Study of Performance Evaluation of Quasi Orthogonal Space Time Block Code MIMO-OFDM System in Rician Channel for Different Modulation Schemes

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Abstract –A Quasi-Orthogonal Space Time Block Coded MIMO-OFDM system is simulated using MATLAB to study performance of BER, MSE & Throughput. The system is modulated using different digital modulation techniques like BPSK, QPSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM. The mentioned analysis of MIMO-OFDM System is done in Rician fading channel. Quasi Orthogonal Space Time Block Coding technique is used for the system.

Index Terms –OFDM, MIMO, QO-STBC, BER, MSE, Throughput, Diversity, LoS.

1. INTRODUCTION

We have progressively moving towards 3rd generation, and 4th generation wireless systems, essentially because of the rapid popularity of wireless systems, rapid popularity that has, the 2G wireless systems have gained. There has been a tremendous demand for increase in the data rates to support not only voice calls, but also video related applications such as video calls video conferencing and so on, over future wireless systems. This demand has led to the requirement & development to have high band width, over existing cellular networks; and that is led to the development of 3G standards & also 4G wireless standards [1]. The goal for the 4G of mobile communications system is to effortlessly integrate a wide variety of communication services such as high speed data, video and multimedia traffic as well as voice signals. This paper is organised as follows. In Section II, background of such techniques is discussed. Here MIMO system, OFDM system and the Rayleigh Fading Channel are studied. In Section III, quasi-orthogonal space time block code technique is discussed. Finally in Section IV, the simulated results based on system have been shown in the plots of BER vs. SNR for QPSK and M-QAM modulation. Section V concludes this paper.

2. RELATED WORK

Before moving further, let’s revise the concepts of Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM).

2.1. Multiple Input Multiple Output (MIMO)

MIMO communication uses multiple antennas at both the transmitter and receiver to exploit the spatial domain for spatial multiplexing and/or spatial diversity. Spatial multiplexing has been generally used to increase the capacity of a MIMO link by transmitting independent data streams in the same time slot and frequency band simultaneously from each transmit antenna, and differentiating multiple data streams at the receiver using channel information about each propagation path, future standards need to specify both bandwidth requirements and type of signalling that achieves the data rate required for minimal predefined qualities of services for future applications.

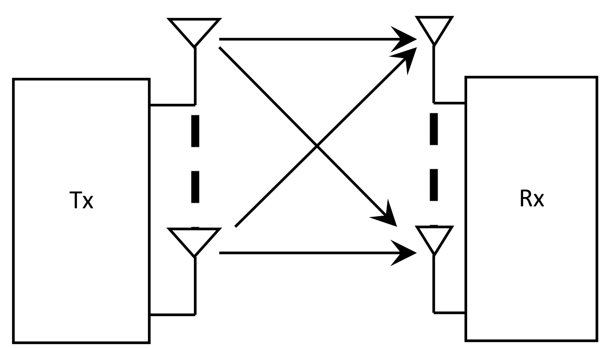

Fig. 1. MIMO Wireless Transmission System

2.2. Orthogonal Frequency Division Multiplexing (OFDM)

OFDM signal is basically a bundle of narrowband carriers transmitted in parallel at different frequencies from the same source. In is often termed multicarrier as opposed to conventional single carrier schemes. Each individual carrier commonly called a subcarrier, transmits information by modulating the phase and possible the amplitude of the subcarrier over the symbol duration. However OFDM or multicarrier systems use a large number of low symbol rate subcarriers. Each subcarrier is orthogonal or non-interfering.Spread spectrum technique of OFDM distributes the data over a large number of carriers that are spaced apart at precise frequencies. This spacing provides the orthogonality, in this technique, which prevents the demodulators from seeing frequencies other than their own. The benefits of OFDM are high spectral efficiency, resiliency to RF interference and lower multipath distortion. This is useful because in a typical terrestrial broadcasting scenario there are multipath channels. Since multiple versions of the signal interfere with each other it becomes very hard to extract the original information.An OFDM system takes a data stream and splits it into N parallel data streams, each at a rate 1/N of the original rate. Each stream is then mapped to a tone at a unique frequency and combined together using the inverse fast Fourier transform (IFFT) to yield the time domain waveform to be transmitted. The idea was to use parallel data transmission and frequency division multiplexing (FDM) with overlapping subcarriers to avoid the high speed equalization. It can also combat impulsive noise, multipath distortion and fully utilize the available bandwidth. OFDM can be efficiently realized using discrete Fourier transform (DFT) techniques at the transmitter and the receiver. This reduces the amount of hardware both at the transmitter and the receiver. The inverse DFT (IDFT) at the transmitter performs multiplexing and modulation simultaneously, while DFT at the receiver performs de-multiplexing and demodulation simultaneously. Both DFT and IDFT are implemented using fast Fourier transform (FFT) algorithms. Advances in very large scale integration (VLSI) and digital signal processing (DSP) technologies have reduced the implementation cost of OFDM systems drastically

[9].

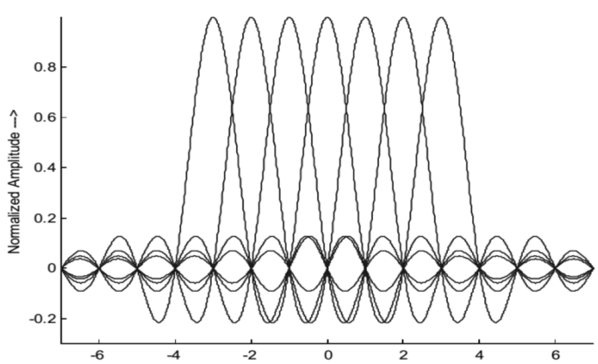

Fig. 2. Spectra of Individual Sub-carriers in OFDM

One of the main advantages of OFDM is its effectiveness against the multi-path delay spread, frequently encountered in Mobile communication channels. Also OFDM is very effective over channel distortion. OFDM also exhibit some advantages like low receiver complexity, high spectral efficiency, robustness against inter symbol interference (ISI), ease of implementation using Fast Fourier Transform (FFT) and simple equalization techniques.Like MIMO, OFDM also shows few disadvantages. One of the most serious problems with OFDM transmission is that, it exhibits a high peak-to-average ratio (PAPR). OFDM is sensitive to frequency offsets, timing errors and phase noise.

2.3. Rician Fading Channel

When there is line of sight (*LOS*) direct path is normally the strongest component goes into deeper fade compared to the multipath components. This kind of signal is approximated by Rician distribution. As the dominating component run into more fade the signal characteristic goes from Rician to Rayleigh distribution. The received signal can be simplified to:

$$r(t) = [s(t) \times h(t)] + n(t) \tag{3}$$

where *h(t)* is the random channel matrix having Rayleigh distribution and *n(t)* is the additive white Gaussian noise. The Rician distribution is given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{(r^2+A^2)}{2\sigma^2}} I_0\left(\frac{Ar}{\sigma^2}\right) \; for(A \geq 0, r \geq 0) \tag{4}$$

Where *A* denotes the peak amplitude of the dominant signal and $I_0[.]$ denotes the modified Bessel function of the first kind and zero order [4].

3. Quasi Orthogonal Space Time Block Code

It is proved in [6] that a complex orthogonal design and the corresponding space–time block code which provides full diversity and full transmission rate is impossible for more than two antennas. So authors of [6] proposed space–time block codes which achieve half of the full transmission rate for any number of transmission antennas. Also it was proposed codes with 3/4 of the full transmission rate for the specific cases of three and four transmit antennas. So in [7], author proposed a different strategy for designing of space time block codes. So author designed rate 1 codes that provide half of the maximum possible diversity. The decoder of the new codes processes pairs of transmitted symbols instead of single symbols. Author proposed structures that are not orthogonal designs and, therefore, at the decoder, cannot separate all transmitted symbols from each other. Instead, in our proposed structure, the transmission matrix columns are divided into groups. While the columns within each group are not orthogonal to each other, different groups are orthogonal to each other. Such a structure is called as *quasi-orthogonal* design. An example of a full-rate full-diversity complex space–time block code is Alamouti scheme [5], which is defined by the following transmission matrix:

$$A_{12} = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \quad (5)$$

Here the subscript 12 is used to represent the indeterminate x_1 and x_2 in transmission matrix. Now, let us consider the following space–time block code for N=M=4: [7]

$$A = \begin{pmatrix} A_{12} & A_{34} \\ -A_{34}^* & A_{12}^* \end{pmatrix} = \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & -x_4^* & x_1^* & x_2^* \\ x_4 & -x_3^* & -x_2^* & x_1 \end{pmatrix} \quad (6)$$

Here a diversity of *2M* is achieved while the rate of the code is one. The proposed matrix for N=M=8 antenna configurations is given as:

$$\begin{pmatrix} s_1 & s_2 & s_3 & s_4 & s_5 & s_6 & s_7 & s_8 \\ -s_2^* & s_1^* & -s_4^* & s_3^* & -s_6^* & s_5^* & -s_8^* & s_7^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* & -s_7^* & -s_8^* & s_5^* & s_6^* \\ s_4 & -s_3 & -s_2 & s_1 & s_8 & -s_7 & -s_6 & s_5 \\ -s_5^* & -s_6^* & -s_7^* & -s_8^* & s_1^* & s_2^* & s_3^* & s_4^* \\ s_6 & -s_5 & s_8 & -s_7 & -s_2 & s_1 & -s_4 & s_3 \\ s_7 & s_8 & -s_5 & -s_6 & -s_3 & -s_4 & s_1 & s_2 \\ -s_8^* & s_7^* & s_6^* & -s_5^* & s_4^* & -s_3^* & -s_2^* & s_1^* \end{pmatrix} \quad (7)$$

4. SIMULATION RESULTS

For simulation, a combined MIMO and OFDM system is considered where quasi-orthogonal space time block coding technique is used. The system is simulated for modulation schemes such as BPSK, QPSK, 8-QAM, 16-QAM, 32-QAM and 32-QAM. The parameters considered for simulation are BER, MSE and throughput. All these simulations are carried out using MATLAB software.

5. RESULTS AND DISCUSSIONS

In this section all the results and the discussions should be made.

5.1 BER vs SNR:

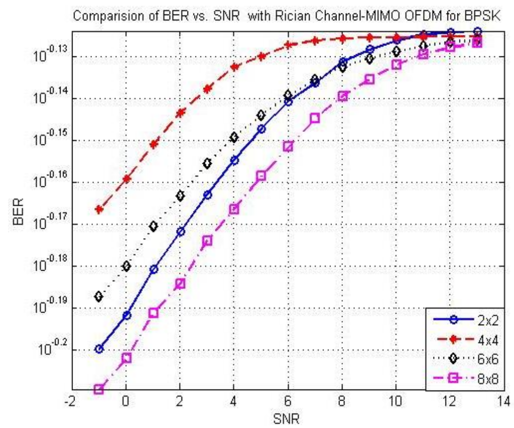

Fig. 3. BER vs. SNR performance of system with BPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

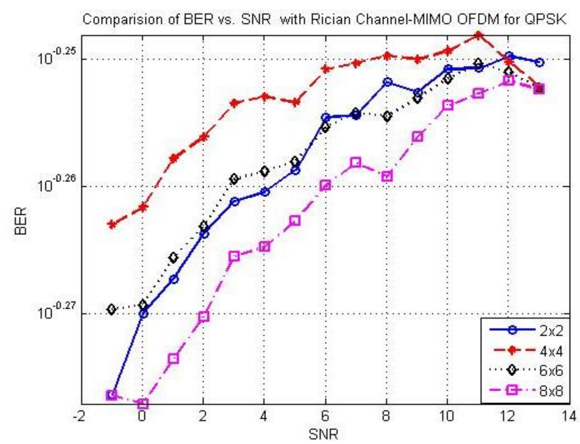

Fig. 4. BER vs. SNR performance of system with QPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

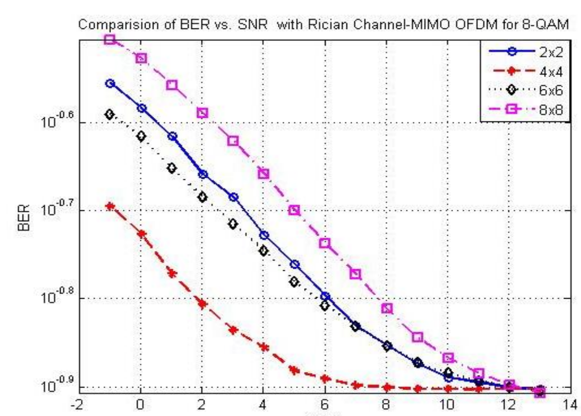

Fig. 5 BER vs. SNR performance of system with 8-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

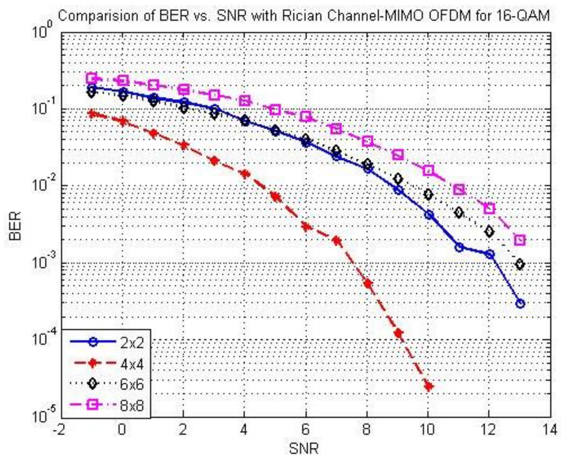

Fig. 6. BER vs. SNR performance of system with 16-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

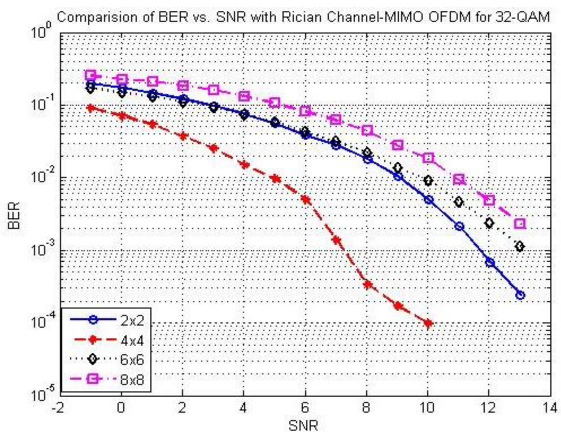

Fig. 7. BER vs. SNR performance of system with 32-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

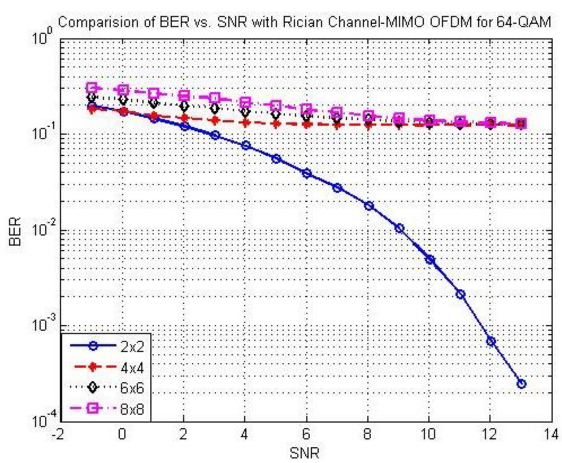

Fig. 8. BER vs. SNR performance of system with 64-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

5.2 Mean Square Error (MSE):

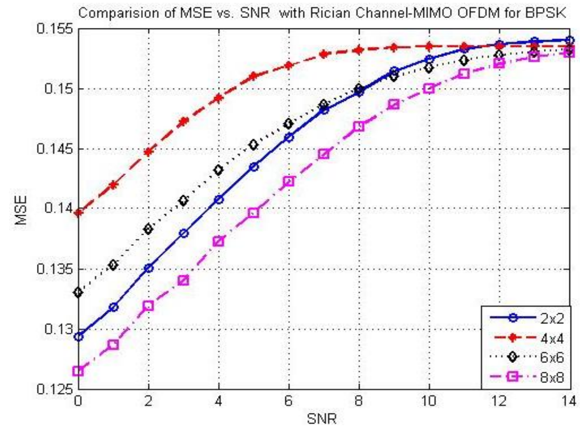

Fig. 9. MSE performance of system with BPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

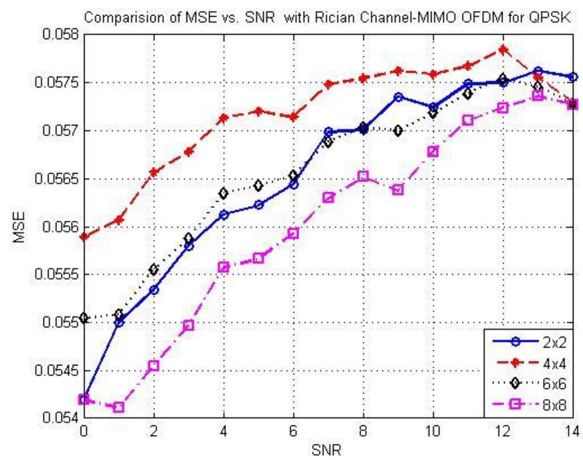

Fig. 10. MSE performance of system with QPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

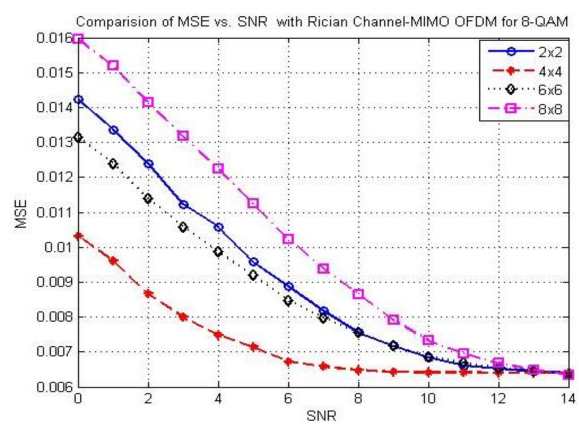

Fig.11. MSE performance of system with8-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

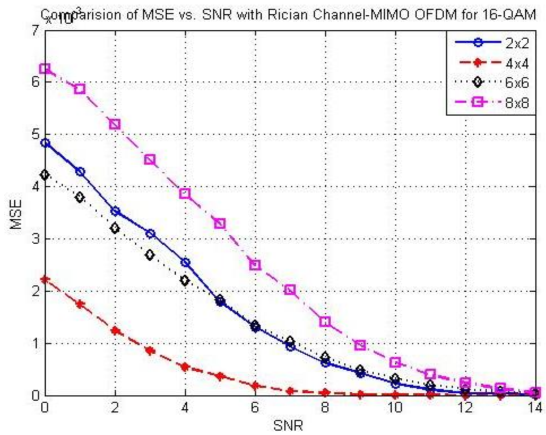

Fig. 12. MSE performance of system with 16-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

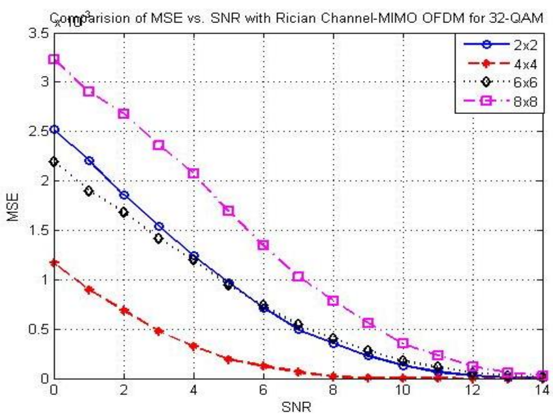

Fig. 13. MSE performance of system with 32-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

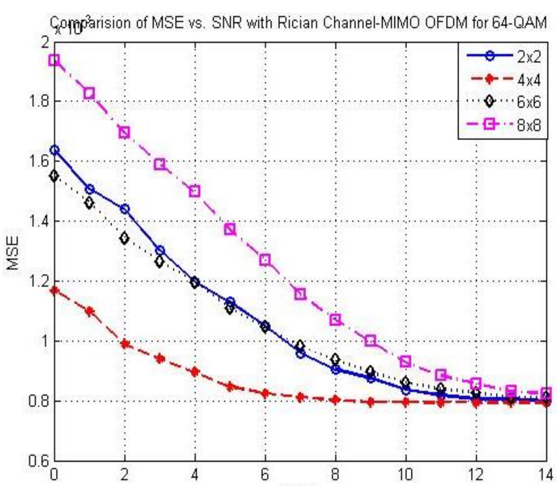

Fig. 14. MSE performance of system with 64-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

5.3 Throughput:

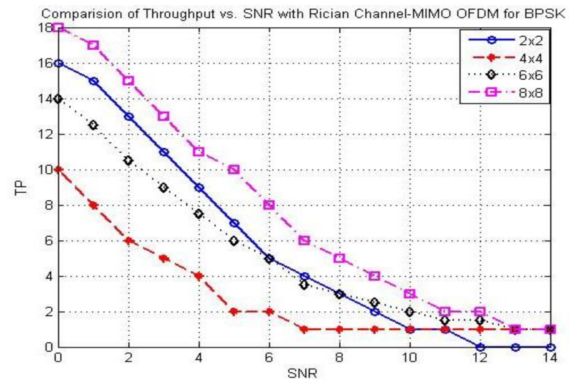

Fig. 15. Throughput performance of system with BPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

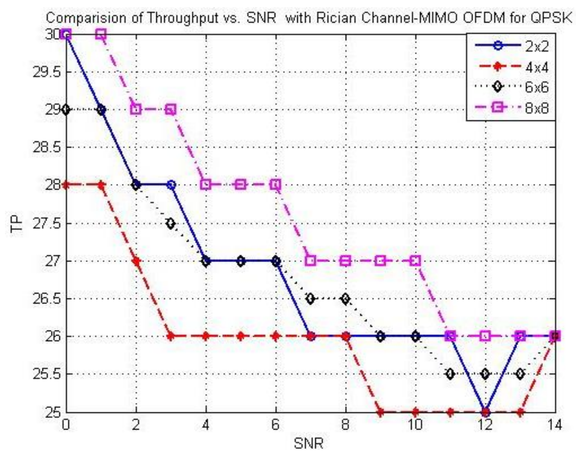

Fig. 16. Throughput performance of system with QPSK for 2x2, 4x4, 6x6 and 8x8 antenna configuration

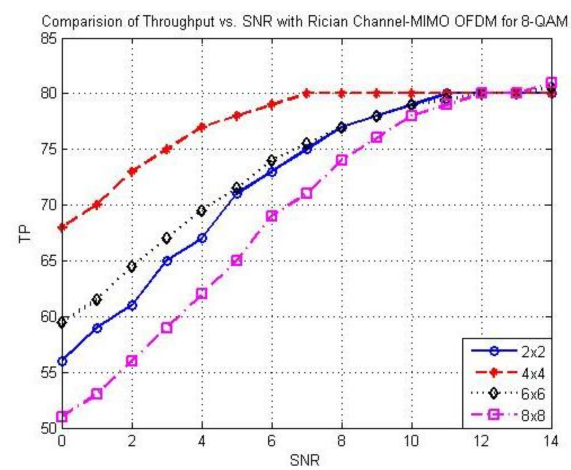

Fig. 17. Throughput performance of system with 8-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

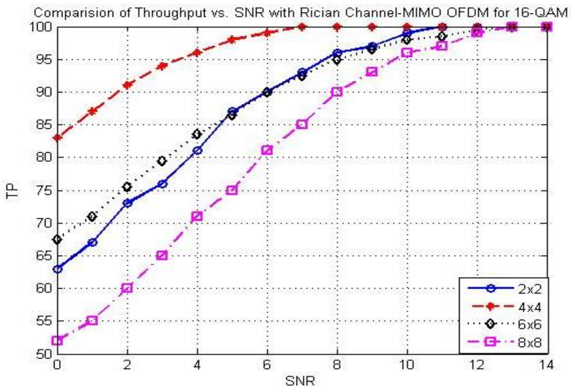

Fig. 18. Throughput performance of system with 16-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

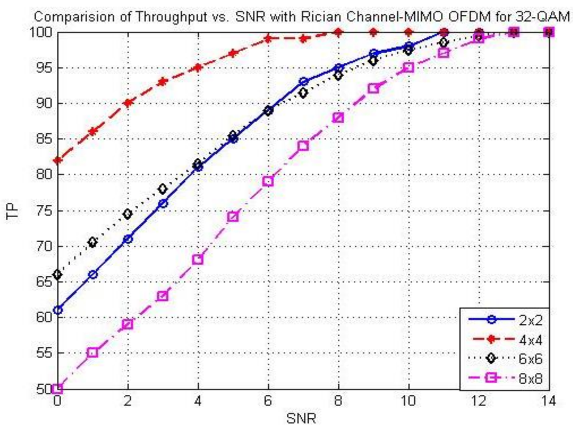

Fig. 19. Throughput performance of system with 32QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

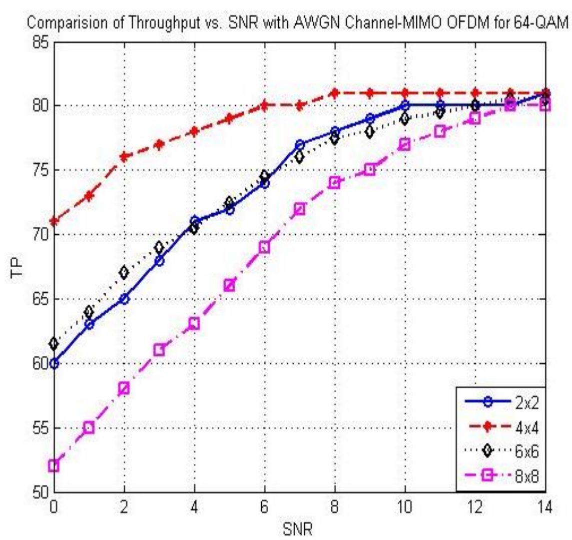

Fig. 20. Throughput performance of system with 64-QAM for 2x2, 4x4, 6x6 and 8x8 antenna configuration

6. CONCLUSION

It can be easily observed from results that performance of system is improved for all parameters like BER, MSE and throughput for higher order modulation schemes and for higher antenna configurations. Use of MIMO has improved system performance in great extent as compared to simple OFDM system. Particularly, 4x4 antenna configuration provides much better results as compared 2x2, 6x6 and 8x8 system. Also it can be noted that 16-QAM and 32-QAM system provides better results.

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