International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)
Volume-2 Number-3 Issue-5 September-2012

BER Analysis of MIMO-OFDM System using BPSK Modulation Scheme

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Abstract

Multiple transmit and receive can be used to form multiple-input multiple-output (MIMO) channels to increase the capacity and data rate. The key advantage of employing multiple antennas is to get reliable performance through diversity and the achievable higher data rate through spatial multiplexing. In MIMO system the some information can transmitted and received from multiple antennas simultaneously since the fading for each link between a pair of transmit and receive antennas can usually be considered to be independent, the probability that the information is detected accurately is higher. Fading of the signal can be mitigated by different diversity techniques, where the signal is transmitted through multiple independent fading paths in terms of the time, frequency or space and combined constructively at the receiver. In this paper we analyze Bit Error Rate (BER) using BPSK modulation and then optimum modulation is analyzed.

Keywords

MIMO, OFDF, BER, Fading, Modulation, Scheme

1. Introduction

Orthogonal frequency division multiplexing (OFDM) is an effective technique to mitigate ISI. OFDM[1] is a frequency division multiplexing(FDM)scheme utilized as a digital multi-carrier modulation method[2] In other words OFDM is frequency division multiplexing of multi-carriers which are orthogonal to each other i.e. they are placed exactly at the nulls in the modulation spectra of each other. This makes OFDM [3] spectrally more efficient. In OFDM data is divided into several parallel data streams or sub-channels, one for each sub carrier which are orthogonal to each other although they overlap spectrally Each sub-carrier is modulated with a conventional modulation scheme(such as QAM or PSK) at a low symbol rate maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

In today's scenario MIMO is very useful with the combination of OFDM system. Exploiting the flexibility of MIMO systems in order to have high data rates is an especially attractive research topic for future scheduling scheme designs and their applications. Multiple-input multiple-output (MIMO) systems offer much larger channel capacity over traditional single-input single-output (SISO) system. Recently, many transmit beam forming Algorithms have been developed to exploit the high capacity in the MIMO systems [4][5].Furthermore, in MIMO systems, after selecting the group of users with the currently maximum feasible rates determined by a packet scheduler in each time-slot, we need to assign them to the transmitter's antennas in such a way that we can achieve the maximum throughput in the system. Diversity techniques such as space-time coding have received a great deal of attention due to their ability to provide higher spectral efficiency than conventional single-input single-output (SISO) systems[6] When applying these techniques in a frequency-selective channel, a space-time equalizer is required at the receiver to compensate for the inter symbol interference (ISI).

It is thus critical that one designs a channel estimator that takes into account the channel correlation and is capable of providing good identification performance. However, such an estimator often requires information of channel correlation, which is to be obtained by on-line measurement error. We propose a model-based channel estimation analysis with different aspects and scheme that can do without knowledge of second order.

We also discuss antenna assignment scheme, referred to as max deviation delete (MDD), for the downlink of a MIMO cellular system based on spatial multiplexing. This exploits multiple antennas to achive a diversity effect from multiple users. Multiple inputs multiple output (MIMO) systems are capable of delivering large increase in capacity through utilization of parallel communication channels [7], [8], [9].

MIMO systems now constitute a major research area in telecommunications. It is also considered to be one of the technologies that have a chance to resolve the bottlenecks of traffic capacity in the forthcoming broadband wireless Internet access networks which is Universal Mobile Telephone Services(UMTS) and beyond Antenna selection has been proposed for enhanced performance in correlated fading [10],[11].Assuming that the number of RF chains is less than the number of antennas ,the antenna selection algorithms choose the optimum subset of transmit and receive antennas based on minimum error rate. The size of the active subsets of transmit and receive antennas is fixed by the number of RF chains, Per-antenna rate control witch equal power allocation is applied to uncorrelated fading channels in [12] ,where it is shown that per-antenna rate control at the fading rate nearly achieves capacity. However, adaptation at the fading rate may be difficult to achieve in practice due to inaccuracies in channel estimates and feedback delays.

The remaining of this paper is organized as follows. We discuss MIMO and OFDM in Section 2. In Section 3 we discuss about Evolution and Recent Scenario.BER in section4.In section 5 we discuss about proposed approach. In section 6 we discuss about result analysis. The conclusions and future directions are given in Section 7. Finally references are given.

2. MIMO and OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising physical layer technologies for high data rate wireless communications due to its robustness to frequency selective fading, high spectral efficiency, and low computational complexity. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n.

MIMO communication uses multiple antennas at both the transmitter and receiver to exploit the spatial domain for spatial multiplexing and/or spatial diversity. Spatial multiplexing has been generally used to increase the capacity of a MIMO link by transmitting independent data streams in the same time slot and frequency band simultaneously from each transmit antenna, and differentiating multiple data streams at the receiver using channel information about each propagation path, future standards need to specify both bandwidth requirements and type of signaling that achieves the data rate required for minimal predefined qualities of services for future applications.

Frequency bands used by mobile devices are strictly specified by responsible regulatory bodies, which set limits on the bandwidth available for communication. Therefore, a very natural and important question is what the maximum data rate is (equivalently, information rate) at which reliable communication over a mobile channel of a given bandwidth is attainable. This quantity is known as the channel capacity .for the well-known expression for the maximum data rate that can be achieved, for reliable communication. That is the average bit error rate (BER) can be made arbitrarily close to zero by use of channel coding, for transmissions up to the maximum achievable rate. For mobile channels, that are time-varying and dispersive in time and frequency however the channel capacity derivation is still an open research area. In this context we point out the lack of equivalent vector channel models for realistic continuous-time SISO and MIMO dispersive fading channels such models serve as the foundation upon which channel capacity results are derived.

In contrast to spatial multiplexing the purpose of spatial diversity is increase the diversity order of a MIMO link to mitigate fading by coding a signal across space and time , so that a receiver could receive the replicas of the signal and combine those received signals constructively to achieve a diversity gain.In recent years we have witnessed an increasing popularity of multimedia applications that run on personal mobile devices. Services such as high quality video calls ,mobile TV, audio and video contents on demand and various interactive map/locator services (such as GPS)are becoming widely supported in new generations of personal mobile devices. A majority of these services require a minimal guaranteed data rate between users (or between a user and a base station) in order to provide a minimal predefined quality of service, which puts a demand on transmission band width and need for spectral efficiency on wireless channels. To provide support for bandwidth demanding applications on the physical layer.

3. Evolution and Result Analysis

In 2002, Christos Komninakis et al. [13] proposed about a low-order autoregressive model approximates the MIMO channel variation and facilitates tracking via a Kalman filter. Hard decisions to aid Kalman tracking come from a MIMO finite-length minimum-mean-squared-error decision-feedback equalizer (MMSE-DFE), which performs the equalization task. Since the optimum DFE for a wide range of channels produces decisions with a delay 0, the Kalman filter tracks the channel with a delay. A channel prediction module bridges the time gap between the channel estimates produced by the Kalman filter and those needed for the DFE adaptation. Their proposed algorithm offers good tracking behavior for multiuser fading ISI channels at the expense of higher complexity than conventional adaptive algorithms.

In 2003, Ravi Narasimhan [14] analysis on spatial multiplexing systems in correlated multiple-input multiple-output (MIMO) fading channels with equal power allocated to each transmit antenna. Under this constraint, the number and subset of transmit antennas together with the transmit symbol constellations are determined assuming knowledge of the channel correlation matrices. They first consider a fixed data rate system and vary the number of transmit antennas and constellation such that the minimum margin in the signal to- noise ratio (SNR) is maximized for linear and Vertical Bell Laboratories Layered Space-Time (V-BLAST) receivers. They also derive transmit antenna and constellation selection criteria for a successive interference cancellation receiver (SCR) with a fixed detection order and a variable number of bits transmitted on each sub stream. They compared with a system using all available antennas, performance results show significant gains using a subset of transmit antennas, even for independent fading channels.

In 2004, Tobias Dahl et al. [15] proposed about a new approach for direct blind identification of the main independent singular modes, without estimating the channel matrix itself. The right and left singular vectors with maximum corresponding singular values are determined using payload data and are continuously updated while at the same time being used for communication. The feasibility of the approach is demonstrated by simulating the performance over a noisy, fading time-varying channel.

In 2005, Nihar Jindal et al. [16] compare the capacity of dirty-paper coding (DPC) to that of time-division multiple access (TDMA)f or a multiple-antenna (multiple input multiple-output (MIMO)) Gaussian broadcast channel (BC). They find that the sum-rate capacity (achievable using DPC)of the multiple-antenna BC is at most min( ) times the largest single-user capacity (i.e., the TDMA sum-rate)in the system, where is the number of transmit antennas and is the number of receivers. This result is independent of the number of receive antennas and the channel gain matrix, and is valid at all signal-to-noise ratios (SNRs).

In 2006, Masoomeh Torabzadeh and Yusheng Ji [17] proposed about nature of independent time-varying channels across different users in a multi-user wireless system provides multi-user diversity. In addition, multiple antennas that spatially separate the signals from different users can be used to provide multiple access gain. Combining fair scheduling and efficient antenna assignment, we can achieve the goal of fairness and maximum capacity.

In 2010, Qihui Liang et al. [18] proposed about the computational complexities of two methods which are analyzed and simulation is done for comparing their PAPR-reducing performance. The simulation results show that active-set method requires less computational complexity than that of SCR method while they achieve similar PAPR reduction performance.

In 2010 , Bhasker Gupta et.[19]show the BER performance improvement of IEEE 802.11a LAN based OFDM systems using these equalizers .Two categories of channels are considered namely frequency flat channels and frequency selective channels.

In 2010, Zhiyong Wang et al. [20] proposed the anti-BER ability of 2PSK is best, but its bandwidth efficiency is lower than other modulation methods. The bandwidth efficiency of 4QAM is as twice as the 2PSK,and the BER of the system is smaller than 10-3 and the required OSNR is about 9dB.When the OSNR is 12dB,the transmission distance is up to1600km.Althought the bandwidth efficiency of 8QAM is higher than other two kinds of modulation methods, its performance of anti-BER is relatively poor.

4. BER

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors.

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. The bit error probability pe is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors. Measuring the bit error rate helps people choose the appropriate forward error correction codes. Since most such codes only bit-flips, but not bit – insertions or bit detection, the hamming distance metric is the appropriate way to measure the number of bit errors. The BER may be improved by choosing strong signal strength by choosing a slow and robust modulation scheme or line coding scheme, and by applying channel coding schemes such as redundant forward error correction codes.

Binary symmetric channel which is used in analysis of decoding error probability in case of non bursty bit errors on Additive white Gaussian noise (AWGN) channel without fading. A worst case scenario is a completely random channel, where noise totally dominates over the useful signal.In a noisy channel, the BER is often expressed as a function of the normalized carrier-to-noise ratio measured denoted Eb/N0 that is energy permit to noise power spectral density ratio, or Es/N0 that is energy per modulation symbol to noise spectral density.

As the name implies, a bit error rate is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be translated into a simple formula:

BER = number of errors / total number of bits sent

If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small - possibly insignificant and having no noticeable effect on the overall system However if noise can be detected, then there is chance that the bit error rate will need to be considered. The main reasons for the degradation of a data channel and the corresponding bit error rate, BER is noise and changes to the propagation path (where radio signal paths are used). Both effects have a random element to them, the noise following a Gaussian probability function while the propagation model follows a Rayleigh model. This means that analysis of the channel characteristics are normally undertaken using statistical analysis techniques.

Signal to noise ratios and Eb/No figures are parameters that are more associated with radio links and radio communications systems. In terms of this, the bit error rate, BER, can also be defined in terms of the probability of error or POE. The determine this, three other variables are used. They are the error function, erf, the energy in one bit, Eb, and the noise power spectral density (which is the noise power in a 1 Hz bandwidth), No.

It should be noted that each different type of modulation has its own value for the error function. This is because each type of modulation performs differently in the presence of noise. In particular, higher order modulation schemes (e.g. 64QAM, etc) that are able to carry higher data rates are not as robust in the presence of noise. Lower order modulation formats (e.g. BPSK, QPSK, etc.) offer lower data rates but are more robust. The energy per bit, Eb, can be determined by dividing the carrier power by the bit rate and is a measure of energy with the dimensions of Joules. No is a power per Hertz and therefore this has the dimensions of power (joules per second) divided by seconds). Looking at the dimensions of the ratio Eb/No all the dimensions cancel out to give a dimensionless ratio. It is important to note that POE is proportional to Eb/No and is a form of signal to noise ratio.

It can be seen from using Eb/No, that the bit error rate, BER can be affected by a number of factors. By manipulating the variables that can be controlled it is possible to optimize a system to provide the performance levels that are required. This is normally undertaken in the design stages of a data transmission system so that the performance parameters can be adjusted at the initial design concept stages. The interference levels present in a system are generally set by external factors and cannot be changed by the system design. However it is possible to set the bandwidth of the system. By reducing the bandwidth the level of interference can be reduced. However reducing the bandwidth limits the data throughput that can be achieved.

It is also possible to increase the power level of the system so that the power per bit is increased. This has to be balanced against factors including the interference levels to other users and the impact of increasing the power output on the size of the power amplifier and overall power consumption and battery life, etc. Lower order modulation schemes can be used, but this is at the expense of data throughput. It is necessary to balance all the available factors to achieve a satisfactory bit error rate. Normally it is not possible to achieve all the requirements and some trade-offs are required. However, even with a bit error rate below what is ideally required, further trade-offs can be made in terms of the levels of error correction that are introduced into the data being transmitted. Although more redundant data has to be sent with higher levels of error correction, this can help mask the effects of any bit errors that occur, thereby improving the overall bit error rate.

Bit error rate BER is a parameter which gives an excellent indication of the performance of a data link such as radio or fibre optic system. As one of the main parameters of interest in any data link is the number of errors that occur, the bit error rate is a key parameter. Knowledge of the BER also enables other features of the link such as the power and bandwidth, etc to be tailored to enable the required performance to be obtained.

As data errors occur in a random fashion it can take some while before an accurate reading can be gained using normal data. In order to shorten the time required for measurements, a pseudorandom data sequence can be used. To expand the reason for using a pseudo random sequences take the example of a typical data link. To make a simple measurement of the number of errors that take place it is possible to use an error detector that compares the transmitted and received data and then counts the number of errors. If one error were detected while sending 10^12 bits, then a first approximation may be that the error rate is 1 in 10^12, but this is not the case in view of the random nature of any errors that may occur. In theory an infinite number of bits should be sent to prove the actual error rate, but this is obviously not feasible.

The remaining noise can be simulated and introduced to the receiver using a noise diode generator. Fading characteristics for radio communications systems: It is very important to simulate the real life characteristics of the transmission path in as realistic a way as possible. With signals constantly varying as a result of many factors it is necessary to simulate a this. To achieve this for a radio link it is necessary to use a fading simulator that adds Rayleigh fading characteristics to the signal. A sophisticated fading simulator may also use multiple channels with variable time delays to simulate changing path conditions. Although fading simulators are complicated items of test equipment they are able to give a realistic medium for testing bit error rate, BER within the laboratory.

One of the main precautions when testing BER in the laboratory is to ensure that none of the transmitted signal leaks directly into the receiver and avoids passing through the fading simulator. If the transmitter power is relatively high, then it is difficult to give adequate levels of screening and some of the testing may not be valid. Great care must be taken to ensure that the entire signal travels via the fading simulator. Considerable levels of screening may be required. In some occasions screened rooms have been used.

5. Proposed Approach

In a communication system, the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization problem, attenuation, wireless multipath fading etc. In this paper we present the variation on BPSK modulation schemes so that we can choose the optimum SNR.

In a circularly symmetric complex Gaussian random variable is of the form, $h=h_{re} + jh_{im}$

Where real and imaginary parts are zero mean independent and identically distributed Gaussian random variables with mean 0 and variance σ^2. The magnitude |h| which has a probability density,

$P(h)=h/ \sigma^2 e^{-} h^2/2 \sigma^2 \quad z>=0$

is called a **Rayleigh random variable.** This model, called **Rayleigh fading channel model**, is reasonable for an environment where there are large numbers of reflectors.

System model:

The received signal in **Rayleigh fading channel** is of the form, Y=hx + n

Where y is the received symbol, h is complex scaling factor corresponding to **Rayleigh** multipath channel.

x is the transmitted symbol (taking values +1′s and -1′s) and
n is the Additive White Gaussian Noise (AWGN).

Assumptions

1. The channel is flat fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication. For a more rigorous discussion on flat fading and frequency selective fading.

2. The channel is randomly varying in time – meaning each transmitted symbol gets multiplied by a randomly varying complex number h. Since h is modeling a Rayleigh channel, the real and imaginary parts are Gaussian distributed having **mean 0** and **variance 1/2**.
3. The noise n has the Gaussian probability density function with
4. $P(n)=1/\mathrm{sqrt}(2\Pi\ \sigma^2)\ e^{-(n-\mu)2\ /}2\ \sigma^2$
   With $\mu=0$ and $\sigma^2 = N_{0\ /2}$
5. The channel h is known at the receiver. Equalization is performed at the receiver by dividing the received symbol y by the apriori known h i.e.

$\hat{y} = y/h = hx + n/H = x + \check{n}$

Where

$\check{N}=n/h$

is the additive noise scaled by the channe coefficient.

BER computation in AWGN, the probability of error for transmission of either +1 or -1 is computed by integrating the tail of the Gaussian probability density function for a given value of bit energy to noise ratio E_b / N_0. The bit error rate is,

$P_b=1/2\ \mathrm{erfc}(\mathrm{sqrt}(E_b/N_0))$

However in the presence of channel h, the effective bit energy to noise ratio is $h^2\ E_b/N_0$. So the bit error probability for a given value of h is,

$P_{b|h}=1/2\ \mathrm{erfc}(\mathrm{sqrt}(|h|^2E_b)\ /N_0) = 1/2\ \mathrm{erfc}(\mathrm{sqrt}(\gamma))$

Where $\gamma = (|h|^2E_b)\ /N_0$

Simulation Model

It will be useful to provide a simple Matlab/Octave example simulating a BPSK transmission and reception in Rayleigh channel. The script performs the following

a. Generate random binary sequence of +1′s and -1′s.
b. Multiply the symbols with the channel and then add white Gaussian noise.
c. At the receiver, equalize (divide) the received symbols with the known channel.
d. Perform hard decision decoding and count the bit errors.
e. Repeat for multiple values of Eb/N0 and plot the simulation and theoretical results.

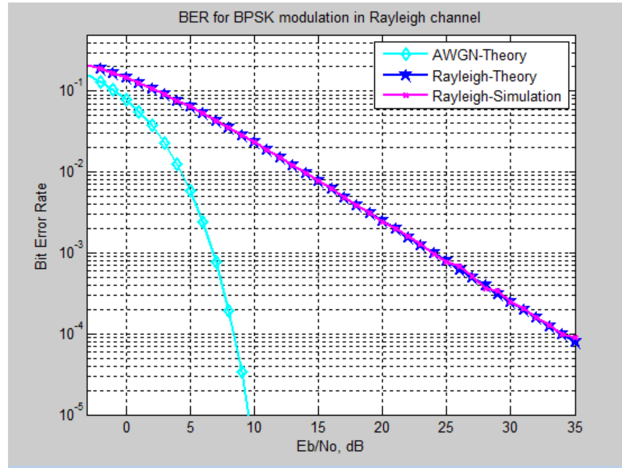

Figure 1: BER for BPSK modulation in Rayleigh Channel

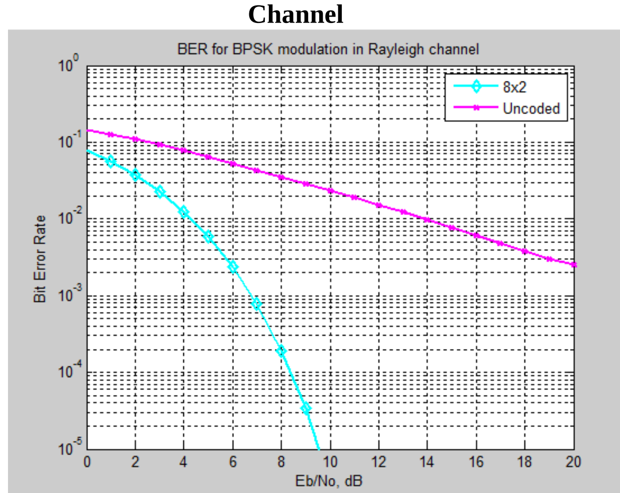

Figure 2: BER for BPSK Modulation

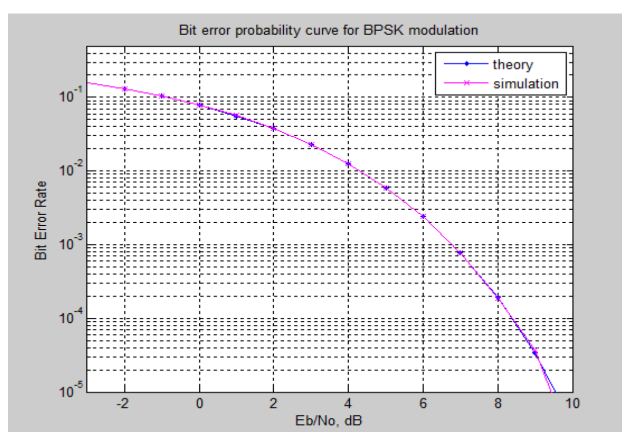

Figure 3: BER Error probability Curve for BPSK Modulation

6. Result Analysis

In result analysis we show the comparison between SNR and BER which is shown in table 1. It is taken from different points to show the comparison. The SNR is ratio of signal power to noise power. If SNR =1, it is for ideal condition where signal=Noise. SNR=Signal Power/ Noise Power So we increase signal power for increasing signal to noise ratio.

Table 1: SNR vs. BER

S.NO	SNR	BER
1	1.0103	bit error probability = 0.217700
2	2.0103	bit error probability = 0.184200
3	3.0103	bit error probability = 0.173600
4	4.0103	bit error probability = 0.146700
5	5.0103	bit error probability = 0.133400
6	6.0103	bit error probability = 0.104700
7	7.0103	bit error probability = 0.086800
8	8.0103	bit error probability = 0.074400
9	9.0103	bit error probability = 0.063400
10	10.0103	bit error probability = 0.051600
11	11.0103	bit error probability = 0.043900
12	12.0103	bit error probability = 0.032200
13	13.0103	bit error probability = 0.027700
14	14.0103	bit error probability = 0.023300
15	15.0103	bit error probability = 0.020300
16	16.0103	bit error probability = 0.015200
17	17.0103	bit error probability = 0.011800
18	18.0103	bit error probability = 0.009150
19	19.0103	bit error probability = 0.007600
20	20.0103	bit error probability = 0.005850
21	21.0103	bit error probability = 0.004733
22	22.0103	bit error probability = 0.003933
23	23.0103	bit error probability = 0.003433
24	24.0103	bit error probability = 0.002180
25	25.0103	bit error probability = 0.001867
26	26.0103	bit error probability = 0.001363
27	27.0103	bit error probability = 0.001222
28	28.0103	bit error probability = 0.001144
29	29.0103	bit error probability = 0.000594
30	30.0103	bit error probability = 0.000667
31	31.0103	bit error probability = 0.000439
32	32.0103	bit error probability = 0.000421
33	33.0103	bit error probability = 0.000263
34	34.0103	bit error probability = 0.000237

7. Conclusion

Multi input Multi output is a very attractive technique for multicarrier transmission and 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. In this paper we present a comparative study with inphase component to show the better noise reduction parameters.

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