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Performance Evaluation of OFDM Based Wimax Physical Layer Under Multipath Fading Channel with Different Modulation Schemes And Cyclic Prefix

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Abstract

WiMAX (Worldwide interoperability for microwave) is basically described as the IEEE 802. 16 standard for Broadband Wireless Access (BWA) that was developed to provide high transmission data rates over larger areas and also to those areas users where broadband coverage is not available. This paper analyzes WiMAX Physical Layer with different modulation schemes and cyclic prefix(CP) under multipath propagation channel conditions. SUI (Stanford University Interim) channel has been chosen as reference for multipath propagation channel. Signal-to Noise Ratio (SNR) vs Bit Error Rate (BER) plots are analyzed for performance evaluation of Physical Layer. It is observed that the performance of Physical Layer with BPSK modulation scheme is better than QPSK,16QAM and 64 QAM modulation schemes. Also, a higher value of cyclic prefix(CP) gives better BER perfrmance .

Keywords: *WiMAX ,BWA,Physical Layer, OFDM , SUI*

1. INTRODUCTION

The growth in the use of the digital information networks(digital networks has led to the need for the design of new communication networks with higher data rates.The telecommunication industry is also changing, with a demand for a greater range of services, such as video conferences, or applications with multimedia contents. The increased reliance on computer networking and the Internet has resulted in a wider demand for connectivity to be provided "any where, any time", leading to a rise in the requirements for higher capacity and high reliability broadband wireless telecommunication systems. Broadband availability brings high performance connectivity to over a billion users' worldwide, thus developing new wireless broadband standards and technologies that will rapidly span wireless coverage. Moreover, the huge uptake rate of mobile phone technology, WiMAX (Wireless Interoperability for Microwave Access) and the exponential growth of Internet have resulted in an increased demand for new methods of obtaining high capacity wireless networks [1]. WiMAX will substitute other broadband technologies competing in the same segment and will become an excellent solution for the deployment of the well-known last mile infrastructures in places where it is very difficult to get with other technologies, such as cable or DSL, and where the costs of deployment and maintenance of such technologies would not be profitable. In this way, WiMAX will connect rural areas in developing countries as well as underserved metro- politan areas. It can even be used to deliver backhaul for carrier structures, enterprise campus, and Wi-Fi hot-spots. WiMA Xoffers a good solution for these challenges because it providesa cost-efective, rapidly deployable solution [2].

2. WiMAX Physical Layer

The WiMAX physical layer is based on orthogonal frequency division multiplexing. OFDM is the transmission scheme of choice to enable high-speed data, video, and multimedia communications and is used by a variety of commercial broadband systems, including DSL, Wi-Fi and Digital Video. Broadcast-Handheld (DVB-H), and MediaFLO, besides WiMAX. OFDM is an elegant and efficient scheme for high data rate transmission in a nonline of-sight or multipath radio environment.

2.1 OFDM Technology

Orthogonal frequency division multiplexing (OFDM) technology provides operators with an efficient means to overcome the challenges of NLOS propagation. OFDM enables simultaneous transmission of multiple signals by separating them into different frequency bands (subcarriers) and sending them in parallel. OFDM is a more spectrum-efficient method that removes all the guard bands but keeps the modulated signals orthogonal to mitigate the interference level. OFDM uses fast Fourier transform (FFT) and inverse FFT to convert serial data to multiple channels. The FFT size is 256, which means a total number of 256 sub channels (carriers) are defined for OFDM. In OFDM, the original signal is divided into 256 subcarriers and transmitted in parallel. Therefore, OFDM is referred to as a multicarrier modulation scheme. Compared to single-carrier schemes, OFDM is more robust against multipath propagation delay owing to the use of narrower subcarriers with low bit rates resulting in long symbol periods. A guard time is introduced at each OFDM symbol to further mitigate the effect of multipath delay spread.The WiMAX OFDM waveform offers the advantage of being able to operate with the larger delay spread of the NLOS environment. By virtue of the OFDM symbol time and use of a cyclic prefix, the OFDM waveform eliminates the inter-symbol interference (ISI) problems and the complexities of adaptive equalization. Because the OFDM waveform is composed of multiple narrowband orthogonal carriers, selective fading is localized to a subset of carriers that are relatively easy to equalize. The ability to overcome delay spread, multi-path, and ISI in an efficient manner allows for higher data rate throughput. [3]

2.2 OFDM Parameters in WiMAX

As mentioned previously, the fixed and mobile versions of WiMAX have slightly different implementations of the OFDM physical layer. Fixed WiMAX, which is based on IEEE 802.16- 2004, uses a 256 FFT-based OFDM physical layer. Mobile WiMAX, which is based on the IEEE 802.16e-20055 standard, uses a scalable OFDMA-based physical layer. In the case of mobile WiMAX, the FFT sizes can vary from 128 bits to 2,048 bits.

2.3 Fixed WiMAX OFDM-PHY

For this version the FFT size is fixed at 256, which 192 subcarriers used for carrying data, 8 used as pilot subcarriers for channel estimation and synchronization purposes, and the rest used as guard band subcarriers.6 Since the FFT size is fixed, the subcarrier spacing varies with channel bandwidth. When larger bandwidths are used, the subcarrier spacing increases, and the symbol time decreases. Decreasing symbol time implies that a larger fraction needs to be allocated as guard time to overcome delay spread. WiMAX allows a wide range of guard times that allow system designers to make appropriate trade-offs between spectral efficiency and delay spread robustness.

2.4 Mobile WiMAX OFDMA-PHY

In mobile WiMAX, the FFT size is scalable from 128 to 2,048. Here, when the available bandwidth increases, the FFT size is also increased such that the subcarrier spacing is always 10.94 kHz. This keeps the OFDM symbol duration, which is the basic resource unit, fixed and therefore makes scaling have minimal impact on higher layers. A scalable design also keeps the costs low. The subcarrier spacing of 10.94 kHz was chosen as a good balance between satisfying the delay spread and Doppler spread requirements for operating in mixed fixed and mobile environments. This subcarrier spacing can support delay spread values up to 20μs and vehicular mobility up to 125 kmph when operating in 3.5GHz.

3. Simulation Model

Fig. 1 shows the implementation model of WIMAX Physical Layer used as for simulation. SUI channel has been employed for transmission purpose. The mandatory Channel coding modulation parameters for the simulation model are specified in the IEEE 802.16 Standard document[4].The simulation parameters used in the system model are given in Table 2.

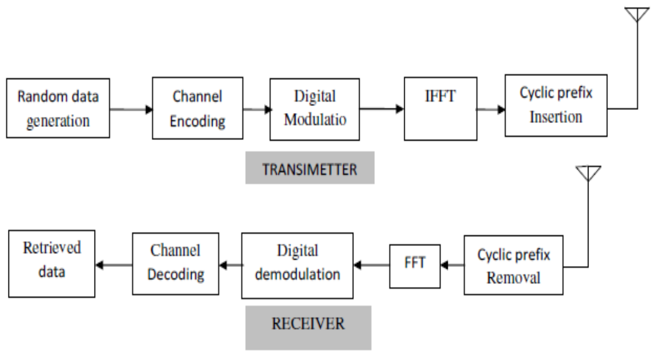

Fig. 1 Wimax Physical Layer simulation Model

The simulation model is composed of a transmitter, SUI communication channel and receiver. Transmitter consists of data generator, channel encoder, bit to symbol mapper, modulator, Inverse Fourier Transform (IFFT)and cyclic prefix addition blocks. Using the data generator, Random data is fed into the transmitter in form of binary pulses. The channel encoder acts upon the input data and helps to improve the capacity of a channel by adding some carefully designed redundant information to the data being transmitted through the channel. The bit to symbol mapper helps to convert the data bits into symbols. This is needed because the higher order modulation techniques operate on symbols but not on bits. There is a need of pilot carriers in data carriers for channel estimation and used in receiver detection. Pilot carrier insertion is followed by an IFFT which converts a number of complex data points, of length which is a power of 2, into the time domain signal of the same number of points. Cyclic prefix is the most effective guard period attached in front of every OFDM symbol. The cyclic prefix is the copy of the last part of the OFDM symbol added in front of the transmitted symbol, provided that the length is of equal or greater than the maximum delay spread of the channel. The transmitter is followed by SUI channel. At the receiver end the exact reverse process take place to recover the data. This data is used to compute BER from the simulations.

4. SUI Channel Model

For performance evaluation of any communication system, an accurate description of the wireless channel is required to address its propagation environment. The radio architecture of a communication system plays very significant role in the modeling of a channel. The wireless channel is characterized by Path loss, Multipath delay Spread, Fading characteristics, Doppler spread, Cochannel and adjacent channel interference [4].All the model parameters are random in nature and only a statistical characterization of them is possible, i.e. in terms of the mean and variance value. They are dependent upon terrain, tree density, antenna height and beam width, wind speed. SUI channel models are an extension of the earlier work by AT&T Wireless and Erceg etal [6]. In this model a set of six channels was selected to address three different terrain types that are typical of the continental US. This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications [7]. The parameters for the model were selected based upon some statistical models. The table 1 and table 2 below depict the parametric view of the SUI channels.

Table 1. Terrain type for SUI channel

Terrain Type	SUI Channel	Characteristics
C	SUI-1 , SUI-2	Mostly flat terrain with light tree densities
B	SUI-3 ,SUI-4	Hilly terrain with light tree density or flat terrain with moderate to heavy tree density
A	SUI-5 ,SUI-6	Hilly terrain with with moderate to heavy tree density

Table 2. Channel Model parameters

Parameter	SUI-1	SUI-2	SUI-3	SUI-4
P(Power in each path in dB)	[0 -15 -20]	[0 -12 -15]	[0 -5 -10]	[0 -4 -8]
K(Ricen Distribution)(linear scale)	[4 0 0]	[2 0 0]	[1 0 0]	[0 0 0]
Tap Delay (µses)	[0.0 0.4 0.9]	[0.0 0.4 1.1]	[0.0 0.4 0.9]	[0.0 0.5 0.9]
Dop(maximum Doppler frequency)(Hz)	[0.4 0.3 0.5]	[0.2 0.15 0.25]	[0.4 0.3 0.5]	[0.2 0.15 0.25]
Auto-corr(Coefficient of antenna Correlation factor)	0.7	0.5	0.4	0.3
Normalized factor of gain(dB)	-0.1771	-0.3930	-1.5113	-1.9218

5. Performance Analysis

The performance analysis was done using simulation in MATLAB. The parameters and their corresponding values used in the simulation are shown in the table 3. The performance analysis was carried out for two different cases.

Table 3. Parameters used in simulation.

PARAMETERS	VALUES
Number of OFDM symbols	100
Total data bits	2000
Number of bits per OFDM symbol	96(BPSK),192(QPSK),384(16QAM),768(64QAM)
Number of data sub-carriers	192
Number of FFT points	256
Cyclic prefix	1/4 , 1/8 , 1/16, 1/32
Modulation scheme	BPSK, QPSK, 16QAM, 64QAM
Coding	Convolution Coding, code rate 1/2 and 2/3

In the first case ,for a given modulation scheme like BPSK,QPSK,16QAM,and 64QAM the BER for different SUI channels was obtained by MATLAB simulation, In the second case, for a given cyclic prefix(CP) time like ¼,1/8,1/16 and 1/32, the BER for different modulation schemes was obtained using MATLAB simulation.

6. Results and Analysis

The SNR Vs BER plots for various modulation schemes for different SUI channel shows that ,in general ,for a given SNR , the higher order modulation schemes have higher BER. That is 64QAM modulation scheme will have highest BER and BPSK modulation scheme will have lowest BER. But at same time spectral efficiency of higher order modulation schemes will be high. For example, 64QAM will have spectral efficiency of 6bits/sec/Hz ,16QAM BPSK will have spectral efficiency of 1bit/sec/Hz.

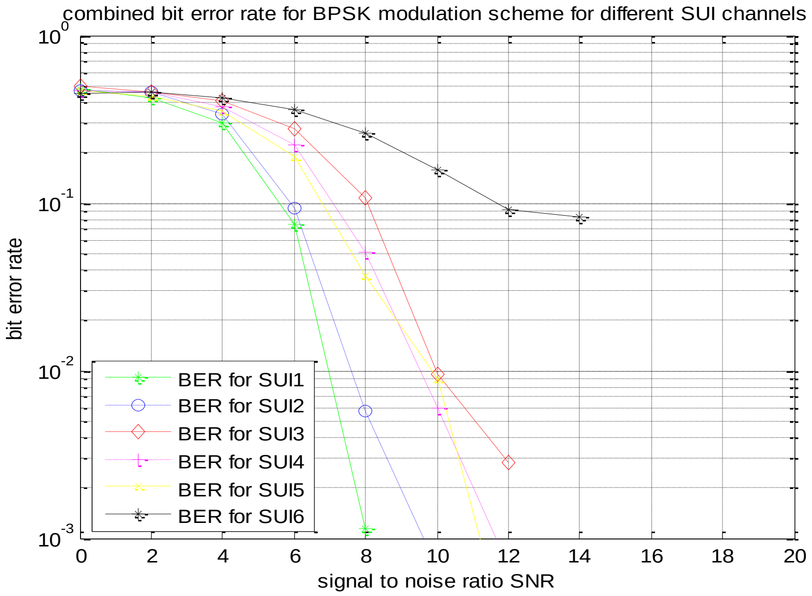

Fig.2 Combined BER for BPSK modulation Scheme for different SUI Channels

Hence ,higher order modulation schemes are more spectral efficient but less power efficient. Also, the SNR VS

BER plots for different modulation schemes for a given cyclic prefix (CP) time shows that as cp time is decreased from ¼ to 1/32 the BER increases for all modulation schemes. Also BER plots for all cp times shows QPSK is more tolerant of interference/ QPSK has lowest BER than other modulation schemes for a given SNR value. The BER plot for BPSK for different SUI channels shown in Fig. 2 shows that BER performance of BPSK for SUI-1 channel is better than its performance for other SUI channels. For SUI-6 its performance is worst.

Fig. 3 shows BER plot for QPSK for different SUI channels. The BER performance of QPSK is inferior than BPSK i.e. for a given value of SNR ,the BER for QPSK is higher than BPSK for all SUI channels.

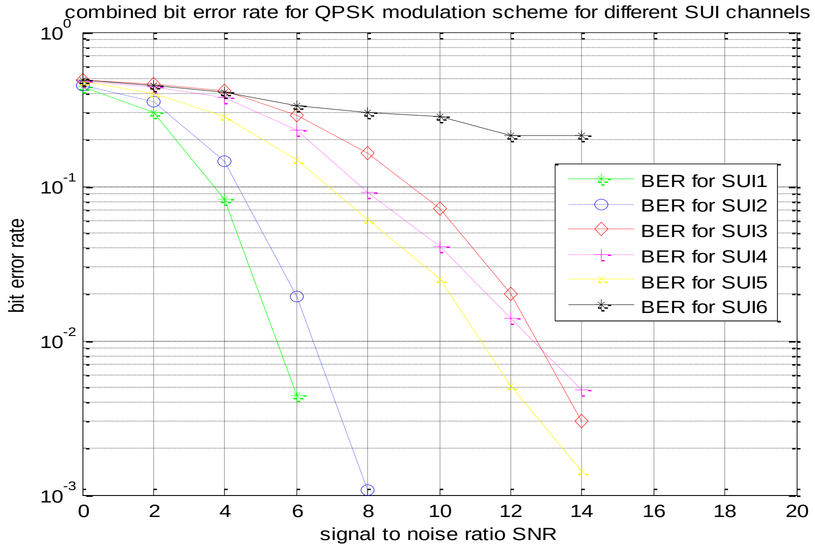

Fig. 3 Combined BER for QPSK Modulation Scheme for different SUI Channels

Fig. 4 shows BER plot for 16QAM for different SUI channels. The BER performance of 16QAM is inferior as compared BPSK and QPSK. Its BER performance is worst for SUI-6 channel as BER is almost constant for all SNR values.

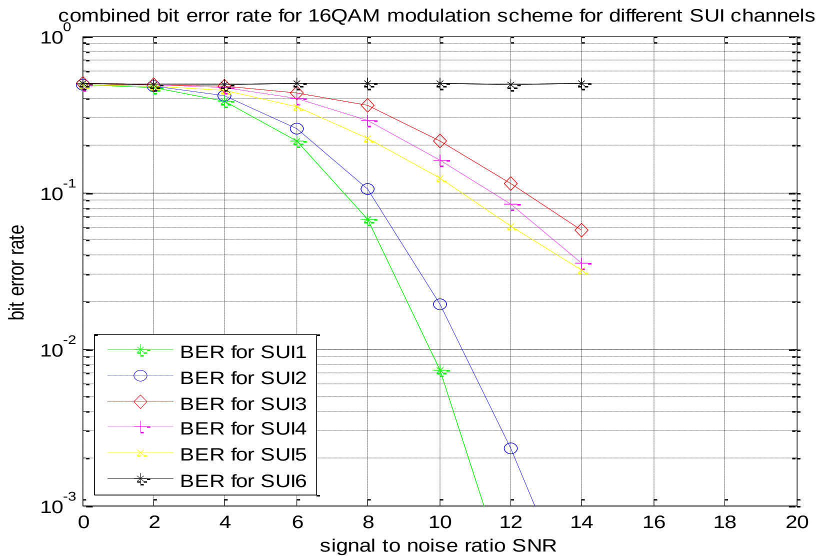

Fig. 4 Combined BER for 16QAM Modulation Scheme for different SUI Channels

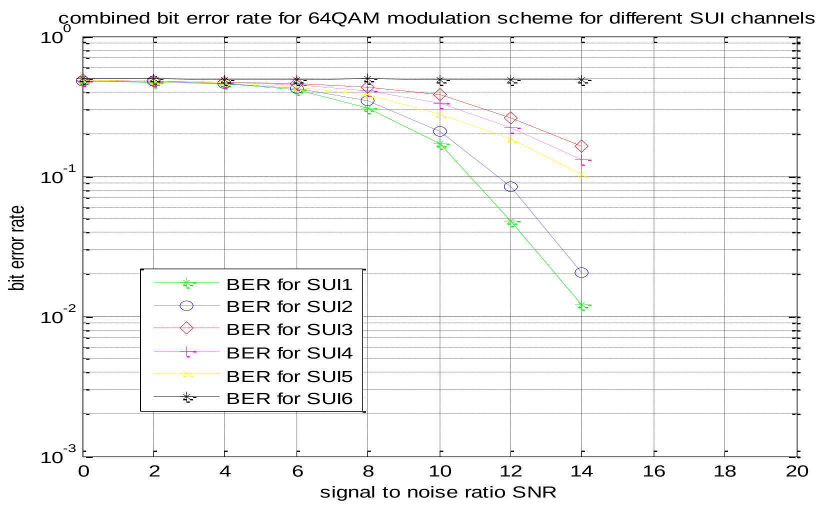

Fig. 5 Combined BER for 64QAM Modulation Scheme for different SUI Channels

Fig. 5 shows BER plot for 64QAM for different SUI channels. The BER performance of 64QAM is inferior as compared BPSK ,QPSK and 16QAM Its BER performance is worst for SUI-6 channel as BER is almost constant for all SNR values.

Figs. 6, 7, 8 and 9 show the combined BER for BPSK,QPSK,16QAM and 64QAM modulation schemes for cyclic prefix(CP) time of ¼ ,1/8 ,1/16 and 1/32 respectively. For all CP times, the BER performance of QPSK is better as compared to all other modulation schemes. The BER performance of higher modulation schemes like 16QAM and 64QAM is worst than lower modulation schemes like BPSK and QPSK. However, higher modulation schemes have high spectral efficiency(4 and 6 bits/sec./Hz respectively for 16QAM and 64QAM) as compared to lower modulation schemes(1 and 2 bits/sec./Hz respectively for BPSK and QPSK). Hence, QPSK can be considered as a modulation scheme which gives optimum performance with low BER and moderate spectral efficiency. Also, it can be considered a trade off between BER and spectral efficiency.

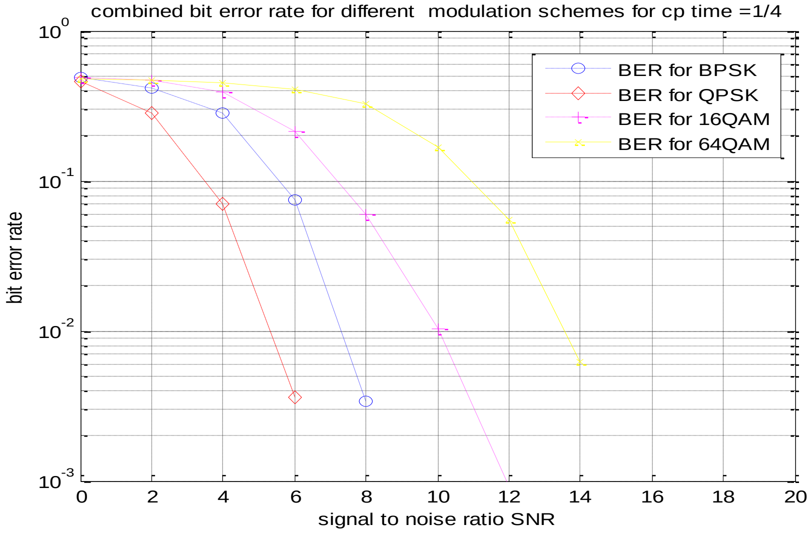

Fig. 6 Combined BER for different Modulation Schemes for cp time=1/4

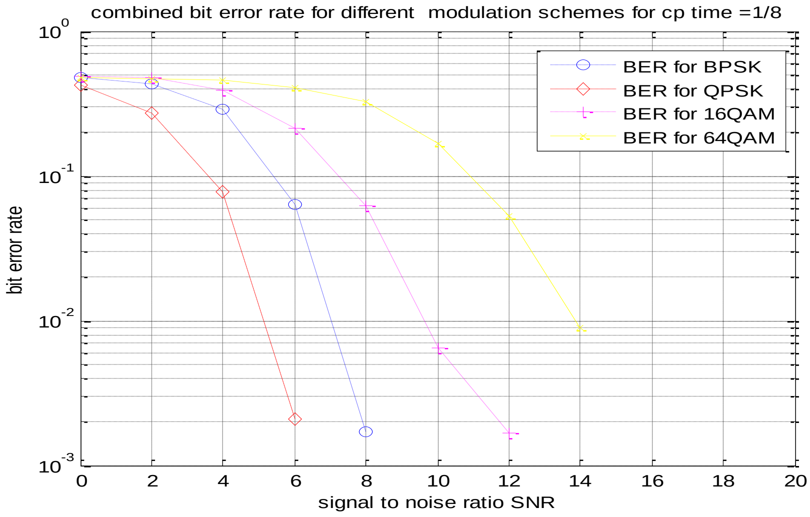

Fig. 7 Combined BER for different Modulation Schemes for cp time=1/8

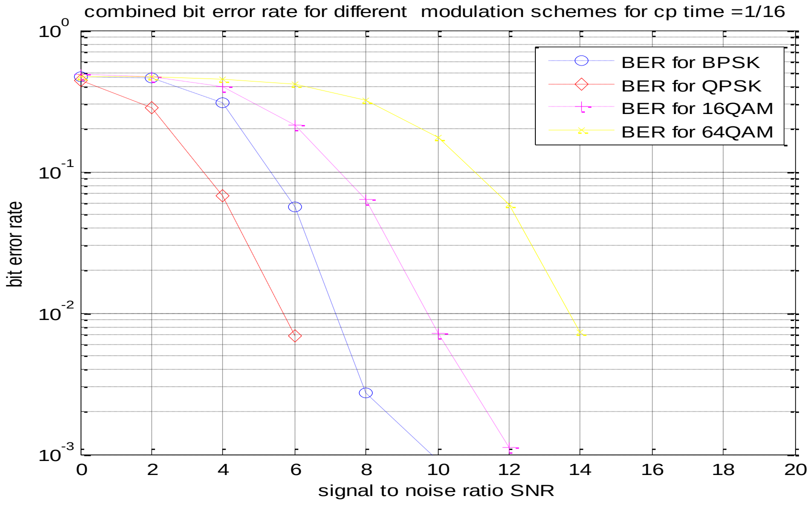

Fig.8 Combined BER for different Modulation Schemes for cp time=1/16

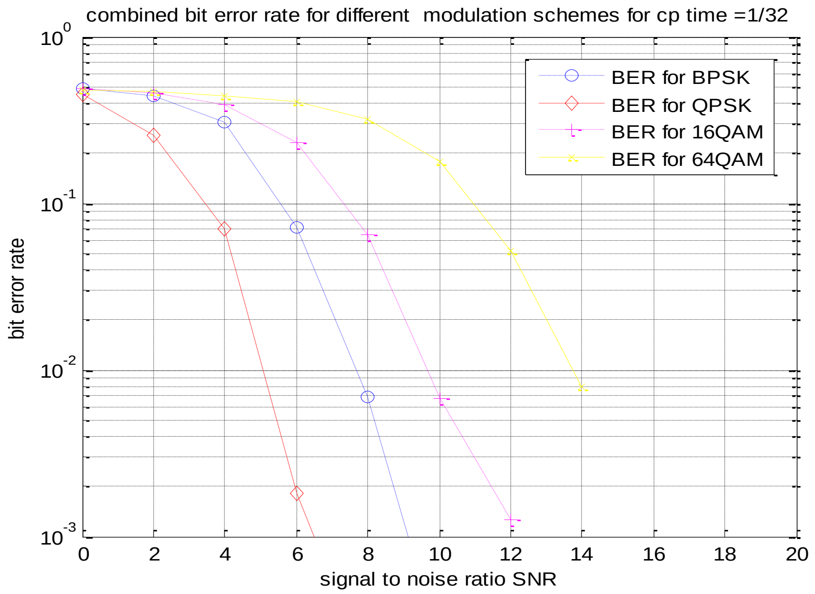

Fig. 9 Combined BER for different Modulation Schemes for cp time=1/32

7. Conclusions

The performance of WiMAX Physical Layer for different SUI channel models was carried out. The performance was carried out with SUI channel because it takes into account the actual environmental conditions like Terrain type ,tree density ,path loss and delay. These parameters characterize the real practical channel. Since SUI channel model is based on these characteristics, the performance of Physical Layer with SUI channel model can be considered as the practical performance under practical conditions. Also, the BER performance of QPSK modulation scheme is better as compared to all other modulation schemes under all CP times.

References

[1] S. Sampei: "Applications of Digital Wireless Technologiesto Global Wireless Communications," Prentice Hall, 1997

[2] Intel White Paper, Wi-Fi and WiMAX Solutions: "Understanding Wi-Fiand WiMAX as Metro-Access Solutions,"Intel Corporation, 2004. http://www.intel.com netcomms/technologies/wimax/304471.pdf

[3] Jeffrey G.Andrews, Arunabha Ghosh, Rias Muhamed,"Fundamentals of WiMAX", Prentice Hall Communications Engineering and Emerging Technology Series, February 2007

[4] IEEE Standard for Local and Metropoliton area networks Part 16:Air Interface for Fixed Broadband Wireless Access Systems IEEE Computer Society

[5] V.Erceg ,K.V.S. Hari,M.S.Smith,D.S. Baum et al,"Channel Models for Fixed Wireless Applications",IEEE 802.16.3 Tas Group Corporation 2001,Feb.01

[6] Daniel S. Baum," Simulating the SUI Channel Models" Project IEEE 802.16 Broadband Wireless Access Working Group **http://ieee802.org/16** Date Submitted 2001-04-11

[7] Maninder Singh, Kiran Ahuja, "Performance Evaluation of adaptive Modulation Techniques of WiMAX Network with Cyclic Prefix", IJAEST ,Vol.No.3,Issue No.1,Page-34-38

[8] T. Manochandar,R.Krithika,"Bit Error Rate of Mobile Wimax (Phy) Under Differen Communication Channels and Modulation Techniques", International Journal of Engineering Inventions,ISSN:2278-7461,Vol.1,Issue 3,September 2012,pp:06-11

[9] Loutfi Nuaymi,"WiMAX Technology For Broadband Wireless Access", Jhon Willey publication, 2007.

[10] A.Salleh, N.R. Mohamad, M.Z.A. Abd Aziz, M.H. Misran, M.A. Othman, N.M.Z. Hashim,"Simulation of WiMAX System Based on OFDM Model with Difference Adaptive Modulation Techniques",*IJCSMC, Vol. 2, Issue. 9, September 2013, pg.178 – 183*

[11] Vineet Sharma, Anuraj Shrivastav, Anjana Jain, Alok Panday,"BER performance of OFDM-BPSK, QPSK,QAM over AWGN channel using forward error correcting code", IJERA,ISSN:2248-9622www.ijera.comVol.2,Issue3,May-Jun2012,pp1619-1624