Performance Analysis of MIMO-OFDM for Various Modulation Techniques over Different Fading Channels

Uthira Mohan, Harshavardan Tirupur Venugopal

Abstract:

Due to the escalation in number of users, the wireless systems require tremendously high data rates and high reliability to meet the expectation. MIMO – OFDM (Multiple input and Multiple Output-Orthogonal Frequency Division Multiplexing) is being considered as an optimum solution, considering the ability to serve large number of users with a high speed communication, utilizing the bandwidth proficiently. The Multi carrier modulation provides an advantage of reduction in inter symbol interference. The efficiency of this system is subjected to vary with the channel and modulation techniques. This project is used to obtain the efficiency in terms of the Bit Error Rate performance versus Signal to Noise Ratio. In addition it includes variations based on different channels i.e. AWGN (Additive white Gaussian Noise), Rayleigh, Rician fading channel and various modulation techniques i.e. BPSK, QPSK, M-PSK, D-BPSK, DQPSK, DPSK, QAM.

Keywords: BPSK, QPSK, M-PSK, D-BPSK, DQPSK, DPSK, QAM. , OFDM, MIMO-OFDM.

I. Introduction:

The quest for high data usage at a high speed transmission with extreme reliability is promptly aggregating in the modern world. The telecom providers witness this to be a dominant issue and are actively researching on an ideal solution. The OFDM is widespread over the decade and is one of the promising schemes. Its significance is prominent in areas such as reliability, robustness, frequency selective fading and provides ease of implementation.

In the recent years, the idea of using MIMO is protuberant as it uses multiple carrier technology. This uses multiple antennas at the transmitter as well as the receiver. The best received signal form a transmitter is chosen at the receiver. MIMO spreads the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) or to achieve a diversity gain that improves the link reliability (reduced fading).This thus provides high resolution and reliability. The fact that high data rate and high performance is necessary made wireless systems prefer MIMO to SISO (Single input Single Output).

The MIMO –OFDM pair is regarded favorable, by wireless communication systems operating with a narrow band spectrum. In order to implement this in physical networks , a number of modifications is needed which may include time and frequency domain synchronization, channel estimation and MIMO detection.

The goal of this project is to classify the MIMO OFDM systems based on their channel estimation and modulation techniques utilization. The modulation techniques BPSK, QPSK, M-PSK, D-

BPSK, DQPSK, DPSK, and QAM are implemented in AWGN, Rayleigh, Rician channels. The performance is measured with respect to Bit Error Rate and Signal to Noise Ratio and is implemented using MATLAB.

The rest is organized as MIMO – OFDM [II] which gives a picture of the implemented system followed by channels [III] and modulation techniques [IV]. This is followed by proposed work [V]. Which describes the different channel models and modulation schemes.

II. MIMO- OFDM

a. OFDM

OFDM is a multi-carrier transmission technology in which the frequency band is discrete into a number of sub channels. Usual multiplexing techniques involve a number of filters to prevent interference among the sub-carriers and the non – overlapping must be preserved with a minimum frequency separation. On the other hand, OFDM uses signal processing techniques which thus eliminates this issue moreover, the sub- carriers are orthogonal in nature eliminating the need of many filters.

An OFDM system consists of a transmitter and a receiver. The signal is mapped in to a suitable constellation by the different modulation techniques. This serial data is then converted into parallel data stream, to which ofdm is performed. It consists of N sub carriers which carries the symbols. An OFDM transmitter involves an IFFT block.

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

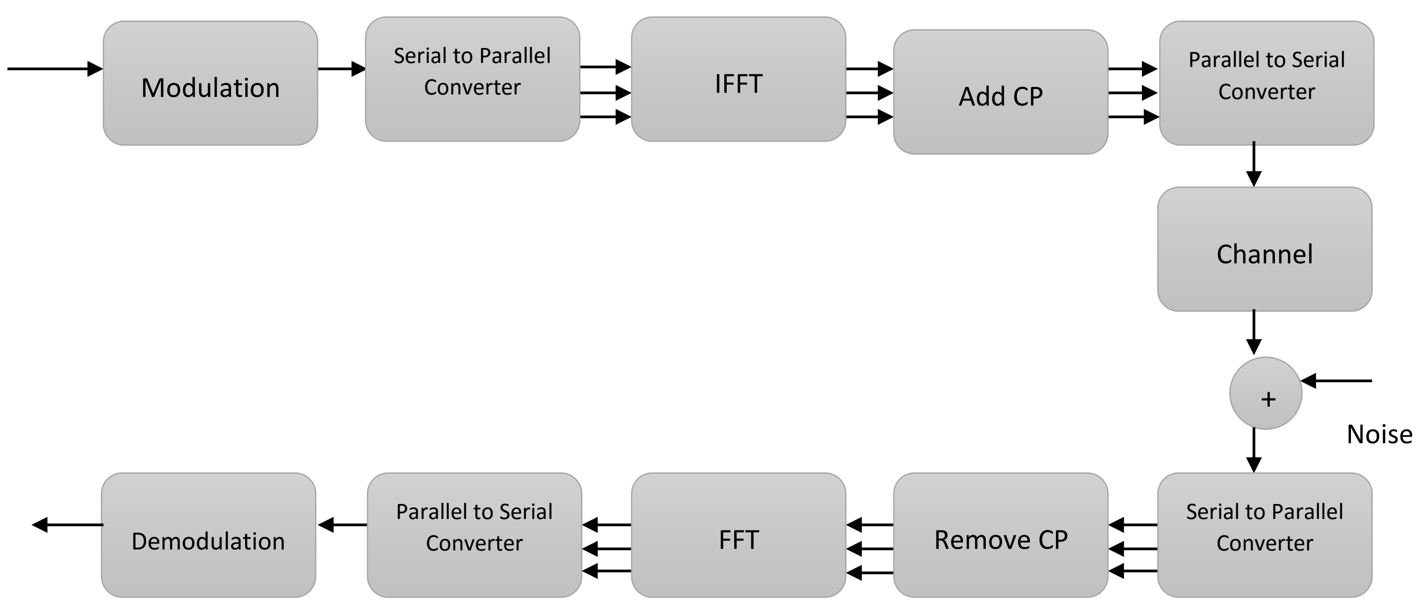


Fig1. OFDM MODEL

Cyclic prefix is added to the output to reduce ISI. This is then processed to a serial output which is passed through the corresponding channel.

At the receiver the data is converted into parallel input and the cyclic prefix is removed. This is then subjected to FFT. The frequency domain signal in kth receiving subcarrier is expressed as

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

b. MIMO system model

Multiple antennas are present in both the transmitting and receiving end, thus ensures increased channel capacity. However, the capacity is limited to the correlation of the sub channels in non-scattering environments. A path / channel is established between each transmitting antenna and receiving antenna. The signal with highest efficiency at any receiver is taken. The MIMO is used in wireless networks, cellular networks, WiMAX. The proposed system is a combination of

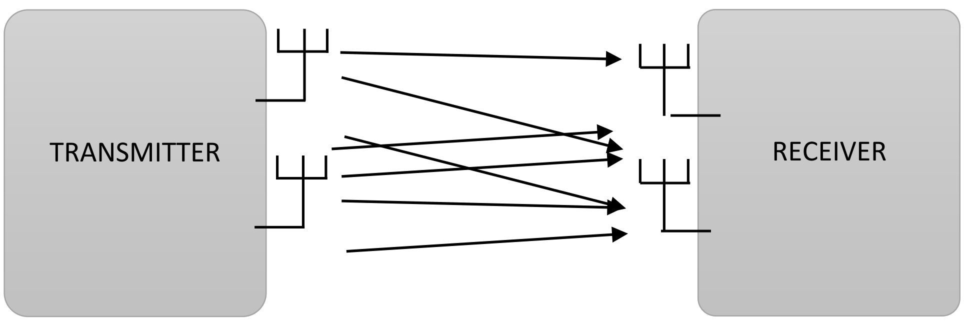


Fig.2 MIMO MODEL

c. **MIMO-OFDM**.

Thus the combination of the MIMO and the OFDM model can be represented as

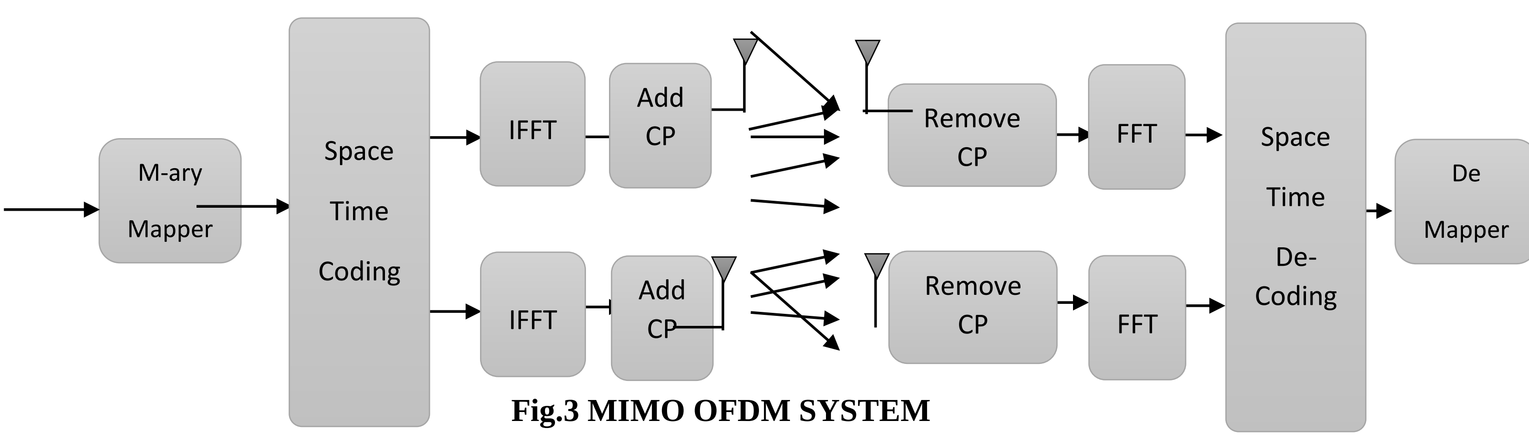


Fig.3 MIMO OFDM SYSTEM

III. CHANNELS

Wireless environments provides a challenging platform for maintaining good communication. The performance is mostly affected by fading (Multipath fading and motion induced fading).In a wireless communication channel, the signal can travel in more than one path in between the transmitter and receiver. The presence of multipath components in a transmission may have variant causes including atmospheric reflection or refraction, or due to reflections from other Interfering Objects (IO) like buildings, sub channels, etc. Generally, the multipath propagation, which involves a radio channel with several IOs and a moving receiver need to resort to statistical methods rather than a deterministic description of the radio channel which is proven to be less efficient. The statistical description of the radio channels is essential for wireless communication applications. The project features the characteristics of MIMO-OFDM over AWGN, Rayleigh and Rician Channels.

a. AWGN CHANNEL

Additive white Gaussian noise (AWGN) channel is widely used in analysis of different modulation schemes. The channel adds a white noise to the signal passing through it. The advantage of using this channel is the absence of Fading.

The received signal is expressed as:

R (t) = s (t) + n (t)

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

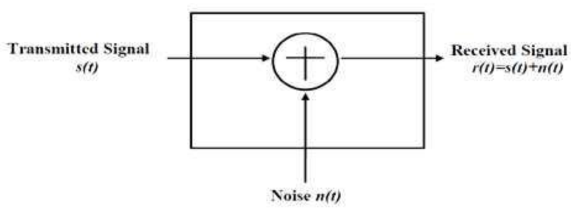


Fig.4 AWGN CHANNEL

b. RAYLEIGH CHANNEL

In a Rayleigh fading channel, the signal passing through the channel is distorted by a Rayleigh distribution .Multipath Reception is the root cause of Rayleigh Fading. The antennas receive a large number reflected and scattered waves. The effects of multipath causes constructive and destructive interference. Rayleigh fading is more accurate when there is a non-line of sight communication established between the transmitter and receiver.

c. RICIAN CHANNEL

In Rician fading Channel the amplitude gain is characterized by the Rician distribution. Here the channel involves a line of sight signal between the transmitter and the receiver. The Rician fading occurs when one of the received signal is stronger (typically line of sight component) is stronger when compared to the other.

IV. MODULATION TECHNIQUES

Modulation techniques play a significant role in wireless communications. It is a method of processing the data symbols to be transmitted in the carrier. Nowadays most of the wireless transmissions are in digital in nature and critical utilization of bandwidth is important. The type of modulation used plays a vital role in this step, where in the constellation determines the bandwidth usage. One of the goal of modulation, is to achieve maximum spectral efficiency (i.e.) squeeze as much data into the least amount of spectrum possible. Spectral efficiency measures how quickly data can be transmitted in an assigned bandwidth. The unit of measurement is bits per second per Hz (b/s/Hz). Multiple techniques have emerged to achieve and improve spectral efficiency. In this project we use BPSK, QPSK, M-PSK, D-BPSK, DQPSK, DPSK, and QAM

a. BPSK

The Binary shift keying has two message signals. In BPSK, the transmitted signal is a sinusoid of fixed amplitude. It has one fixed phase when the data is at one level and when the data is at the other level, phase is different by 180 degree. A Binary Phase Shift Keying (BPSK) signal can be defined as

$$\mathbf{v}_{\mathbf{BPSK}} = \pm\sqrt{\mathbf{2P}}\cos 2\pi \mathbf{f_c t} \qquad 0<t<T$$

Where **fc** *is* the carrier frequency, and *T* is the bit duration.

Signal power P= $A^2/2$, so that A = $(2P)^{1/2}$, where **A** represents the peak value of sinusoidal carrier. The bit error rate

$$P_b = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_o}}\right)$$

b. QPSK

QPSK (Quadrature Phase Shift Keying) is type of phase shift keying. QPSK is a modulation scheme which sends two bits of digital information a time (without the use of another carrier frequency).The amount of radio frequency spectrum required to transmit QPSK reliably is half that required for BPSK signals, which in turn makes room for more users on the channel.

Hence, the signal constellation consists of the signal-space 4 points

$$\pm\sqrt{E_s/2}, \pm\sqrt{E_s/2}$$

The factors of 1/2 indicate that the total power is split equally between the two carriers.

The Probability of error

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right)$$

The probability of symbol error

$$. 2Q\left(\sqrt{\frac{E_s}{N_o}}\right) - \left[Q\left(\sqrt{\frac{E_s}{N_o}}\right)\right]^2$$

c. QAM

Quadrature amplitude modulation (**QAM**) conveys the two digital bit streams, by changing (*modulating*) the amplitudes of two carrier waves, using the amplitude-shift keying(ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components. The modulated waves are summed, and the final waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK).In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. Arbitrarily high spectral efficiencies can be achieved with QAM by setting a suitable constellation size, limited only by the noise level and linearity of the communications channel.

The probability of error for a Rectangular QAM

$$P_{bc} = \frac{P_{sc}}{\frac{1}{2}k} = \frac{4}{k}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\sqrt{\frac{3k}{M-1}\frac{E_b}{N_o}}\right)$$

The probability of error for a Rectangular QAM

$$P_s < (M-1)Q\left(\sqrt{\frac{d_{min}^2}{2N_o}}\right)$$

d. M-PSK

A PSK could be constructed with any number of phases When more than 8 phases, the error-rate becomes too high and there are better, though more complex, modulations available such as quadrature amplitude modulation (QAM). The probability of error

$$P_s \approx 2Q\left(\sqrt{2\gamma_s} sin \frac{\pi}{M}\right)$$

$$P_b \approx \frac{1}{k} P_s$$

e. DPSK

Differential phase shift keying (DPSK) is a common form of phase modulation that conveys data by changing the phase of the carrier wave. The problem of the rotation of the constellation due to some effect is overcome by using the data to change rather than set the phase. In differentially encoded QPSK (DQPSK), the phase-shifts are 0°, 90°, 180°, −90° corresponding to data '00', '01', '11', '10'. This kind of encoding may be demodulated in the same way as for non-differential PSK but the phase ambiguities can be ignored. Thus, each received symbol is demodulated to one of the M points in the constellation and a comparator then computes the difference in phase between this received signal and the preceding one. The difference encodes the data as described above.

The probability of error

$$P_b = \frac{1}{2} e^{-E_b/N_o}$$

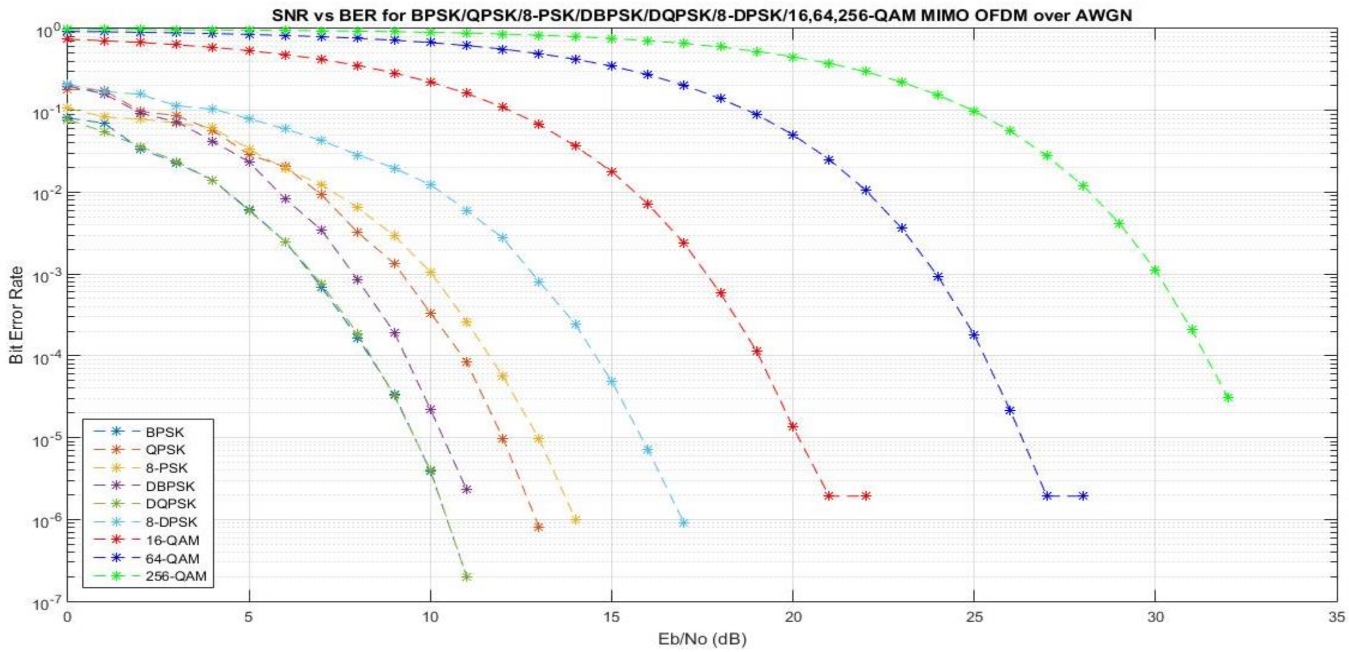
V. PROPOSED WORK

The implemented project involves MIMO-OFDM and a comparison in of different modulation schemes in various wireless channels. MIMO-OFDM is a combination of MIMO and OFDM. Thus multiple inputs and outputs are added to the orthogonal frequency division multiplexing. Here the elimination of ISI due to signal processing , apart from eliminating the inter-symbol interference also increases the spectral efficiency enabling more number of users to share the available bandwidth. The implementation is performed using MATLAB.

Properties:	**Values**
FFTLength	64
NumGuardBandCarriers	[6 ; 5]
InsertDCNull	True
PilotInputPort	True
CyclicPrefixLength	16
Windowing	False
NumSymbols	1
NumTransmitAntennas	2

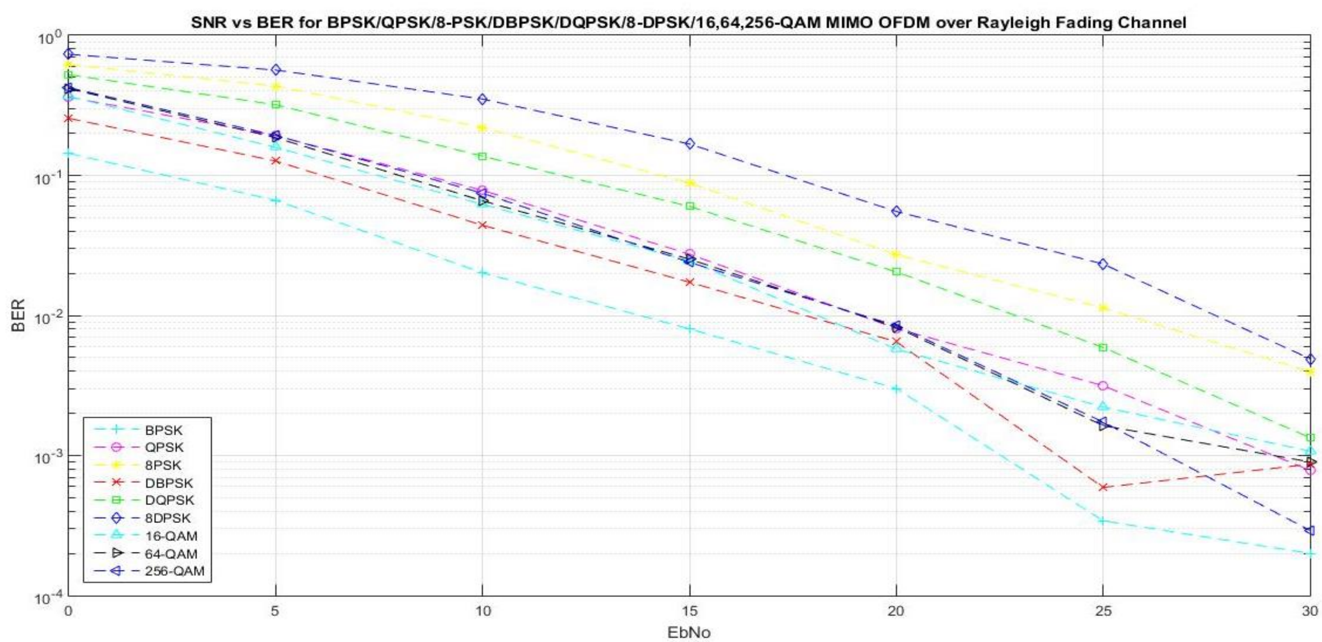
a. Comparison in AWGN

On applying different modulation schemes to the AWGN channel under MIMO- OFDM we observe the efficiency of the system. The simulation produces the plot of Bit Error Rate vs Signal to Noise ratio. The system with minimum bit error rate under even under low signal to ratio is considered to be efficiency. From the result it is shown that at any instant if SNR (eg. 10 dB) the bit error rate is minimum for 256 QAM and is maximum for DQPSK. On repeating the procedure for more modulation schemes, shall produce a clear idea on the efficiency, thus enabling to choose the most optimum scheme based on the requirement.



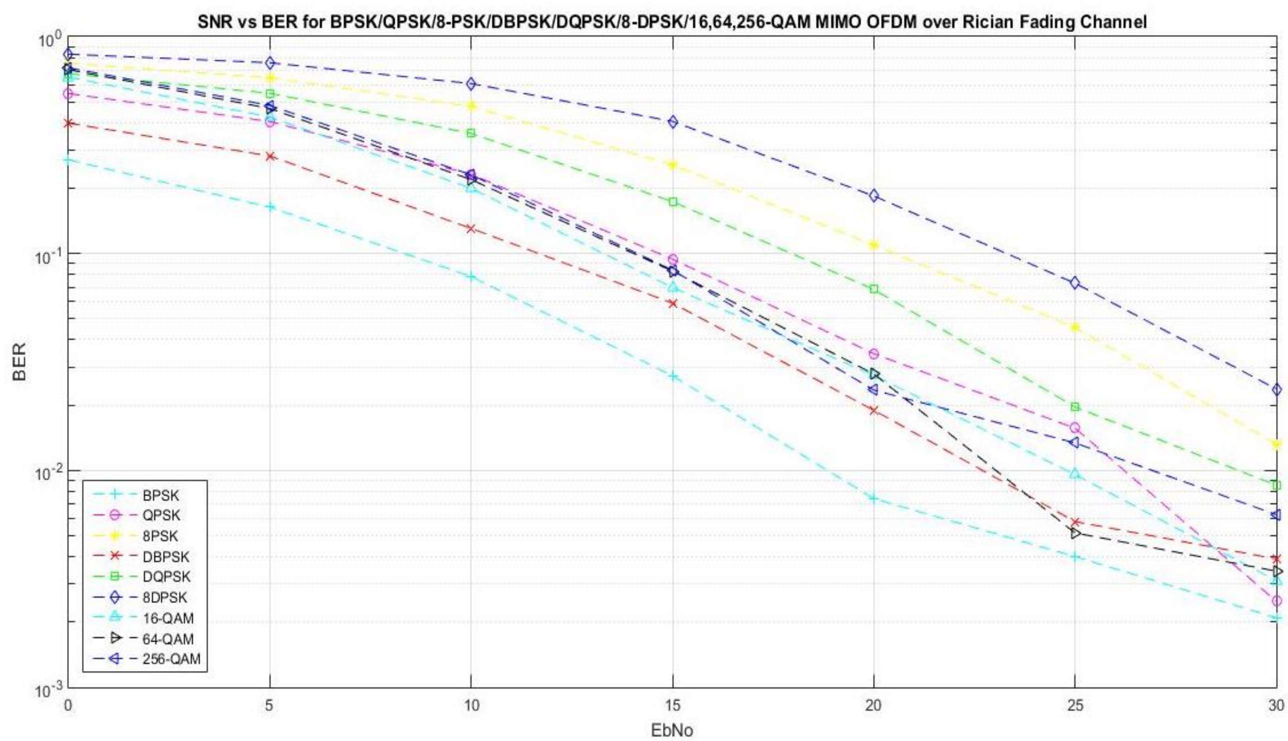
b. Comparison in Rayleigh

The similar procedure is applied to Rayleigh Channel retaining the same conditions. The efficiency which is obtained based on the simulation result (i.e.) Bit Error Rate vs Signal to Noise ratio aids in showing the most suitable modulation scheme based on the users requirement. The plot shows that the Bit Error Rate is minimum for 8 DPSK and is maximum for BPSK when plotted against SNR (eg. 10 dB). This result proves that the modulation efficiency varies with the channel as the result varies when compared to that of the AWGN channel.



c. **Comparison in Rician Fading Channel**

The below simulated output proves that the efficiency of 8 DPSK is higher when compared to the other considered modulation schemes under a Rayleigh fading channel. In the accounted modulation techniques for this channel the efficiency is observed to be lowest for the BPSK. Hence in order to accompany users with spectral efficiency and accuracy 8 DPQSK proves to be an optimum technique when compared to the other modulation schemes in this project.



VI. CONCLUSION

The goal of the project to obtain a performance analysis of different modulation schemes in AWGN, Rayleigh and Rician fading channel for a MIMO-OFDM system is satisfied. This helped in obtaining the efficiency of the modulation techniques in terms of accuracy or reliability by plotting Bit Error Rate against Signal to Noise for a modulation scheme. This could further be enhanced by applying more modulation schemes across different wireless communication channels on a MIMO- OFDM system.

VII. REFERENCES

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