

Performance Comparison of BER with MIMO-OFDM for various Modulation methods using MRRC Technique

B.Ramesh¹, M.M.Arunprasath², S.Karthick³ R.Arul Arumugam⁴

Assistant Professor, Department of ECE, Annapoorana Engineering College, Salem, India ^{1,2,3}

Abstract—Wireless communication systems need tremendously fast data rates and speedy transmission consistency so as to meet the quickly increasing request for multimedia requests such as great quality audio and video. OFDM is a renowned and the most auspicious modulation techniques. Newly, nearby has been a lot of attentiveness to use OFDM in amalgamation with a MIMO transceiver system, termed MIMO OFDM system which is used to increase the gain of diversity model and capacity of system. The Bit Error Rate performance of the MIMO-OFDM for several modulation methods i.e., Binary PSK, Quadrature PSK, 16-PSK, 8-PSK, 64-PSK and QAM using AWGN (Additively increased 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 great data rate, larger reliability, interferences among inter symbol (ISI) lessening, and improved presentation in multipath fading.

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

1. INTRODUCTION

The major challenges' facing in up-to-date communications is to fulfill the ever growing plea of high speed consistent communications with the constraints of enormously restricted frequency spectrum and narrow power. 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 systems with multiple spread and multiple combine antennas can provide high capacity at low probability of bit error with extremely low power, even in colonized urban areas. Orthogonally frequency division multiplexing (OFDM) is widely used in communications structures to function in frequency selective channels. Communication systems with a MIMO-OFDM combination can significantly improve signal strength and consistency by exploiting the robustness of OFDM to fading.

1.1 Methodology

Our projected work is Performance investigation of MIMO-OFDM for various encoding schemes under numerous channel models. The main purpose of proposed practice is to appraise the presentation of MIMO-OFDM for various encoding schemes under different channels. The main step is to pull off the intention is to study the basics of OFDM systems then, the OFDM procedure is applied to a multiple-input multiple-output (MIMO) system. Multicarrier intonation is employed with different M-array values of PSK and QAM. The design is simulated both in an added white Gaussian unwanted signal (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 diversity grouping (MRRC) technique with the assumption of perfect knowledge of information at the channel state (CSI) at the receiver end. The presentation is calculated Bit Error Rate (BER) versus Signal to Noise power Ratio (SNR) using MATLAB. The paper has been structured as follows: In section II, MIMO-OFDM system model, and in section III channel models, Digital modulation and MRRC have been studied. Simulation results were analyzed with Matlab.

2 MIMO-OFDM

2.1(a) OFDM System Model: Orthogonal frequency-divisible multiplexing is a process of discrete time signal encoding method in which a single data stream is split across numerous divide narrowband channels at

various frequencies to lessen intervention and crosstalk. Figure 1 illustrates the figure of OFDM system [5], consist of transmitter and receiver. The data bits taken are initially mapped via various modulation methods and it is renewed from sequential to corresponding forms through convertor. N branch carriers are nearby and each branch-carrier involves of information symbol. These N branch carriers are generated by inverse FFT (IFFT) block. The outcome of Inverse FFT block is written as $S(n) = \sum_{k=0}^{N-1} f(k) \exp j2\pi kn/N$ (1)

Cyclic Prefix is added to the return of the inverse FFT block in order to mitigate the symbol interference. Later addition of Cyclic Prefix, the signal is fed 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 s/p to convertor and cyclic prefix is detached. After detaching the CP, the established samples are sent to a FFT block to demultiplex the several-carrier signals. The response of FFT block is given as

$$f(k) = \sum_{n=0}^{N-1} \frac{1}{N} S(n) \exp j2\pi kn/N \text{ (2)}$$

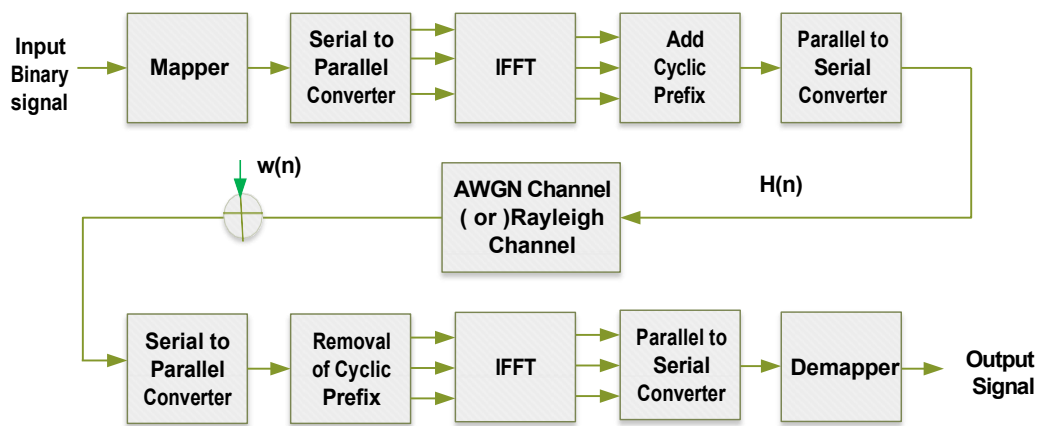


Fig.1: Illustration of OFDM System

Subcarrier arrangement in continuous domain for OFDM and OFDM-IM. Every shade refers to a single subcarrier.

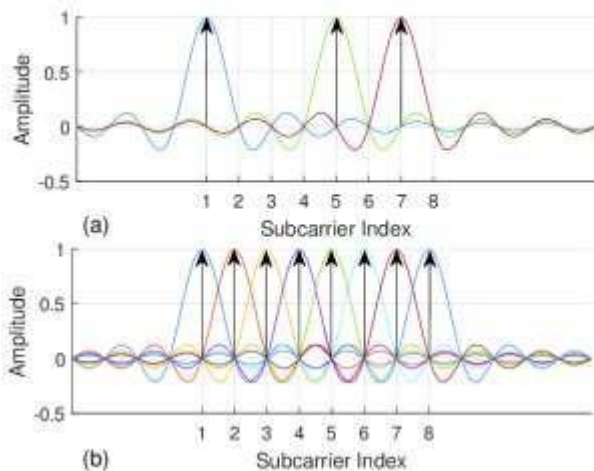


Fig.2: (a) 3 out of 8 branch carriers are activated in OFDM-IM. (b) All of eight subcarriers are utilized in OFDM.

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

It is a manner for repeatedly adding the capacity of a wireless link using numerous broadcast and combining antennas to make the most of several path propagation. MIMO has turned out to be a necessary constituent of wireless communication ideals and standards. Recently, MIMO has been functional to power-line communication for 3-wire installation as part of ITU. In modern era in communication the word "MIMO" used to the use of numerous antennas at the broadcaster and the combiner. In modern usage, "MIMO" specifically gives to a realistic operation for transfer and getting more than a data signal at the same time over the same channel by exploiting multipath propagation. MIMO is essentially different as of smart antenna methods designed to improve the presentation of a single data signal, such as beam forming and diversity. Multiple-antenna setup [8] can be given into three types, Spatial Diversity, Spatial several transmitting and Adaptive Antenna System. In radio link MIMO means multiple antennas both on spreader and recipient side of a precise radio link. Several antennas will be used to decrease the error rate plus to advance the quality and capacity of wireless broadcast. The procedure used in this paper is spatial several transmission variants where dissimilar data bits are spread on the radio link by various antennas on the same frequency within the same time interval. MIMO communication can be derived by the time instance variant channel matrix.

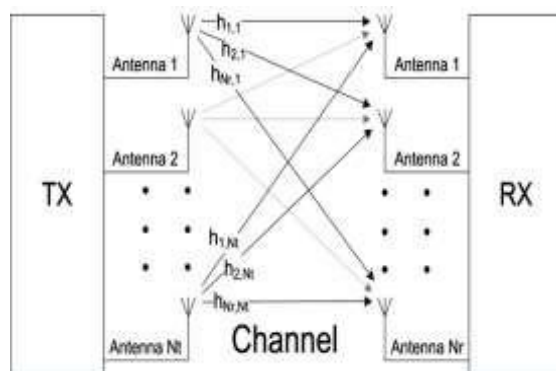


Fig.3: MIMO setup beside M transmit antennas and N receive antennas

Let us presume a MIMO setup with M spreading antennas and N combining antennas as shown in figure 3, then a matrix of dimension $N \times M$ with complex relocate factors H_{ij} , can simply state the channel behavior.

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

Here H is the channel matrix and it is named as the channels relocate function.

MIMO being sub-separated into three major categories: precoding, spatial multiplexing, and diversity coding. Precoding is several -stream beam forming, it is measured to be all spatial dispensation that occurs at the spreader. In beam forming, the similar signal is spit from each of the spread antennas with suitable phase and gain weighting so that the signal power is improved at the combiner input. The profit of beam forming are to amplify the customary signal gain by manufacture signals emitted from different antennas add up constructively – and to reduce the several path fading effect. In LOS propagation, beam forming outcome in a distinct directional pattern. When the combiner has several antennas, the spread beam forming will not simultaneously exploit the level of signal at all of the combining antennas, and precoding.

In spatial multiplexing, a more-rate signal is dividing into multiple slower-rate streams and every tributary is spreader from a dissimilar spread antenna in the identical frequency channel. A signal entering at the combiner antenna array with satisfactorily and the receiver has perfect CSI, it can split these data's into corresponding channels. The greatest number of spatial method is limited by the minimal of the number of

antennas at the spreader or recipient. Spatial multiplexing can be used without CSI at the spreader, but can be collective with precoding if CSI is obtainable. Spatial several transmitting may be used for concurrent broadcast to multiple combiners, as space-division several access or several-user MIMO, in which case CSI is needed at the spreader. The scheduling of combines with various spatial signatures allows good separation.

Diversity methods are adopting when no channel information at the spreader. In this method, a lone stream is transmitted, and the signal is coded using approach called space-time coding. The signal is spit from each of the spread antennas with normal coding. Diversity coding spits the autonomous fading in the various antenna associations to enhance signal diversity. Coding is collective with spatial several transmissions when some channel information is available at the spreader

2.1(c) MIMO – OFDM

Multiple-input, multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) is the leading air interface for communications. It adds multiple-input, multiple-output (MIMO) knowledge, which multiplies competence by spreading dissimilar signals over multiple antennas, and orthogonal frequency-division multiplexing (OFDM), which separated a radio channel into a large number of strongly spaced subchannels to offer more consistent communications at larger speeds. MIMO can be linked with additional accepted air interfaces such as time-division multiple access (TDMA) and code-division multiple access (CDMA). MIMO and OFDM collection is mostly sensitive at faster data rates. MIMO-OFDM will be the basis for the most advanced wireless LAN and mobile network standards, as it achieves the highest spectral efficiency and thus provides the highest capacity and data throughput.

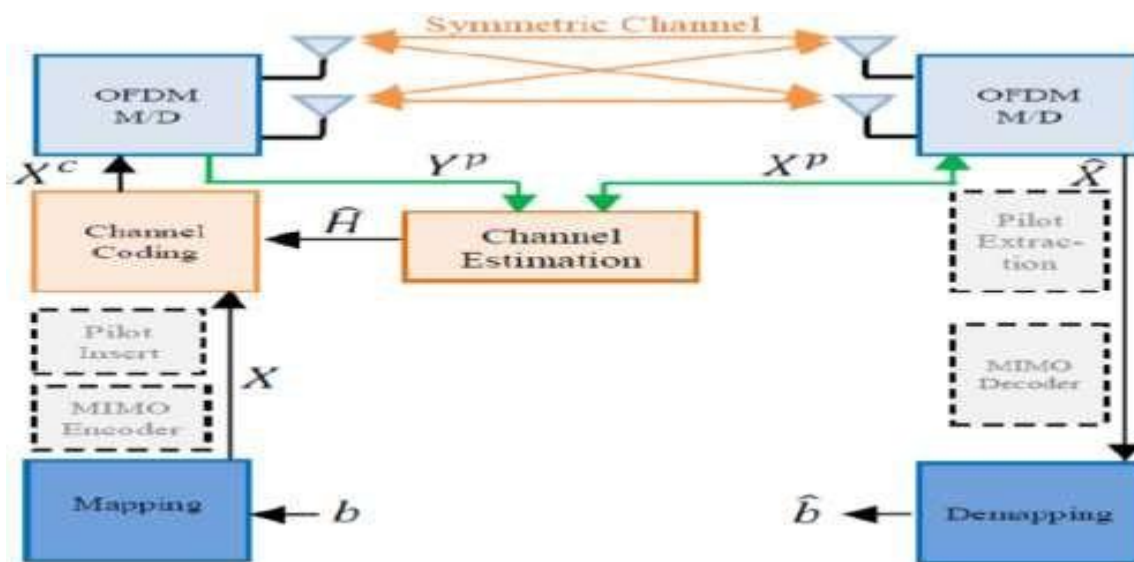


Fig 3: Block diagram of MIMO-OFDM

This arrangement enables the greatest barrier to reliable high speed communication, inter-symbol interference (ISI), to be removed. ISI occurs when there is a large gap between successive symbols compared to the duration of the symbols. Usually, high data rates are required. Symbols of shorter duration, increasing the risk of ISI. OFDM allows for longer duration symbols by isolating a high-speed data into numerous low-rate data. Creating a guard interval that completely prevents ISI; a cyclic prefix may be added. If the interval of guard is bigger than the spread of delay—the variation in delays qualified by symbols transmitted over the channel—then there will be no gap involving adjacent symbols and therefore no interference between symbols. While the CP marginally decreases spectral efficiency by using a small percentage of the available bandwidth, eliminating ISI makes it extremely valuable.

The Orthogonal Frequency Multiplexing Division (OFDM) is used in wireless communication for high data levels. For maximize diversity gain and device efficiency, OFDM can be used in combination with a Multiple-Input Multiple-Output (MIMO) transceiver.

3. CHANNEL MODELS

3.1(a) AWGN Channel:

Additively White Gaussian Noise channel is a broadly used channel model for study of modulation schemes [1]. Additively White Gaussian Noise (AWGN) is a simple noise ideal used in information concept to simulate the consequence of many accidental processes occurring in nature. The modifiers denote specific characteristics: it is applied to any noise that may be intrinsic to the data. White denotes to the clue that for the info system it has uniform control crosswise the frequency band. The white color that has uniform emissions in the spectrum at all frequencies. It has an average time domain value of zero in the time domain. A white Gaussian noise is applied to the signal passing through it in the AWGN channel. Fading does not exist for this channel.

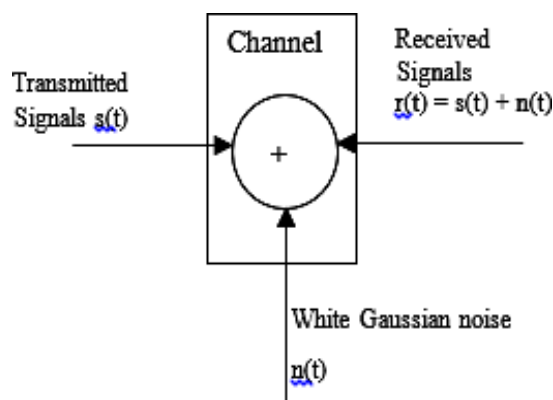


Fig 4.: Arrangements of AWGN channel Model

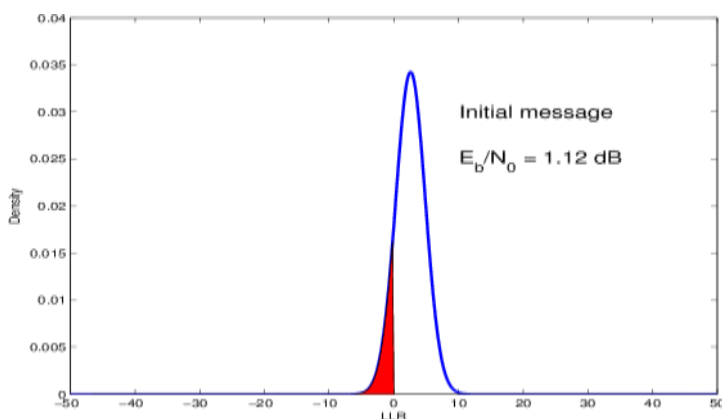


Fig 5.: The probability density function for additive white Gaussian noise

The mathematical expression of the received signal is: $r(t) = s(t) + n(t)$ ————— (4) Where $s(t)$ is a signal transmitted and $n(t)$ is a white Gaussian noise additive.

3.1(b) Rayleigh Channel:

Rayleigh fading is a model that can be used to describe the fading form that happens when there is multipath propagation. In any terrestrial world, a radio signal travels from the transmitter to the receiver through a number of different routes. Understandable path is the sight path, direct or line. Form fading from Rayleigh [1] Assume that the signal going through such a stream will be skewed by the Rayleigh distribution. Multi-path results result in constructive and destructive interference. This triggers the loss of

Rayleigh. Rayleigh fading is most important when the transmitter and the receiver have non-line sight contact. The received signal can be given as: $R(n) = h(n) \tau s(n - m) + w(n)$ (5) Where $w(n)$ is AWGN and $h(n)$ is channel impulse response. The distribution of Rayleigh is a continuous distribution of probabilities for non-negative random variables. It's essentially a two-degree chi distribution. One example of the natural occurrence of the Rayleigh distribution is when the storm speed is measured in two dimensions. In that case, Rayleigh-distributed is the absolute value of the complex number. Rayleigh's name is given to the delivery. The distribution of Rayleigh is essentially the sum of two equivalent independent orthogonal Gaussian random variables and the definition of probability density is given by

$$P(z) = \frac{z}{\sigma^2} e^{-z^2/\sigma^2} \quad (6)$$

Where σ^2 is the received signal and equations time-average power. (6) Is known as the random Rayleigh variable.

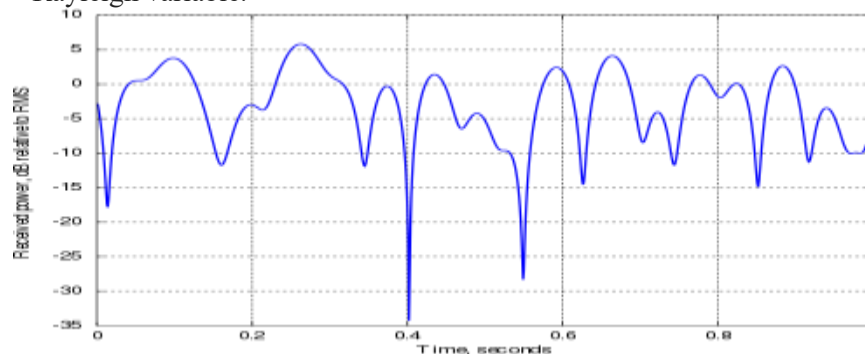


Fig6.: Rayleigh's one second fading with a maximum 10 Hz Doppler shift.

3.2 Digital Modulation

Digital modulation schemes [8] convert digital signals into waveforms consistent with the design of the channel of communication. One class uses a constant carrier of amplitude and the other carries the information in phase or frequency variations (FSK, PSK) DM stands for **Digital Modulation** and is a Common name for variety practices that modulate a carrier wave using discrete signals.

3.3 Maximum-ratio combining

It is a method of combining diversity in which: each channel's signals are added together, each channel's gain is made proportional to the Rms signal is contrariwise proportional to that channel's mean squared noise flat. For each stream, different constants of proportionality are used. It is also referred to as the combination of ratio-squared combination and re-detection. Combining the maximum ratio is the ideal combiner for independent white Gaussian noise channels.

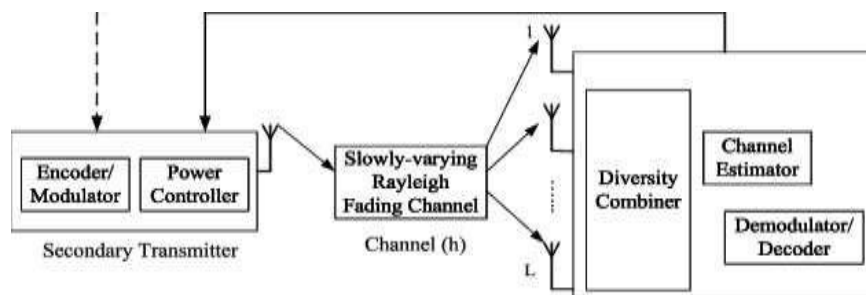


Fig7: Maximum-ratio combining

On the i^{th} receive antenna, the received signal is, $y_i = h_i x + n_i$ ------(7)

Where,

y_i is the received symbol on the i^{th} collective antenna,

h_i is the network on the i^{th} receive antenna,

x is the spread symbol and

n_i is the noise on i^{th} receive antenna.

The attained signal is represented in matrix form, $y = hx + n$,------(8)

Where,

$y = [y_1 y_2 \dots y_N]^T$ ------(9) is the collective symbol from all the combine antenna

$h = [h_1 h_2 \dots h_N]^T$ ------(10) is the channel on all the combine antenna

x is the transmitted symbol and

$n = [n_1 n_2 \dots n_N]^T$ ------(11) is the noise on all the obtain antenna.

The equalized symbol is,

It is intuitive to note that the term,

$h^H h = \sum_{i=1}^N |h_i|^2$ ------(12) i.e sum of the channel powers across all the collect antennas.

Eb/No with Maximal Ratio Combining (MRC)

We prominent that in the incidence of channel h_i , the instantaneous bit energy to noise ratio at i^{th} receive antenna is

$\gamma_i = \frac{|h_i|^2 E_b}{N_0}$ ------(13)

Given that we are balancing the channel with h^H , with the N collect antenna case, the effective bit energy to noise ratio is,

$\gamma = \sum_{i=1}^N \frac{|h_i|^2 E_b}{N_0}$
 $= N \gamma_i$ ------(14)

For a single antenna case, effective bit energy to noise ratio is N times the bit energy to noise ratio.

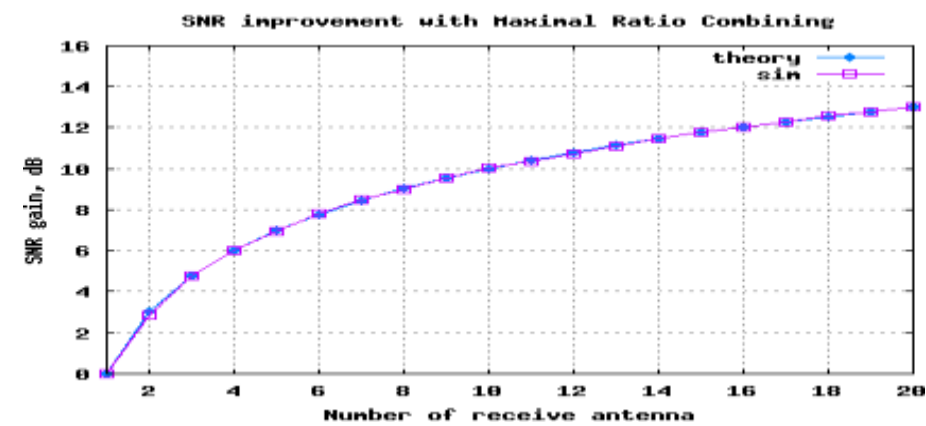


Fig 8: Effective SNR with maximum ratio in the fading channel of Rayleigh

Result Analysis:

Table 1: Collection of parameters for simulation

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

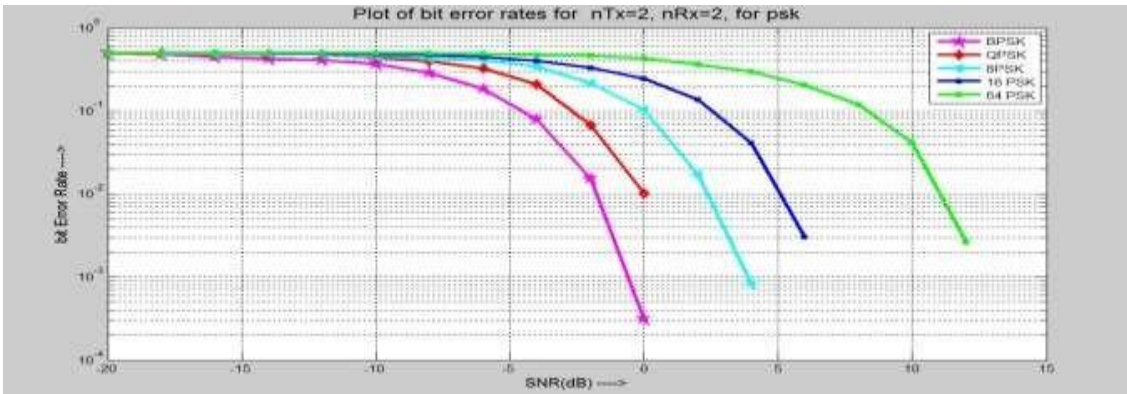


Fig 9: Simulation result (a): MIMO-OFDM performance review of various PSK modulation schemes in the AWGN stream

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

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

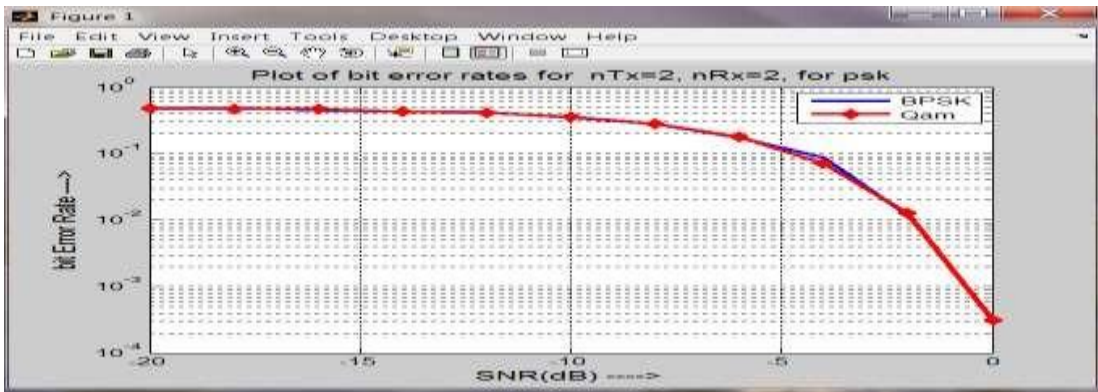


Fig 9: Simulation result (b): MIMO-OFDM performance analysis for QAM in AWGN channel

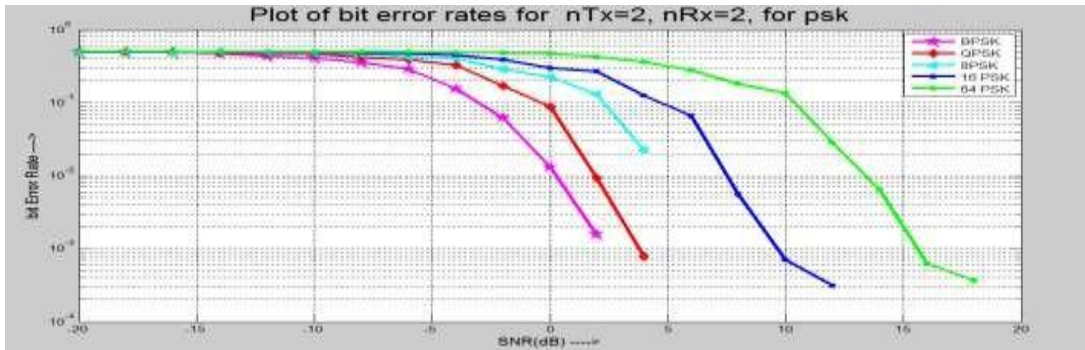


Fig 10: Simulation result (c): MIMO-OFDM performance analysis for various PSK modulation schemes in the Rayleigh channel

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

Modulation scheme	SNR(dB)	Bit 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

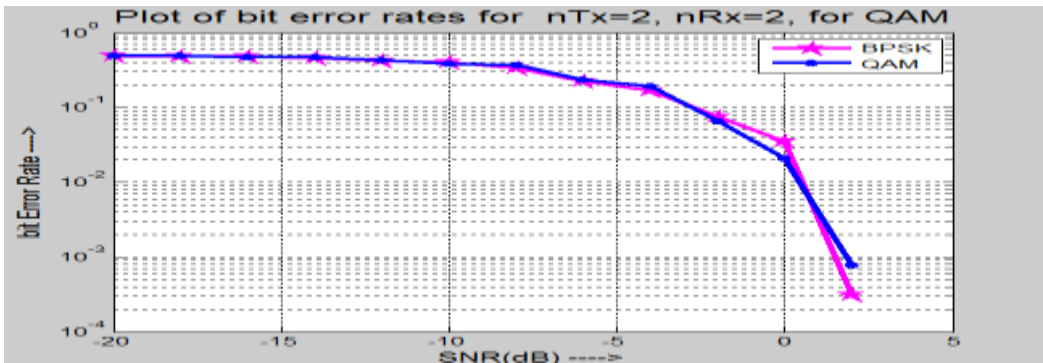


Fig 11: Simulation result (d): MIMO-OFDM performance analysis for QAM in Rayleigh

Results of the simulation (a), (b), (c), (d) show the BER performance of MIMO-OFDM for different modulation schemes as a function of varying SNR for the MRC technique under the channels AWGN and Rayleigh. By looking at Table 2 and Table 3. We have analyzed that the BPSK modulation provides the least bit error rate, is an effective method for transmitting data in all modulations and for all channels in terms of bit error rate. In both cases we get better performance for the QAM modulation scheme by

observing simulation results where its efficiency is close to that of BPSK.

CONCLUSION

Similar to the bit error rate of higher order modulation schemes, the bit error rate of BPSK modulation scheme is less. The performance analysis of the AWGN channel and Rayleigh Fading Channel is therefore found to be more effective in a general communication system under the BPSK modulation scheme. So it is noticeable that under the AWGN channel and the Rayleigh fading channel, BPSK modulation serves well in MIMO-OFDM systems. Here we discussed with QAM for high speed data rate applications and its presentation is related to that of BPSK. So at this point we can infer that QAM has better performance than PSK by observing simulation results (b) and (d).

REFERENCES

- [1] Bhasker Gupta.; Gagan Gupta.; and Davinder S. Saini, "BER Performance Improvement in OFDM system with ZFE and MMSE equalizers" IEEE-2011.
- [2] Chenyang Yang and Taewon Hwang, "Ofdm And its Wireless Applications :A survey" IEEE transactions on vehicular technology vol.58.no.4,MAY2009.
- [3] Hemanth Sampath.; Shilpa Talwar.; Jose Tellado and Vinko Erceg, "A Fourth generation MIMO-OFDM Broadband Wireless system: Design , performance, and Field Trial results".-IEEE –September 2002 .
- [4] Justin Barnes.; Nick Lasorte.; W. Hazen H. Refai.; "The History of Orthogonal Frequency Division Multiplexing" IEEE-March 31st, 2008.
- [5] Jiang Xuehua and Chen Peijiang, "Study and Implementation of MIMO-OFDM system based on Matlab" IEEE-2009 International Conference on Information Technology and Computer Science.
- [6] Le Chung Tran.; Xiaojing Huang.; Erky Dutkiewicz and Joe Chiccharo, "STC-MIMO Block Spread OFDM in Frequency Selective Rayleigh Fading Channels"-IEEE 2006.
- [7] Pavel Loskot and Norman C. Beaulieu "Performance analysis of coded mimo-ofdm systems over generalized rician fading channels"- IEEE May 2006.
- [8] Madanlal and Hamneet Arora, "BER Performance of different Modulation Schemes for MIMO Systems" –International Journal of Computer Science and Network Security, Vol.11 No.3, March 2011.
- [9] Muhammad Razin Ibn Azad "Multiple Antenna Technique (MIMO)" Thesis, Helsinki Metropolia University of Applied Sciences
- [10] Md. Sipon Miah.; M. Mahbubur Rahman.; T. K. Godder, Bikash Chandra Singh and M. Tania Parvin, "Performance Comparison of AWGN, Flat Fading and Frequency Selective Fading Channel for Wireless Communication System using 4QPSK" 2011 IJCIT, VOLUME 01, ISSUE 02.
- [11] Mohammed Safiqul Islam.; Gourin Rani Barai, "Performance analysis of different modulation schemes using ofdm techniques in Rayleigh channel",-International journal of fundamental Physical sciences, vol-1, March 2011.
- [12] Siavash M. Alamouti, "A simple transmit Diversity Technique for Wireless communications" IEEE-Journal on select areas in communications, Vol-16, No.8, October 1998.