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MIMO-OFDM Techniques for Wireless Communication System: Performance Evaluation Review

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---ABSTRACT---

The use of multiple antennas in wireless communication systems has resulted in multiple channels that facilitate the speed of data transfer and improved channel capacity. This technique that basically involves multiple input and multiple output (MIMO) antennas helps to improve system performance by reducing bit error rate (BER) while increasing signal to noise ratio (SNR). Also, the use of orthogonal frequency division multiplexing (OFDM) has helped in mitigating inter-symbol interference (ISI). A combination of MIMO and OFDM produces the MIMO-OFDM scheme. This paper reviewed the performance of BER in MIMO-OFDM system considering various digital modulation techniques. An empirical review of previous studies on MIMO-OFDM system regarding BER performance evaluation was carried out. The study demonstrated the performance of digital modulation schemes in OFDM system with respect the Quadrature Amplitude Modulation (QAM). The results of the simulation based on MATLAB code revealed that lower order modulation yielded better BER performance than higher order. Furthermore,MIMO-OFDM system was modeled in MATLAB/Simulink and simulated to show that the use of multiple antennas at the transmitter and receiver helps in improving the performance of wireless communication system by reducing BER while increasing SNRconsidering two multipath channels – Rayleigh and Rician.

Keywords **-Bit error rate, MIMO, MIMO-OFDM, OFDM, Signal to noise ratio**

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I. INTRODUCTION

Communicating effectively over a large distance has been a challenge in wireless communication and the transition of modulation systems from analog to digital has further complicated the situations. Digital modulation schemes offer more information carrying capacity, better quality communication, data security and RF spectrum sharing to accommodate more services. Nevertheless, the implementation of digital modulation techniques like the Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK) comes with the different compromise. There is a tradeoff needed to be made between the available bandwidth and the number of bits/symbol that can be transmitted over the line, which in turn limits the maximum data rate on the link. Thus the selection of digital modulation techniques is absolutely critical, especially in an environment like the satellite uplink-downlink where resources are very limited and time slots are assigned at very high cost. The primary standards to determine modulation scheme depends on Bit Error Rate (BER), Signal to Noise Ratio (SNR), Available Bandwidth, Power efficiency, better Quality of Service(QoS), cost effectiveness. Hence, it is necessary to ascertain which modulation technique that is capable of transmitting more bits per symbol and is more immune to error caused by noise and interference induced in the channel.

The digital modulation technique is an indispensible module for transmitting and receiving information instead of analog modulation. Compared to analog modulation, the digital modulation has improved noise immunity and robustness to channel impairment. However, the transmission of audio or video signal requires more cost of bandwidth and need to have no loss of information at receiving end. Hence, it is very important and useful to analyze the performance of digital modulation schemes in wireless communication system.

One of the key determinant performance factors of wireless communication system is the Bit Error Rate (BER). Thus selecting the best modulation scheme that can transmit more data and offer low error rate will be economically worthwhile.

It is obvious that the advance in wireless technology for the purpose of achieving higher data rates as well as the expectation for high spectral efficiency has largely increased. Of course achieving these data rates requires cautious selection of multicarrier modulation scheme available. Hence, this necessitates the study focusing the performance of BER in MIMO-OFDM system considering different modulation schemes.

In this paper, the objective is to examine various studies that have been carried out to improve the performance of wireless communication system using Multiple Input Multiple Output (MIMO) combined with OFDM technique to improve BER.

II. DIGITAL MODULATION TECHNIQUE

Digital modulation concept involves varying one or more periodic waveform or carrier signal properties with a modulating signal that usually contains information to be transmitted. Modulation is carried out at the transmitter side of wireless communication system by a modulator. Then on the receiver side, the inverse of modulation is performed by a demodulator. The process of modulation and demodulation can be done by a single unit called modem. Digital modulation is designed to transfer a binary stream of data over an analog band pass channel, for instance, over the public switched telephone network (where the frequency range is limited by a band pass filter to 300-3400Hz) or over a limited radio frequency band pass [1].

A modulating structure is needed to transmit information over a communication channel. Among the various modulation methods are; amplitude modulation (data encoded by changing the amplitude of the signal), frequency modulation (data encoded by changing the frequency of the signal), and phase modulation (data encoded by changing the phase of the signal). The various digital modulation techniques considered in this paper are presented as follows.

2.1 Phase Shift Keying

The phase modulation offers many phase shift keying techniques such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Differential QPSK (DQPSK).

The BPSK (2bits) was developed during the early days of deep space program. PSK is now widely used in both military and commercial communication systems. The BPSK is more efficient of all digital modulation schemes [2, 3]. So BPSK is used for high bit rates with lower power efficiency. In binary phase shift keying, phase of the carrier waveform is variedaccording to the data bit to be transmitted. Besides, a bipolar non-return to zero (NRZ) signal is used to denote the digital data coming from the digital source [2, 4]. The coherent binary phase shift keying has one dimensional signal space with two message points, the input binary data in polar form with symbol '0' and ' with a constant amplitude level of $-\sqrt{E_b}$ and $\sqrt{E_b}$, (with E_b signifying the energy per Bit of the transmitted signal).

The QPSK modulation method is similar to the BPSK, which is characterized by the fact that the information carried by the transmitted wave is contained in phase. There two successive bits in a bit stream in QPSK modulation scheme. These bits combine to form a message and each message is characterized by a distinct value of phase shift of the carrier. With four phases, two bits per symbol can be encoded by QPSK. There are two parts (phases) that make up the QPSK signal, In-phase and Quadrature phase. The real part of the signal is the In-phase while the imaginary part of the signal is the Quadrature phase. Since QPSK is higher order PSK, its implementation is more complex than that of BPSK. In particular, in QPSK, the phase of the carrier takes on one of four equally spaced values, such as $\pi/4$, $3\pi/4$, $5\pi/4$ and $7\pi/4$.

The Differential QPSK (DQPSK) is developed from QPSK system but in the DQPSK the initial phase of modulated signal is effected by the initial phase of the previous modulated signal. The previous modulated signal in QPSK is assumed to have zero initial phase, but for the DQPSK, the initial phase of previous modulated signal is combined with initial phase of transmitted signal [5]. Just like in QPSK the pair of bits will modulate the carrier signal and determines the initial phase of modulated output signal.

2.2 Quadrature Amplitude Modulation

Quadrature Amplitude Modulation (QAM) has fast become the dominant modulation scheme for high speed digital signals [6]. From the wireless 802.11 protocols to ADSL modems to personal communicators for the military, QAM has become a necessary part of wireless communication system. QAM is a technique that combines two amplitude modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90degrees (one quarter of a cycle, from which the term quadrature arises). One signal is called the In-phase signal, and the other is called the Quadrature signal.

III. MIMO-OFDM TECHNIQUE

3.1 MIMO System

The technology of wireless communication system using different antenna configurations resulting in improved channel capacity has evolved with time as demand for better data rate/speed increases. Thus, Single Input Single Output (SISO) antenna system has been gradually modified to Single Input Multiple Output (SIMO) and Multiple Input Multiple Single (MISO) up to Multiple Input Multiple Output (MIMO) systems, which is the one with multiple antennas at transmitting end and multiple antennas at receiving end as well. In the middle of a transmitter and receiver, signal can go through many paths and if the antenna is moved a small distance, with the use of MIMO technology, the different paths available can be used to advantage. That is, employing MIMO, these additional paths can be used to advantage. They can be used to provide additional robustness to the radio link by improving the signal to noise ratio, or by increasing the link data capacity. MIMO systems often employs Spatial Multiplexing which enable signal to be transmitted across different spatial domains. A MIMO system can employ a transmit diversity scheme at the transmitter and a receive diversity at the receiver at the same time, allowing it to combine all the advantages offered by SIMO and MISO systems. Figure 1 shows a MIMO system. MIMO systems have a highest throughput when compared to the other types of wireless systems such as SISO, SIMO, and MISO.

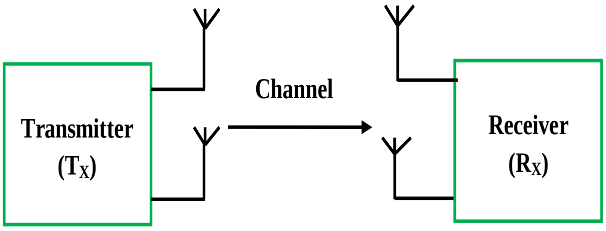

Figure 1 Illustration of MIMO system

In a MIMO system, data (x_1, x_2… x_N) are transmitted with N transmitting antenna arrays. The receiver is constructed of M (M>=N) antenna arrays. Let rj(j= 1, 2,…, M) represents the signal received by the j-th antenna (see Figure 2), then the signals received at the receiver can be represented as:

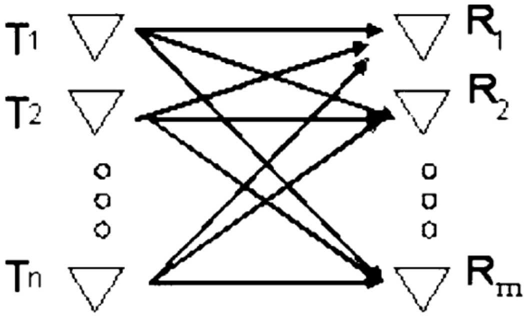

Figure 2 Basic MIMO structure

$$
\begin{aligned}
R_1 &= H_{11}X_1 + H_{12}X_2 + ... + H_{1N}X_N \\
R_2 &= H_{21}X_1 + H_{22}X_2 + ... + H_{2N}X_N \\
&\vdots \\
R_M &= H_{M1}X_1 + H_{M2}X_2 + ... + H_{MN}X_N
\end{aligned} \quad (1)
$$

wherehij is a weight coefficient that represents the impact of the **j**th transmitting signal xj on the jth receiver signal strength. We define a channel matrix H as:

$$
H = \begin{bmatrix} H_{11} & H_{12} & .... & H_{1N} \\ H_{21} & H_{22} & .... & H_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ H_{M1} & H_{M2} & \dots & H_{MN} \end{bmatrix} \quad (2)
$$

Therefore, in MIMO system, the transmitted signals $\{x_i\}$ can be recovered by estimating the channel matrix H and the receiving signal vector R.

MIMO system can provide two types of gains: diversity gain and spatial multiplexing gain. And in past work, it is known that there is a fundamental tradeoff between these two gains: higher spatial multiplexing gain comes at the price of sacrificing diversity [7].

Diversity is used in MIMO to combat channel fading. Since in MIMO each pair of transmitting and receiving antennas provides a signal path from the transmitter to the receiver and each path carry the same information simultaneously, the signal achieved in the receive antenna is more reliable and the fading can be effectively decreased. If the path gains between individual transmit–receive antenna pairs fade independently, in this case multiple parallel spatial channels are created. By transmitting independent information streams in parallel through the spatial channels, the data rate can be increased. This effect is also called spatial multiplexing [8].

So the benefit of diversity is lower error probability and the benefit of multiplexing is higher rate though the difference between them is that the requirement of diversity is sending the same information and the requirement of multiplexing is send independent information. Obviously, the conflicts between the two suggest fundamental tradeoff between benefits obtained from diversity and multiplexing.

In multiple input and single output systems, selection diversity selects the branch providing the largest magnitude of log-likelihood ratio (LLR). The LLR for BPSK signals in fading channels is found to be proportional to the product of the fading amplitude and the matched filter output after phase compensation [9].

Channel state includes statistics information such as fading amplitudes, phases and delay. In selection diversity technique, none of these channel information is required. Selection diversity uses one receiver antenna which greatly reduces the complexity of the wireless systems. Here, the receiver simply looks at the outputs from each fading channel and selects the one with the highest signal-to-noise ratio (SNR). In this case, the strongest signal is picked up and other signals that have undergone deep fades are unlikely to be picked by the receiver, which can avoid the deep fading effect. Therefore, the more the channels are, the more accurate the recovered would be. There is also no need for any

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addition of the fading channel outputs, which further decreases the complexity. Since Selection diversity does not require any knowledge of the phases, it is usually used in non-coherent or differential coherent modulation schemes. The structure of selection diversity is shown in Figure 3. The signals from the transmitter antenna are sent through multiple channels, selected by the detector system and finally received by the receive antenna.

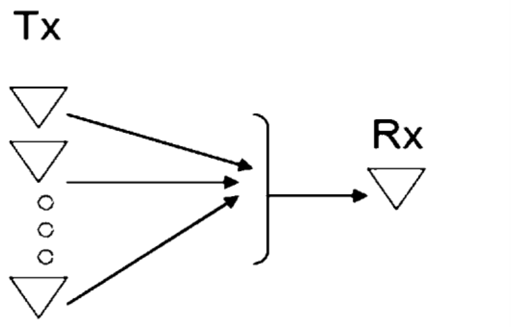

Figure 3Basic structure of transmit selection diversity

3.2 OFDM System

In Orthogonal Frequency Division Multiplexing (OFDM), a block of data is converted into a parallel form and mapped into each subcarrier in time domain. By transmitting the symbols in parallel, the interval between the signals becomes much larger and this effectively eliminates inter symbol interference in time dispersive channels. Inverse fast Fourier transformation (IFFT) is in turn used to transfer the signal from time domain to frequency domain. It takes in N symbols at one time where N is the number of subcarriers in the system. Each of these N input symbols has a period of T seconds. As we know, the basic functions for an IFFT are N orthogonal sinusoids. Each input symbol acts like a complex weight for the corresponding sinusoidal basis function. Since the input symbols are complex, the value of the symbol determines both the amplitude and phase of the sinusoid for that subcarrier. The IFFT output is the summation of all the N sinusoids. Thus, the IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. The block of N output samples from the IFFT make up a single OFDM symbol [10]. The basic structure of OFDM transmitter is shown in Figure 4.

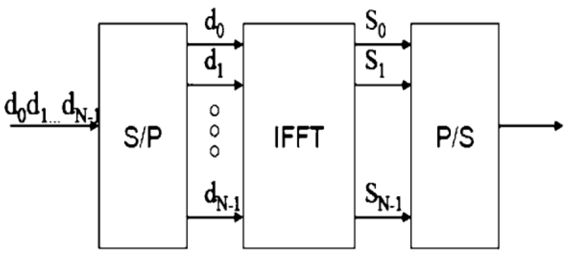

Figure 4 Basic Structure of OFDM transmitter system [9]

After transmitted through the channel (channel means the route through which the message is sent), when the frequency signals reach the receiver, the receiver has to perform Synchronization (both timing and frequency), Channel Estimation, Demodulation and Decoding. The data processing at receiver end reverses that at the transmitter side, that is, at the receiver, an FFT block is firstly used to transfer the received time-domain signal into frequency-domain. Ideally, the output of the FFT block should be identical to the transmitted symbols before the IFFT block. Assuming channel information is known, the symbols will be demodulated and estimated based on these channel information. The structure of OFDM receiver is shown in Figure 5. The basic structure of OFDM system is shown in Figure 6.

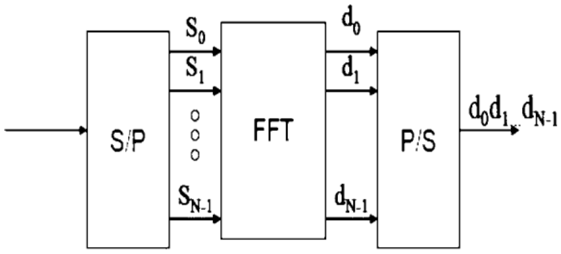

Figure 5 Basic structure of OFDM receiver system [9]

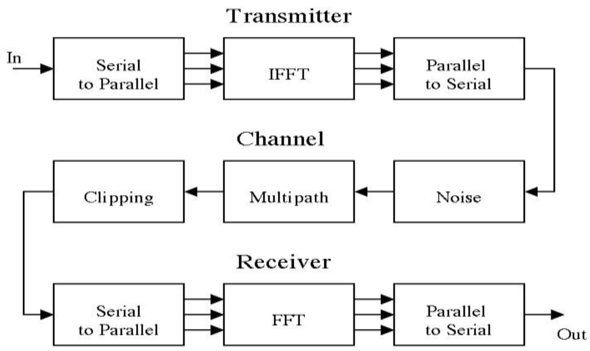

Figure 6 Block diagram of OFDM system [11]

When there are more than one transmission path between the transmitter and the receiver, or received signal is the sum of many versions of the transmitted signal with varying delay and attenuation, the multi-path effect occur, among which ISI effect is the most important. To reduce this effect, two methods are generally used in the OFDM scheme: parallel data transmission and cyclic prefix. Usually the length of the cyclic prefix is no shorter than the length of the channel's impulse response. The basic idea is to replicate part of the OFDM time-domain waveform from the back to the front to create a guard period. The duration of the guard period T_G should be longer than the worst-case delay spread of the target multi-path environment. In Figure 7, the structure of cyclic prefix is illustrated [12].

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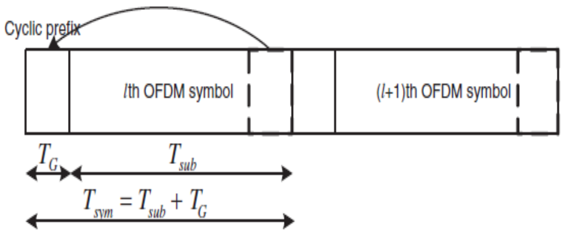

Figure 7 OFDM signal with cyclic prefix [13]

3.3 MIMO-OFDM System

Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is a technology that combines MIMO and OFDM together to transmit data in wireless communications in order to deal with frequency selective channel effect. The OFDM signal on each subcarrier can overcome narrowband fading; therefore, OFDM can transform frequency-selective fading channels into parallel flat ones. Then by combining MIMO and OFDM technology together, MIMO algorithms can be applied in broadband transmission.

A MIMO-OFDM system transmits data modulated by OFDM from multiple antennas simultaneously. At the receiver, after OFDM demodulation, the signal are recovered by decoding each the sub-channels from all the transmit antennas [14]. MIMO OFDM will allow service providers to deploy a Broadband Wireless Access (BWA) system that has Non-Line-of-Sight (NLOS) functionality. Specifically, MIMO-OFDM takes advantage of the multipath properties of environments using base station antennas that do not have LOS. By combining both techniques, MIMO-OFDM can offer both robustness and high throughput. In a multiuser scenario where many users communicate with a central station (base station or access point), MIMO-OFDM becomes even more appealing because it provides an additional opportunity to exploit due to many users.

In Figure 8, the basic structure of MIMO-OFDM is demonstrated. In this figure, the signals are modulated by OFDM modulator, then they are transmitted by MIMO system, finally, the signals are recovered by the OFDM demodulator.

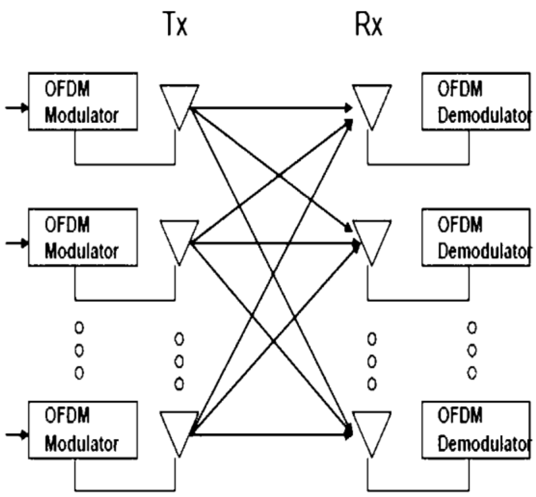

Figure 8 MIMO OFDM structure [9]

Therefore, MIMO-OFDM achieves spectral efficiency, increased throughput and the inter-symbol interference (ISI) can thus be prevented.

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

IV. TECHNIQUES FOR BER EVALUATION IN MIMO-OFDM

In this section strategies that have been implemented to carry out performance evaluation in MIMO-OFDM systems are presented.

Singh et al. [15] examined the performance of OFDM-MIMO wireless system. The objective of the study was to introduce the basic structure of OFDM and MIMO, including the basic implementation of a MIMO model using Orthogonal Space-Time Block Code (OSTBC) structure, the effectiveness of introducing encoders and inter-leavers in a OFDM-MIMO system, the transmitter and receiver modeling of OFDM, and hence constructing a simple OFDM-MIMO wireless communication system in the terms of WLAN and Wi-Fi with 16-QAM modulation composed of transmitter, channel, receiver, and so on. The performance simulation of the system was carried out using the MATLAB software. All the models were studied for different number of antennas configurations at the transmitter and receiver of the communication system. The results are obtained and compared in terms of Bit Error Rate (BER), throughput and bandwidth.

Tewari and Singh [1] presented performance comparison of digital modulation techniques used in wireless communication system. The main objective of the study was to give an overview of the digital modulation methods used in wireless communication systems and to investigate a better modulation technique among the various digital modulation schemes such as amplitude shift keying (ASK), quadrature phase shift keying (QPSK), binary phase shift keying (BPSK), frequency shift Keying (FSK) ,On-off keying (OOK), DPSK & 8-PSK. The different modulation techniques were studied the help of MATLAB/SIMULINK. Simulation of models developed using MATLAB software for the modulation techniques was carried out. The performance comparison of the different modulation schemes was done. The performance of all the modulation techniques is more or less the same. However, for higher SNR values, BPSK modulation technique provided better bit error rate (BER) performance than the other discussed techniques.

Oyetunji and Ale [16] investigated the performance of different digital modulation techniques in Multipath fading channel interface air. The study described features of wireless communication channels with emphasis on fading channel. It examined the inherent qualities of the digital modulation schemes to overcome the impairment introduced by the channel. The channel was modeled and simulated using 6 rays. The evaluation of the different modulation techniques was done in terms of the modeled multipath channel. This was conducted to know the contributions of channel characteristics to effective wireless communication. The BER for simulated modeled channels agreed with the theoretical results. It was also seen that multipath fading channel characteristic limits the data rate in wireless communication.

Mahalakshmi [2] studied the performance evaluation of different digital modulation schemes for an efficient wireless mobile communication system. The Bit Error Rate and Signal to Noise Ratio were chosen as the major key component for determining any modulation schemes. The digital modulation techniques were used to develop a new level of expectation to wireless communication devices. The performance of each modulation technique was measured by estimating its probability of error produced by noise and channel interference. The main objective of the study was to measure Bit Error Rate with different modulation schemes and to provide the most suitable configuration to achieve better utilization of bandwidth in OFDM systems. The modeling, designed and simulation were carried out in MATLAB simulation environment with various digital modulation techniques such as BPSK, QPSK, DQPSK and π/4-DQPSK. As per design and comparison of modulation schemes, it was observed that π/4-DQPSK could transmit more data with low error rate than others.

Alade [6] examined the effectiveness of both MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Frequency Division Multiplexing) in communications system. The performance comparison of various modulation schemes in both OFDM only and MIMO-OFDM systems in terms of BER (Bit Error Rate) was carried out. This was done for both additive White Gaussian Noise (AWGN) channel and Rayleigh Fading channel, where channel noise is considered as the channel condition. The performance analysis of the developed system was carried out using Simulink tool in MATLAB to model MIMO OFDM system.

Achra et al. [17] presented performance analysis of MIMO OFDM system for different modulation schemes under various fading channels. The performance was analyzed in terms of Bit Error Rate (BER) versus the Signal to Noise Ratio (SNR). This study discussed the BER performance of the MIMO-OFDM system with two different equalizers, Zero forcing and minimum mean square error (ZF and MMSE) , for various modulation techniques. The different modulation schemes used are BPSK, QPSK, 16-QAM and 64-QAM using multipath fading channels such as AWGN (Additive White Gaussian Noise), Rayleigh and Rician channel. A multicarrier modulation was employed, which offered advantages like inter symbol interference (ISI) reduction, high data rate, higher reliability, and better performance in multipath fading. The simulation results indicated that, with MMSE and ZF equalizers, the BER performances were better in MMSE equalizer. Further analysis in different fading channels for various modulation techniques in both the equalizers was carried out.

Bhagya and Ananth [18]presented a detailed study of the performance of MIMO-OFDM transmission on Wi-MAX physical layer specified in IEEE 802.16-2004 which was carried out using MATLAB Simulink. A multipath fading channel adaptive modulation and coding techniques were used so as to overcome the temporal variations in quality. The technique employed multiple modulation and coding schemes to instantaneously adapt to variations in the channel SNR, thus maximizing the system throughput and improving BER performance. The Wi-MAX system incorporated Reed-Solomon (RS) encoder with Convolution encoder with 1/2 and 2⁄3 rated codes in FEC channel coding. Orthogonal Frequency Division Multiplexing (OFDM) accesses used adaptive modulation technique such as BPSK, QPSK and 16-QAM, on the physical layer of Wi-MAX and the concept of cyclic prefix that adds additional bits at the transmitter end. The simulation results of estimated Bit Error Rate (BER) indicated that the implementation of interleaved RS code (255, 239, 8) with 2/3 rated Convolution code under BPSK modulation technique was found to be highly effective for Wi-MAX communication system. The Implementation of MIMO systems on Wi-MAX networks showed that there was a significant improvement.

Akhtar et al. [19] presented a comprehensive performance analysis of MIMO-OFDM technology using different MIMO configurations and M-QAM modulation schemes for LTE cellular network. A MIMO-OFDM hybrid model was designed with proper frequency synchronization and antenna diversity that reduces Inter Carrier Interference (ICI) with improved signal strength. Using the model a comprehensive analysis in terms of Bit Error Rate (BER) performance with respect to Signal to Noise Ratio (SNR) and Bit Rate for different M-ary QAM modulation schemes and different MIMO configurations were presented over Rayleigh fading and AWGN channel. The analysis showed that propose OFDM scheme offered improved Bit Error rate (BER) performance for 64-QAM than any other M-ary QAM modulation schemes and the optimum MIMO configuration that provided good quality performance was found to be 3×2 configuration.

Ajose et al [13] presented bit error rate analysis of different digital modulation schemes in orthogonal frequency division multiplexing (OFDM) systems that uses single input and single output (SISO) antenna configuration. The OFDM system was modeled and different modulation schemes: M-ary phase shift keying (M-PSK) and M-ary quadrature amplitude modulation (M-QAM) were employed over two different channels: additive white Gaussian noise (AWGN), and Rayleigh multipath fading channels. Bit error rate (BER) analysis was carried out for the different digital modulation schemes over the two channels, and the number of fast Fourier transform (FFT) points used during the transmission was examined. Simulation results revealed that over both AWGN and Rayleigh fading channels, lower order modulation schemes performed better than the higher order schemes. This occurred at the detriment of the data rate, as lower order schemes have lower data rates compared with their higher order counterparts. Furthermore, it was observed that the system performed better over AWGN channel than Rayleigh fading channel for all modulation schemes used. On the number of FFT points used during the transmission, findings revealed that the performance of the system is more or less not really affected by the number of FFT points employed during transmission.

Veeranna and Nidhi [20]studied performance of modulation schemes over Rayleigh fading channel in MIMO system. The performance comparison were carried out based on bit error rate(BER) and symbol error rate(SER) performance metrics over Rayleigh fading channel with BPSK,QPSK,8PSK and QAM modulation technique. The comparison results revealed that in Rayleigh fading the bit error rate and symbol error rate was least for QAM modulation technique as compared to other three modulation techniques, that is, BPSK, QPSK and 8PSK.

Chandel and Gautam [21] examined the performance analysis of MIMO OFDM system under different fading channels. The study analyzed fading channel by using different modulation techniques. The performance of MIMO-OFDM was tested for modulation techniques such as BPSK, QPSK, and 16-QAM using MATLAB software. The authors maintained that BPSK modulated MIMO -OFDM system achieved better SNR results for Rayleigh channel in comparison to Gaussian and Rician fading while Rician was better than Gaussian channel. Also in 16-QAM modulation format, Gaussian showed better BER values in comparison to Rician Fading whereas Rayleigh indicated lowest BER values.

Rathore and Sharma [22] performed software simulation of OFDM system in a mobile radio channel using the MATLAB software design tools and SIMULINK model. The study used different modulation techniques such as BPSK, QPSK, 16-PSK, 64-PSK and so on to evaluate bit error rate for OFDM system using Simulink model. The authors concluded that OFDM promised to be a suitable technique for data communication in a mobile radio channel and would offer a major role in wireless communication in the present and the future.

Philip-Kpae and Omijeh [23] studied bit error rate (BER) and signal to noise ratio (SNR) performance evaluation of OFDM system with QPSK and M-ary QAM modulation technique in Rayleigh, Rician and AWGN channel using MATLAB/Simulink. Simulink models were developed to study the performance of the various digital modulation schemes in different channels. The result showed that QPSK outperformed M-ary QAM for the proposed OFDM system. That is, QPSK provided lower BER than QAM in AGWN, Rayleigh and Rician channel. Therefore, the authors concluded that QPSK was better than QAM in the OFDM system.

Ogale et al. [24] evaluated the performance of two models of MIMO-OFDM system developed in MATLAB/Simulink. The models were 2×2 spatial multiplexing OFDM (2×2 SM-OFDM) and 2×2 space time block coding OFDM (2×2 STBC-OFDM). The performance of the MIMO-OFDM models were examined in terms of BER and throughput employing 64 QAM modulations for processing of real image input. The study observed that STBC-OFDM system provided significantly reduced BER in low to medium signal to noise ratio (SNR) compared to SM-OFDM system. On the other hand, the SM-OFDM was able to offer improved throughput and minimal error rate at high SNR. In addition to BER and throughput, the models were examined based on the quality of received images transmitted through them. It was again ascertained from the resulting image output that the STBC-OFDM scheme received image has zero or very negligible noise compared to obvious noise produced in image transmitted through the SM-OFDM system.

Manju and Dessai [25] designed a 4×4 MIMO-OFDM system to evaluate BER, SNR, peak SNR (PSNR) and mean square error (MSE) using QPSK modulation technique over additive white Gaussian noise (AWGN) channel. Simulations were conducted in MATLAB. The system performance was estimated in MATLAB for image input with performance measures in terms of MSE and PSNR. The simulation result showed that indicated that the BER was reduced and the error was very low for QPSK integrated MIMO-OFDM such that noise level was completely reduced at 2 dB. In terms of image colour, QPSK offered PSNR of 58.6713 dB at SNR of 5 dB and for a binary image, it provided PSNR of 78.195 dB at SNR of 3 dB respectively.

Elsanousi&Ozturk [26] carried out performance evaluation of BER for OFDM and MIMO-OFDM systems employing convolutional channel coding and different digital modulation techniques. The study showed that at highest number of transmit and receive antennas, the lowest BER could be determined. The results of the simulation revealed that MIMO-OFDM scheme offered better performance than OFDM scheme. For the three channels considered namely AWGN, Rayleigh, and Rician, the best performance was provided by AWGN. Besides Rician channel showed better performance than Rayleigh. Also, of the modulation schemes, 16 QAM, 64QAM, and QPSK, the modulation that offered best performance was QPSK.

Devi and Talwar [27] presented an enhanced strategy for data transfer in MIMO-OFDM system. The study was designed to improve the rate of data transfer in a channel. A problem of user rapidly varying location in an attempt to transfer data from one point to another was addressed using machine and artificial intelligent learning solutions. The users were divided into regions. This was done by optimizing the data intend to be sent by user, which was achieved through the integration of natural and swarm intelligence scheme and then eventually classified with AI algorithm to make data transfer better. The AI algorithm combined two optimization algorithms from genetic algorithm (GA) and artificial bee colony (ABC) algorithm. The SNR is computed after the optimization of the data with both GA and ABC. Three modulation schemes were considered 16 QAM, 32 QAM, and 64QAM. The system performance was evaluated in terms of mean square error (MSE) and BER. The simulation results indicated that the solution presented in the study significantly reduced both MSE and BER.

Nithiya et al. [28] applied forward error correction (FEC) in MIMO-ODFM system. FEC was described as scheme for obtaining error control in the transmission of data wherein redundant data is transmitted by the transmitter and the receiver only detects the portions of the data that has no clear errors. FEC employs two main categories block codes and convolutional codes. While the block codes utilized predetermined size blocks (packets) of bits or symbols, the convolution codes utilized bit or symbol streams of arbitrary length. The MIMO-OFDM system used FEC which was concatenated codes that formed a class of error-correcting codes. The MIMO-OFDM system was modeled in MATLAB/Simulink. The system was evaluated over different ranges of SNR and the corresponding BER. The results revealed that the BER of MIMO-OFDM system with concatenated FEC outperformed OFDM system without MIMO. Furthermore, on performance the system over the fading channels, Rician channel offered better effect than Rayleigh channel.

So far, some of the approaches that studied and implemented the performance of MIMO-OFDM system in terms of BER via simulations using computer software such as MATLAB have been significantly reviewed.In this paper, simulations were conducted to examine the OFDM system considering Quadrature Amplitude Modulation (QAM) using MATLAB code. The simulation curves for 16-QAM, 64-QAM, and 128-QAM are shown in Figures 9-11.

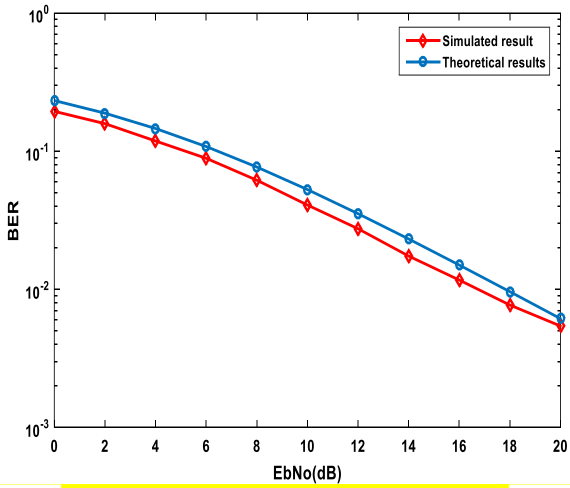

Figure 9 BER against SNR with 16-QAM

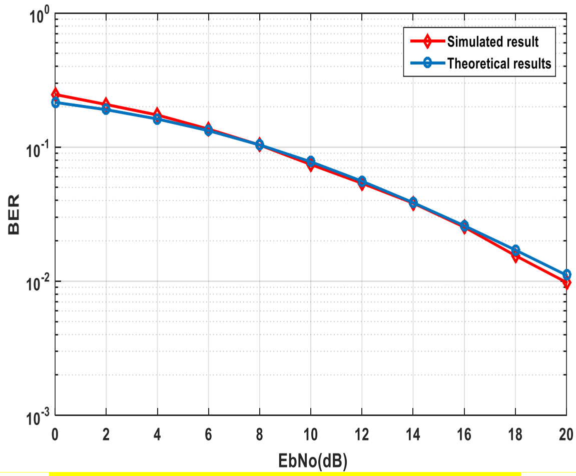

Figure 10 BER against QAM with 64-QAM

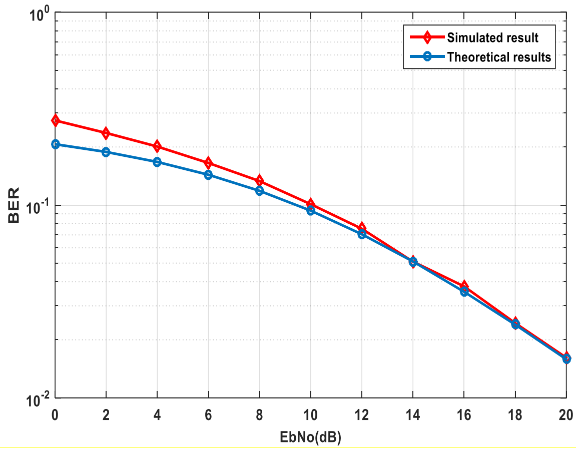

Figure 11 BER against QAM with 128-QAM

The simulation results in Figures 9-11 are presented for various order of QAM modulation scheme with number of bits equal to 104. Therefore, for 16-QAM, the theoretical and simulated values for the BER at SNR of 20 dB were 0.006135 and 0.005425 respectively. In the case of 64-QAM, the values were 0.01109 and 0.0098 for theoretical and simulated respectively. With 64-QAM, the BER for theoretical was 0.01585 and simulated was 0.01616. It can be seen that has the order of modulation increases the BER performance of OFDM system reduces. Hence, lower order modulation scheme yields better BER than higher order scheme.

In order to further demonstrate the OFDM technique with MIMO technology,a MATLAB/Simulink model for 2×2 MIMO-OFDM shown in Figure 12, was simulated considering 16-QAM modulation technique with a modulated data source transmitted over Rayleigh and Rician fading channel. The maximum number of errors was 100 and the maximum number of bits was 10^8. The evaluation of the BER performance against SNR of 20 dB was carried out using the MATLAB bertool. Simulation result is shown in Figure 13.

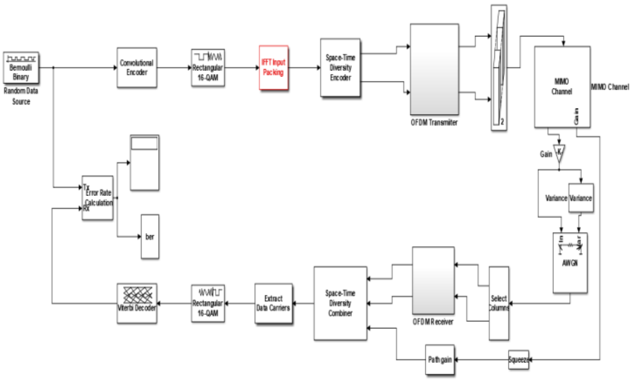

Figure 12 Simulink model of 2×2 MIMO-OFDM system

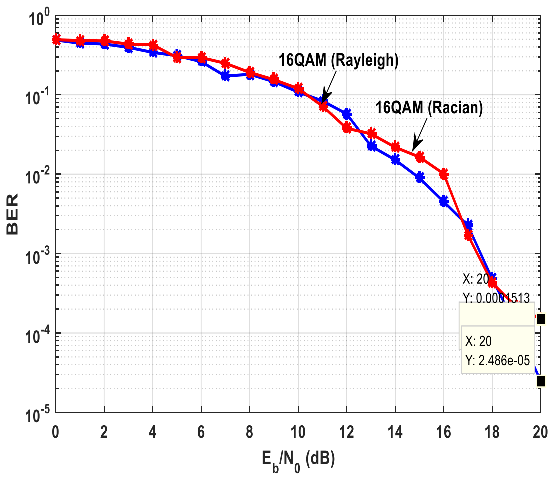

Figure 13 BER against SNR

The result of the simulation showed that the modulation over Rayleigh fading channel provided BER of 2.486e-05 while for Rician fading channel, the BER was 0.0001513 at SNR of 20 dB respectively. Thus the BER achieved for transmitted signal over Rayleigh fading channel was better than for Rician fading channel.

V. Conclusion

This paper has presented performance evaluation review of MIMO-OFDM techniques for wireless communication system. The study considered various digital modulation schemes that have used in wireless communication system to improve data transmission or information sharing between communicating terminals. The method of MIMO was described as a strategy that uses more than one antenna at both transmit and receive sides to increase the channel capacity of a wireless system and provide higher rate of data transfer. Also, OFDM technique was examined as a multicarrier scheme that uses cyclic prefix to reduce or mitigate inter symbol interference (ISI). Then MIMO-OFDM system was presented as a scheme tailored towards increasing spectral efficiency in wireless communication system. In order to narrow down the study, previous studies that have designed and implemented MIMO-OFDM for evaluating BER performance were empirically reviewed. Furthermore, a MIMO-OFDM system utilizing two antennas at the transmitter and the receiver was modeled in MATLAB/Simulink and simulated to demonstrate that the use of multiple antennas helps in improving the performance of wireless communication system by reducing BER while increasing SNR.

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