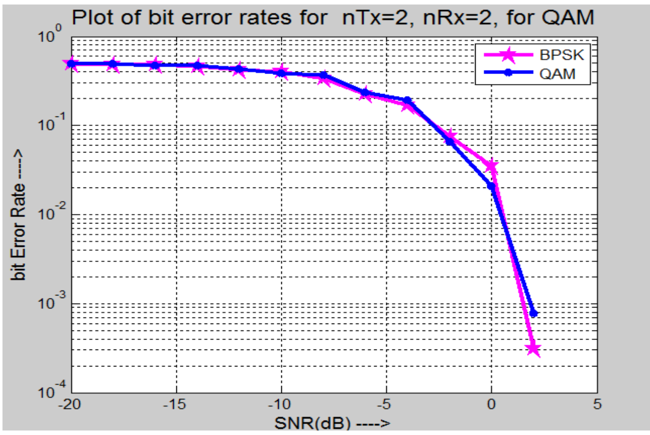
Simulation result (b): Performance analysis of MIMO-OFDM for QAM in AWGN channel



Simulation result (c): Performance analysis of MIMO-OFDM for different modulation schemes of PSK in Rayleigh channel

Modulation scheme	SNR(dB)	Bit error rate(BER)
BPSK	2dB	0.0016
QPSK	2dB	0.0095
8-PSK	2dB	0.0098
16-PSK	2dB	0.2108
64-PSK	2dB	0.3827

Table-3: Comparison of different M-ary values of PSK in MIMO-OFDM under Rayleigh Fading Channel.



Simulation result (d): Performance analysis of MIMO-OFDM for QAM in Rayleigh channel

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Simulation results (a), (b),(c),(d) shows the BER performance of MIMO-OFDM for different modulation schemes as a function of varying SNR for the MRRC technique under AWGN and Rayleigh channels respectively.

By observing table-2 and table-3 we analyzed that the BPSK modulation gives the least bit error rate, it is an effective method for data transmission in all of the modulations and for all the channels in terms of bit error rate. In both the cases by observing simulation results we get better performance for QAM modulation scheme where its performance is similar to BPSK.

5. CONCLUSION

The bit error rate of BPSK modulation scheme is less when compared to the bit error rate of higher order modulation schemes. Thus the performance analysis of AWGN channel and Rayleigh Fading Channel in a general communication system under BPSK modulation scheme is found to be more efficient. So it is obvious that BPSK modulation serves good in MIMO-OFDM systems under AWGN channel and Rayleigh fading channel. For high data rate applications we can consider QAM where its performance is similar to BPSK. So, at this stage by observing simulation results (b) and (d) we can conclude that QAM has got better performance than PSK.

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