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Research Article

# Performance Analysis of MIMO-OFDM System using MMSE Receiver

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***Abstract***

*Orthogonal Frequency Division Multiplexing (OFDM) technique has been proposed as a standard for the next generation wireless communication system. Next generation wireless communication technologies require multimedia service such as internet services, audio, video and mainly high data rate with high mobility. OFDM fulfills these requirements. It provides high data rates and high spectral efficiency. Also high data rate can be achieved by the Multiple Input and Multiple Output (MIMO) technique. MIMO technique increases the diversity gain. This improves the Bit Error Rate (BER) performance of the system. These two technique bring together resulting MIMO-OFDM system to get the benefit of both the techniques. In this paper performance of MIMO-OFDM system is analyzed by using Minimum Mean Square Error (MMSE) technique. Simulation results show that improved BER is obtained with MIMO system than the without MIMO system. In addition BER performance is also investigated for different number of transmitting and receiving antennas and different modulation techniques.*

***Keywords:*** *OFDM, MIMO, BER, MIMO-OFDM, MMSE.*

## 1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) technique has been proposed as a standard for the next generation wireless communication system. The next generation wireless communications systems demand higher data rates transmission in order to meet the high quality services [R. V. Nee *et al*.]. Also there is need to provide high data rate in a mobile environment for new services like multimedia, internet, audio and video. OFDM fulfills these requirements. It provides high data rates and high spectral efficiency. OFDM is multicarrier transmission scheme [S. Shrikanth*et al*. and Y. Rahmatallah *et al*.]. In which these multicarrier are orthogonal and overlapping. By using overlapping carrier OFDM can save fifty percent of bandwidth. Therefore in OFDM spectrum is efficiently utilized. For wireless communication OFDM provides greater immunity against multipath fading and impulse noise [S. Hara *et al*.]. Also high data rate can be achieved by the Multiple Input and Multiple Output (MIMO) technique. MIMO technique can be used for diversity combining or spatial multiplexing. In spatial multiplexing multiple data streams transmit on multiple antennas in parallel leading to a substantial increase in capacity [T. Hwang *et al*.]. Therefore MIMO technique promises a significant increase in capacity. MIMO system has the ability to exploit multipath propagation rather than combat Most of MIMO techniques are developed for flat fading channels. However, multipath will cause frequency selectivity of broadband wireless channels. Therefore, MIMO-OFDM, which has originally been proposed to exploit OFDM to mitigate Inter Symbol Interference (ISI) in MIMO systems, turns out to be a very promising choice for future high-data-rate transmission over broadband wireless channels. These two technique bring together resulting MIMO-OFDM system to get the benefit of both the techniques [S. Catreux *et al*.].

In this paper, performance of MIMO-OFDM system is analyzed by using Minimum Mean Square Error (MMSE) technique. Simulation results show that improvement in BER is obtained with the MIMO technique than the without MIMO technique. The comparative study of BER over different modulation techniques show that minimum BER can be achieved by lower order modulation technique having lower coding rate.

The rest of the paper is organized as follows: Section 2 describes of the transmitter and receiver model for MIMO-OFDM system. Simulation results are shown in section 3 and paper is concluded in section 4.

## 2. System Model

MIMO-OFDM is considered for the system model. This combines MIMO technique and OFDM technique. MIMO-OFDM transmitter and receiver are described in next section.

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### *2.1 MIMO-OFDM Transmitter*

MIMO-OFDM transmitter consists of OFDM and MIMO system. Orthogonal Frequency Division Multiplexing (OFDM) technique has been proposed as a standard for the next generation wireless communication system as it offers high data rate. Further MIMO technique is used for high data rate. There are different MIMO techniques which make possible to transmit data through multiple antenna and receive data through multiple antenna. For MIMO technique Space Time Block code is used. MIMO-OFDM transmitter is shown in Fig-1.

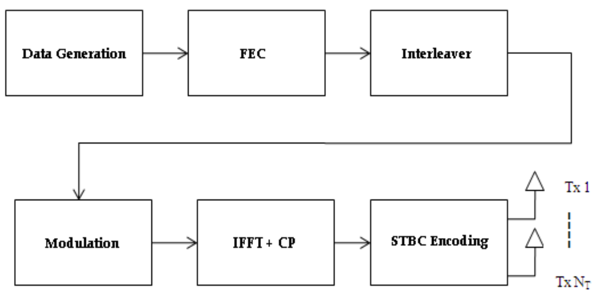


**Fig.1** MIMO-OFDM transmitter

Randomly generated data are encoded by forward error correcting code, in which Reed Solomon and convolutional coding are used. This coded data are interleaved and modulated. The multicarrier modulated signal is obtained after IFFT processing. The OFDM modulated signal is given by [T. Hwang, *et al.*]

$$x(k) = \sum_{i=1}^{M} x_k \, e^{2\pi k \Delta f t} \qquad 0 \leq t \leq T_s \tag{1}$$

Where $T_s$, $\Delta f$ and $M$ are the symbol duration, the subcarrier space, and number of subcarriers of the OFDM signals, respectively. These multicarrier modulated signals are encoded by STBC encoding technique. Finally, these signals are transmitted through multiple transmitting antennas.

### *2.2 MIMO-OFDM Receiver*

Receiver model of MIMO-OFDM with $N_T$ transmit antennas and $N_R$ receive antennas is shown in Fig-2. The transmitted symbol or data stream $\{x_n\}$ converts into $N_T$ substreams $\{x_k^{(m)}\}$ by Space–time processing and transmitted through different antennas. The signal at receiving antennas is given by [T. Hwang, *et al.*]

$$y_k^i = \sum_{m=1}^{N_T} H_k^{(i,m)} x_k^m + \eta_k^i \tag{2}$$

for $i = 1, \ldots, N_R$, where $H_k^{(i,m)}$ denotes the frequency response at the $k$th subchannel corresponding to the $m$th transmit and the $i$th receive antenna and $\eta_k^i$ is the channel noise at the $k$th subchannel of the $i$th receive antenna. Received signal is decoded by STBC decoder. For STBC decoder MMSE is used. The received signal can be expressed as

$$r = Hs + \eta \tag{3}$$

For perfect channel state information (CSI) estimated

$$r_e = G(Hs + \eta) \tag{4}$$

Where $G = (H^H H + \sigma^2 I)^{-1} H^H$. $\sigma^2$ is the variance of the noise. This output is passes through the every block of the receiver model. Finally after channel decoding we get the data.

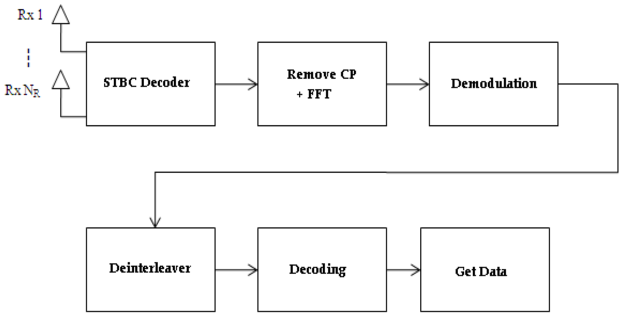


**Fig.2** MIMO-OFDM Receiver

## 3. Simulation Results

Physical layer of fixed WiMAX is simulated using OFDM with MIMO. Each block of MIMO-OFDM transmitter and receiver is individually coded in MATLAB. The simulation parameters are given in Table 1. For FEC, RS and convolution channel coding is used. In channel coding, overall coding rate is taken as ½, and ¾.

**Table 1** OFDM parameters of fixed WiMAX

| S.No | Parameters | Values |
|---|---|---|
| 1 | FFT size | 256 |
| 2 | Number of used data subcarrier | 192 |
| 3 | Number of pilot subcarrier | 8 |
| 4 | Number of null/guardband subcarrier | 56 |
| 5 | Cyclic prefix | 1/4 |
| 6 | Coding rate | ½, ¾ |

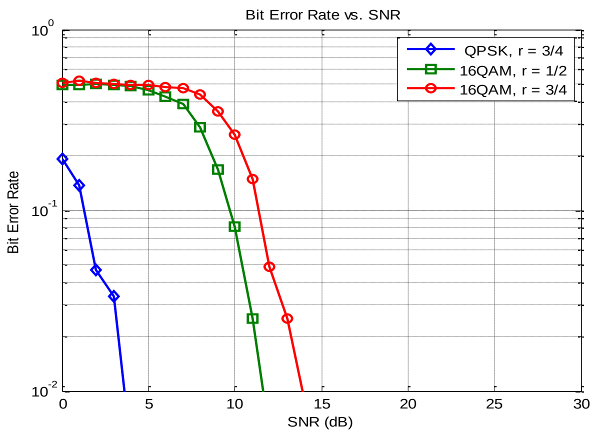


**Fig.3** BER versus SNR at $N_T = 2$, $N_R = 2$

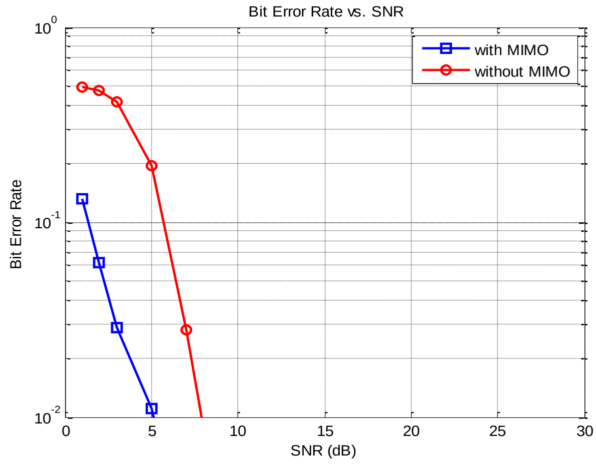


**Fig.4** BER versus SNR for QPSK, overall rate r =¾ and $N_T = 2$, $N_R = 2$.

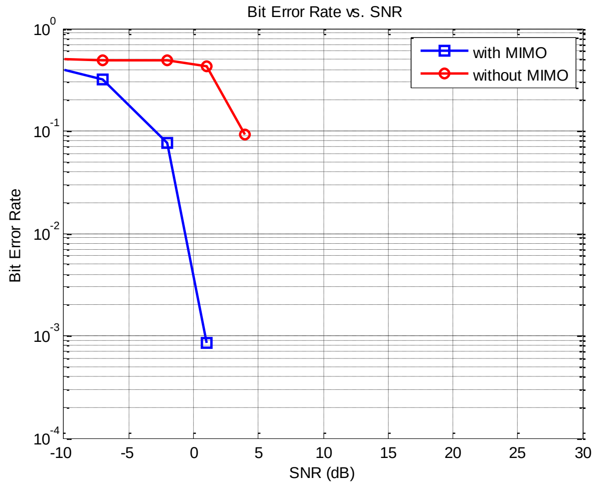


**Fig.5** BER versus SNR for QPSK, overall rate r = ½ and $N_T = 2$, $N_R = 2$.

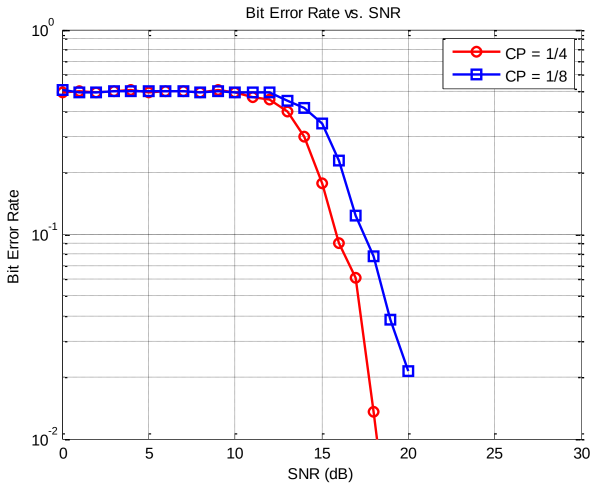


**Fig.6** BER versus SNR for 64QAM, overall rate r = 2/3 and $N_T = 2$, $N_R = 2$

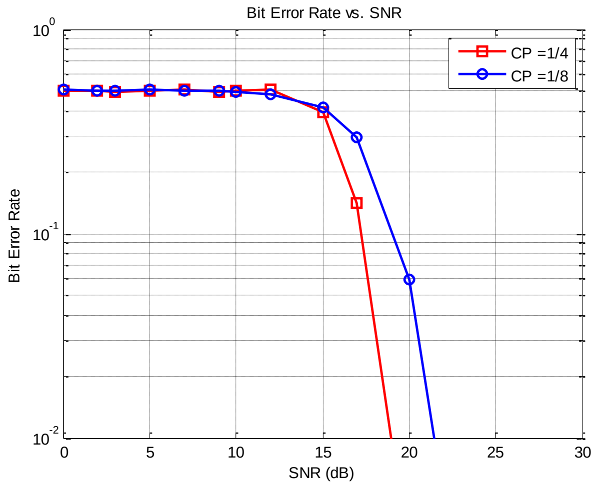


**Fig.7** BER versus SNR for 64QAM, overall rate r = ¾ and $N_T = 2$, $N_R = 2$

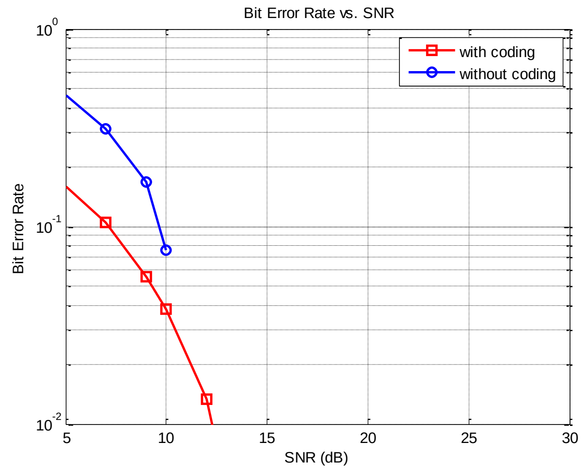


**Fig.8** BER versus SNR at 16QAM, overall rate r = ½ and $N_T = 2$, $N_R = 2$

In Fig-3 comparison is shown among the different modulation techniques. Among all modulation techniques for QPSK bit error rate is low.

BER of MIMO-OFDM system with MIMO cannel and without MIMO channel is shown in Fig-4 and 5 for QPSK modulation at $N_T = N_R = 2$. Without MIMO channel bit error rate is more as compared to with MIMO channel.

With cyclic prefix CP = 1/4 and 1/8 comparison for 64QAM is shown in Fig.6 and 7. If cyclic prefix fraction value is more bit error rate is less because of less ISI.

From Fig-8 it is observed that bit error rate depends on channel coding technique. Without channel coding technique bit error rate is more as compared to with channel coding.

## Conclusions

In this paper MIMO-OFDM with MMSE receiver is investigated. Simulation results show that improved bit error rate is obtained with MIMO system than the without

MIMO system by exploiting diversity gain. In addition bit error rate performance is also investigated for different modulation techniques. Among all modulation techniques for QPSK modulation bit error rate is low. For higher order modulation and higher coding rate bit error rate is also higher. On comparing the performance among the different cyclic prefix, it is shown that minimum bit error rate can be achieved with the higher fraction valued cyclic prefix. Bit error rate for MIMO-OFDM system with channel coding is less as compared to without channel coding.

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