BER ANALYSIS OF MIMO-OFDM SYSTEM USING NAKAGAMI-M DISTRIBUTION

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***ABSTRACT*: Recently, there have been a lot of interests in combining the OFDM systems with the multiple-input multiple-output (MIMO) technique. These systems are known as MIMO-OFDM systems. MIMO-OFDM system has been currently recognized as one of the most competitive technology for 4G mobile wireless systems. MIMO system can provide the spatial diversity with the help of Space Time Coding when no channel side information is available at the transmitter side.**
This paper provides an overview of the basics of MIMO-OFDM technology and focuses on the BER Analysis of MIMO-OFDM systems. The signal detection technology used in this work for MIMO-OFDM system is Nakagami Distribution. In the present work, the analysis of high level of modulations on MIMO-OFDM system is presented.
The combination of OFDM systems with MIMO technology has provided us with increase in link reliability and an improvement in spectral efficiency.

***Keywords*: BER ANALYSIS, OFDM, MIMO, Nakagami-M Distribution etc**

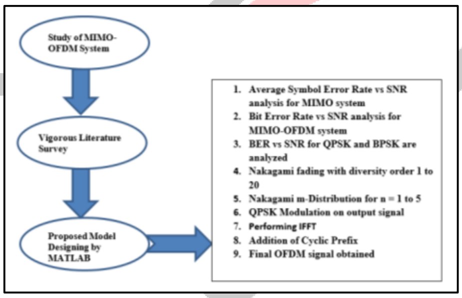
I-INTRODUCTION

1.1 Preamble

Wireless communication is one of the most vivacious areas in the communication field now a day. Although the development in this area was started way back in 1960s, but a lot of research is done in this area in last decade. The reason for this is due to a variety of factors discussed below:

- The demand for seem-less connectivity has risen manifolds, mainly due to cellular telephony but expected to be soon eclipsed by wireless data applications.
- The sophisticated signal processing algorithms can be implemented with the advent of VLSI technology. Due to the success of 2G wireless standards especially CDMA it has been shown that communication ideas can be implemented in practice. The research push in the past decade has led to a much better-off set of perspectives and tools on how to communicate over wireless channels, and the scenario is still very much in the emerging stages.

Various steps to gain the results.



II-LITERATURE REVIEW

P. S. Mundra et.al describes the emerging modulation technologies in the family of linear modulation and constant envelope techniques of digital modulation. Both of these techniques have been used extensively in mobile communication systems. The selection of one over the other depends on the priorities set in the system requirements. If most efficient bandwidth utilization and moderate hardware complexity is the key note – QPSK (π/4 QPSK) will be a better choice. Whereas continuous phase modulation schemes offer constant envelope, narrow power spectra, good error rate performance, etc. GMSK is the solution when out of band signal power, tolerance against filter parameter and non-linear power amplifiers are important features and compromise in channel separation is permissible and higher circuit complexity is of less consideration. Spectral efficiency can be further improved by using suitable coding techniques.

Higher modulation schemes with COFDM for a Rician fading channel with two frequency bands are considered by W.A.C. Fernando. Rectangular QAM and 8-PSK constellation modulation schemes are considered with convolutional coding and TCM. Coding gain is considered at two different values of BER. It has been shown that there is no significant difference of BER performance between two frequency bands considered. BER slope is high for CC-OFDM for high SNR values whereas, TCM-OFDM performance seems to be better compared to CC-OFDM by considering the fact that TCM code has a lower trellis size.

III-MIMO-OFDM SYSTEM

3.1 Introduction

Multicarrier transmission, also known as OFDM is a technique with a long history back to 1960 that has recently seen rising popularity in wireless and wire line applications. The recent interest in this technique is mainly due to the recent advances in digital signal processing technology. International standards making use of OFDM for high-speed wireless communications are already established or being established by IEEE 802.11, IEEE, 802.16, IEEE 802.20 and ETSI BRAN committees. For wireless applications, an OFDM-based system can be of interest because it provides greater immunity to multipath fading and impulse noise, and eliminates the need for equalizers, while efficient hardware implementation can be realized using FFT techniques .

OFDM is a multi-carrier modulation technique where data symbols modulate a parallel collection of regularly spaced sub-carriers. The sub-carriers have the minimum frequency separation required to maintain orthogonality of their corresponding time domain waveforms, yet the signal spectra corresponding to the different sub-carriers overlap in frequency. The spectral overlap results in a waveform that uses the available bandwidth with a very high bandwidth efficiency.

OFDM is simple to use on channels that exhibit time delay spread or, equivalently, frequency selectivity. Frequency selective channels are characterized by either their delay spread or their channel coherence bandwidth which measures the channel decorrelation in frequency. The coherence bandwidth is inversely proportional to the root-mean-square (rms) delay spread.

By choosing the sub-carrier spacing properly in relation to the channel coherence bandwidth, OFDM can be used to convert a frequency selective channel into a parallel collection of frequency flat subchannels. Techniques that are appropriate for flat fading channels can then be applied in a straight forward fashion. The frequency domain of an OFDM and FDM system is represented in the diagram below for ten channels.

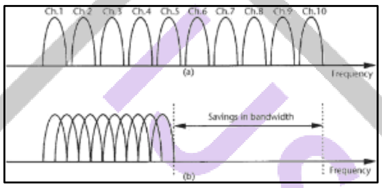


Figure 3.1: Concept of the OFDM signal (a) conventional multicarrier technique and (b) orthogonal multicarrier modulation technique

If one observe the Figure 3.1 given above, one can easily notice that the bandwidth taken by the convectional parlor system (FDM) is far higher then that of OFDM system for the same number of channel. Thus one can easily sense the advantage of OFDM system over ordinary FDM systems.

OFDM is similar to FDM technique except that the 'N' sub-carriers are made orthogonal to each other over the OFDM symbol (frame) duration Ts. By orthogonality of the carriers, we mean that the carrier frequencies satisfy the following requirement:

$$f_k = f_0 + k/T_s \text{ , k=1,2,...N-1} \qquad (3.1)$$

Ts= OFDM symbol duration
K = an integer
f_k= frequency of k^{th} carrier
f_0 = fundamental frequency

Key advantages of OFDM Transmission:

OFDM is an efficient way to deal with multipath; for a given delay spread, the implementation complexity is significantly lower than that of a single-carrier system with an equalizer.

In relatively slow time-varying channels, it is possible to enhance capacity significantly by adapting the data rate per SC according to the signal-to-noise ratio (SNR) of that particular SC.

- OFDM is robust against narrowband interference because such interference affects only a small percentage of the SCs.
- OFDM makes single-frequency networks possible, which is especially attractive for broadcasting applications.

Disadvantages of OFDM Transmission:

- OFDM is more sensitive to frequency offset and phase noise.
- OFDM has a relatively large peak-to-average-power ratio, which tends to reduce the power efficiency of the radio frequency (RF) amplifier.

Application of OFDM

During the past decade, OFDM has been adopted in many wireless communication standards, including European digital audio broadcasting, terrestrial digital video broadcasting, and satellite terrestrial interactive multiservice infrastructure in China. In addition, OFDM has been considered or approved by many IEEE standard working groups, such as IEEE 802.11a/g/n, IEEE 802.15.3a, and IEEE 802.16d/e.

The applications include wireless personal area networks, wireless local area networks, and wireless metropolitan networks. Currently, OFDMA is being investigated as one of the most promising radio transmission techniques for LTE of the 3rd Generation Partnership Project (3GPP), International Mobile Telecommunications-Advanced Systems.

3.2 OFDM Signal Model

Figure 3 2 shows the block diagram of an OFDM system with SISO configuration.

Denote X1(l=0,1,2,....,N −1) as the modulated symbols on the lth transmitting subcarrier of OFDM symbol at transmitter, which are assumed independent, zero-mean random variables, with average power σ_x^2. The complex baseband OFDM signal at output of the IFFT can be written as:

$$x_n = 1/\sqrt{N}\sum_{l=0}^{N-1} X_1 e^{jnl\frac{2\pi}{N}} \quad (3.2)$$

where N is the total number of subcarriers and the OFDM symbol duration is T seconds.

At the receiver, the received OFDM signal is mixed with local oscillator signal, with the frequency offset deviated from f the carrier frequency of the received signal owing to frequency estimation error or Doppler velocity, the received signal is given by:

$$\hat{x}_n = (x_n \times h_n)e^{jn\Delta fT\frac{2\pi}{N}} + z_n \quad (3.3)$$

where h_n , $e^{jn\Delta fT\frac{2\pi}{N}}$ and z_n represent the channel impulse response, the corresponding frequency offset of received signal at the sampling instants: Δf .

At the receiver, removing the guard interval becomes equivalent to removing the cyclic prefix, while the effect of the channel transforms into the periodic convolution of the discrete time channel with the IDFT of the data symbols. Performing a DFT on the received samples after the cyclic prefix is discarded, the periodic convolution is transformed into multiplication, as it was the case for the analog Multi Carrier receiver.1/2 or 1/4 or1/8 or 1/16 or 1/32 times of data symbol is added at beginning of the OFDM.

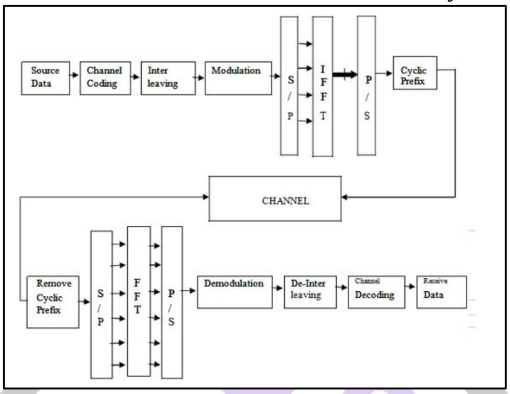


Figure 3.2: Block Diagram of OFDM system

In the above figure we can see the block diagram of the basis OFDM system; now in the following subsection we will investigate the operation and the importance of each block in brief.

The source entropy is bounded below by zero if there is no uncertainty, and above by log2 M if there is maximum uncertainty. As an example, consider a binary source xj that generates independent symbols 0 and 1 with respective probabilities of p0 and p1. The source entropy is given by

H(xj)= -[p1 log2(p1)+ p0 log2(p0)] (3.4)

The basic measure of channel coding performance is coding gain, which is usually measured in dB s as the reduction of required Signal to Noise Relation SNR to achieve a certain bit error rate (BER) in AWGN channel. The minimum free distance of the code determines the performance of the convolutional code.

The coding gain is:

Cgain = 10log10(CRdfree) (3.4)

where CR is the coding rate and dfree is the free distance defined as the minimum Hamming distance between two different code words.

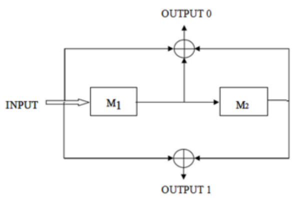


Figure 3.3: Block Diagram of Convolutional Encoder k/n = 1/2 , m=2

Unlike a block code that has a fixed word length n, a convolution code has no particular size. However, convolution codes are often forced into a block structure by periodic truncation. This requires a number of zero bits to be appended to the end of input data sequence, for the purpose of clearing of flushing the encoding shift register of the data bits. Since the added zeros carry no information, the effective code rate falls below k/n. To keep the code rate close to k/n, the truncation period is generally made as long as practical.

An example of signal-space diagram for 8-PSK

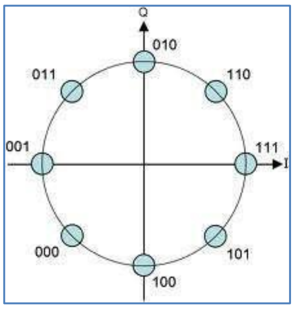


Figure 3.4: Signal-space diagram for 8-PSK

In M-ary PSK modulation, the amplitude of the transmitted signals was constrained to remain constant, thereby yielding a circular constellation . By allowing the amplitude to also vary with the phase, a new modulation scheme called quadrature amplitude modulation (QAM) is obtained.

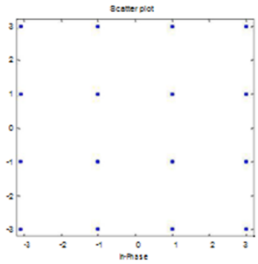


Figure 3.5: QAM Constelations for 16-QAM

Interleaving aims to distribute transmitted bits in time or frequency or both to achieve desirable bit error distribution after demodulation. What constitutes a desirable error distribution depends on the used FEC code. What kind of interleaving pattern is needed depends on the channel characteristics. If the system operates in purely AWGN environment, no interleaving is needed, because the error distribution cannot be changed by relocating the bits. Communication channels are divided into *fast* and *slow* fading channels. A channel is fast fading if the impulse response changes approximately at the symbol rate of the communication system, whereas a slow fading channel stays unchanged for several symbols .

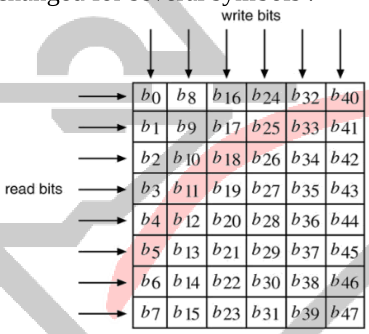


Figure 3.6: Bit write and read structure of 8×6 Block Interleaver

A convolutional interleaver is another possible interleaving solution that is most suitable for systems that operate on continuous stream of bits. This interleaver structure was published by Ramsey.

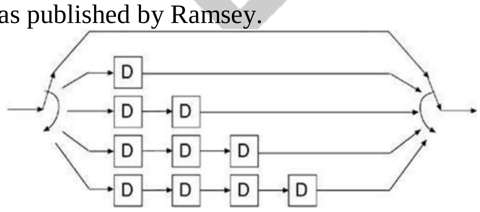


Figure 3.7: Basic structure of Convolutional Interleaver

FFT can be implemented in two ways i.e. DIT and DIF. Two main differences between decimation in time (DIT) and decimation in frequency (DIF) are noted . First, for DIT, the input is bit-reversed and output is in natural order, while in DIF, the reverse is true. Secondly, for DIT complex multiplication is performed before the add-subtract operation, while in DIF the order is reversed. While complexity of the two structures is similar in typical DFT, this is not the case for partial FFT. The reason is that in the DIT version of partial FFT, a sign change (multiplication by 1 and -1) occurs at the first stages, but in the DIF version it occurs in later stages. One variation, decimation in time, is shown in Figure 3.8.

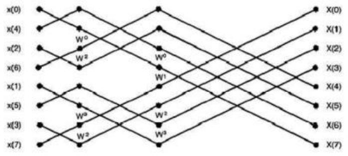


Figure 3.8: An FFT Implementation (Decimation In Time)

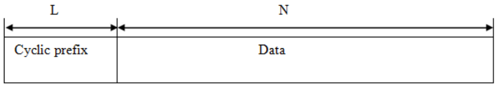


Figure 3.9: Cyclic Prefix in OFDM Transmission

When the guard interval is longer than the channel impulse response, or the multipath delay, the IS1 can be eliminated.

IV-RESULTS AND DISCUSSIONS

In this paper behavior of the MIMO-OFDM system under different environments is studied and the effects of increasing the order of the modulation on the BER performance of the system are presented. The system discussed above has been designed using the Nakagami Distribution for MIMO-OFDM system.

The performance of MIMO-OFDM system is analyzed using the criterion namely: BER Analysis

4.1 BER Analysis of MIMO-OFDM system

In this section BER analysis of MIMO-OFDM system using QOSTBC code structure is done for higher order Modulations over different fading channels. First, the analysis of MIMO-OFDM system using M-PSK is presented over different fading channels and then same procedure is done for M-QAM.

4.2 Nakagami Distribution

The Nakagami distribution or the Nakagami-m distribution is a probability distribution related to the gamma distribution. It has two parameters: a shape parameter {m ≥1/2} and a second parameter controlling spread {Ω >0}. {\displaystyle Y} {\displaystyle X={\sqrt {Y}}\,}

4.4 RESULTS

The graph below (Fig 4.1) is plotted by using only MIMO system with the assistance of Nakagami Distribution:

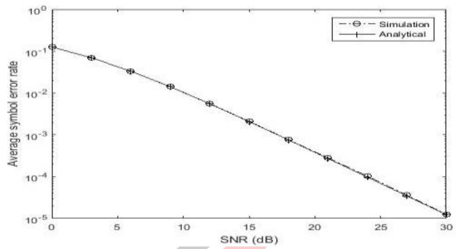


Figure 4.1: Average Symbol Error Rate vs SNR for MIMO system

It is observed that for 10^{-4} Bit error rate, the SNR obtained is 22.5 dB. Whereas, in case MIMO-OFDM system, the SNR obtained is 25 dB, which is shown in Fig 4.2.

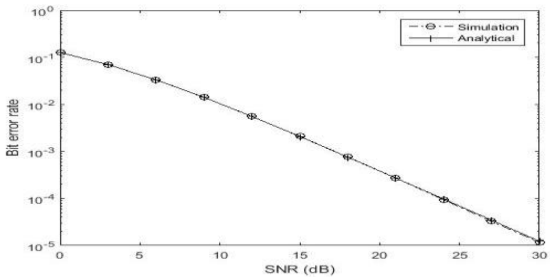


Figure 4.2: Bit Error Rate vs SNR for MIMO-OFDM system

The data is initially modulated by using the QPSK modulation technique. The BER vs SNR for Nakagami m-distribution over the diversity of 1 to 20 is shown in Fig 4.3.

It is clearly seen that, with increase in the value of 'n', BER is decreasing exponentially and SNR(dB) for a particular BER is increasing.

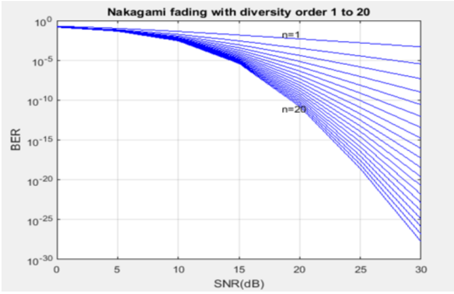


Figure 4.3: Nakagami fading with diversity order 1 to 20

Different output at the end of each block in a MIMO-OFDM system is depicted in the figure below (Fig 4.4)

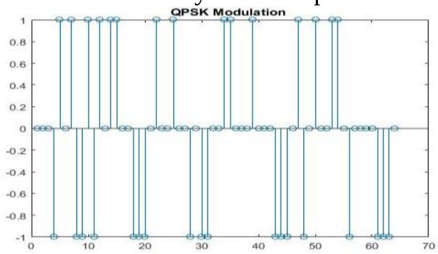


Figure 4.4: QPSK Modulated Signal

The superimposed modulated signal onto 4 different sub-carriers is shown in Fig 4.5.

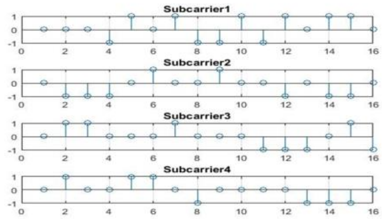


Figure 4.5: Superimposed Signals onto 4 Different Sub-Carriers

The application of IFFT on these sub-carriers converts them from a frequency domain to time domain which maps the complex data symbols to a Time Domain OFDM symbol (Fig 4.6). The result obtained after adding the cyclic prefix to these 4 sub carriers is shown in Fig 4.7.

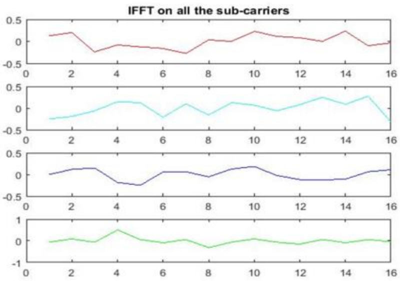


Figure 4.6: IFFT on 4 Different Sub-Carriers

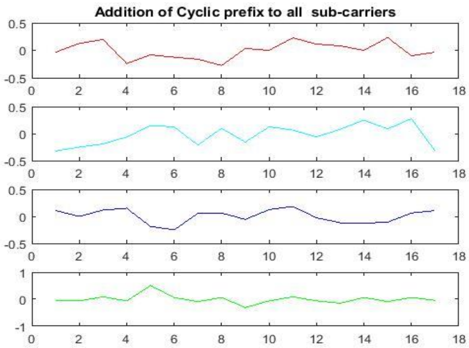


Figure 4.7: Addition of Cyclic Prefix on 4 Different Sub-Carriers

Final OFDM signal obtained is shown in Fig 4.8, which shows an uniform amplitude of 0.25 obtained throughout.

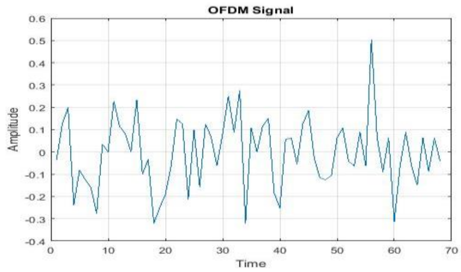


Figure 4.8: Final OFDM Signal

The PDF obtained for Nakagami m-distribution when ‘n’ varied from 1 to 5 is shown in Fig 4.9. It is seen that the PDF value decreases with increase in the value of ‘n’.

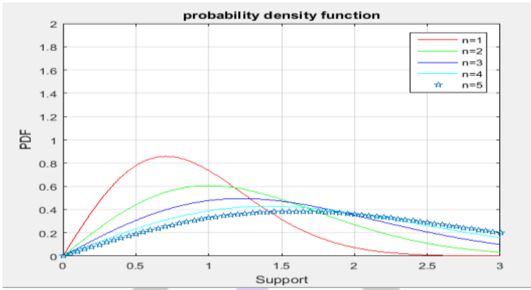


Figure 4.9: Nakagami m-Distribution

Also, a comparison between QPSK and BPSK has been obtained on the basis of BER vs SNR graph, which is shown in Fig 4.10, where it is obtained that coded QPSK performs well as it reflects higher SNR for less BER values.

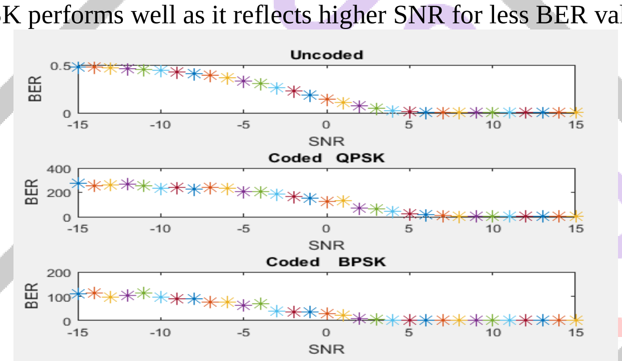


Figure 4.10: BER vs SNR for QPSK and BPSK

Hence by using a MIMO-OFDM with Nakagami distribution system, the overall SNR of the system can be drastically improved. Different antenna configurations were used for analysis and in all the cases there was an improvement in SNR and when compared with systems that only used MIMO system. One important advantage of MIMO OFDM system is data capacity, as it combines advantages of both MIMO and OFDM.

4.5 COMPARISON OF BER OBTAINED ANALYSING MIMO-OFDM SYSTEM BY ALAMOUTI’S SPACE-TIME CODING SCHEME WITH BER OBTAINED ANALYSING MIMO-OFDM SYSTEM BY NAKAGAMI DISTRIBUTION

The base paper considered for the completion of the present project is “BER ANALYSIS OF CODED AND UNCODED MIMO-OFDM SYSTEM IN WIRELESS COMMUNICATION” by M.P Chitra and Dr. S.K Srivatsa, published in Indian Journal of Computer Science and Engineering, where the proposed MIMO-OFDM system has been simulated in mat lab and analyzed in terms of BER with signals to noise ratio (SNR) by the method of Alamouti’s Space-Time Coding Scheme.

The performance of A-STBC OFDM with MIMO-OFDM, obviously space time coded system performs well in higher SNR region when the SNR is greater than 15 dB the BER is less than 10^{-3} in coded MIMO-OFDM system. But in uncoded MIMO system the bit error rate is greater than $10^{-2}$when the SNR is greater than 15 dB.

The performance graph is shown below in Fig 4.11. Comparing the result with the one obtained using Nakagami m-distribution (Fig 4.2), it is clearly seen that the performance of a Nakagami m-distribution MIMO-OFDM system is highly appreciable when compared to the performance of A-STBC OFDM with MIMO-OFDM as SNR is greater than 25 dB when the BER is less than 10^{-3}.

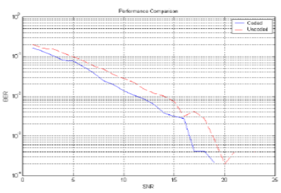


Figure 4.11: Performance of A-STBC OFDM with MIMO-OFDM

V-CONCLUSION

5.1 Conclusion

In the present work, an idea about the performance of the MIMO-OFDM systems at higher modulation levels and for different antenna configurations is presented. Performance of MIMO-OFDM system is analyzed under different fading channels. MIMO-OFDM system can be implemented using higher order modulations to achieve large data capacity. But there is a problem of BER (bit error rate) which increases as the order of the modulation increases. Because on increasing the order of modulation the decision region for the demodulator in the constellation diagram also decreases, as a result of this the demodulator will produce erroneous results at its output. The channel will distort the signal more severely at lower values of SNR (signal to noise ratio). These distortions will cause the shifting of the constellation points of the signal and this will cause the demodulator to produce the degraded results at its output. But as SNR is increased the effect of the distortions introduced by the channel will also goes on decreasing, as a result of this the BER will also decreases. In this way large data capacity can be achieved over the existing channels by using higher order modulations, the only thing that should be kept in mind is the extent to which we can increase the values of the SNR. Higher the SNR higher will be the data capacity.

The motive of using high order antenna configuration is to increase the space diversity, which will further decrease the BER at given SNR as compared to lower order Antenna configurations.

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