

Multiple-Input Multiple-Output Transmission Over a Multipath Faded Channels

Qatawneh, I.A.Z.

Department of Electrical Engineering,
Faculty of Engineering, Mutah University, AL-Karak, Postal Code: 61710, Jordan

Received 2012-10-30, Revised 2013-02-22; Accepted 2013-04-16

ABSTRACT

The use of multiple antennas at the transmitter as well as at the receiver can greatly improve the capacity of a wireless link when operating in a rich scattering environment. In such an arrangement all transmitting antennas radiate in the same frequency band so the overall spectral efficiency becomes very high. Such a multiple antenna scheme, popularly known as Multiple Input Multiple Output (MIMO) has potential application in Wireless Local Area Networks (WLAN) and cellular micro-cells. One reason is that the WLANs and other short range wireless systems often operate in an indoor environment, which offers rich scattering. The other reason is the demand for higher data rates in cellular and WLAN systems to scatter for multimedia services. Also to meet the requirement of very high data rates for wireless Internet and multimedia services, multiple transmitting and multiple receiving antennas have been proposed for fourth generation wireless systems. In cellular systems, performance is limited by fading and co channel interference from other users. Most of the current studies on Multiple-Input Multiple-Output (MIMO) systems assume that the co-channel interference is both spatially and temporally white. Recently researchers have proposed different architectures for materializing the potential of the MIMO scheme. We consider three different types of channels: AWGN, Rician fading and Rayleigh fading. The entire work will be simulated in the Monti Carlo simulations. The main contribution of this study includes: A comparative study and a head to head comparison of the different modulation types based MIMO systems. The application of adaptive modulation in the MIMO system will be considered.

Keywords: A Multiple Antenna, Rayleigh Fading, Wireless Communication Channel, Wireless local Area Network

1. INTRODUCTION

The major impairments of the wireless channel are fading and co-channel interference. Which is created due to typical wave propagation such as diffraction, scattering and reflection, when a signal is modulated and launched onto the wireless environment, at the receiver the signal arrives as a number of different paths, referred to as multi paths. Each of these paths has 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. Because one of the major bottlenecks encountered in the wireless channel has been multipath propagation .there are different methods have been devised to reduce its effect on the quality of information being transmitted. Multiple-Input Multiple-Output (MIMO) can be used to reduce power consumption and increase capacity of the MIMO systems. Also, we must consider that, 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 principles used to mitigate fading and CCI is to implement antenna arrays in the system (Godara, 1997; Liberti and Rappaport, 1999; Winters, 1998). Antenna arrays can be employed at the transmitter and receiver. fading can be reduced by using diversity techniques, i.e., combining independently faded signals on different antennas that are separated sufficiently apart. Recently, antenna arrays located at transmitters have attracted much interest. Transmit diversity was first introduced by in (Wittneben, 1993) and by space-time codes (Tarokh *et al.*, 1998). This a similar principle 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 (Rashid-Farrokhi *et al.*, 1998; Lozano *et al.*, 2001). To meet the requirement of 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 (Lozano *et al.*, 2001; Murch and Letaief, 2002; Sampath *et al.*, 2002; Foschini and Gans, 1998).

One of the major bottlenecks encountered in the wireless channel has been multipath propagation. There are many methods have been devised to reduce its effect of multipath on the quality of information being transmitted. Multiple-Input Multiple-Output (MIMO) can be used to reduce power consumption and increase capacity of the MIMO system.

The considerable work has been conducted to exploit the MIMO capacity using the already highly developed one-dimensional coding and decoding techniques (Agrawal *et al.*, 2002; Tarokh *et al.*, 1999a; 1999b; Hochwald and Sweldens, 2000) as shown in **Fig. 1**. As a result, different layered space-time architectures were proposed, including Diagonal-(Tarokh *et al.*, 1998), Vertical-(Golden *et al.*, 1999) and Turbo-Bell Labs Layered Space-Time (Sellathurai and Haykin, 2002; Gesbert *et al.*, 2003), also known as D-, V- and T-BLAST, respectively. State-of-the-art research of MIMO systems was reviewed in (Ebrahimi *et al.*, 2006; Femnias, 2004). Information capacity of MIMO channels under different environment has been summarized in (Goldsmith *et al.*, 2003; Sampath *et al.*, 2002).

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 multipath fading (Gjendemsjo *et al.*, 2007;

Bialkowski *et al.*, 2006; Sadek *et al.*, 2006) 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. Multicarrier techniques especially Orthogonal Frequency Division Multiplexing (OFDM) has been used as a modulation scheme that can achieve high data rate by efficiently handling multipath effects.. 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 (Sampath *et al.*, 2002). In order to achieve high data rate in OFDM, the receivers must be well designed and it must estimate the channel efficiently and subsequently the data. The receiver also needs to be of low complexity. 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 (Huih *et al.*, 2006; Intarpanich *et al.*, 2004). Another type of blind channel estimator capitalizes on the finite alphabet property of the modulated symbols (Hui *et al.*, 2004).

1.1. Essential Elements of OFDM

In an OFDM system, data is transmitted in symbols X_i of length N each. The symbol undergoes an IFFT (Molisch and Zhang, 2004) operation to produce the time domain symbol X_i , i.e. Equation 1:

$$x_i = \sqrt{NQX_i} \quad (1)$$

where, Q is the $N \times N$ IFFT matrix Equation 2:

$$Q = \left[\frac{1}{N} e^{j\frac{2\pi}{N}(l-1)(m-1)} \right] \quad (2)$$

When juxtaposed, these symbols result in the sequence $\{x_k\}$. We assume a non-ideal channel \underline{h} of maximum length $L + 1$. To avoid Inter-Symbol Interference (ISI) caused by passing through the channel, a Cyclic Prefix (CP) \underline{x}_i (of length L) is appended to X_i , resulting finally in super-symbol \bar{X}_i (of length $N + L$). The concatenation of these symbols produces the underlying sequence $\{\bar{x}_i\}$: When passed through the channel \underline{h} , the sequence $\{\bar{x}_k\}$ produces the output sequence $\{\bar{y}_k\}$ i.e. Equation 3:

$$\bar{y}_k = \underline{h}_k * \bar{x}_k + \bar{n}_k \quad (3)$$

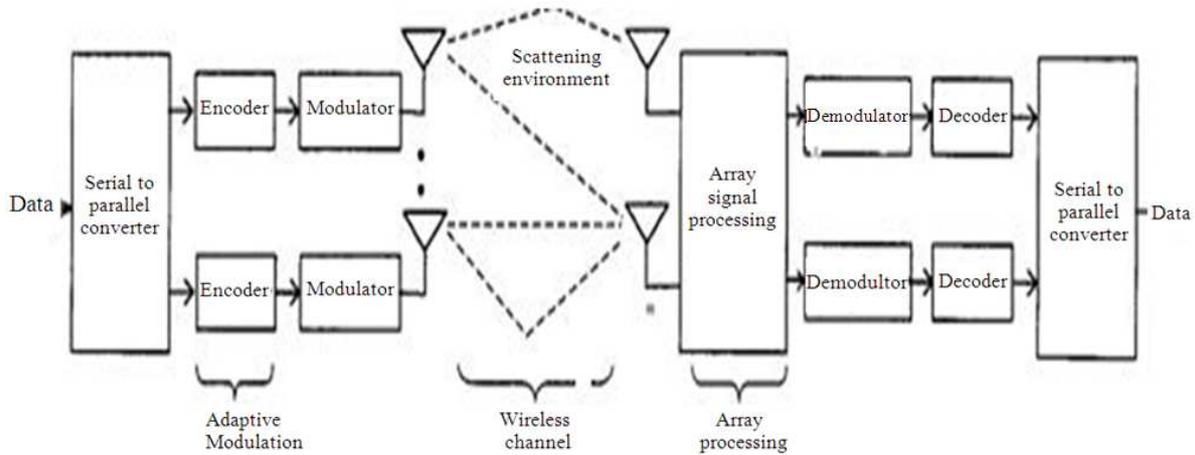


Fig. 1. MIMO modulator and demodulator

where, \bar{n}_k is the additive white Gaussian noise and * stands for linear convolution.

Motivated by the symbol structure of the input, it is convenient to partition the output into symbols of length $M = N + L$; i.e. Equation 4:

$$\bar{y}_i = \begin{bmatrix} y_i \\ y_i \end{bmatrix} \tag{4}$$

This is a natural way to partition the output because the prefix y_i actually absorbs all ISI that takes place between the adjacent symbols \bar{x}_{i-1} and \bar{x}_i . Moreover, the remaining part y_i of the symbol depends on the i th input OFDM symbol X_i only.

1.2. Circular Convolution

Due to the presence of the cyclic prefix, the input and output OFDM symbols X_i and y_i are related by circular convolution (denoted by \odot), i.e. Equation 5:

$$y_i = h_i \odot x_i + n_i \tag{5}$$

where, h_i is a length- N zero-padded version of \underline{h}_i . In the frequency domain, the cyclic convolution (5) reduces to the element-by-element operation Equation 6:

$$y_i = H \square X_i + N_i \tag{6}$$

where, H , X_i , N_i and y_i are the DFT's of h , x_i , n_i and y_i respectively Equation 7:

$$H = Q^* h, X_i = \frac{1}{\sqrt{N}} Q^* x_i, N_i = \frac{1}{\sqrt{N}} Q^* n_i, \text{ and } y_i = \frac{1}{\sqrt{N}} Q^* y_i \tag{7}$$

Since \underline{h} corresponds to the first $L + 1$ elements of h , we can show that Equation 8:

$$H = A^* \underline{h} \text{ and } \underline{h} = AH \tag{8}$$

where, A^* consists of the first $L + 1$ columns of Q^* and A consists of first $L + 1$ rows of Q . This allows us to rewrite (6) as Equation 9:

$$y_i = \text{diag}(X_i) A^* \underline{h} + N_i \tag{9}$$

1.3. Description of Data Detection Approach

Consider input/output Equation 6, reproduced here for convenience Equation 10 and 11:

$$y = H \square X + N \tag{10}$$

$$y = H \square X + N = \text{diag}(X_i) H + N \tag{11}$$

This equation can be written as Equation 12:

$$y(j) = X(j)H(j) + N(j) \tag{12}$$

Or since $H = A^* \underline{h}$ Equation 13:

$$y(j) = X(j)a_j^* \underline{h} + N(j) \tag{13}$$

where, a_j^* is j th row of A^* (so that a_j is the j th column of A).

We would like to minimize the objective function Equation 14:

$$0 = \min_{h, x \in \mathbb{Q}^{N_i}} \|y - \text{diag}(X)A^* \underline{h}\|^2 \tag{14}$$

where, Ω^N denotes the set of N-dimensional signal vector.

Let us consider a partial data sequence $X_{(i)}$ up to the time index i and define $M_{x(i)}$ as Equation 15:

$$M_{x(i)} = \min_{\mathbf{h}, \mathbf{x} \in \Omega^N} \|y_{(i)} - \text{diag}(X_{(i)})A_{(i)}^* \mathbf{h}\|^2 \quad (15)$$

where, $A_{(i)}^*$ consists of the first i rows of A^* .

Now, as per in papers (Garth *et al.*, 2006; King *et al.*, 2007), let R be the optimal value for our objective function in (14), if $M_{x(i)} > R$, then $X_{(i)}$ cannot be the first i symbols of the ML solution $\hat{X}_{(i)}$ to (14) Equation 16-18:

$$R = \|y_{(i)} - \text{diag}(X_{(i)})A_{(i)}^* \mathbf{h}\|^2 + \sum_{j=i+1}^N \|y_{(j)} - x_{(j)}a_j^* \mathbf{h}\|^2 \quad (16)$$

$$\geq \min_{\mathbf{h}} \|y_{(i)} - \text{diag}(X_{(i)})A_{(i)}^* \mathbf{h}\|^2 + \sum_{j=i+1}^N \|y_{(j)} - X_{(j)}a_j^* \mathbf{h}\|^2 \quad (17)$$

$$\geq \min_{\mathbf{h}} \|y_{(i)} - \text{diag}(X_{(i)})A_{(i)}^* \mathbf{h}\|^2 = M_{x(i)} \quad (18)$$

Since \mathbf{h} has $L + 1$ degrees of freedom, we need $L+1$ pilots to identify it, or we need to guess $L + 1$ solution before we can move on. The reason is that \mathbf{h} has $L + 1$ degrees of freedom.

Alternatively, we can set the following approximation to our regularization problem, minimizing instead Equation 19:

$$0 = \min_{\mathbf{h}, \mathbf{x} \in \Omega^N} \|\mathbf{h}\|_{\mathbf{r}^{-1}}^2 + \|y - \text{diag}(X)a_j^* \mathbf{h}\|^2 \quad (19)$$

where, $\mathbf{\Pi}$ is some weighting matrix that could be taken as the autocorrelation matrix of \mathbf{h} . In this case, $M_{x(i)}$ will be Equation 20:

$$M_{x(i)} = \min_{\mathbf{h}, \mathbf{x} \in \Omega^N} \|\mathbf{h}\|_{\mathbf{r}^{-1}}^2 + \|y_{(i)} - \text{diag}(X_{(i)})a_j^* \mathbf{h}\|^2 \quad (20)$$

Which we can solve it using regularized least squares solution (Sadek *et al.*, 2006). If the value R of the objective function in (19) can be estimated, we can restrict the search of the blind ML solution \hat{X} to the offsprings of those partial sequences $X_{(i)}$ which satisfy $M_{x(i)} > R$. In the following algorithm description, we denote the k th constellation point in the modulation constellation Ω as $\Omega(k)$.

1.4. Exact Blind ML Detection Algorithm 5

Input: the received channel output y , the search radius r , the modulation constellation Ω and a $1 \times N$ index vector I :

- Set $i = 1$, $r_i = r$, $I(i) = 1$ and set $x_i = \Omega(I(i))$
- (Computing the bounds) Compute the metric $M_{x(i)}$. If $M_{x(i)} > r$, go to 3; else, go to 4
- (Backtracking) Find the largest $1 \leq j \leq i$ such that $I(I) < |\Omega|$. If there exists such j , set $i = j$ and go to 5; else go to 6
- If $i = N$, store current $X_{(N)}$, update $r = M_{x(i)}$ and go to 3; else set $I = I + 1$, $I(i) = 1$ and $X_{(N)} = \Omega(I(i))$, go to 2
- Set $I(i) = I(i) + 1$ and $X_{(i)} = \Omega(I(i))$. Go to 2
- If any sequence $X_{(N)}$ is ever found in Step 4, output the latest stored full-length sequence as ML solution; otherwise, double r and go to 1

1.5. Adaptive Modulation for MIMO Systems

1.5.1. Introduction

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 in (King *et al.*, 2007; Qatawneh, 2003; Yang, 2008; Dababneh and Qatawneh, 2005) 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 (Qatawneh, 2003; Yang, 2008). Recently, a QAM system becomes most popular modulation scheme for digital communication systems (Dababneh and Qatawneh, 2005; Shannon, 2006). This popularity is due to spectral efficiency of M-ary QAM system. Also QAM system is a combination between 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 (Shannon, 2006). 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 (Qatawneh, 2003; Dababneh and Qatawneh, 2005). In recent years QAM research is used fading mobile channels which have 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 application (Yang, 2008; Hirosaki *et al.*, 1986). 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 important modulation schemes used in the new technology.

1.6. 16 Star QAM

The QAM modulation is important for mobile radio applications, the latest technology is to use square QAM constellations. In general 16 star QAM (square) requires coherent detection. However, the performance of coherent detection is severely affected by multipath fading, (mainly because of carrier recovery issues), the 16 Star QAM constellation combined with differentially coherent detection is preferred (Hirosaki *et al.*, 1986).

1.7. Fading Channel Models

To simulate the flat fading MIMO channel, we use a Rayleigh fading model (Qatawneh, 2003; Hirosaki *et al.*, 1986). 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 study. A typical channel model in land mobile radio is known as frequency flat Rayleigh fading. 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 Rician fading may be characterized by a factor which is defined as the power ratio of the specular α (line of sight or direct path) component to the diffuse components d (King *et al.*, 2007; Qatawneh, 2003; Shannon, 2006). This ratio α , defines how near to Rayleigh statistics the channel is. In fact, when the power ratio of the specular $\alpha = 0$ there is a Rayleigh fading (Qatawneh, 2003; Shannon, 2006; Qeting, 1979; Hirosaki *et al.*, 1986) and there is no fading at all when $\alpha = \infty$. 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 $f_d T_s$ (Chiani *et al.*, 2006; Dai *et al.*, 2006; Smith *et al.*, 2003) 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 Doppler rate is equal to the Doppler rate (Shannon, 2006). In general, normalized Doppler rates less than 0.01 are applicable to most systems. 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). Also the simple frequency selective channel model is known as the two path-fading channel. In this model the first arriving path experiences Rician fading and the second arriving path (which has a delay set by the delay parameter, z) experiences Rayleigh fading. In addition, we define a ratio (d) between the power in the first path and the power in the second path. In this study, $d = 20$ and the ratio α for the Rician 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 (Qatawneh, 2003; 2012; Smith *et al.*, 2008). **Figure 2** shows the simulation model.

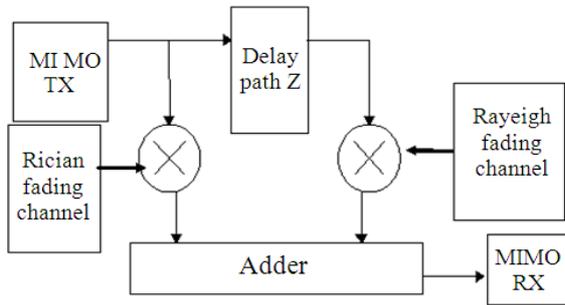


Fig. 2. Frequency selective fading channel model for two path fading channel model

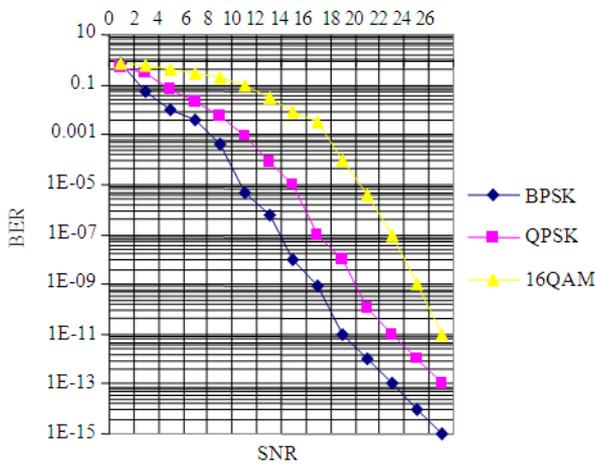


Fig. 3. Performance of the MIMO/BPSK, MIMO/QPSK system and MIMO/16QAM in presence of AWGN

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

1.8.1. Performance of MIMO/BPSK, MIMO/QPSK and MIMO/16QAM with AWGN Channel

The simulation results in **Fig. 3**, shows, the performance of the MIMO/BPSK, MIMO/QPSK system and MIMO/16QAM in presence of AWGN. The BER performances presented in **Fig. 3** compares the output of MIMO/BPSK, MIMO/QPSK and MIMO/16QAM systems in the Gaussian channel ($a = \text{Infinity}$) (Qatawneh, 2012) It can be observed that the SNR performance of the multiple outputs MIMO/BPSK systems by about 5 dB compared with that achieved over the multiple output/QPSK and 6dB compared with

that achieved by the MIMO/QAM at a BER of 1×10^{-5} . The MIMO/16QAM channel system performance is some 6 dB better than the MIMO/QPSK system at the same BER in AWGN.

1.9. Performance of MIMO/QPSK and MIMO/16QAM with Two-Path Channel Fading

The simulation results in **Fig. 4**, shows, performance of the MO/QPSK system and MO/16QAM for various values of second path delay. For a second path of delay:

$$z = -1, a = 20, d = 20, f_d = 0.1 \text{ Hz}$$

From these curves in **Fig. 4**. It can be seen that the performance improvement in terms of values of irreducible BER decrease as the delay between first and second paths rises. From The comparison of the BER of the MO/QPSK and MO/QAM, using the Doppler rate of 0.1 Hz used in these simulations is much more severe than is likely to be experienced in most indoor channels. Also we have an improvement in the simulation results using multiple outputs 16QAM over multiple output QPSK using the same Doppler rate a of 01Hz.

The results in **Fig. 5** Shows the BER performance of MIMO/16QAM in presence of AWGN and two path fading channel for various second path delay: $a = 20, d = 20, f_d = 0.1 \text{ Hz}$. The results explain that when the delay of the second path (z) increases, the performance of the MIMO/16QAM becomes worse, if we take an example when $z = -1$ the performance of the system (the Bit Error Rate equal 1×10^{-3}) But for $z = -7$, the bit error rate is (1×10^{-2}) for the same SNR = 30dB for both cases.

The results in **Fig. 6** Shows the BER performance of MIMO/16QAM in presence of AWGN and two path fading channel for various second path delay : $A = 20, d = 20, f_d = 0.01 \text{ Hz}$. The results explain that when the delay of the second path (z) increases, the performance of the MIMO/16QAM becomes worse, if we take an example when $z = -1$ the performance of the system (the Bit Error Rate equal 5×10^{-4} this is because of the Doppler rate $f_d = 0.01 \text{ Hz}$). But for $z = -7$, the bit error rate is (8×10^{-2}) for the same SNR = 30dB for both cases. If we compare the results in **Fig. 5**. With the results in **Fig. 6**, we see that there is an improvement in the results in **Fig. 6**. Compared with the results in **Fig. 5** due to the reduction of the Doppler rate from $f_d = 0.1 \text{ Hz}$ to $f_d = 0.01 \text{ Hz}$.

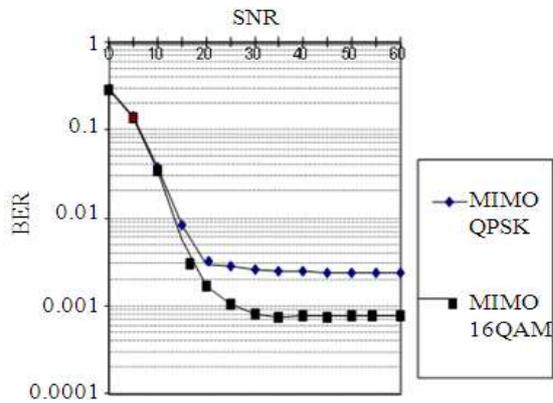


Fig. 4. BER performance for MIMO/QPSK and MIMO/QAM with for a second path of delay $z = -1$, $a = 20$, $d = 20$, $f_d = 0.1$ Hz

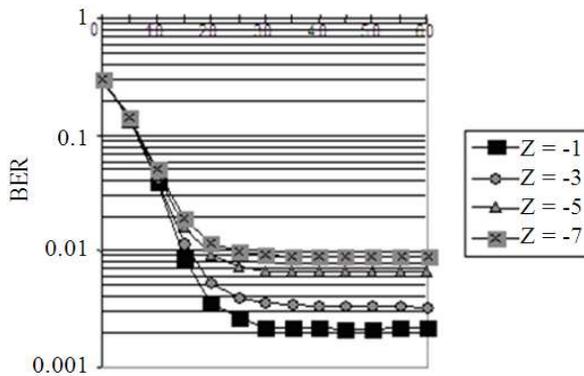


Fig. 5. BER performance of MIMO/16QAM in presence of AWGN and two path fading channel for various second path delay; $a = 20$, $d = 20$, $f_d = 0.1$ Hz

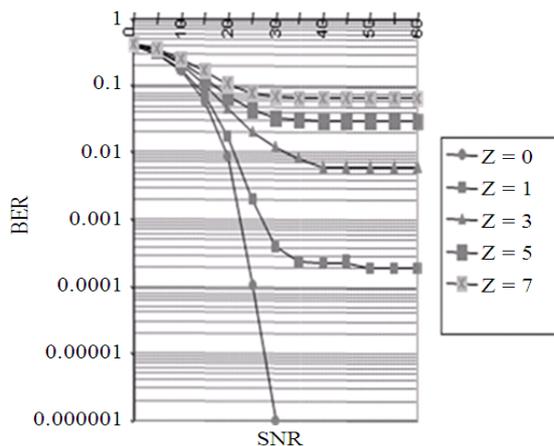


Fig. 6. BER performance of MIMO/16QAM for various second path delay; $a = 20$, $d = 20$, $f_d = 0.01$ Hz. in presence of AWGN and two path fading channel

2. CONCLUSION

In this study, the Bit Error Rate (BER) performance of MIMO/BPSK, MIMO/QPSK and MIMO/QAM in AWGN, flat Rayleigh fading and two-path fading channels has been investigated with different transmitting and receiving antennas. In this simulation, the high digital transmission MIMO technique's performance has been investigated the presence of AWGN, flat Rayleigh fading and two-path fading channels, 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 ($a = 20$) the channel is Rician at a normalized Doppler rate of 0.1Hz and 0,01Hz, the degradation from Rayleigh channel ($a = 0$) gives rise to an unacceptable irreducible BER of about 0.01. With a defuse components (d) which is a ratio between the power in the first path and the power in the second path. In this study, ($d = 20$) the channel is Rayleigh channel With two-path fading and a normalized Doppler rate of 0.1 Hz, the BER performance is not acceptable, even at low values of second path delay. Also we have a simulation results using a normalized Doppler shift of 0,01 Hz and $d = 20$ with better BER performance for the values considered in the simulation. This actually improves the performance of the coherent demodulator. However, for channels with delay spread, the BER performance for coherent demodulation of MIMO is poor at a Doppler rate of 0.1 Hz. 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.

3. REFERENCES

- Agrawal, A., G. Ginis and J.M. Cioffi, 2002. Channel diagonalization through orthogonal space-time coding. Proceedings of the IEEE International Conference on Communications, Apr. 28-May 2, IEEE Xplore Press, pp: 1621-1624. DOI: 10.1109/ICC.2002.997123
- Bialkowski, M.E. P. Uthansakul, K. Bialkowski and S. Durrani, 2006. Investigating the performance of MIMO systems from an electromagnetic perspective. Microw. Opt. Technol. Lett., 48: 1233-1238. DOI: 10.1002/mop.21664

- Chiani, M., M.Z. Win and H. Shin, 2006. CTH09-6: Capacity of MIMO systems in the presence of interference. Proceedings of the IEEE Global Telecommunications Conference, Nov. 27-Dec. 1 IEEE Xplore Press, San Francisco, CA., pp: 1-6. DOI: 10.1109/GLOCOM.2006.86
- Dababneh, M. and I. Qatawneh, 2005. Novel mathematical model for capacity evaluation of modern digital radio systems. Inform. Technol. J., 4: 293-298. DOI: 10.3923/itj.2005.293.298
- Dai, L., S. Sfar and K.B. Letaief, 2006. Optimal antenna selection based on capacity maximization for MIMO systems in correlated channels. IEEE Trans. Commun., 54: 563-573. DOI: 10.1109/TCOMM.2006.869778
- Ebrahimi, M., M.A. Maddah-Ali and A.K. Khandani, 2006. Power allocation and asymptotic achievable sum-rates in single-hop wireless networks. Proceedings of the 40th Annual Conference on Information Sciences and Systems, Mar. 22-24, IEEE Xplore Press, Princeton, NJ., pp: 498-503. DOI: 10.1109/CISS.2006.286519
- Femnias, G., 2004. BER performance of linear STBC from orthogonal designs over MIMO correlated nakagami-m fading channels. IEEE Trans. Veh. Technol., 53: 307-317. DOI: 10.1109/TVT.2004.823475
- Foschini, G.J. and M.J. Gans, 1998. On limits of wireless communications in a fading environment when using multiple antennas. Wireless Personal Commun., 6: 311-335.
- Garth, L.M., T.W. King, P.J. Smith and M. Dohler, 2006. An analysis of low complexity algorithms for MIMO antenna selection. Proceedings of the IEEE International Conference on Communications, Jun. 11-15, IEEE Xplore Press, Istanbul, pp: 1380-1385. DOI: 10.1109/ICC.2006.254941
- Gesbert, D., M. Shafiq, D.S. 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., 21: 281-302. DOI: 10.1109/JSAC.2003.809458
- Gjendemsjo, A., G.E. Oien and D. Gesbert, 2007. Binary power control for multi-cell capacity maximization. Proceedings of the IEEE 8th Workshop on Signal Processing Advances in Wireless Communications, Jun. 17-20, IEEE Xplore Press, Helsinki, pp: 1-5. DOI: 10.1109/SPAWC.2007.4401341
- Godara, L.C., 1997. Applications of antenna arrays to mobile communications. I. Performance improvement, feasibility and system considerations. IEEE Proc., 85: 1031-1060. DOI: 10.1109/5.611108
- Golden, G.D., C.J. Foschini, R. Valenzuela and P.W. Wolniansky, 1999. Detection algorithm and initial laboratory results using V-BLAST space-time communication architecture. Electron. Lett., 35: 14-15. DOI: 10.1049/el:19990058
- Goldsmith, A., S.A. Jafar, N. Jindal and S. Vishwanath, 2003. Capacity limits of MIMO channels. IEEE J. Select. Areas Commun., 21: 684-702. DOI: 10.1109/JSAC.2003.810294
- Hirosaki, B., S. Hasegawa and A. Sabato, 1986. Advanced groupband data modem using orthogonally multiplexed QAM technique. IEEE Trans. Commun., 34: 587-592. DOI: 10.1109/TCOM.1986.1096582
- Hochwald, B.M. and W. Sweldens, 2000. Differential unitary space-time modulation. IEEE Trans. Commun., 48: 2041-2052. DOI: 10.1109/26.891215
- Hui, T.H., W.T.O. Yong and K.B. Toh, 2004. Signal correlation between two normal-mode helical antennas for diversity reception in a multipath environment. IEEE Trans. Antennas Propag., 52: 572-577. DOI: 10.1109/TAP.2004.823950
- Huih, T., H.P. Low, T.T. Zhang and Y.L. Lu, 2006. Receiving Mode Helical Antennas (NMHAs). IEEE Antennas Propag. Mag., 48: 92-96.
- Intarapanich, A., P.L. Kafle, R.J. Davies and A.B. Sesay, 2004. Effect of tap gain correlation on capacity of OFDM MIMO systems. Electron. Lett., 40: 86-88. DOI: 10.1049/el:20040042
- King, T.W., P.J. Smith and L.M. Garth, 2007. Capacity and fairness of MIMO broadcast algorithms in shadow fading environments. Proceedings of the IEEE Global Telecommunications Conference, Nov. 26-30, Washington D.C., pp: 3617-3622. DOI: 10.1109/GLOCOM.2007.687
- Liberti, J. and T.S. Rappaport, 1999. Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications. 1st Edn., Prentice-Hall, ISBN-10: 0137192878, pp: 528.
- Lozano, A., F.R. Farrokhi and R.A. Valenzuela, 2001. Lifting the limits on high speed wireless data access using antenna arrays. IEEE Commun. Mag., 39: 156-162. DOI: 10.1109/35.948420

- Molisch, A.F. and X. Zhang, 2004. FFT-based hybrid antenna selection schemes for spatially correlated MIMO channels. *IEEE Commun. Lett.*, 8: 36-38. DOI: 10.1109/LCOMM.2003.822512
- Murch, R.D. and K.B. Letaief, 2002. Antenna systems for broadband wireless access. *IEEE Commun. Mag.*, 40: 76-83. DOI: 10.1109/35.995854
- Qatawneh, I.A.Z., 2003. Performance of orthogonal frequency division multiplex utilising differential quadrature amplitude modulation in AWGN and Rician fading channels. *Alexandria Eng. J.*, 42: 429-436.
- Qatawneh, I.A.Z., 2012. Performance of MIMO system in Rician channels. *World Applied Sci. J.*, 19: 766-771.
- Qetting, J.D., 1979. A comparison of modulation techniques for digital radio. *IEEE Trans. Commun.*, 27: 1752-1763. DOI: 10.1109/TCOM.1979.1094370
- Rashid-Farrokhi, F., K.J.R. Liu and L. Tassiulas, 1998. Transmit beamforming and power control for cellular wireless systems. *IEEE J. Select. Areas Commun.*, 16: 1437-1449. DOI: 10.1109/49.730452
- Sadek, A.K., W. 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. DOI: 10.1109/TCOMM.2006.873986
- Sampath, H., S. Talwar, J. Tellado, V. Erceg and A. Paulrag, 2002. A fourth-generation MIMO-OFDM broadband wireless system: Design, performance and field trial results. *IEEE Commun. Mag.*, 40: 143-149. DOI: 10.1109/MCOM.2002.1031841
- Sellathurai, M. and S. Haykin, 2002. Turbo-BLAST for wireless communications: Theory and experiments. *IEEE Trans. Signal Proc.*, 50: 2538-2546. DOI: 10.1109/TSP.2002.803327
- Shannon, C.E., 2006. A mathematical theory of communication. *Bell Labs. Tech. J.*, 27: 379-423.
- Smith, P.J., T. King, L.M. Garth and M. Dohler, 2008. A power scaling analysis of norm-based antenna selection techniques. *IEEE Trans. Wireless Commun.*, 7: 3140-3149. DOI: 10.1109/TWC.2008.070211
- Smith, P.J., S. Roy and M. Shafi, 2003. Capacity of MIMO systems with semicorrelated flat fading. *IEEE Trans. Inform. Theory*, 49: 2781-2788. DOI: 10.1109/TIT.2003.817472
- Tarokh, V., A. Naguib, N. Seshadri and A.R. Calderbank, 1999b. Space-time codes for high data rate wireless communication: Performance criteria in the presence of channel estimation errors, mobility and multiple paths. *IEEE Trans. Commun.*, 47: 199-207. DOI: 10.1109/26.752125
- Tarokh, V., H. Jafarkhani and A.R. Calderbank, 1999a. Space-time block codes from orthogonal designs. *IEEE Trans. Inform. Theory*, 45: 1456-1467. DOI: 10.1109/18.771146
- 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*, 44: 744-765. DOI: 10.1109/18.661517
- Winters, J.H., 1998. Smart antennas for wireless systems. *IEEE Personal Commun.*, 5: 23-27. DOI: 10.1109/98.656155
- Wittneben, A., 1993. A new bandwidth efficient transmit antenna modulation diversity scheme for linear digital modulation. *IEEE International Conference on Communications Geneva Technical Program, Conference Record*, May. 23-26, IEEE Xplore Press, Geneva, pp: 1630-1634. DOI: 10.1109/ICC.1993.397560
- Yang, L., 2008. On the capacity of MIMO Rayleigh fading channels with log-normal shadowing. *Proceedings of the Congress on Image and Signal Processing*, May. 27-30, IEEE Xplore Press, Sanya, China, pp: 479-482. DOI: 10.1109/CISP.2008.11