# Hybrid Communication System using MIMO-OFDM

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**Abstract:**The enormous growth for Wireless broadband services and huge take up of mobile technology demands for higher data rate services.For a communication network to be successful only provisioning of high data rates alone is not sufficient, but also should provide wide coverage.Both satellite and terrestrial networks cannot guarantee this on their own. This incapability is attributed to capacity of coverage issues in densely populated areas for satellites and lack of infrastructure in rural areas for terrestrial networks.

Therefore hybrid architecture between terrestrial and satellite networks based on MIMO-OFDM with frequency reuse is employed here.In hybrid architecture, the users will be able to avail the services through the terrestrial networks as well as the satellite networks. The users located in urban areas will be served by the existing terrestrial mobile networks and similarly the one located in rural areas will be provided services through the satellite networks providing global connectivity. Andthe combination of multiple-input multiple-output (MIMO) signal processing with orthogonal frequency division multiplexing (OFDM) is regarded as a promising solution for enhancing the data rates of next-generation wireless communication systems.

However, this frequency reuse introduces severe co-channel interference (CCI) at the satellite end. To mitigate CCI, we propose an OFDM based adaptive beamformer implemented on-board the satellite with pilot reallocation at the transmitter side. The system performance is simulated by using the software MATLAB, the experimental result shows the efficiency MIMO-OFDM communication system.

Keywords: Adaptive beamforming, Co-channel interference (CCI), Multiple-input multiple-output (MIMO),Orthogonal frequency division multiplexing (OFDM).

section.

## 1. INTRODUCTION

In today's worldthe need for communication has driven the growing demand of multimedia services and the growth of Internet related contents lead to increasing interest to high speed communication with higher data rates. This has lead to the evolution of 4G [1] networks which will employ Orthogonal Frequency Division Multiplexing (OFDM) [2] at the physical layer. Similarly in parallel, Multiple Input Multiple Output (MIMO) [3–5] technology has emerged as the most significant breakthrough in modern communication providing higher capacity by utilising multiple antenna arrangements at both the transmitter and receiver side. The combination of OFDM with advanced antenna systems thus forms an intuitive and formidable solution towards higher capacity communication systems.

Success of a communication network does not only depend on provisioning of high data rates, but also on the coverage it can offer. Future networks also need to incorporate global connectivity to ensure a rich customer base. Standalone existing terrestrial mobile networks are unable to provide such coverage due to lack of infrastructure in rural areas. This is where satellite networks are favoured as they have the potential to offer true global coverage as well as rapid network deployment. However satellite links suffer from reduced signal penetration and capacity/coverage issues in urban areas as well as at lower elevation angles, hence the users located in urban areas are served by existing terrestrial system.

In order to deal with respective disadvantages of both satellite and terrestrial networks, a hybrid architecture based on OFDM system using MIMO is modeled and is presented in Fig 1. In this architecture the users located in rural areas are served directly from the satellite spot beam due to lack of infrastructure of terrestrial networks [2] [3]. On the other hand users located in urban areas are served by existing terrestrial system as satellite signal cannot penetrate in buildings [4]. Likewise, the spectrum is being shared between two networks that is terrestrial and satellite for providing throughout connectivity and the arrangement of multiple antennas at the transmitter and the receiver (MIMO) provide high data rates at reasonable cost.

Here the satellites in order to support a rich customer base by providing all time connectivity employs frequency reuse.However, this frequency reuse introduces severe co-channel interference (CCI) at the satellite end. To mitigate CCI, we propose an OFDM based adaptive beamformer implemented on-board the satellite with pilot reallocation at the transmitter side.

The rest of this paper is structured as follows: Section 2 gives the OFDM with MIMO. Section 3 describes the system model Section 4 presents Simulation results obtained using MATLAB and the results are discussed with reasons. Section 5 presents Conclusion and References are given in last section

## 2. MIMO in OFDM

All wireless links are affected by three common problems: speed, range and reliability. One parameter is interlinked with other by strict rules, i.e. no one parameter is independently achieved. Speed could be increased only by sacrificing range and reliability. Range could be extended at the expense of speed and reliability. And reliability could be improved by reducing speed and range. The improvement in parameter is obtained at the cost of the other two. [6]
But MIMO OFDM provides the 'all in one package" by providing the speed, range and reliability simultaneously.Nortel defines the OFDM-MIMO combination as (Herman, 2006) "With OFDM, a single channel within a spectrum band can be divided into multiple, smaller sub-signals that transmit information simultaneously without interference[7]. Because MIMO technology is able to link together many smaller antennas to work as one, it can receive and send these OFDM's multiple sub-signals in a way that allows the bandwidth to be substantially increased to each user as required".

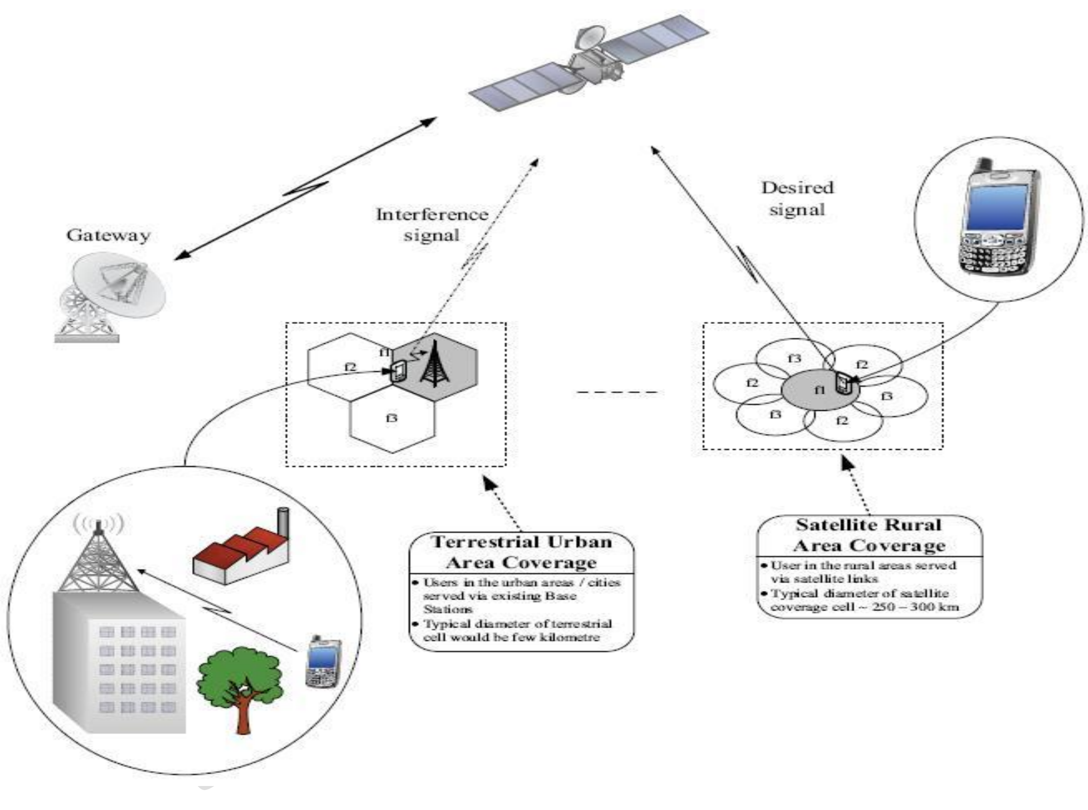


**Figure 1:** Hybrid System Scenario

OFDM is the technique used to mitigate the multipath propagation problem and MIMO is used for the efficient usage of spectral bandwidth thus combining these techniques results in wireless system that has best spectral coverage, reliable transmission in highly obstructive environment with higher data rates.

OFDM creates the slow time varying channel streams and MIMO has capacity of transmitting the signals over multiple channels by use of an array of antennas thus the combination of OFDM & MIMO can generate extremely beneficial results.

## 3. SYSTEM MODEL

The block diagram of MIMO-OFDM system model [1] is presented in Fig 2 respectively with the beamforming at the satellite end. The data generation block or source generates random data and sends it to the Modulator for modulation of the generated data according to the type of modulation scheme used. Here we are using both BPSK and QPSK and will analyse their performance. After modulation the pilot insertion takes place. Pilots are known data to the receiver which is used to estimate the channel [5]. Pilots can either be inserted with specific period uniformly between the data sequence [8]. Here in our data sequence five pilots have been inserted. After pilot insertion the mapped output of the data the in frequency domain of multiuser case is expressed as, taking one symbol at a time.

$$x_{(i,j)} = (x_{(1,j)}, x_{(2,j)}, \dots\dots, x_{(N,j)})^T \qquad (1)$$

Where $x_{(n,j)}$ shows the $n^{th}$ subcarrier of the $j^{th}$ user, where n = 1, 2, 3, . . . . , N and j = 1, 2, 3,…. , J and (.)T represents the transpose.Now the mapped data signal is in frequency domain is transformed into time domain by using IFFT.

$$x_j = F^H x_j \qquad (2)$$

Eq.2, is the time domain symbol of an OFDM system and F shows the matrix for FFT operation and (.)H shows the Hermitian transpose. After the transformation of signal from time domain to frequency domain, then comes the block of cyclic prefix extension to overcome the effect of ISI (Inter Symbol Interference) [9][10]. The guard interval is introduced using the following equation [11].

$$x_j = \int_N^{N,G} KF^H \qquad (3)$$

In (3), $\widetilde{x_j} = [x(N-G+1,j), x(N-G+2j), \dots, x(N-1,j), x(N,j), x(1,j), x(2,j), \dots, x(N,j)]^T$ is the OFDM symbol with the cyclic prefix of 1/4th of the symbol length and N,G in (3) is containing the last G rows of matrix IN, which is an identity matrix of size N. After this the parallel to serial converter (P/S) converts the data to serial form and readily transmits over the channel. Channel effect can be expressed as [11].

$$y_j = x_j N h_j k \qquad (4)$$

Where k is the index of time in (4), so passing through the channel, the signal is received by the receiver from the desired source and other sources of interference. In this paper the channel effect is not considered. When the signal is received at the satellite antenna element, the signal matrix for one OFDM symbol after removing the cyclic prefix can be represented [12]

$$V = AY^H + N \qquad (5)$$

In (5); A is the array response, Y is the received OFDM symbol and N is the noise. The important point to notice here

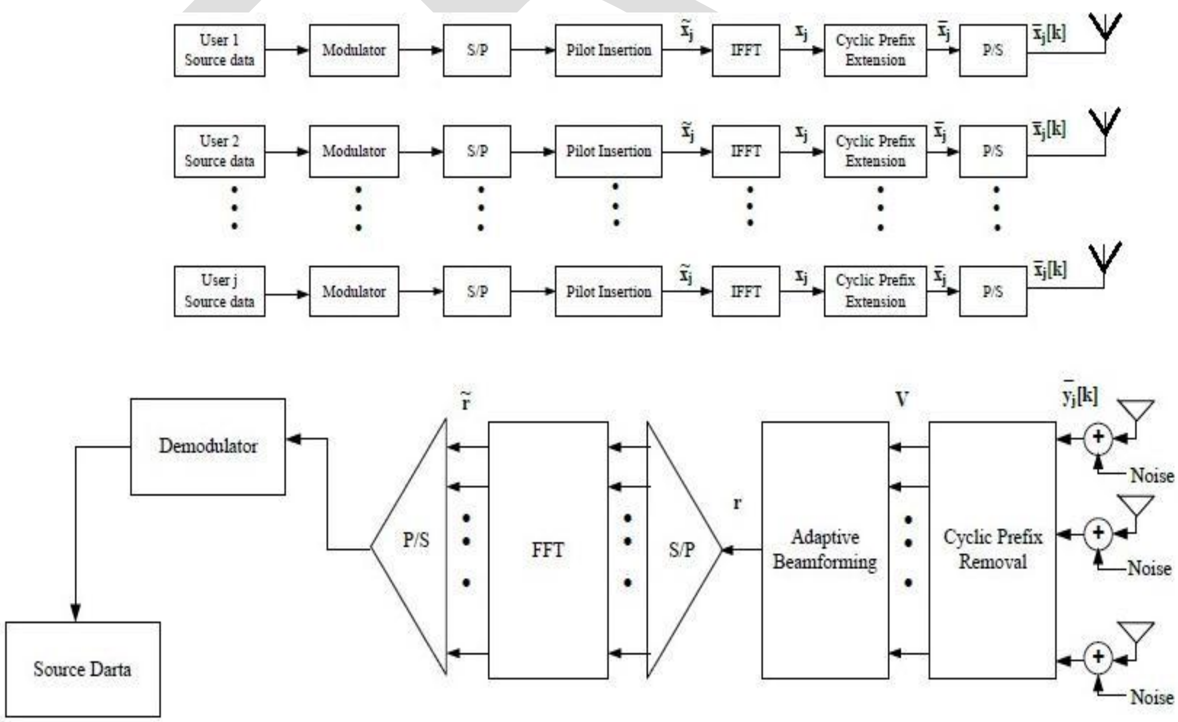


**Figure 2:** MIMO-OFDM System model

is that the beamformer will take one OFDM symbol at time so the noise for that one symbol will be randomly generated.

Similarly the received signal for $j^{th}$ user and $n^{th}$ subcarrier is given by y(j, n) i.e., is the element of Y matrix. Also n(s, n) and v(s, n) are the elements of matrix N and V respectively representing the noise and output of beamformer for $s^{th}$ antenna element and $n^{th}$ OFDM subcarrier and the element of A matrix which is the array response of $s^{th}$ antenna elements and $j^{th}$ user is given by(6).

$$a(s,j) = e^{j2\pi s}\lambda^{dsn\theta} \quad (6)$$

Where the total number of antenna elements are s = 1, 2, 3, . . . ,S. And the inter antenna element distance is given by d, and the direction of Arrival (DOA) for the $j^{th}$ user is given by $\theta_j$ and the carrier wavelength is given by λ. Since we have modelled the linear array so the distance between inter-elements is $d_a = \lambda/2$, the array response will be $e^{j2\pi s}\lambda^{dsn\theta}$

### 3.1. Adaptive Beamforming

Beamforming (BF) is a type of spatial filtering provided by a array of antenna elements to mitigate interference.Use of BF (spatial filtering) with array of antenna elements offers two principle advantages:

1) In view to the CCI problem, the capability of interference mitigation is directly proportional to the size (or length) of the spatial aperture. An array of antenna elements or sensors is able to synthesize a much larger spatial aperture as compared to a single physical antenna.

2) The more important advantage is that BF gives the ability to perform active signal suppression. This can be done by adaptively changing the spatial filtering functions to effectively track the desired user and mitigate the interference.

A beamformer is analogous to a Finite impulse response (FIR) filter in the sense that an FIR filter linearly combines temporally sampled data whereas a beamformer linearly combines spatially sampled data. Therefore, beamformer response can be defined as a function of location and frequency.

The beamformer processes the output of the antenna elements by applying complex weights to the symbols. The complex weights of the beamformer can only be considered as a constant value if the statistics of the signal at the input of the beamformer remain unchanged. In wireless communication systems, the users are not bound to a constant position. Moreover, users can be present in any location within the service region and hence weights cannot be hard-wired. Hence the beamformer should have the capability of changing its weights depending on the DOA of desired and interference signals. This requires computation of weights at frequent intervals and the subsequent class of BF is referred to as adaptive BF and this process is expressed as

$$r = w^H V \quad (7)$$

where r in (7) is termed as the weighted beamformer output and r = [r(1), r(2), . . . . , r(N)] and w is $[w(1), w(2), . . . . , w(N)]^T$ termed as complex weights. After the beamformer, the received data is applied to serial to parallel (S/P) converter and is converted into parallel sequence. Finally the obtained parallel sequence is converted into frequency domain by applying FFT.

$$r = Fr^H \quad (8)$$

In (8) $r=r_1, r_2, r_3,\ldots\ldots, r_N$ is the OFDM symbol received in frequency domain. In order to update the weight for the next symbol the beamformer takes the transmitted pilot sequence and also the pilots received using these pilots it calculates the error vector [12]. Depending upon this error vector, adaptive algorithm based upon Mean Square Error (MSE) computes the next weight for the next symbol[13][14]. The error vector is as shown below

$$e^p = r^p x_d^p \quad (9)$$

But the error vector obtained is in frequency domain while pre-FFT beamforming is done in time domain as said in the previous section. So there is a need to convert this error vector into time domain [15]. The transformation of error vector from frequency domain to time domain is expressed as below [16]

$$e_p = F_p^H e^{\sim p} \quad (10)$$

Here $e_p$ is the error in time domain $F_p$ is the IFFT which transforms the error vector from frequency domain to time domain.

After the process of error calculation, Least Mean Square (LMS) algorithm is implemented in order to update the beamformers complex weights [11][17]. Hence a new weight for the next symbol is calculated we repeat the process till all the weights for all the symbols are calculated and the desired data is extracted.

## 4. SIMULATION RESULTS

This section gives the simulation results generated from implementation of single and multiuser OFDM system

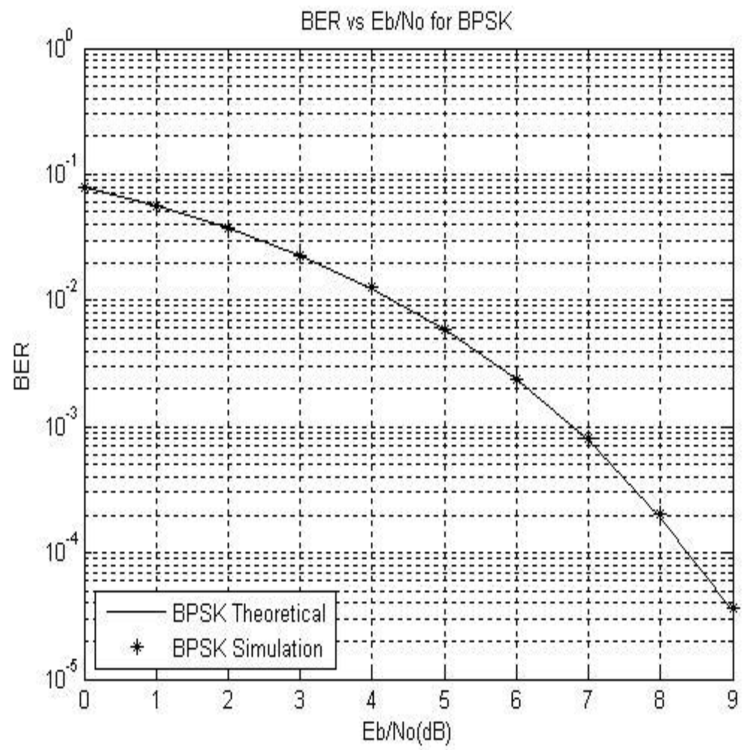


**Figure 3:** BER vs Eb/No for BPSK

Fig 3 shows the performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is working properly in BPSK

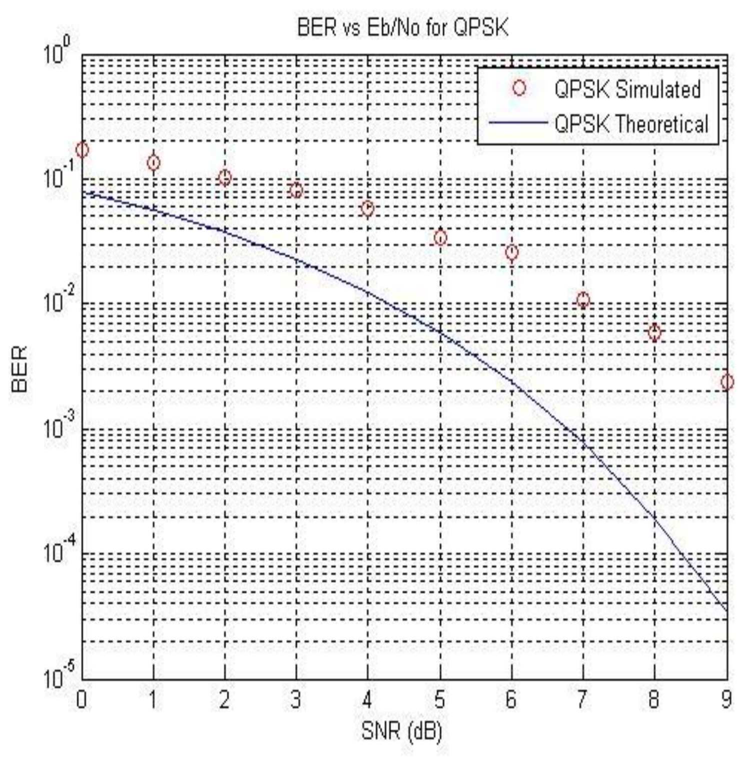


**Figure 4:** BER vs Eb/No for QPSK

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Fig 4shows the performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is working properly in QPSK

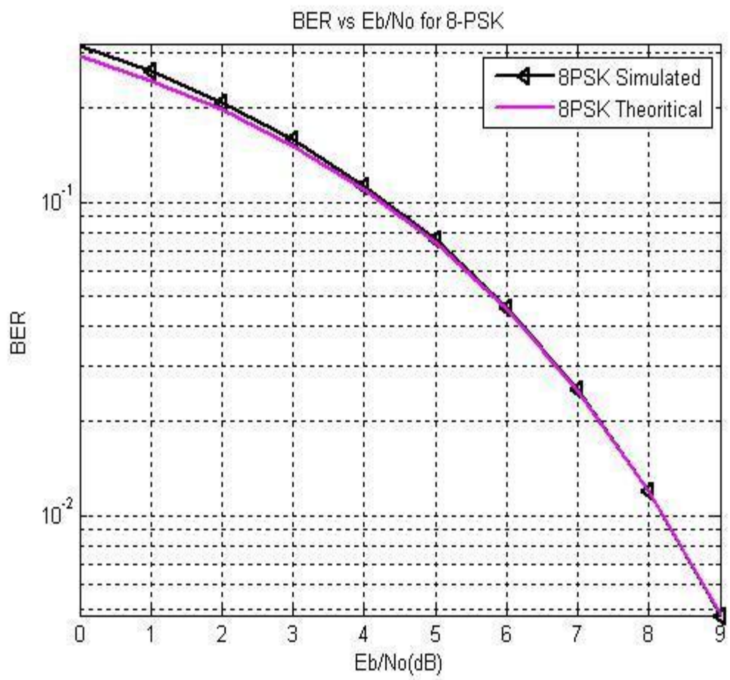


**Figure 5:** BER vs Eb/No for 8-PSK

Fig 5 shows the performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is working properly in 8-PSK.

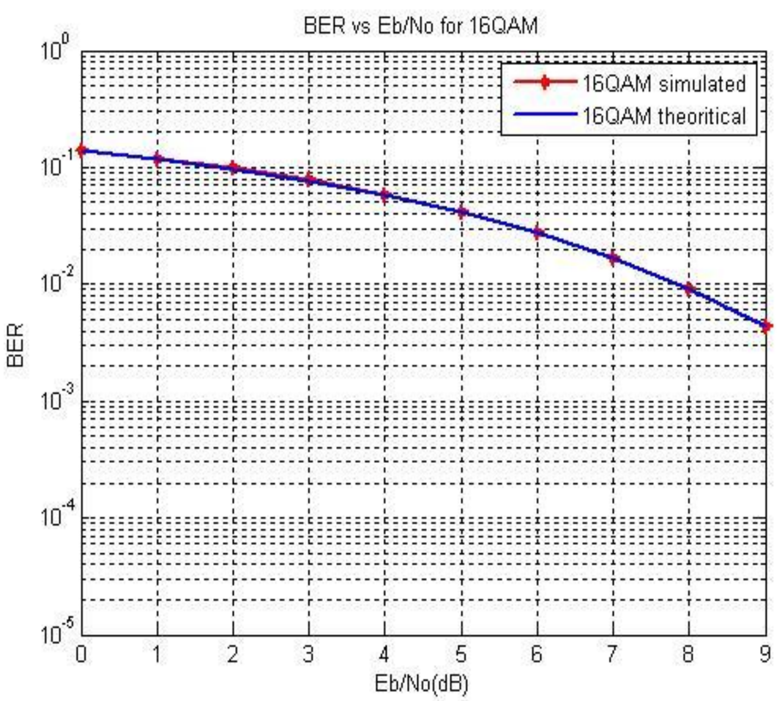


**Figure 6:** BER vs Eb/No for 16QAM

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Fig 6 shows the performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is working properly in 16QAM

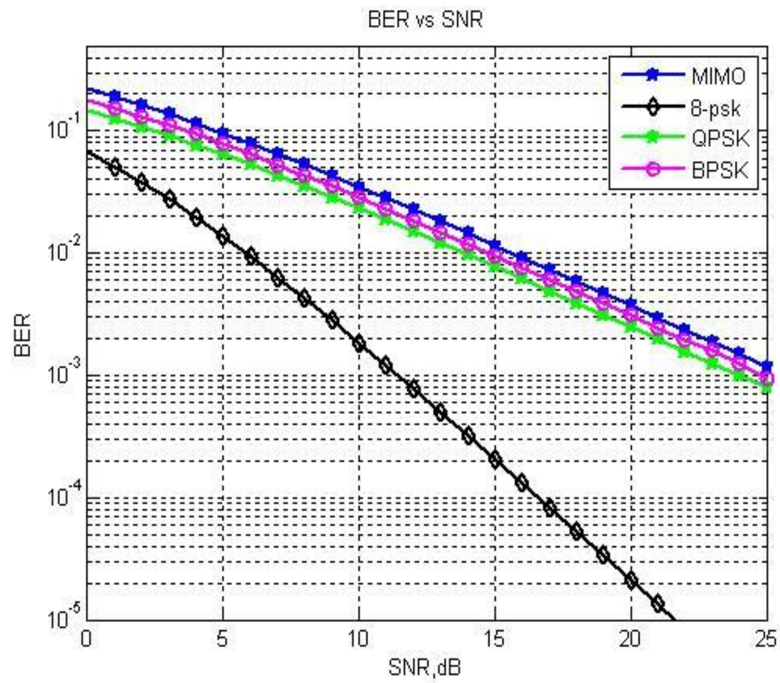


**Figure 7:**System performance vs desired user Eb/No for MIMO and M-PSK{M=2,4,8}

Performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is between 8-psk, QPSK, BPSK and MIMO where MIMO have least BER w.r.t SNR comparatively other methods.

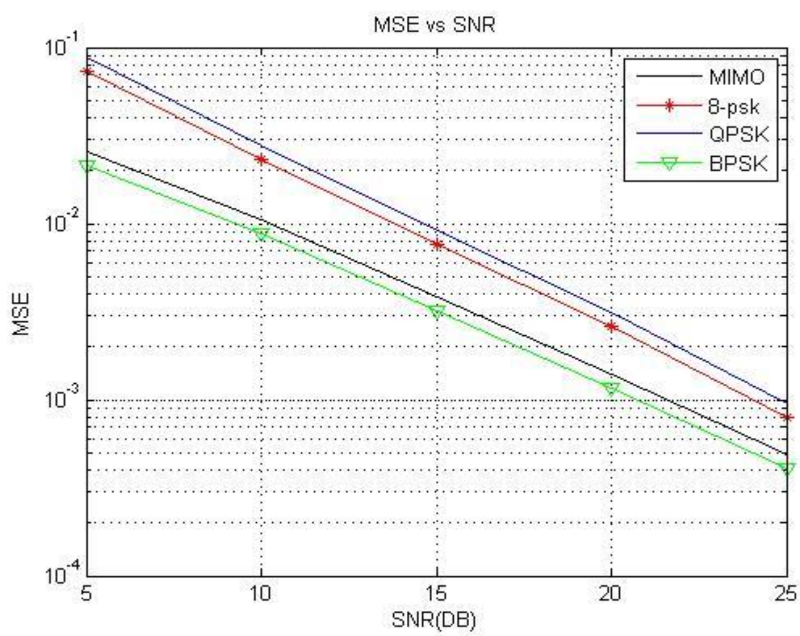


**Figure 8:** MSE vs SNR for MIMO and M-PSK{M=2,4,8}

Performance of the system in terms of BER and Eb/No. Simulated curve is plotted against the theoretical curve which proves that the OFDM system is between 8-psk, QPSK, BPSK and MIMO where MIMO have better means more MSE w.r.t SNR comparatively other methods

## 5. CONCLUSION

MIMO-OFDM is the solution to obtain significant higher data rates and increase range performance at the same time. This increases the link capacity by simultaneously transmitting multiple data streams using multiple transmit and receive antennas. It makes it possible to reach data rates that are several times larger than the current highest rate i.e., up to 54 Mbps.

With the introduction of MIMO-OFDM wireless LAN and the advent of the MIMO-OFDM based 802.11n standard, the performance of wireless LAN in terms of throughput and range is brought to a significantly higher level, enabling new applications outside the traditional wireless LAN area. Greater spectral efficiency translates into higher data rates, greater range, and an increased number of users, enhanced reliability, or any combination of the preceding factors. By multiplying spectral efficiency, MIMO-OFDM opens the door to a variety of new applications and enables more cost-effective implementation for existing applications

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