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An Investigation into Bit Error Rate (BER) Performance of WiMAX Standard Compliant Systems

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ABSTRACT

This research effort investigated the Bit Error Rate (BER) performance of the WiMAX standard compliant system with different data rates in AWGN channel using a simulation approach. Worldwide Interoperability for Microwave Access (WiMAX) is the emerging wireless system which uses IEEE 802.16 standard. MATLAB software tool is suitable for building the OFDM model and analyzing the performance of WiMAX system using the Bit Error Rate (BER) and Signal to Noise Ratio (SNR) indicators. To do this, we used different adaptive modulation techniques such as BPSK, QPSK, and QAM on its physical layer. Our simulation results show that for the same SNR, BPSK has better BER performance than the other modulation schemes. Also, the 64-QAM provides higher bandwidth and offers superb data rates as compared to the others. QPSK and 16-QAM performance is in between these two (BPSK and 64-QAM) and need less power than BPSK. These results are significant because signal fading caused by obstructions attenuate radio signal at receiver end due to higher levels of interference and noise.
Keywords: Performance, Evaluation, Bit Error, WiMAX, Standards, Compliant Systems

Aims Research Journal Reference Format:
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1. INTRODUCTION

Wireless communications is the fastest growing segment of the communications industry. It has grown from an obscure, unknown service to an ubiquitous technology that serves almost half of the people on planet Earth. Worldwide interoperability for microwave access (WiMax) is a wireless broadband technology based on IEEE 802.16 standard. This system is based on the Orthogonal Frequency Division Multiplexing (OFDM) and realized broadband data transmission by using a radiofrequency range of 2-11 GHz and 10-66 GHz. WiMax system is a telecommunication technology which enables wireless transmission of voice and data and provide wireless access in urban, suburban, and rural environments, and it has two potential access methods; Line-of Sight (LOS) method, and Non-Line of Sight (NLOS) method. There are two main classes of WiMAX systems called fixed WiMax and mobile WiMAX. Fixed WiMAX is targeted for providing fixed and nomadic services, while mobile WiMAX will also provide portable and mobile connectivity. WiMAX systems operating in the frequency range of 2-11 GHz are suitable for communication even in NLOS conditions, when direct visibility between the transmitting and receiving antenna does not exist (Baig, 2005).

1.1 Wireless Broadband Access (WBA

Wireless Broadband Access (WBA) is a technology that promises high-speed connection. Users can transmit and receive data directly through radio waves using technologies such as 3G, WiFi, WiMax, and UWB work together to provide faster Web surfing, quicker file downloads, real-time audio and video streaming, multimedia conferencing, and interactive gaming to customer. Broadband connections are also being used for voice telephony using voice-over-Internet Protocol (VoIP) technology.WBA is a point-to-multipoint system made up of base station and subscriber equipment. Instead of using physical connection between the base station and the subscriber, the base station uses an outdoor antenna to send and receive high-speed data and voice-to-subscriber equipment. WiMAX is able to deliver data at the rates prescribed by the standards for Broadband Wireless Access (Al-Adwany, 2011).

1.2 Fading Effects in Wireless Communications Links

Reflection, diffraction, and scattering are the three basic propagation mechanisms which impact propagation in a mobile communication system. Reflection occurs when a propagating electromagnetic wave impinges an object which has very large dimensions when compared to the wavelength of the propagating wave. Reflections occur from the surface of the earth and from buildings and walls. Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, giving rise to a bending of waves around the obstacle, even when a line-of-sight path does not exist between transmitter and receiver. At high frequencies, diffraction, like reflection, depends on the geometry of the object, as well as the amplitude, phase, and polarization of the incident wave at the point of diffraction.

Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects, or by other irregularities in the channel. In practice, foliage, street signs, and lamp posts induce scattering in a mobile communications system. Wireless medium is different from the wired equivalent and possesses several advantages including mobility, better productivity, lower cost, easier installation, flexibility and scalability. On the other hand, it has some limitations and disadvantages inherited from the transmission channels between receiver and transmitter, whereby transmitted signals arrive at receiver with different power and time delay owing to reflection, diffraction and scattering effects (Rappaport, 2003). In addition the BER (Bit Error Rate) value of the wireless medium is relatively high. These drawbacks sometimes lead to reduced wireless data transmission performance. As a result, error control is necessary in these applications. During digital data transmission and storage operations, performance criterion is commonly determined by BER. It is the ratio of the number of error bits to the number of total bits. Noise in transmission medium disrupts the signal and causes data corruptions. Relation between signal and noise power is described with SNR (signal-to-noise ratio). Generally, SNR is explained with signal power/BER. It means, the reduction in the BER result in increase in the SNR and the better communication quality (Jin et al., 2007).

1.3 AWGN Fading Channel

In communication systems, the most common type of noise added over the channel is the Additive White Gaussian. Noise (AWGN). It is additive because the received signal is equal to the transmitted signal plus the noise. It is white because it has a constant power spectral density. It is Gaussian because its probability density function can be accurately modeled to behave like a Gaussian distribution. It is noise because it distorts the received signal. Because the bandwidth of the signal is very less as compare to the bandwidth of the AWGN channel. The higher the variance of the noise, the more is the deviation of the received symbols with respect to the constellation set and, thus, the higher is the probability to demodulate a wrong symbol and make errors [7].

Since high data rate communication over additive white Gaussian noise channel (AWGN) is limited by noise .The received signal in the interval $0 \leq t \leq T_S$ may be expressed as:

R(t) = S(t) + n(t)……………………………………………………………………………………(1)

Where
S(t) denotes the transmitted signal
n(t) denotes the additive white Gaussian noise (AWGN) process with power-spectral density.

1.4 Orthogonal Frequency Division Multiplexing (OFDM) Systems
Orthogonal frequency-division multiplexing (OFDM) is a method of digital modulation in which a signal is divided into a number of equally spaced frequency bands (Jun et al., 2000). A subcarrier carrying a portion of the user information is transmitted in each band. Each subcarrier is orthogonal with every other subcarrier, differentiating OFDM from the commonly used frequency division multiplexing (FDM). OFDM is a very effective way of protecting data transmitted over communication channels that experience narrow-band fading. It is a digital multi-carrier modulation technique in which each subcarrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. This is because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time spreading and eliminate inter-symbol interference (ISI). Also OFDM can be implemented using IFFT (Inverse Fast Fourier Transform) on the sender side, and the FFT algorithm on the receiver side.

2. WiMAX TECHNICAL STANDARDS OVERVIEW

IEEE 802.16 Standard-2005 details several specifications for WiMAX standardized by the IEEE 802.16 working group. In 2001, the first IEEE 802.16 standard was published, which aimed to support the communications in the 10-66 GHz frequency band. Two years later, IEEE 802.16a was introduced to provide additional physical layer specifications for the 2-11 GHz frequency band. These two standards were revised further in 2004 to introduce IEEE802.16-2004 standard, where QoS (Quality of Service) provisioning was one of its essential features (Cicconetti et al, 2006 and Liu et al, 2006). In 2005, IEEE 802.16e was approved as the official standard for mobile applications. In addition to the IEEE 802.16 working group, companies in the industry also have formed the WiMAX forum to promote the development and deployment of WiMAX systems.

2.1 Problem Statement
The major quality of service (QoS) problems in WIMAX networks arise from poor planning of the network such that some areas are not covered while other areas have neighbor base stations too close leading to high levels of interference. The implementation of high data rate modulation techniques that have good bandwidth efficiency in broadband communication systems require perfect modulators, demodulators, filter and transmission path that are difficult to achieve in practical radio environments. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by interference on the channel. Moreover, errors can be easily introduced as the number of users is increased.

2.2Bit Error Rate
In digital modulation techniques, due to some noise, interference, and distortion the received bits are altered .So bit error rate is defined as the no of error bits divided by total no of transferred bits (El-Najjaret al, 2008).

$$\text{Bit Error Rate (BER)} = \frac{\text{No. of bits in error}}{\text{Total no. of transferred bits}} \quad \text{............ (2)}$$

For BPSK, the error probability is given by

$$Pe \cong \frac{1}{2} erfc\left(\sqrt{\frac{Es}{No}}\right) \quad \text{.......... .(3)}$$

For M-QAM, the error probability is given by

$$Pe \cong 2\left(1 - \frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{3Es}{2(M-1)No}}\right) \quad \text{..........(4)}$$

Where M may take values of 4, 8, 16, 32, 64 etc for the respective modulation schemes and E_S = ($\log_2 M$) E_b is the energy per sample, E_b is the energy per bit and T_S = ($\log_2 M$) T_b is symbol period.

The performance of modulation is calculated while measuring BER with assumption that system is operating with Additive white Gaussian noise. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be produced as the number of users is increased and the mobile terminal is subjected to mobility. Thus, it has driven many researches into the application of higher order modulations [6].

3. SIMULATION MODEL

Simulation of M-PSK (where M is 2, 4, 8, 16, 32 and 64) as baseband modulation along with AWGN was done using the model shown in Figure 1. The WiMAX physical layer model shown was built using MATLAB Simulink library and the parameters for the component blocks were set. The model begins with the Random Integer Generator block which generates uniformly distributed random integers in the range [0, M-1], where M is the M-ary number. Then the uniformly generated random integer is then fed to baseband modulator on which M-PSK modulation is performed with a large carrier. The output is a baseband representation of the modulated signal.

The modulated signal is then passed through the AWGN channel which adds white Gaussian noise to a real or complex input signal. This block inherits its sample time from the input signal. On the receiver end the demodulator receives the copy of the original signal, which is now affected due to ISI and noise in the channel and bit error rate is calculated. The demodulated signal is also a baseband representation. Next we have error rate calculator in which the transmitted and received signal are compared and the difference is treated as “error”. The error rate, total number of transmitted bits and total number of error bits are displayed by display block. Error performance analysis was performed by plotting the bit error-rate versus signal to noise ratio (SNR) for AWGN. Simulations were run for different code rates.

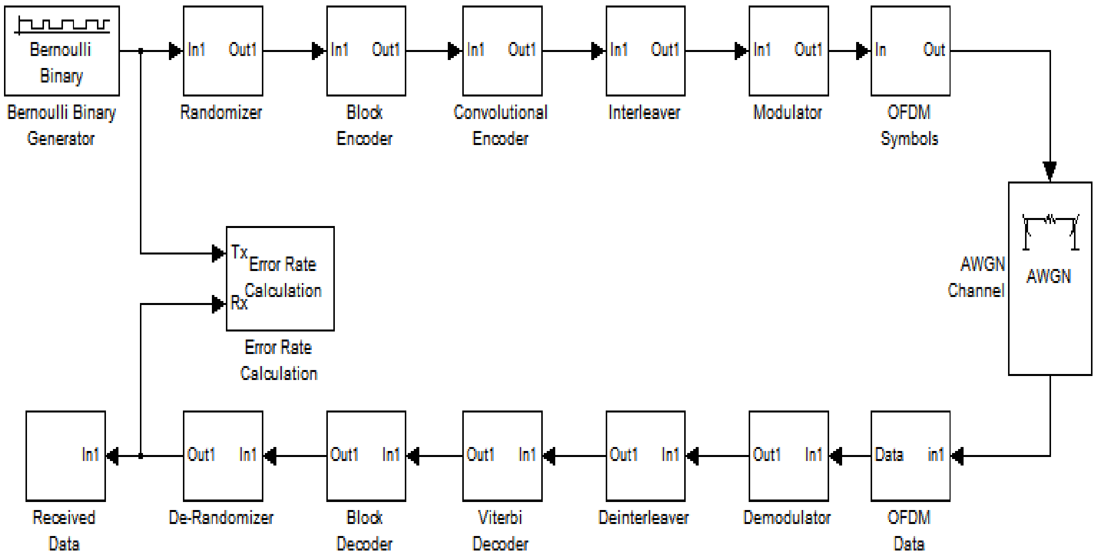

Figure 1 WiMAX physical layer model

4. RESULTS AND DISCUSSION

The results of the simulation runs are presented in table 1 below.

Table 1: BER vs SNR Values for different Modulations

SNR	BPSK ½	QPSK ½	QPSK ¾	16 QAM ½	16 QAM ¾	64 QAM 2/3	64 QAM ¾
0	0.0786	0.0895	0.1063	0.1409	0.1615	0.1998	0.2256
1	0.0562	0.0642	0.0886	0.1189	0.1326	0.1776	0.1986
2	0.0375	0.0408	0.0601	0.0977	0.1189	0.1569	0.1823
3	0.0228	0.0293	0.0382	0.0774	0.0946	0.1371	0.1481
4	0.0125	0.0137	0.0234	0.0586	0.0792	0.1185	0.1249
5	0.0059	0.0071	0.0166	0.0418	0.0571	0.1007	0.1120
6	0.0023	0.0036	0.0093	0.0278	0.0384	0.0838	0.0936
7	7.72E-4	8.97E-4	0.0041	0.0169	0.0216	0.0675	0.0725
8	1.90E-4	2.61E-4	9.26E-4	0.0092	0.0141	0.0523	0.0596

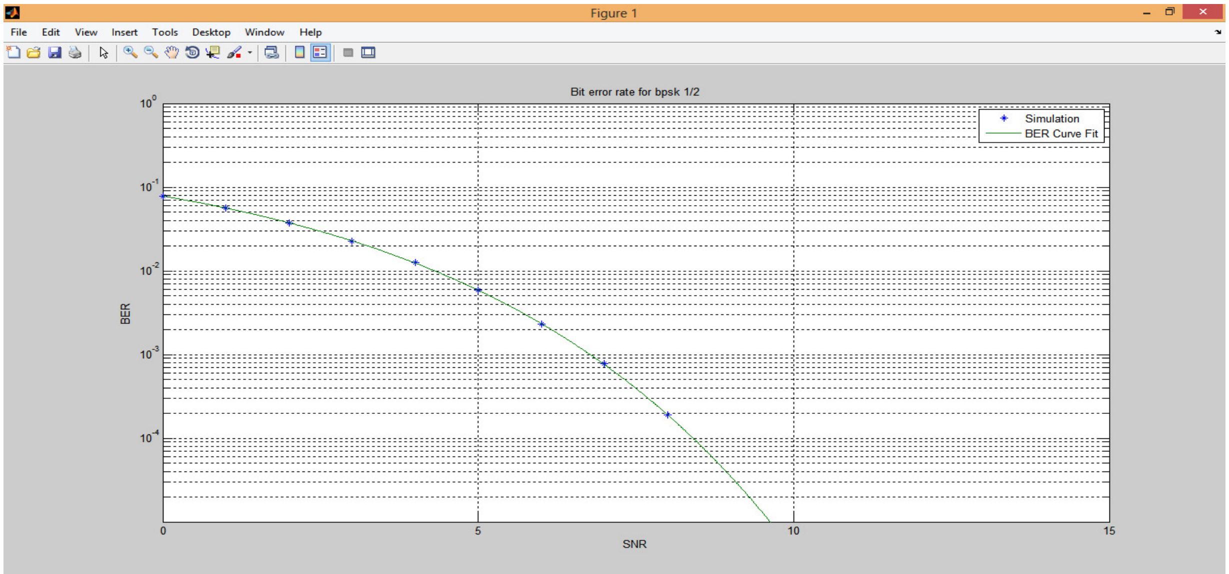

Figure 2: BER vs SNR for BPSK ½

Figure 2 shows the BER vs SNR plot for the BPSK (Binary Phase Shift Keying) modulation type with code rate of ½. It is observed that as the SNR increases, Bit Error Rate is reduced drastically. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications.

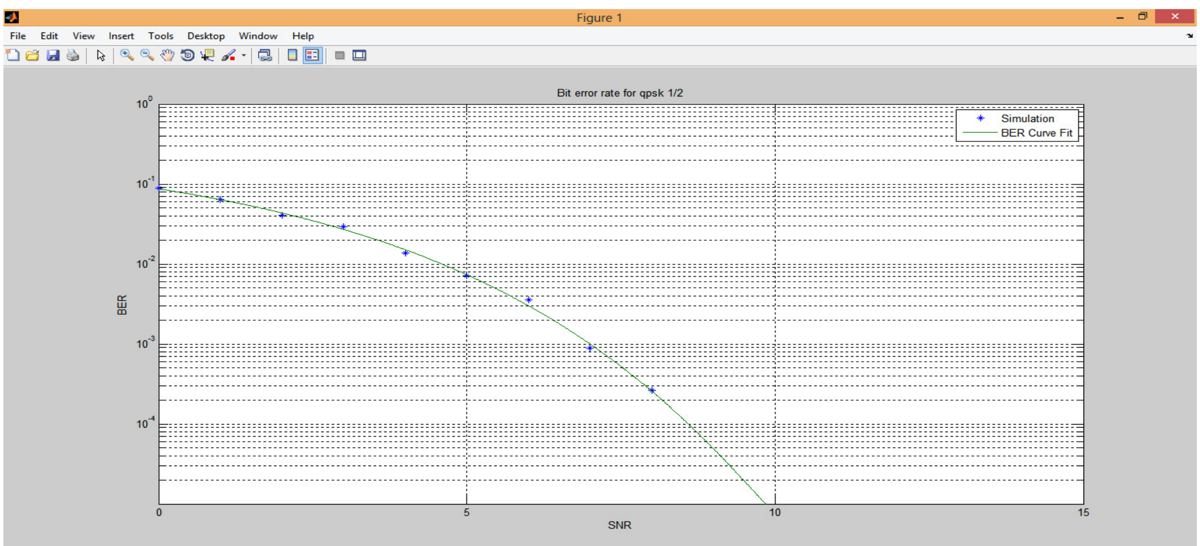

Figure 3: BER vs SNR for QPSK ½

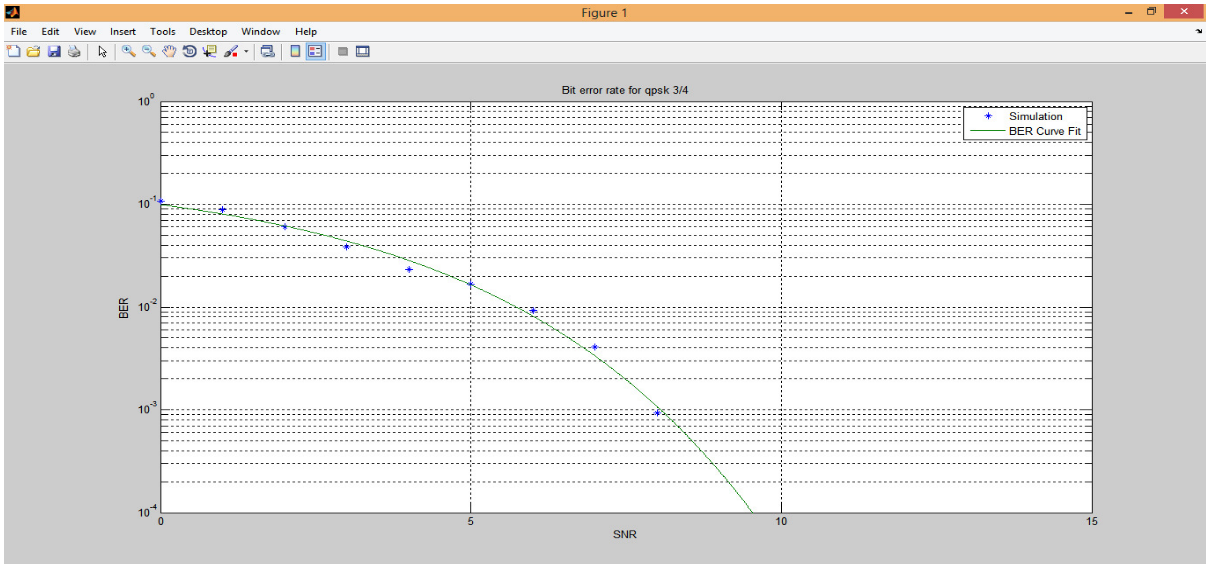

Figure 4: BER vs SNR for QPSK ¾

Figures 3 and 4 show the BER vs SNR graphs for QPSK modulation type with code rate ½ and ¾ respectively. It can be seen that BER reduces as SNR increases but not as fast as the BPSK modulation. The modulation type is modulated at 2 bits/symbol, which is also unsuitable for high data rate applications but it has higher capacity with respect to signal than the BPSK and therefore uses less power for transmission. The probability of bit-error for QPSK is the same as for BPSK however, so as to attain a similar bit-error probability as BPSK, QPSK uses half the power (since 2 bits are transmitted simultaneously).

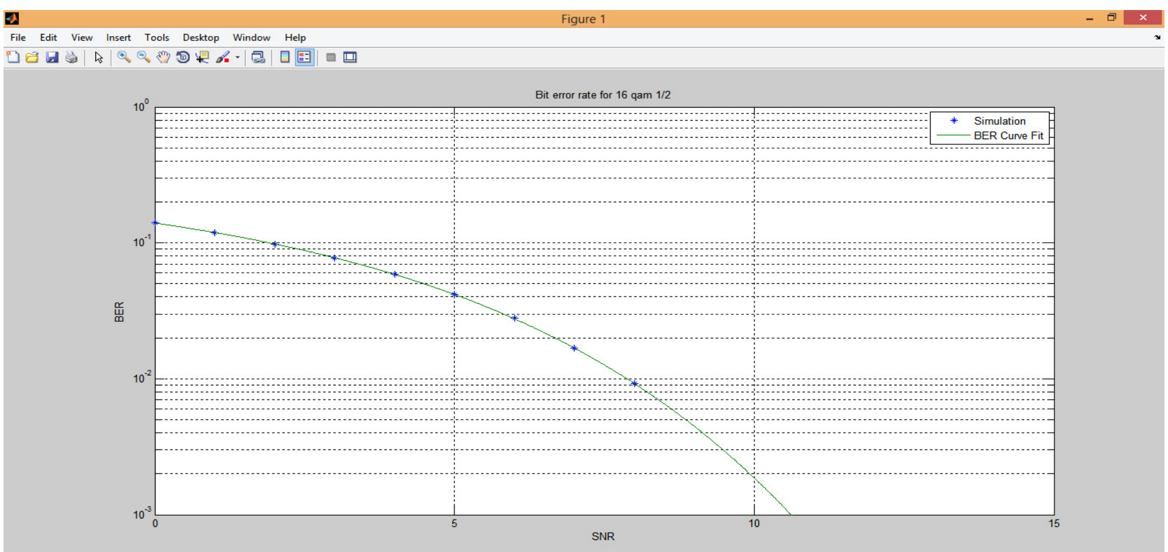

Figure 5: BER vs SNR for 16 QAM ½

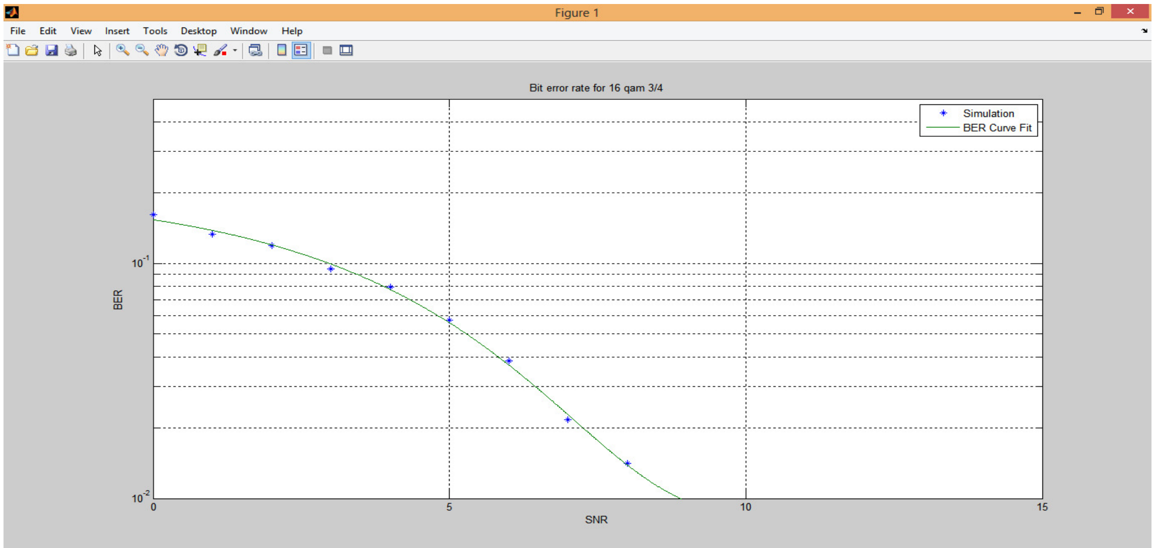

Figure 6: BER vs SNR for 16 QAM ¾

Figures 5 and 6 respectively show the BER vs SNR plot for 16 QAM type modulations with code rates ½ and ¾ respectively. From the graph, it is seen that the BER reduces slowly as the SNR increases. 16 QAM modulates 4 bits/symbol which gives it a higher capacity than BPSK and QPSK modulations.

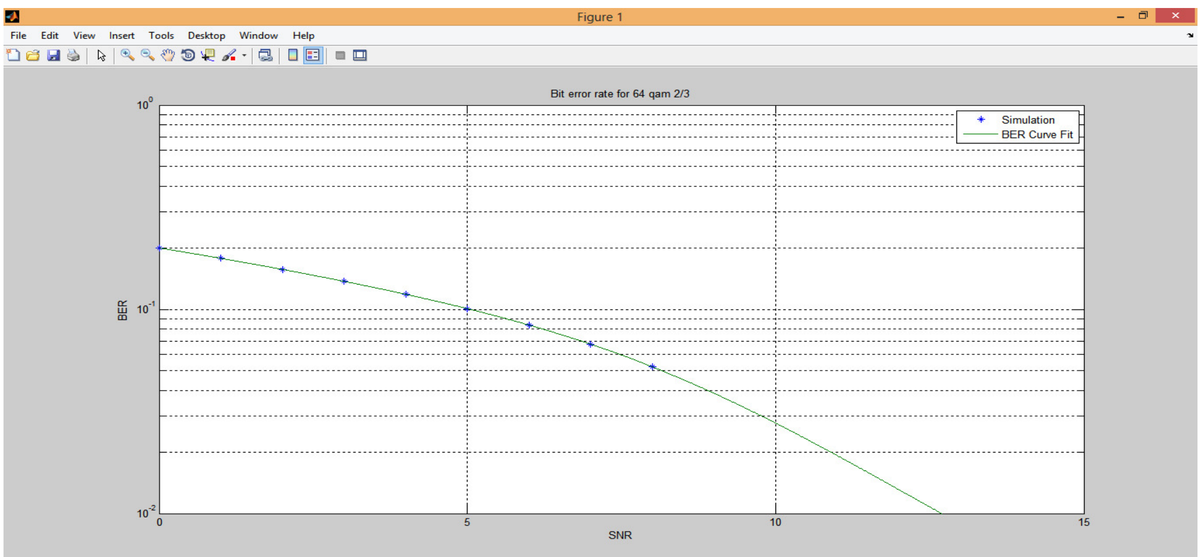

Figure 7: BER vs SNR for 64 QAM 2/3

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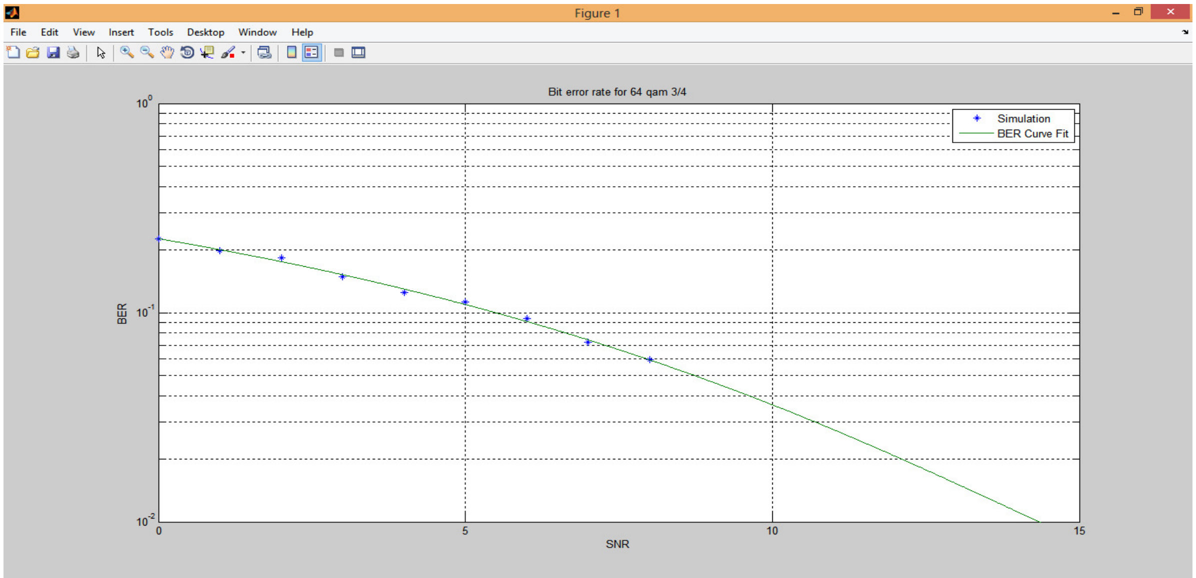

Figure 8: BER vs SNR for 64 QAM ¾

The 64 QAM (Quadrature Amplitude Modulation) as shown in figures 7 and 8 with code rates 2/3 and ¾ respectively. It can be seen that the BER reduces very slowly as SNR increases, this modulation type exhibit higher error-rates, in exchange however they deliver a higher raw data-rate.

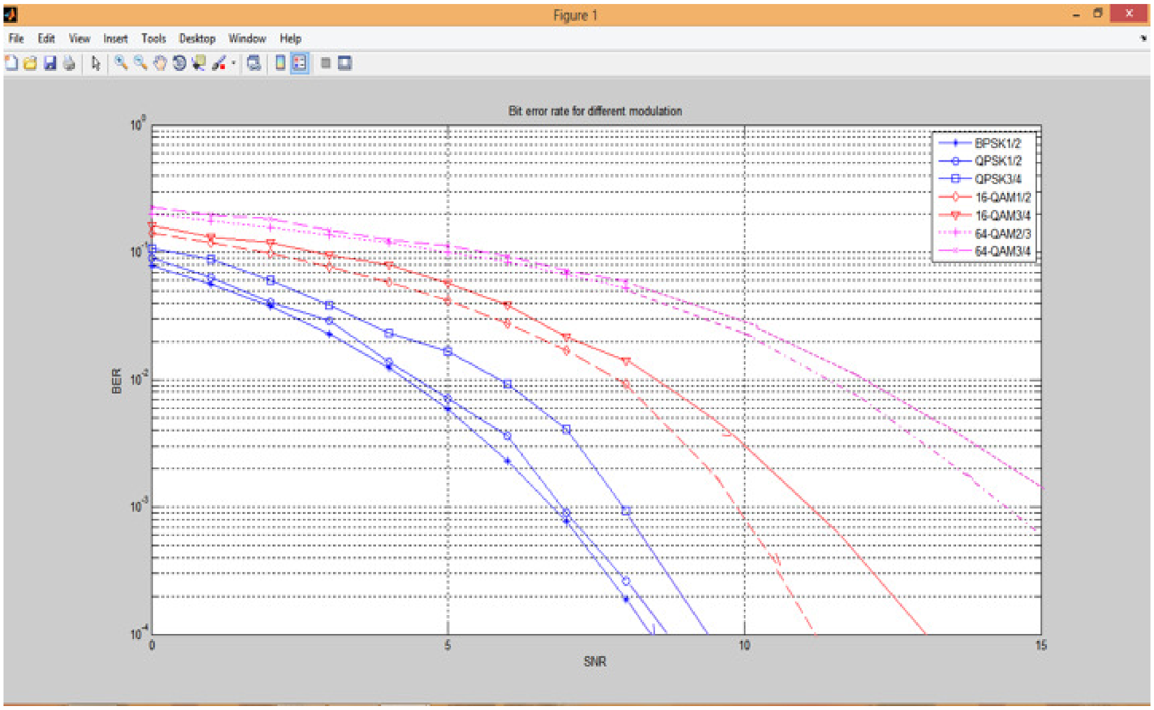

Figure 9: Bit Error Rate for different Modulations

It is observed that for the same SNR, BPSK has a better BER than do the higher modulation rate schemes. In case of information measure utilization the 64QAM modulation can provide higher bandwidth and offers superb data rates as compared to others, whereas the QPSK and therefore the 16QAM performance are within these two and need less power than BPSK. However they provide lesser bandwidth and lower data rates than 64QAM. BPSK has the lowest BER whereas the 64-QAM incorporates a higher capacity than the other modulation techniques.

5. CONCLUSION

The simulation and BER performance analysis of WiMAX system can be used perceptively to improve diversity gain and multi-user performance. The fundamental idea of adaptive Modulation is to adapt different order modulations that enable sending more bits per symbol and therefore achieving higher throughputs or higher spectral efficiencies. Simulation as a methodology for investigating the PHY layer performance of WiMAX systems has been shown to be very valuable since it saves time and capital investment. A key performance measure of a wireless communication system is the BER. The BER curves for the different modulation systems were used to compare the performance of the different modulation and coding scheme used.It is observed that for a particular value of Bit error rate SNR value for BPSK/ QPSK is lower than 16QAM and 64QAM. BPSK has the lowest BER whereas the 64-QAM incorporates a higher capacity than the other modulation techniques.QPSK and 16-QAM modulations are in the middle of the two (BPSK and 64-QAM) because there provide higher data rates than BPSK and lower data rates than 64-QAM with reasonable Bit error rate.

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