# Performance Evaluation of V-BLAST Algorithm for IEEE 802.11n (MIMO-OFDM) System

Heba Rifat[1] and Dr. Ritesh Sadiwala[2]

[1]Department of Electronics and Communication Engineering, RKDF University, Bhopal, India
[2]Department of Electronics and Communication Engineering, RKDF University, Bhopal, India

* Corresponding Author: Dr. Ritesh Sadiwala

***Abstract***

Multiple input multiple output (MIMO) systems are currently one of the most active research areas in wireless communication. Here, both the transmitter and the receiver employ multiple antennas, which yield great advantages over single antenna communication systems.. Recent advancements in wireless research and smart antenna technology has resulted in an upgrade to the wireless networks and removed the bottlenecks thereby providing access to the users with extended range and increased throughput by using MIMO-OFDM systems for wireless communication. In this paper with a motivation of choosing the best suited equalization technique along with the proper selection of modulation, we have compared various detection techniques used in MIMO OFDM systems. We have also applied V-BLAST algorithm on detection techniques and compared the BER/SNR results for the same and simulation results shows that the use of V-BLAST technique improves the BER of the signal. In our work performance of the system is improved using V-BLAST algorithm.

***Keywords: -** MIMO, OFDM, Modulation , Bit Error Rate,SNR*

## I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is one of the most promising physical layer technologies for high data rate wireless communication, the IEEE 802.11a and the upcoming 4G technology is also based on OFDM. In OFDM systems the data is divided into several parallel channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as Quadrature amplitude modulation or phase shift modulation) at a low symbol rate maintaining total data rates similar to single carrier modulation scheme in the same bandwidth. In OFDM the signal is modulated with several subcarriers having frequency which is integral multiple of a fundamental frequency and orthogonal to each other avoiding Inter-Symbol Interference (ISI) between different subcarriers.

The main aim of the research work is a comprehensive study about MIMO –OFDM and about the various techniques used to improve its performance. The rest of the paper is organized as follows. Section II presents Literature Review about the topic. Section III tells us about MIMO Techniques and its Applications. Section IV gives us simulation results and finally Section V discusses results and discussions. Finally Section VI gives concluding remarks which are then followed by the bibliography.

## II. LITERATURE REVIEW

- In the paper of **Arman Farhang et al**. [35] discussed that Generalized Frequency Division Multiplexing is taken into consideration when we talk about the new candidate waveforms of fifth generation (5G) communication systems. This decision is taken on the basis of several facts that prove GFDM can replace the previous OFDM communication systems. Cyclic prefix is one the reason for GFDM in place of OFDM. GFDM is using only one cyclic prefix to the aggregation of the symbols whereas in case of OFDM the CP is added to every subcarrier. GFDM is more bandwidth efficient because of this approach. There is a transceiver proposed which uses the FFT at the transmitter side and IFFT at the receiver side. With the help of DFT and IDFT matrices we can reduce the computational complexity.

- The high peak-to-average power ratio (PARP) is the major issue in all multicarrier communication systems introduced by **Hanwang et.al** [33]. In past time the methods used to reduce the PARP in OFDM were as: clipping and filtering scheme, SLM (selective mapping scheme), PTS (partial transmit sequence) scheme, and TR (tone reservation) scheme, but due to the different structure of FBMC these schemes were not useful for FBMC. A hybrid scheme for FBMC/OQAM signals to reduce the PARP (peak-to-average ratio) and this is depends upon the multi data block PTS (partial transmit sequence) and TR (tone reservation) approaches. Hybrid PTS scheme the data blocks are divided into segment and this is used to optimize every data block signal for which the optimalphase rotation is needed to choose. To achieve this iterative clipping filtering is used to generate peak canceling signal for each segment of signal. This operation is very useful to cancel peak of signals.
- **Stefan H. Muller et al.** [4] proposed a flexible and distortion free technique for OFDM that is eradicating redundancy that was present in it. This technique may enhance the complexity of the OFDM. It is brought to our notice that the results of PAR reduction obtained from the performed histogram are not good as compared to those which are theoretically found. When the 4-DPSK isimplemented in alliance with PTS-OFDM along with the subcarriers, it is found that redundancy is Rap=2(V-1) which was independently of W. V is depicting the number of sub blocks used in PTS and W is depicting the admitted angles for bµv which must not be quite high.

## III. MIMO TECHNIQUES AND ITS APPLICATIONS

In wireless environment the signal propagates from the transmitter to the receiver along number of different paths, collectively referred as multipath. While propagating the signal power drops of due to the following effects: path loss, macroscopic fading and microscopic fading. To obtain diversity, the signal is transmitted through multiple independent fading paths e.g. in time, frequency or space and combined constructively at the receiver. To achieve a high system capacity for multimedia applications in wireless communications, various methods are there. Among them, the MIMO system using multiple antennas at both the transmitter and the receiver has a potential to increase the system capacity without extra bandwidth [15]. Multiple-Input Multiple-Output (MIMO) exploits spatial diversity by having several transmit and receive antennas. OFDM can be used in conjugation with a MIMO transceiver to increase the SNR gain and the system capacity by exploiting spatial domain [17]. In OFDM systems the data is divided into several parallel channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme at a low symbol rate maintaining total data rates similar to single carrier modulation scheme in the same bandwidth. OFDM transforms the frequency-selective fading channels into parallel flat fading sub channels, as long as the Cyclic Prefix (CP) inserted at the beginning of each OFDM symbol is longer than or equal to the channel length [18]. The signals on each subcarrier can be easily detected by a time-domain or frequency-domain equalizer.

## 3.1MIMO-OFDM Model

A MIMO-OFDM system with P transmit antennas and M receive antennas is presented in Figure 3.1. To achieve a high throughput, spatial multiplexing is applied, and independent data streams are transmitted through different antennas. Before transmission, each data stream is modulated by an N-point IDFT, and a CP with length of $L_{cp}$ is inserted at the beginning of each OFDM symbol. Let the $i^{th}$ block signal from the $p^{th}$ transmit antenna before OFDM modulation be

$$\beta_{i,p} = \left[\beta_{i,p}[0]\beta_{i,p}[1]---\beta_{i,p}[N-1]\right]^T \quad \mathrm{p} \in \{1,2,....,p\} \tag{3.4.1}$$

This is the frequency-domain signal vector [3]. Here, the frequency-domain signal is assumed to be white with zero mean and unit variance. Performing N-point IDFT, the so-called time-domain signal vector is generated as:

$$b_{i,p} = \left[b_{i,p}[0]\ \mathrm{b}_{i,p}[1]\ ---\mathrm{b}_{i,p}[N-1]\right]^T = F_N * \beta_{i,p} \tag{3.4.2}$$

where $F_N$ is an N × N IDFT matrix. After the CP insertion, the transmitted $i^{th}$ OFDM symbol from the $p^{th}$ transmit antenna is:

$$S_{i,p} = \left[S_{i,p}[0]\ \mathrm{S}_{i,p}[1]\ ----\mathrm{S}_{i,p}[N'-1]\right]^T \qquad \mathrm{N'=N+L}_{CP} \tag{3.4.3}$$

$$S_{i,p}[n] = \begin{cases} b_{i,p}\left[n-L_{cp}+N\right], & 0 \le \mathrm{n} \le \mathrm{L}_{cp}-1 \\ b_{i,p}\left[n-L_{cp}\right], & \mathrm{L}_{cp} \le n \le N'-1 \end{cases} \tag{3.4.4}$$

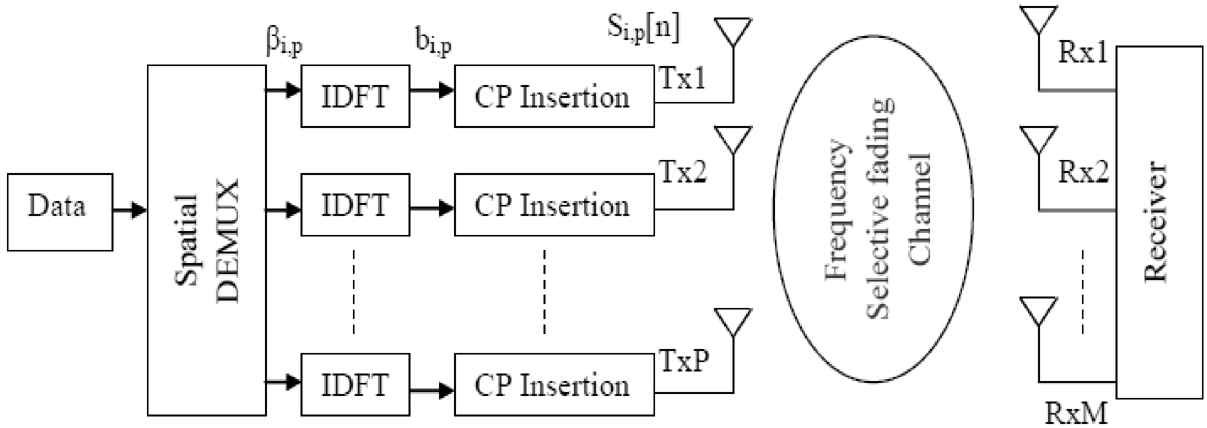


Figure 3.1: MIMO-OFDM system model

Each OFDM symbol is then simultaneously transmitted over quasi-static frequency-selective fading MIMO channels. Generally, the frequency-selective fading channel is modeled as an L-tap FIR filter, so that the M × 1 sampled received signal vector in the $i^{th}$ received OFDM symbol is written as:

$$y_i[n] = \sum_{p=1}^{p}\sum_{l=0}^{L} h_p(l) * S_{i,p}[n] + w_i[n], \qquad \text{n=0,1,....,N-1.} \qquad (3.4.5)$$

Where $h_p(l)$ is an M × 1 channel response vector; $w_i[n]$ represents the M × 1 additive noise vector; and $s_{i,p}[n] = s_{(i-1)}[N+n]$ when n < 0, and $s_{i,p}[n] = s_{(i+1)}[n-N']$ when $N' \le n$. Without loss of generality, the channel length is assumed to be far less than the number of subcarriers in one OFDM symbol, i.e., L<< N. The noise is assumed to be independent of the transmitted signals $s_{i,p}[n]$ and is independently identically distributed complex Gaussian with zero mean and variance $\sigma^2$ [31].

Similarly to [C], the CP is not discarded, and 'N' sampled received signal vectors are collected at the receiver as:

$$y_i^{(k)} = \left[ y_i[-k]^T \quad \mathrm{y}_i[-k]^T \quad ...\mathrm{y}_i[N'-1-k]^T \right]^T \qquad \text{k=0,}\pm1,\pm2,... \qquad (3.4.6)$$

where, $y_i[n]$ corresponds to the signal vector at the $(i-1)^{th}$ received OFDM symbol and is equal to $y_{i-1}[n+N']$ when n<0, whereas it corresponds to the signal at the $(i+1)^{th}$ received OFDM symbol and is equal to $y_{i+1}[n-N']$ when $N' \le n$. In fact, the received signal vector $y_i^{(k)}$ corresponds to the $i^{th}$ received OFDM symbol shifted by k samples and can be expressed as:

$$y_i^{(k)} = H * X_i^{(k)} + w_i^{(k)} \qquad \text{k=0,}\pm1,\pm2,... \qquad (3.4.7)$$

where H, $X_i^{(k)}$ and $w_i^{(k)}$ are given in, shown at the bottom of the page. Here, the channel matrix H is assumed to be of full column rank after removing all-zero columns. This assumption is a sufficient condition to detect the time-domain signals based on the Second Order Statistics (SOS) of the received signal vector $y_i^{(k)}$ [34, 35] and is generally consistent with real situations [11].

## 3.2 APPLICATIONS OF OFDM

- DAB - OFDM forms the basis for the Digital Audio Broadcasting (DAB) standard in the European market and for the global ADSL (Asymmetric Digital Subscriber Line) standard.
- ADSL - OFDM forms the basis for the Wireless Local Area Networks - development is ongoing for wireless point-to-point and point-to-multipoint configurations using OFDM technology.

## IV. SIMULATION RESULTS

The IEEE 802.11n system was introduced with an aim to achieve high data rates with less bandwidth, replacing the 802.11a and 802.11g systems. Although 802.11n system achieved high data rates but it still faces problems due to various parameters such as channel errors. The main goal of this chapter is to analyze the performance of various detection techniques and implement V-Blast algorithm on them so that high speed receivers can be implemented.

### 4.1 System Model and its Simulation

The simulation model used for the performance evaluation is discussed here. The performance of the various detection techniques along with V-Blast are analyzed and compared on the basis of BER/SNR. The MIMO-OFDM system considered here consist of 2 TX and 2 RX antennas $\left(N_t = 2, N_r = 2\right)$. The incoming signal bits are multiplexed and then modulated with BPSK modulation [36]. The modulated signal is processed through inverse discreet Fourier transform (IDFT) to insert a cyclic prefix and convert it to a radio frequency and then transmit through channel [20].

At the receiver end, the signal is received through $N_R$ antennas and processed through discreet Fourier transform (DFT) and then passed through V-BLAST detector. The received signal is passed through DFT to convert it to frequency domain. Hence the equation of received signal at first antenna is,

$$y_1 = [h_{1,1} h_{1,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \qquad (1)$$

and the received signal at the second receive antenna will be,

$$y_2 = [h_{2,1} h_{2,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \qquad (2)$$

So, the equivalent equation for the received signal can be written as,

$$y = Hx + n \qquad (3)$$

where x denotes the transmitted signal and n denotes the additive white Gaussian noise(AWGN) added to the signal.

The wideband MIMO channel is converted into a set of N parallel narrow band channels from (3). Now the receiver obtains the transmitted signal from the received signal. The block diagram of the system under consideration is shown in figure(5.6.1).

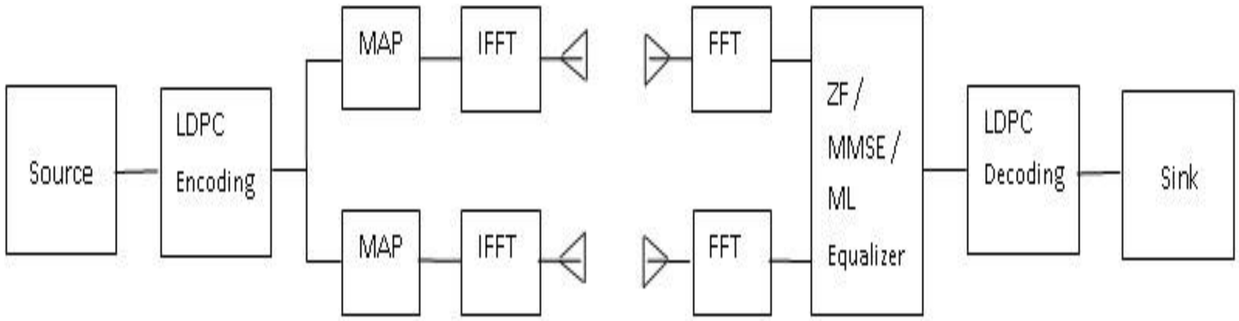


Fig 4.1: Block diagram of a 2X2 MIMO-OFDM system under consideration

## **V.**RESULSTS AND DISCUSSIONS

The performance of all modulation techniques is compared for a 2X2 MIMO-OFDM system on the basis of BER/SNR. The simulation results are shown in figure 5.1.1. As it is clear from the figures, the performance of BPSK modulation is best on the basis of BER but its efficiency is less because less information is contained in the same bandwidth in which the higher level modulations send more data but with less accuracy. Therefore if more accurate system is required then BPSK will be preferred and if more efficient system is required then QAM64 will be preferred.

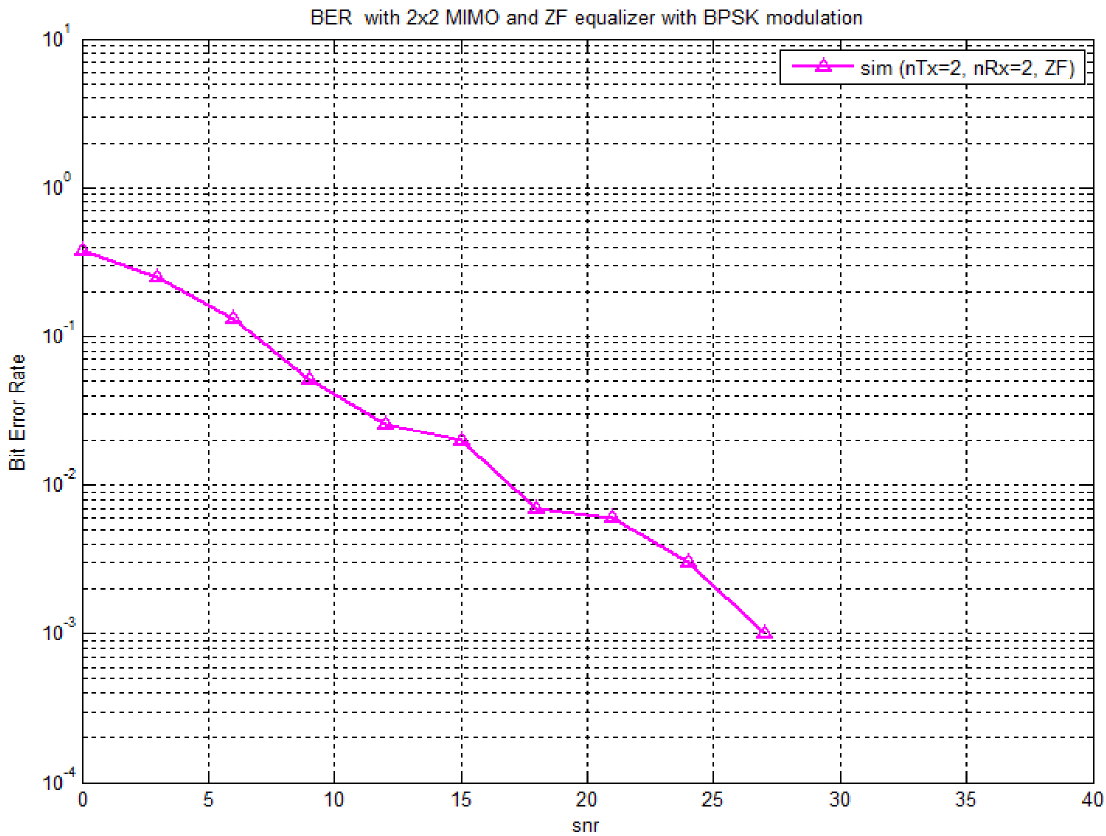


Figure 5.1.1: BER/SNR for ZF equalizer with BPSK modulation.

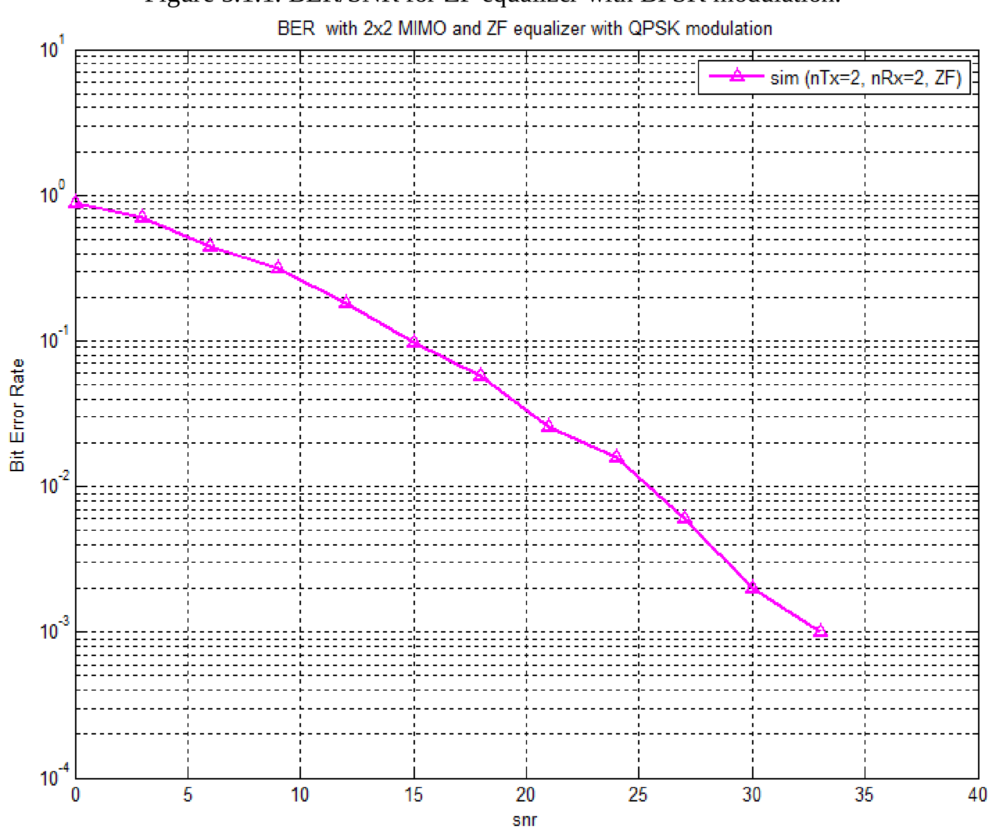


Figure 5.1.2: BER/SNR for ZF equalizer with QPSK modulation.

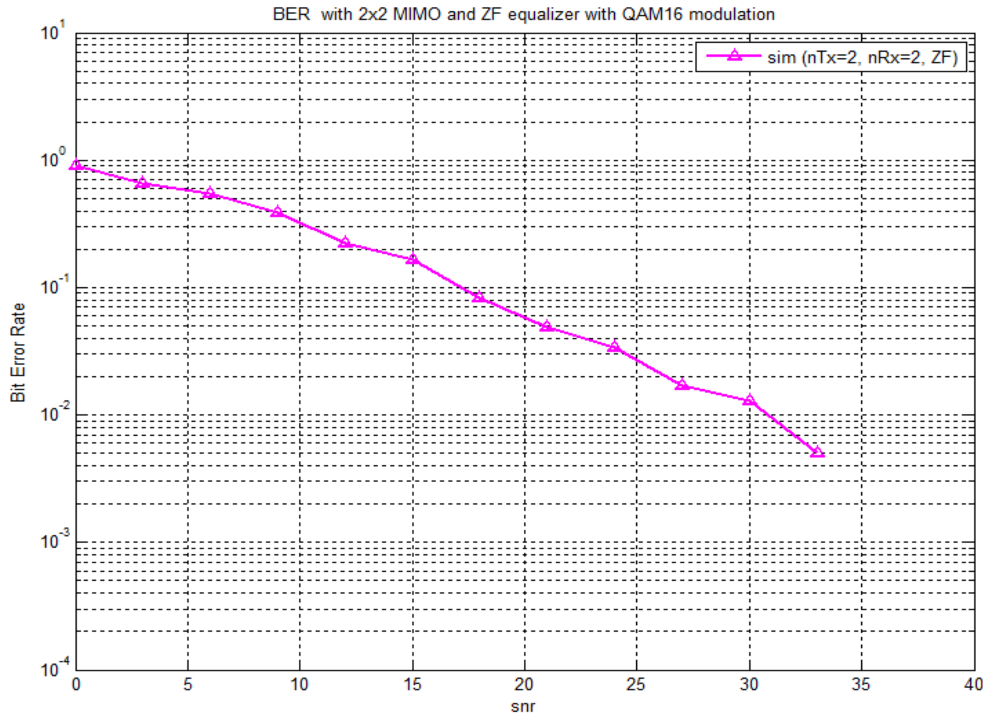


Figure 5.1.3: BER/SNR for ZF equalizer with QAM16 modulation.

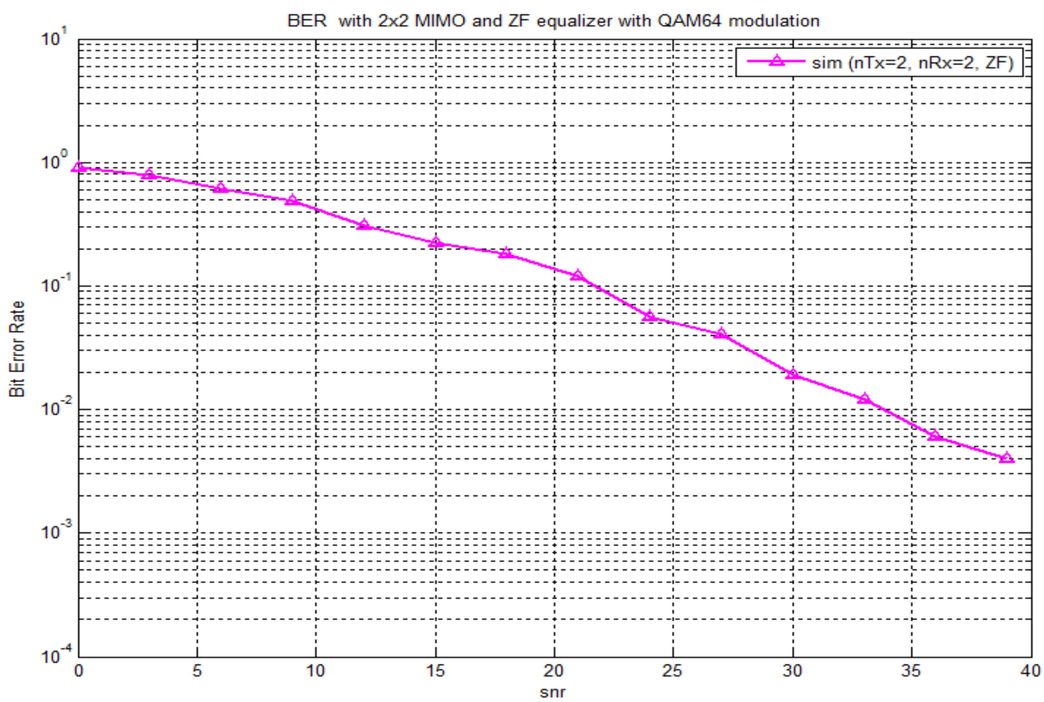


Figure5.1.4: BER/SNR for ZF equalizer with QAM64 modulation.

Figure 5.1.1-4 shows the BER performance for a ZF equalizer with coded MIMO-OFDM system under various modulations. As the figures show, the BER decreases with the increase in SNR. Hence if the SNR is low then we will have to use a modulation with lower BER so that the results are accurate.

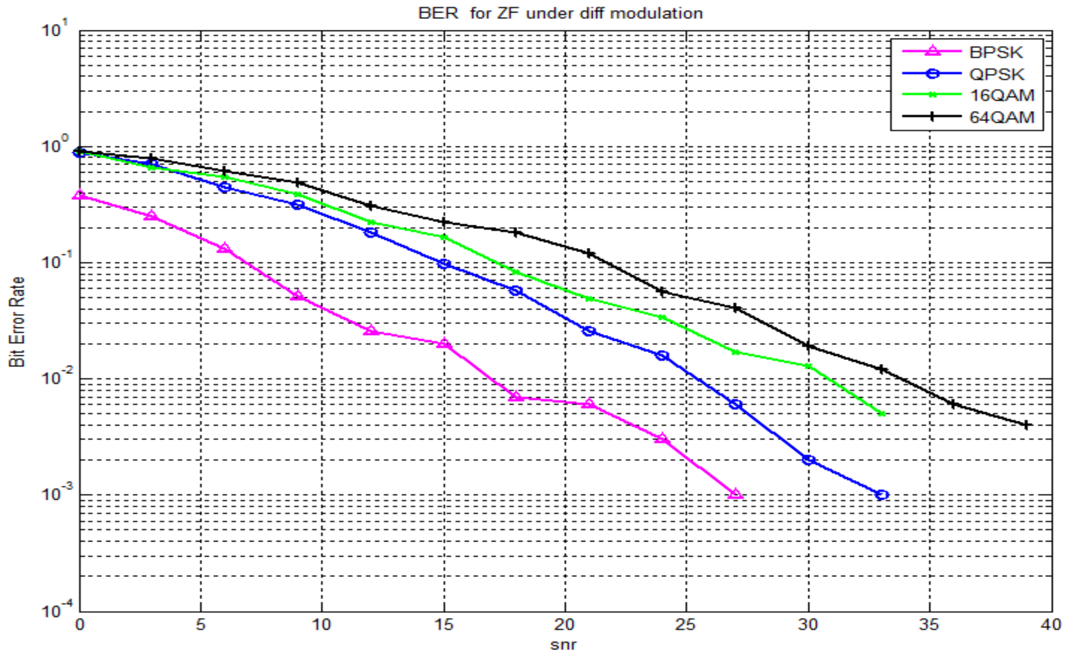


Figure 5.1.5: BER/SNR for ZF equalizer with various modulations.

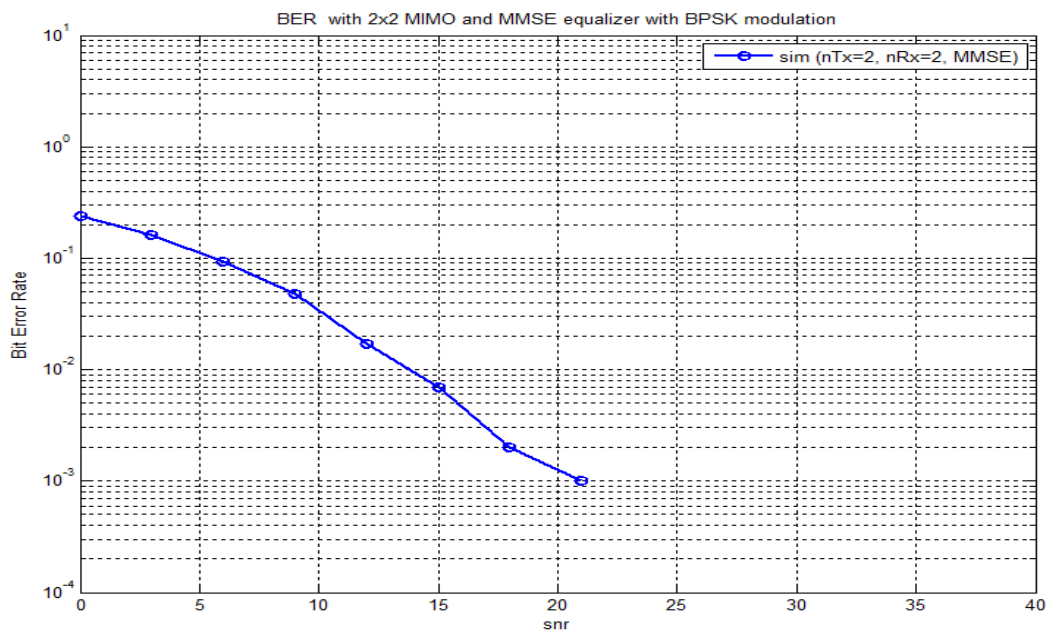


Figure 5.1.6: BER/SNR for MMSE equalizer with BPSK modulation.

Figure 5.1.5 shows the BER comparison of various modulation techniques with ZF equalizer. As it is evident from the figure, BER for BPSK is least for a given SNR, i.e. the chances of error in BPSK are least. And as the SNR is increased BER decreases, so if we want to use higher order modulation techniques then we will need to use higher SNR for accuracy along with efficiency.

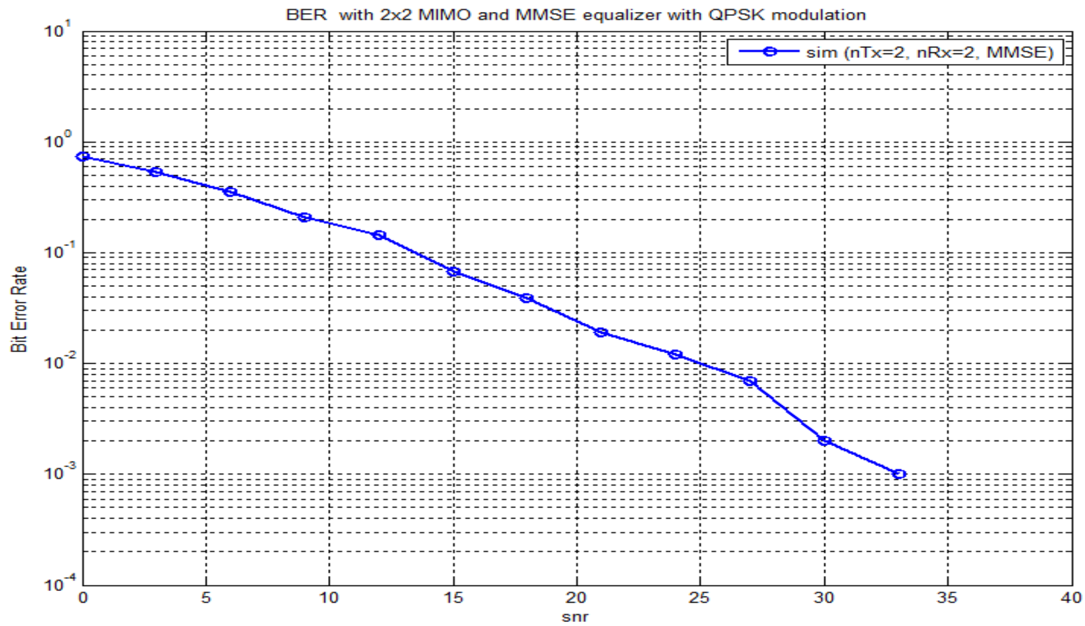


Figure 5.1.7: BER/SNR for MMSE equalizer with QPSK modulation.

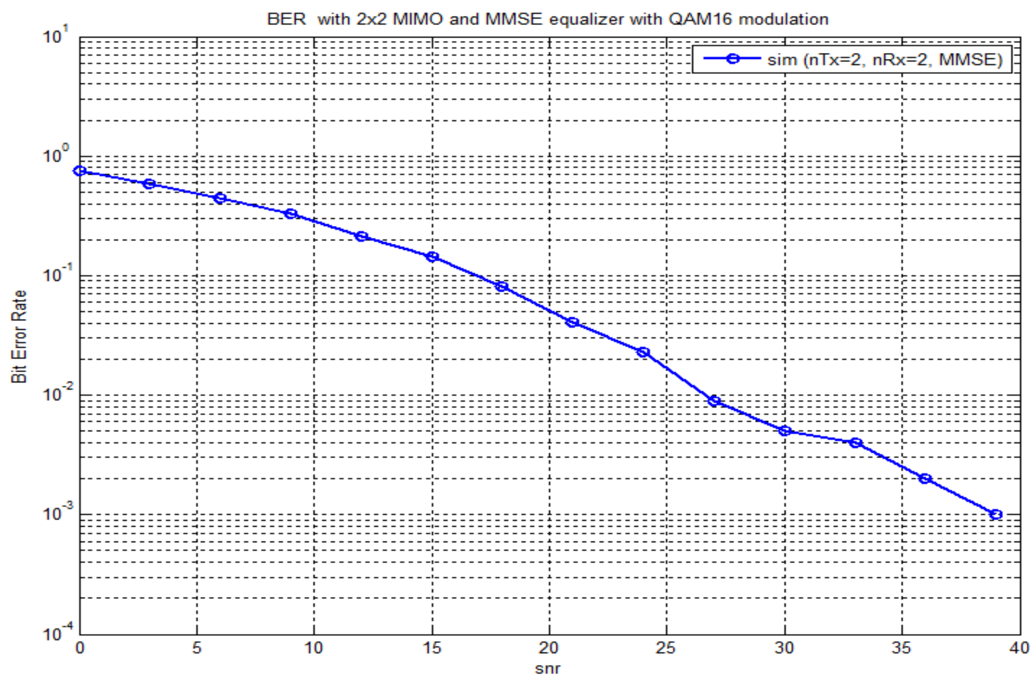


Figure 5.1.8: BER/SNR for MMSE equalizer with QAM16 modulation.

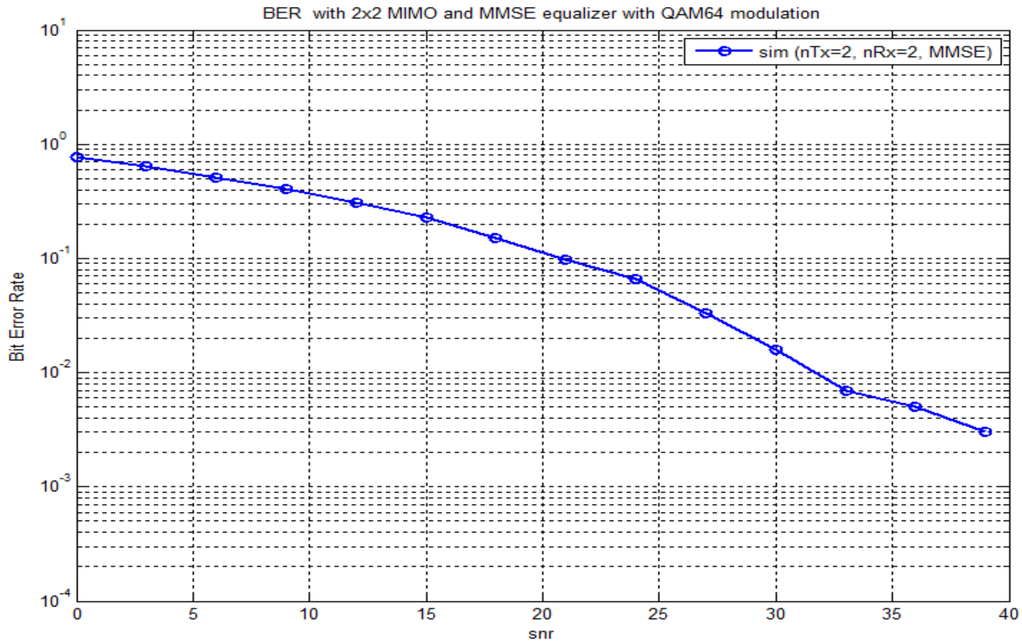


Figure 5.1.9: BER/SNR for MMSE equalizer with QAM64 modulation.

Figure 5.1.9 shows the BER performance for an MMSE equalizer with MIMO-OFDM system under various modulation techniques. Here also the BER decreases with an increase in SNR so while using a higher order modulation technique we will have to make the SNR high so that the results are accurate.

## **VI.** CONCLUSIONS

In this paper a 2X2 MIMO-OFDM system is analyzed using various detection techniques and BER/SNR parameters were found out. These parameters are compared such that a less complex system with higher accuracy and efficiency can be designed. On the basis of its results various parameters of a MIMO-OFDM system can be found out for a particular requirement. Hence this work can be used as a reference for choosing a best suited MIMO-OFDM system for a particular task. In this work , the performance of MIMO-OFDM system is also analyzed with various modulation techniques which are the basic building blocks of modern digital communication. Hence this paper can also be used to compare between various modulations techniques in MIMO-OFDM communication. One can also make appropriate choice of a modulation technique which will best suit his requirements and also the favourable conditions for the system to work efficiently, on the basis of the given comparison.

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