World Applied Sciences Journal 19 (6): 766-771, 2012
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2012.19.06.752

Perfomance of Multiple-Input Multiple-Output (MIMO) Systems in Ricean Channels

Ibrahim. A.Z. Qatawneh

Electrical Engineering Department, Faculty of Engineering,
Mutah University, AL-Karak, postal code: 61710, Jordan

Abstract: Multiple-input multiple-output (MIMO) systems are well known as a technique which allows increasing the throughput of a radio link and overcoming the effects of multipath fading. The phenomenon of multipath propagation, channel models, variations in the radio channel and channel estimation are addressed. In this paper we consider two different types of channels: AWGN, Ricean fading. The entire work will be simulated in the Monti-Carlo simulations. The main contribution of this work includes: a comparative study and a head to head comparison of the different modulation type based MIMO systems. The application of adaptive modulation in the MIMO system will be considered

Key words: A multiple antenna · Wireless channel · Adaptive modulation · Fourth generation · Fading

INTRODUCTION

Communicating over a wireless channel is highly challenging due to the complex propagation medium. The major impairments of the wireless channel are fading and co-channel interference. Due to ground irregularities and typical wave propagation phenomena such as diffraction, scattering and reflection, when a signal is launched modulated onto the wireless environment, it arrives at the receiver along a number of distinct paths, referred to as multipaths. Each of these paths has a distinct and time-varying amplitude, phase and angle of arrival. These multi paths add up constructively or destructively at the receiver. Hence, the received signal can vary over frequency, time and space. These variations are collectively referred to as fading and deteriorate the link quality. Moreover, in cellular systems, to maximize the spectral efficiency and accommodate more users while maintaining the minimum quality of service, frequencies have to be reused in different cells that are separated sufficiently apart. Therefore, the desired user's signal may be corrupted by the interference generated by other users operating at the same frequency. This kind of interference is called co-channel interference (CCI). As a result, to increase capacity and spectral efficiency of wireless communication systems, it is crucial to mitigate fading and CCI. One of the key technologies to mitigate fading and CCI is to implement antenna arrays 1in the system [1]. Antenna arrays can be employed at the transmitter, or receiver, or both ends. With an antenna array at the receiver, fading can be reduced by diversity techniques, i.e., combining independently faded signals on different antennas that are separated sufficiently apart. If antennas receive independently faded signals, it is unlikely that all signals undergo deep fades, hence, at least one good signal can be received. There are three common diversity schemes, selection combining (SC), equal gain combining (EGC) and maximal ratio combining (MRC). You have to develop independent language or jargon for your research content To reduce strong interference, appropriate combining weights can be chosen to maximize the signal-to-interference-plus-noise ratio (SINR), i.e., enhance the desired signal and suppress the interfering signals, as well as reduce fading. If the desired and interfering signals are highly directional, the array radiation pattern may form a beam, i.e., beam form, to the desired user and null the interfering signals. Recently, antenna arrays located at transmitters have attracted much interest. Transmit diversity was first introduced by Wittneben in [2] and later popularized by Tarokh's space-time codes [3]. Similar to the receiver-based beam forming, if the channel information of the desired and co-channel users is available at the transmitter, transmit beam forming can be used to enhance the signal-to-noise ratio (SNR) for the intended user and minimize the interference energy sent towards co channel users [4]. To meet the requirement of

Corresponding Author: Ibrahim A.Z. Qatawneh, Electrical Engineering Department,
Faculty of Engineering, Mutah University, AL-Karak, postal code: 61710, Jordan.

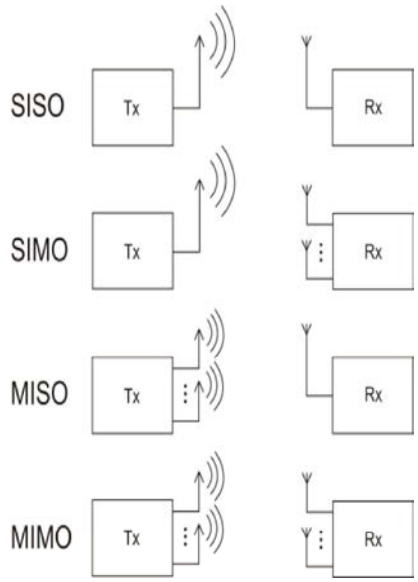

Fig. 1: Different types of transmission systems (SISO, SIMO, MIMO)

very high data rates for wireless Internet and multimedia services, multiple antennas at both the transmitter and receiver have been proposed for fourth generation broadband wireless systems [5]. In a rich scattering environment where channel links between different transmitters and receivers fade independently, it was shown that, by decomposing a multiple-inputs multi-outputs (MIMO) channel into several single-input single-output (SISO) sub channels, the Shannon's information capacity of a MIMO channel increases linearly with the smaller of the numbers of transmitting and receiving antennas [6] Fig. 1 shows different types of transmission systems (single input single output(SISO), Single input multiple output(SIMO) and Multiple input multiple outputs(MIMO). To realize this high capacity, various space-time transmission schemes were investigated, including space-time trellis coding [7] Space-time codes for high data rate wireless communication and space-time differential coding [8,9]. Moreover, considerable work has been conducted to exploit the MIMO capacity using the already highly developed one-dimensional coding and decoding techniques as shown in Fig. 1. for different types of transmission systems.

As a result, different layered space-time architectures were proposed, including Diagonal-Vertical-[10] and Turbo-Bell Labs Layered Space-Time [11,12] also known as D-, V-and T-BLAST, respectively. State-of the-art research of MIMO systems was reviewed in [13] Information capacity of MIMO channels under different environment has been summarized in [14] The motive of modern broadband wireless communication systems is to offer high data rate services. The main hindrance for such high data rate systems is fading [15] as they are more prone to inter-symbol interference (ISI). It therefore becomes essential to use such modulation techniques that are robust to multipath fading. Multi carrier techniques especially Orthogonal Frequency Division Multiplexing (OFDM) [16] has emerged as a modulation scheme that can achieve high data rate by efficiently handling multipath effects. The additional advantages of simple implementation and high spectral efficiency due to orthogonality contribute towards the increasing interest in OFDM. This is reflected by the many standards that considered and adopted OFDM, including those for digital audio and video broadcasting (DAB and DVB),. OFDM is also being considered for fourth-generation (4G) mobile wireless systems [14].. In order to achieve high data rate in OFDM, the receivers must be well designed i.e. it must estimate the channel efficiently and subsequently the data. The receiver also needs to be of low complexity and should not require too much overhead. The problem becomes especially challenging in the wireless environment when the channel is time-variant. Several blind channel estimation algorithms have been devised for OFDM systems. Some of them are based on a subspace approach exploiting the cyclo stationary property that is inherent to OFDM transmissions in the cyclic prefix [15].

Adaptive Modulation for MIMO Systems

Introduction: The major impairments of the wireless channel are fading and co-channel interference. To overcome the problems of the channel impairments we used adaptive modulation for MIMO systems. The modulation schemes as BPSK, QPSK, 16-square QAM, has a spectral efficiency of a MIMO system is expressed in terms of data rate per unit bandwidth in bits/sec/Hz. Adaptive modulation for MIMO systems maximizing information rate has been considered for flat and frequency selective fading channels [17] in assuming perfect channel knowledge at both the transmitter and receiver. In practical systems, the channel Similar adaptive modulation algorithms that are used for orthogonal frequency division multiplexing (OFDM) systems can be adapted and applied to MIMO systems. In addition to traditional modulation schemes (Amplitude, phase and frequency modulations), sometimes Hybrid form of modulation is used, for example changes in both amplitude and phase of the carrier are combined to produce another type of modulation known as Amplitude Phase Keying (APK), which open up another format for digital modulation, also there is an M-ary (APK). M-ary QAM is more spectrally efficient than M-ary PAM and M-ary PSK, which come from them; also it can encode the most number of bits per symbol for a given average energy [18]. Since the information in QAM system is carried at the phase and amplitude., so this modulation scheme required a coherent detection in the receiver side (the phase of the transmitted signal that is received by antenna of the receiver must equal and matched to the phase of the locally generated carrier in the receiver). Recently, a QAM system becomes most popular modulation scheme for digital communication systems [19]. This popularity is due to spectral efficiency of M-ary QAM system. Also since QAM system is a combination of ASK and PSK schemes, the complexity of ASK system is low compared to PSK system which is high, so the complexity of QAM system is in between the two schemes above. Mobile radio systems require spectrally efficient modulation schemes due to the fact that available radio spectrum is limited. With the increasing demands of various mobile communication services, transmission at higher rates will be required in band limited mobile radio systems. A Quadrature Amplitude Modulation QAM scheme is an attractive technique to achieve an improved high rate transmission over wireless links without increasing the bandwidth [19]. For this reason, QAM signaling is strongly recommended for future wireless communication systems. Until quite recently QAM developments were focused at the AWGN telephone line and point to point radio applications. A great deal of recent attention has been devoted to the study of bit error probability for M-ary QAM [20]. In recent years QAM research for hostile fading mobile channels has been motivated by the ever-increasing bandwidth efficiency demand for mobile telephony. The mobile satellite channel has different modulation requirements than the terrestrial systems which has impact on overall system design, many designers have proposed a mobile video transmission system based on highly bandwidth efficient QAM for cellular applications [21]. Also as mentioned above, in the current and future mobile communication systems, data transmission at high bit rates is essential for many services such as video, high quality audio and mobile integrated Digital Network (ISDN), the QAM modulation scheme is one of the most important modulation schemes used in the new technology.

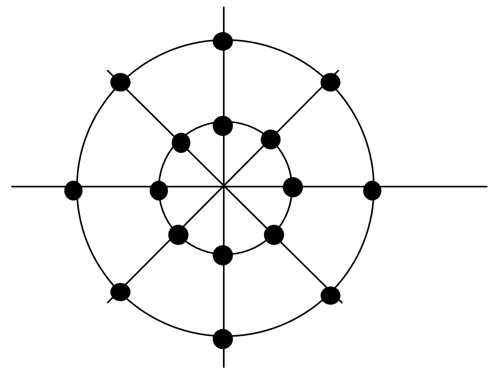

Fig. 2: 16 level star QAM constellation.

16 Star QAM: The majority of work concerning QAM for mobile radio applications has utilized square QAM constellations. In general 16 QAM (square) requires coherent detection. However, since the performance of coherent detection is severely affected by multipath fading, (mainly because of carrier recovery issues), the 16 Star QAM constellation shown in Figure 2 combined with differentially coherent detection is preferred [22].

Fading Channel Models: To simulate the flat fading MIMO channel, we use a Ricean channel [18, 23] The comparison of multiple outputs with QPSK and 16 QAM modulation is considered for mobile and wireless applications, for this reason, the appropriate radio channel models are chosen to support the simulation process for this work. A typical channel model in land mobile radio is known as frequency flat. This model is suitable for modeling urban areas that are characterized by many obstructions, e.g., buildings, or any objects surrounding the mobile station where a line of sight path does not exist. In suburban areas, a line of sight path may exist between transmitter and receiver and this will give rise to Ricean fading. Ricean fading may be characterized by a factor which is defined as the power ratio of the specular *a* (line of sight or direct path) component to the diffuse components *d* [18] This ratio α, defines how near to Rayleigh statistics of the channel. In fact, when the power ratio of the specular $\alpha\infty$ and there is no fading at all. The rate of change of the fading is defined by the Doppler rate. The Doppler rate is proportional to the velocity of the mobile station and the frequency of operation. The normalized Doppler rate is given by $f_d T_s$ where f_d is the maximum Doppler rate and T_s is symbol duration for Multiple input multiple output with QPSK or 16 QAM modulation. For these work simulations, the symbol duration is equal to one second so that the normalized

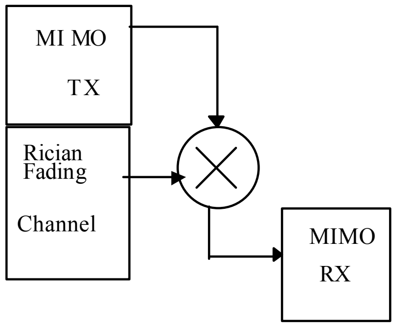

Fig. 3: Frequency selective fading channel model for simulation for one path fading channel model

Doppler rate is equal to the Doppler rate [22]. In general, normalized Doppler rates less than 0.01 are applicable to most systems. A more complex propagation model includes many discrete scatters, where each propagation path may have a different amplitude, propagation delay and Doppler shift. When the components of a signal are received with different delays, the phase difference between them is a function of the frequency of the components. Thus the transmitted signal will experience a channel with a non-flat frequency response, which also varies with time. This type of channel is said to be frequency selective and is usually modeled as a tapped delay line, where the number of taps is equal to the number of discrete delayed paths. Clearly, the effect of the tapped delay line is to introduce overlap between the transmitted symbols. This form of degradation is known as Inter Symbol Interference (ISI. In this model the first arriving path experiences Ricean fading the ratio α for the Ricean fading path is equal to 20 for all the simulations. the symbol duration is equal to one second so that the normalized Doppler rate is equal to the Doppler rate. In general, normalized Doppler rates less than 0. 1 are applicable to most systems [23,24]. Figure 3 shows the simulation model.

Performance of MIMO/BPSK, MIMO/QPSK and MIMO/16QAM

Performance of MIMO/BPSK, MIMO/QPSK and MIMO/16QAM with AWGN Channel: The simulation results in Fig 4, shows, the performance of the MIMO/BPSK, MIMO /QPSK system and MIMO/16QAM in presence of AWGN. The BER performances presented in Fig.4 compares the output of MIMO/BPSK, MIMO/QPSK and

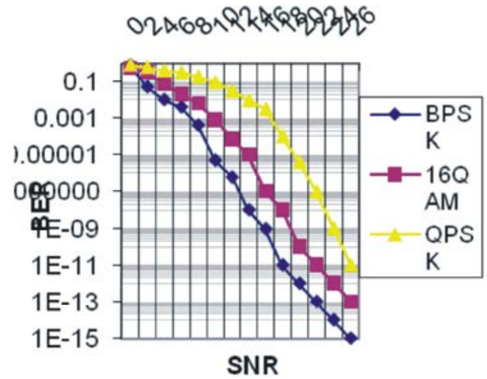

Fig. 4: Performance of the MIMO/BPSK, MIMO/QPSK system and MIMO/16QAM in presence of AWGN.

MIMO/16QAM systems in the presence of Gaussian channel (a = Infinity∞). It can be observed that the SNR performance of the multiple outputs using MIMO/BPSK systems is about 4 dB better than the results that achieved using MIMO/QPSK and 10 dB better than the results achieved using multiple outputs MIMO/16QAM at the same BER of 1×10^{-5}. This means that we have an improvement of 6 dB for the system performance using MIMO/16QAM over the system performance using MIMO/QPSK system at the same BER in AWGN channel. Also we have an improvement of 10 dB for the system performance using MIMO/16QAM compared to the performance using MIMO/BPSK system at the same BER 1×10^{-5} in AWGN

Performance of MIMO/QPSK and MIMO/16QAM with Rician Fading Channel: The BER performances presented in Fig. 5, Shows the Comparison of single channel SISO/QAM and multiple channel MIMO/16 QAM systems in the presence of Gaussian channel (a = Infinity∞) and a specular component for Ricean channel (a = 20) for a Doppler rate of 0.01 Hz.

It can be observed that the Ricean channel degrades the SNR performance of the multiple input multiple outputs MIMO/16 QAM systems by about 5 dB compared with results that achieved over the Gaussian channel at a BER of 1×10^{-3}. The single input single output SISO/16 QAM channel system performance is some 2 dB worse than the MIMO16/QAM system at the same BER (1×10^{-3}) in the Ricean channel. The irreducible BER is also higher for the single channel system. This means that the system performance of MIMO/16QAM is better than the system performance SISO/ 16QAM at the same specular

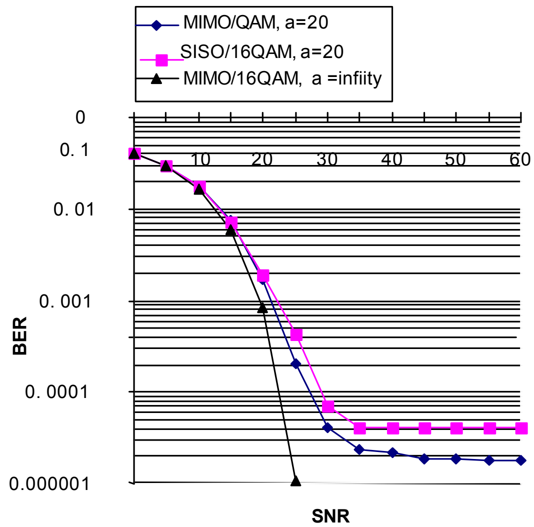

Fig. 5: Comparison of single channel SISO/QAM and MIMO/16QAM systems in the presence of Gaussian channel (a = Infinity∞) and a specular Rician channel (a = 20) for a Doppler rate of 0.01 Hz.

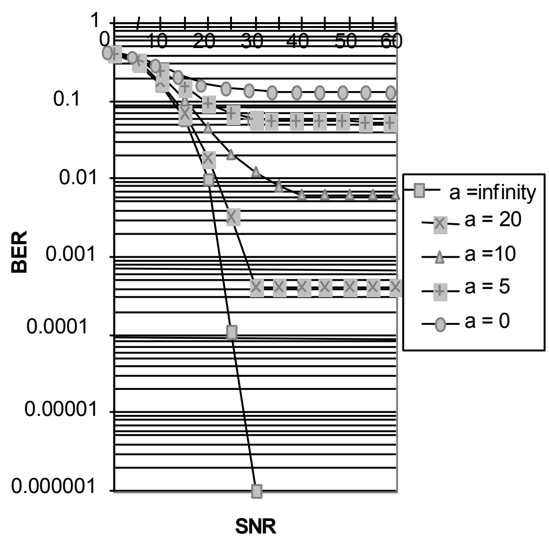

Fig. 6: BER performance MIMO with 16 star QAM in the presence of AWGN with various Rician fading channels for a Doppler rate of 0.1Hz.

components (a=20), but the system performance of MIMO/16QAM at the Gaussian channel is better than the system performance at Ricean channel in 4dB.

The results of BER performances presented in Fig.6. compare the performance of MIMO system with 16 star QAM in the presence of AWGN and various Ricean fading channels (a = 0, a =5, a =10, a =20 and a =infinity) for a Doppler rate of 0.1Hz. It can be observed that the BER performance of the multiple input outputs MIMO/16 QAM systems is 6×10^{-5} at a=20 which is better than the BER performance of the multiple input outputs MIMO/16 QAM systems at a=10 which is 1×10^{-2} with the same signal power (25dB). Finally the result shows that when we increase the power ratio of the specular components (a) we improve the SNR performance and the best result with *a is infinity no fading* which is the result of Gaussian channel.

CONCLUSIONS

In this paper, the performance of MIMO/BPSK, MIMO/QPSK and MIMO/QAM has been investigated in AWGN, flat /Rician fading with different transmitting and receiving antenas. With a specular components (a = 20) Ricean channel at a normalized Doppler rate of 0.1 and 0.01, However, for the indoor or microcellular environment a direct path is likely to lead to less hostile channels than flat fading. However, in the indoor or microcellular channel, the normalized Doppler rate is likely to be lower than the 0.1 and 0.01 used in the simulations. In this paper, the high digital transmission MIMO technique's performance has been investigated in the presence of AWGN, flat /Ricean fading, by considering a complete simulation model of the system. This technique is considered as a solution for the digital cellular communications network congestion, due to the high consumer demand through increasing the system's capacity. With a specular component (a=20) the channel is Ricean at a normalized Doppler rate of 0.1. However, for the indoor or microcellular environment a direct path is likely to lead to less hostile channels than Ricean fading. Also the simulation results for MIMO/16QAM for various Ricean fading channel and Doppler frequency of 0.1 Hz has been investigated. Therefore, in conclusion high transmission MIMO technique is capable of solving the modern communications congestion problem by increasing the system's capacity. This would also have a positive impact on the national and international economies.

REFERENCES

1. Godara, L.C., 1997. Application of antenna arrays to mobile communications, part i: Performance improvement, feasibility and system considerations. Proc. IEEE, pp: 1031-1060.

2. Wittneben, A., 1993. A new bandwidth efficient transmit antenna modulation diversity scheme for linear digital modulation. In Proc. IEEE Int. Conf. Communications, pp: 1630-1634.
3. Tarokh, V., N. Seshadri and A.R. Calderbank, 1998 Space-time codes for high data rate wireless communication: Performance criterion and code construction. IEEE Trans. Inform. Theory, pp: 744-765.
4. Rashid-Farrokhi, F., K.J.R. Liu and L. Tassiulas, 1998. Transmit beam forming and power control for cellular wireless systems. IEEE J. Select. Areas Commun., pp: 1437-1449.
5. Sampath, H., S. Talwar, J. Tellado, V. Erceg and A. Paulraj, 2002. A fourth-generation MIMO-OFDM broadband wireless system: design, performance and field trial results. IEEE Commun. Mag., pp: 143-149.
6. King, T.W. and P.J. Smith, 2009. Modified water filling algorithms to increase MIMO-BC system fairness, submitted to EURASIP Journal on Wireless Communication s and Networking.
7. Tarokh, V., A. Naguib, N. Seshadri and A.R. Calderbank, 1999. Space-time codes for high data rate wireless communication: performance criterion in the presence of channel estimation errors, mobility and multiple paths. IEEE Trans. Commun., pp: 199-207.
8. Agrawal, A., G. Ginis and J.M. Cioffi, 2002. Channel diagonalization through orthogonal space-time coding. In Proc. IEEE Int. Conf. Communications.
9. Hochwald, B.M. and W. Sweldens, 2000. Differential unitary space-time modulation. IEEE Trans. Commun., pp: 2041-2052.
10. Foschini, G.J. and Layered, 1996. space-time architecture for wireless communication in afading environment when using multi-element antennas. Bell. Labs. Tech. J., pp: 41-59.
11. Golden, G.D., G.J. Foschini, R.A. Valenzuela and P.W. Wolniansky, 1999. Detection algorithm and initial laboratory results using the V-BLAST space-time communication architecture. Electron. Lett., 35(1): 14-15.
12. Gesbert, D., M. Shafi, D. Shiu, P.J. Smith and A. Naguib, 2003. From theory to practice: an overview of MIMO space-time coded wireless systems. IEEE J. Select. Areas Commun., pp: 281-302.
13. Huang, H., A. Hottinen, M. Shafi, P.J. Smith, M. Trivellato and R. Valen-zuela, 2009. Increasing downlink cellular throughput with limited network MIMO coordination, accepted to IEEE Trans. Wireless Comm.
14. Sampath, H., S. Talwar, J. Tellado, V. Erceg and A. Paulraj, 2002. A fourth-generation MIMO-OFDM broadband wireless system: design, performance and field trial results, IEEE Commun. Mag, 40: 143-149.
15. Sadek, A.K., W.F. Su and K.J.R. Liu, 2006. Diversity analysis for frequency-selective MIMO-OFDM systems with general spatial and temporal correlation model', IEEE Trans. Commun., 54: 878-888.
16. Molisch, A. and X. Zhang, 2004. FFT-based hybrid antenna selection schemes for spatially correlated MIMO channels, IEEE Commun. Lett., 8(1): 36-38.
17. Smith., P.J., T.W. King and L.M. Garth, 2007. Capacity and fairness of MIMO broadcast algorithms in shadow fading environments, in Proc. IEEE Global Telecommunications Conference, Washington D.C., USA, pp: 3617-3622.
18. Qatawneh, I.A.Z., 2002. Bit error rate performance of orthogonal frequency division multiplexing (OFDM) utilizing differentially encoded 16 star quadrature amplitude modulation (QAM) with differentially coherent demodulation in AWGN, frequency flat and two path fading channels Mansoura Engineering Journal (MEJ), Faculty of Engineering, Mansoura University, 27(3). Eygpt, pp: E 37-E48.
19. Dababneh, M. and I. Qatawneh, 2005. Novel Mathematical Model for capacity evaluation of modern digital radio systems Information Technology Journal, 4(3): 293-298.
20. Badruddin, N., J. Evans and S. Hanly, 2008. Maximizing sum rate for two interfering wireless links, in Australian Communications Theory Work-shop, Christchurch, NZ, pp: 75-81.
21. John, D. Qetting, 1979. A comparison of modulation techniques for digital radio IEEE Transactions on communications, Com., 27(12), 1: 752-1763.
22. Hirosaki, B., S. Hasegawa and A. Sabato, 1986. Advanced group band data modem using orthogonally multiplexed QAM techniques IEEE Transactions on communications. Com., 34(6): 587-592.
23. Chiani, M., M.Z. Win and H. Shin, 2006. Capacity of MIMO systems in the presence of interference, in Proc. IEEE Global Telecommunications Conf., San Francisco, CA, USA., pp: 1-6.
24. Smith, P.J., S. Roy and M. Shafi, 2003. Capacity of MIMO systems with Semi correlated flat fading, IEEE Trans. Inform. Theory, 49(10): 2781-2788.