Design, Simulation and Evaluation of SISO/MISO/MIMO-OFDM Systems

Ami Munshi#, Srija Unnikrishnan*

#SVKM's NMIMS MPSTME, Mumbai, India

*FRCRCE, University of Mumbai, India

***Abstract*— In this paper an endeavour is made to design and simulate SISO, MISO and MIMO OFDM systems. We have analysed and compared the performance of these systems for image transmission over AWGN and Rayleigh channels. The effect of LS channel estimation on the BER over a range of SNR for MIMO(2X2) systems is examined. We have also compared the performance based on various M-ary PSK modulation techniques for image transmission over Rayleigh channel in MIMO-OFDM system. The system performance is simulated in Matlab. The results of the simulation show that as the antenna diversity increases, the BER decreases and the channel capacity increases. Also, the BER obtained in MIMO-OFDM system is less when LS estimation is used.**

***Keywords*— OFDM, MIMO, Rayleigh, AWGN, BER, channel capacity**

I. INTRODUCTION

The demand for maximum achievable data rate, less delay time, efficient modulation technique, less interference, reduced effect of multipath propagation and Doppler shift, high picture and voice quality, etc. are increasing day by day in wireless technology. These demands can be met by technologies like multicarrier systems (OFDM), MIMO, CDMA etc. The main advantages of multicarrier systems are its robustness in frequency selective channels and less signal processing complexity as equalization is done in frequency domain. OFDM is amalgamation of modulation and multiplexing. It helps in reducing Inter Symbol Interference for frequency selective channels by adding cyclic prefix. MIMO transforms single point to point channel into multiple parallel channels thus offering higher channel capacity and reduced Bit Error Rate (BER) [4][10].

Here, we attempt to analyze the performance of the three systems namely SISO-OFDM, MISO(1X2)-OFDM and MIMO(2X2) OFDM for image transmission over Rayleigh and AWGN channels. We have also examined the effect of using LS channel estimation technique in MIMO-OFDM system over Rayleigh channel. Matlab simulation results are compared for parameters such as BER and channel capacity.

In section II, we have given brief idea of the abovementioned systems. Section III gives results of simulations performed on the given systems for various conditions. We conclude in section IV by demonstrating the effect of antenna diversity on BER and channel capacity. We also show that by using channel estimation techniques, BER can be reduced.

II. DESIGN AND MODELLING

In this section we have briefly explained MIMO-OFDM systems, mathematical model of AWGN and Rayleigh channel, effect of type of modulation on BER, mathematical model of Least Square channel estimator and expression for channel capacity based on antenna diversity

A. MIMO-OFDM

The basic principle of a multicarrier system is dividing high data rate stream into relatively low data rate sub streams. These sub streams are modulated on different sub carriers. The increase in number of subcarriers reduces the effect of multipath dispersion which in turn reduces ISI (Inter Symbol Interference). More number of subcarriers requires large number of filters and oscillators. Hence OFDM turns out to be an efficient technique in providing multicarrier communication by implementing DFT (Discrete Fourier Transform). OFDM has densely spaced subcarriers with overlapping spectra of modulated signals and avoids the use of steep band pass filters to detect each subcarrier [3][5][6][8].

Based on number of transmit antennas (Nt) and receive antennas (Nr) used, we can have following systems

Nr=1, Nt=1: Single In Single Out (SISO)
Nr=1, Nt>1: Multiple In Single Out (MISO)
Nr>1, Nt=1: Multiple In Single Out (SIMO)
Nr>1, Nt>1: Multiple In Single Out (MIMO)

Fig 1. shows the block diagram of designed system model for 2X2 MIMO.

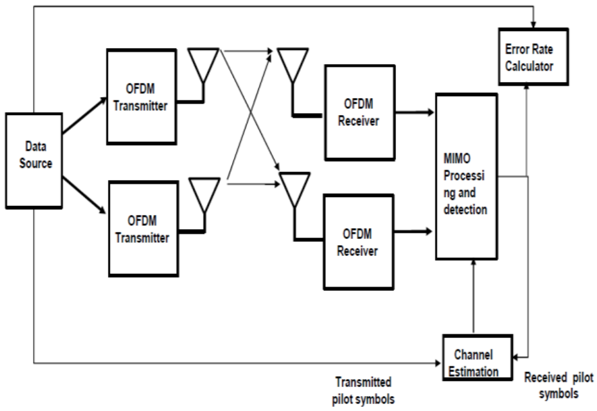

Fig. 1. Block diagram of 2X2 MIMO-OFDM system

For a 2X2 system, symbols received at both the antennas at time instant k is given by

$$y_1(k) = h_{11}x_1(k) + h_{12}x_2(k) + v_1(k)$$
$$y_2(k) = h_{21}x_1(k) + h_{22}x_2(k) + v_2(k)$$
$$Y = HX + V$$

Here Y is the received symbol matrix, H is the channel coefficient matrix, X is the transmitted symbol matrix and V is the noise matrix. We transmit block type pilot symbols for channel estimation.

B. CHANNEL ESTIMATION

We have implemented Least Square algorithm to estimate the channel [9] [11]. For channel estimation purpose, we have transmitted block type pilot symbols, using which the Least Square channel estimate is given by

$$\widehat{H} = YX^T(XX^T)^{-1}$$

After obtaining estimate of channel coefficient matrix, we can obtain the estimate of transmitted symbols using the following expression

$$\widehat{X} = H^{-1}Y$$

C. BIT ERROR RATE IN AWGN AND RAYLEIGH CHANNEL MODEL

We have analysed the designed model for AWGN channel and Rayleigh Channel [2][7]. For AWGN channel, theoretically BER (Bit Error Rate) for a BPSK modulated transmission is given by

$$BER_{AWGN} = Q\sqrt{SNR}$$

For Rayleigh channel, theoretically BER for a BPSK modulated transmission for a SISO is given by

$$BER_{Rayleigh} = \frac{1}{2}\left(1 - \sqrt{\frac{SNR}{2 + SNR}}\right)$$

For MIMO with r receive antennas and t transmit antennas, theoretically BER for a BPSK modulated transmission is given by

$$BER_{Rayleigh} = \left(\frac{1-\lambda}{2}\right)^L \sum_{l=0}^{L-1} {}^{L+l-1}{}_{l}C \left(\frac{1+\lambda}{2}\right)^L$$

where

$$L = r - t + 1$$

here

$$\lambda = \sqrt{\frac{SNR}{2 + SNR}}$$

To find the BER practically, we compare the transmitted data with the received data [5][12]. Then BER is calculated as follows

$$BER_{practical} = \frac{\text{no. of bits in error}}{\text{total number of bits transmitted}}$$

D. CHANNEL CAPACITY IN MIMO

When Channel State Information (CSI) is unknown and when Nt= Nr= N , we can say that MIMO channel is converted into N SISO channels. Then the total channel capacity is given by

$$C = N\log_2(1 + \frac{\lambda_i E_x}{N_0})$$

where, λ_i is the gain for ith SISO channel. Ex is the energy of the transmitted signals and No is the PSD of noise [1][11][12].

III. SIMULATION RESULTS

A. Comparison of SISO-OFDM, MISO (1X2)-OFDM and MIMO (2X2)-OFDM in AWGN channel and in Rayleigh channel for image transmission

Table I below shows comparison of SISO-OFDM, MISO-OFDM and MIMO-OFDM systems for transmitting an image of size 256X256X3 with signal to noise ratio of 5dB and 128 subcarriers, over AWGN channel and Rayleigh channel. We observe that BER for all the three systems over AWGN channel is less than BER over Rayleigh channel. Another important observation made is that the BER decreases with increase in antenna diversity for both the channels. This happens because increase in number of antennas reduces the fading effect.

TABLE I
BER COMPARISON AT 5DB SNR FOR SISO/MISO/MIMO OFDM SYSTEMS FOR AWGN AND RAYLEIGH CHANNELS

System	BER for AWGN Channel(SNR=5dB)	BER for Rayleigh Channel (SNR=5dB)
SISO OFDM	0.0060	0.0773

MISO OFDM	1.7611e-004	0.0211
MIMO OFDM	2.5431e-006	0.0077

The Fig 2, 3, 4 below show the output images of SISO-OFDM, MISO-OFDM and MIMO-OFDM systems respectively over Rayleigh channel which confirm the above results for 5dB SNR.

Fig. 2. Original image

Fig. 3. Output for SISO

Fig. 4. Output for MISO

Fig. 5. Output for MIMO

B. Comparison of various modulation M-ary PSK techniques in MIMO-OFDM system in AWGN channel and Rayleigh channel

Table II below shows comparison of various M-ary PSK modulation schemes implemented in MIMO (2X2)-OFDM for image transmission over Rayleigh channel with signal to noise ratio of 10dB with and without LS estimate. We observe that as number of symbols M increases, BER also increases. This shows that as the Euclidean distance between the symbols decreases, the probability of error increases.

TABLE III

BER COMPARISON AT 10DB SNR FOR BPSK, QPSK AND 16-PSK MODULATION TECHNIQUES FOR MIMO OFDM SYSTEMS OVER RAYLEIGH CHANNEL

	Rayleigh Channel (SNR=10dB)	
Modulation type	**BER with LS estimate**	**BER without estimate**
BPSK	2.8928e-004	0.0069
QPSK	5.8810e-004	0.0136
16-PSK	0.0351	0.1013

C. Image transmission in MIMO (2X2)-OFDM system with and without channel estimation

Table III below demonstrates the performance of MIMO-OFDM system over AWGN channel and Rayleigh channel when LS channel is implemented and without channel estimation for 5dB Signal to noise ratio. We observe that in the case of MIMO (2X2) for both the channels AWGN as well as Rayleigh, BER obtained with LS (Least Square) estimate is less than the BER obtained without using any estimation technique.

TABLE III

BER COMPARISON AT 5DB SNR MIMO OFDM SYSTEMS OVER AWGN CHANNEL AND RAYLEIGH CHANNEL WITH LS ESTIMATION AND WITHOUT ESTIMATION

	AWGN Channel(SNR=5dB)		Rayleigh Channel (SNR=5dB)	
System	**BER with LS estimate**	**BER without estimate**	**BER with LS estimate**	**BER without estimate**
MIMO OFDM	2.5431e-006	2.0154e-004	0.0077	0.0209

Fig 6 below show the plot of SNR vs. BER for image transmission in MIMO-OFDM system over Rayleigh channel when Least Square (LS) estimation is used and without any estimation. We observe that with channel estimation the BER is significantly lower than the BER without estimation over range of SNRs. This demonstrates that improvement in performance of MIMO-OFDM system can be obtained when channel estimation is executed.

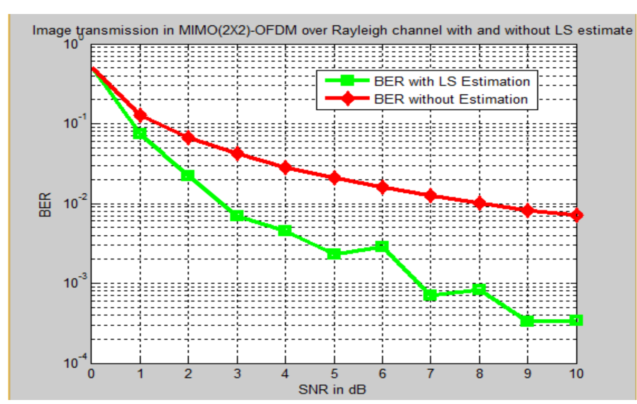

Fig. 6. SNR Vs. BER plot for image transmission in MIMO (2X2)-OFDM over Rayleigh channel with LS estimation and without estimation

D. *Channel capacity with increase in antenna receive diversity*

From the graph below we observe that as the antenna diversity increases, the channel capacity increases.

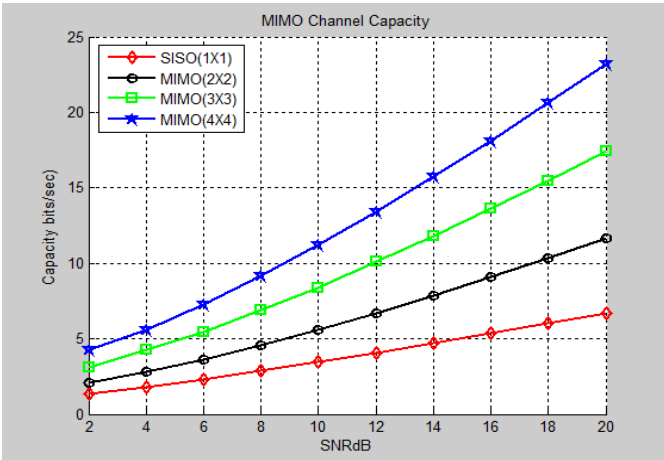

Fig. 7. Channel capacity of SISO, MIMO (2X2), MIMO (3X3) and MIMO (4X4)

IV. CONCLUSIONS

In this paper, we have simulated SISO-OFDM, MISO OFDM and MIMO (2X2)-OFDM systems for image transmission over AWGN channel and Rayleigh Channel. With the results we confirm the fact that as the antenna diversity increases, the BER decreases. We have also compared the performance of MIMO-OFDM system over Rayleigh channel with Least Square channel estimation and without channel estimation. We affirm that with LS estimate, the BER obtained for the range of SNR is less. Also, with increase in antenna diversity, channel capacity increases.

Results show that higher data transmission rates can be achieved, through the use of higher order PSK systems, by employing MIMO OFDM with channel estimation. This can largely increase the capacity of wireless channels.

REFERENCES

[1]. A.K Jaiswal, A. K. (2012). Performance Analysis of MIMO OFDM systems in Rayleigh fading Channels. International Journal of Scientific and Research Publications, 1-5.
[2]. Casu, G., Georgescu, F., Nicolaescu, M., & Mocanu, A. (2015). A comparative performnce analysis of MIMO OFDM systems over different fading channels. 7th International Conference on Electronics, Computers and Artifical Intelligence (pp. 1-4). IEEE Conference Publications.
[3]. Charan Langton, B. S. (2011, October). Finding MIMO. Retrieved from complextoreal: http://complextoreal.com/tutorials/tutorial-27-finding-mimo
[4]. Jiang Xuehua, C. P. (2009). Study and Implementation of MIMO-OFDM System Based on Matlab. International Conference on Information Technology and Computer Science (pp. 554 - 557). IEEE Conference Publications.
[5]. K Fazel, S. K. (2008). Multi-Carrier and Spread Spectrum Systems (2nd ed.). Wiley.
[6]. N.Praba, K. (2016). Image transmisson in OFDM using M-ary PSK modulation shcemes- a comparative study. International Journal of Research in Engineering and Technology, 5(1), 193-197.
[7]. Patil, P. K. (2013). Role of Contributing Factors MIMO-OFDM in 4G-LTE Wireless Transmission Technologies from Technical Perspective. International Journal of Advanced Research in Computer and Communication Engineering, 2(7).
[8]. Poole, I. (n.d.). LTE OFDM, OFDMA SC-FDMA & Modulation. Retrieved April 27, 2017, from Radio-Electronics.com: http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/lte-ofdm-ofdma-scfdma.php
[9]. Principles of Modern CDMA/MIMO/OFDM Wireless Communications. (n.d.). Retrieved April 27, 2017, from NPTEL: http://nptel.ac.in/courses/117104115/#
[10]. S. Ramesh, R. S. (2016). PERFORMANCE ANALYSIS OF MIMO-OFDM FOR MULTIPLE ANTENNAS. International Journal of Pharmacy & Technology, 8(4), 23041-23053.
[11]. Thiruvengadathan, R., & Srikanth, S. (2012). Performance of MIMO Channel Estimation in LTE Downlink. Computing Communication & Networking Technologies (ICCCNT), 2012 Third International Conference on (pp. 1-7). IEEE Conference Publications.
[12]. Yong Soo Cho, J. K. (2010). MIMO-OFDM Wireless Communication with Matlab. Wiley.