Spectral Efficiency & Bit Error Rate Analysis of WiMAX over AWGN Channel

Bindu Handa
M.Tech Scholar
Department of Electronics and Communication Engg.
Beant College of Engineering & Technology,
Punjab, India

Anita Suman
Assistant Professor
Department of Electronics and Communication Engg.
Beant College of Engineering & Technology,
Punjab, India

***Abstract*—WiMAX is the shortened form of Worldwide Interoperability for Microwave Access. WiMAX is one of the most blazing broadband wireless technologies around the world. It picked up popularity in light of its efficiency, high coverage, scalability and high data rate in any field. The WiMAX is based on the Orthogonal Frequency Division Multiplexing (OFDM) transmission technique which is known for its high radio resource use efficiency. In this paper, the performance of WiMAX system has been investigated by analysing the graphs between Spectral Efficiency (SE) vs. Signal to Noise Ratio (SNR) and Bit Error Rate (BER) vs. Signal to Noise Ratio (SNR) for different modulation schemes over AWGN channel. The BER and Spectral efficiency of OFDM based WiMAX is also evaluated under different Guard time intervals as it minimizes the inter-symbol interference which in return improves the bit error rate and reduces the power spectrum. The parameters that are used in this paper are based on IEEE 802.16 standards.**

Keywords--- WiMAX, RS-CC, OFDM, BER, Spectral Efficiency, AWGN.

I. INTRODUCTION

WiMAX is short form of Worldwide Interoperability for Microwave Access which is also known by name IEEE 802.16.The IEEE 802.16 working group create standards which addresses two models. Two models are fixed usage model and mobile usage model. Fixed is standardized as IEEE 802.16d or IEEE 802.16 -2004 in view of the fact that it was released in 2004 and mobile is standardized as IEEE802.16e or IEEE 802.16-2005 in view of the fact that it was released in 2005. WiMAX provides two types of wireless services that is Non-line of sight (NLOS) and Line of sight (LOS) services. In NLOS, WiMAX uses 2 to 11 GHz frequency and in LOS, frequency ranges from 10-66GHz. The physical layer of WiMAX depends on orthogonal frequency division multiplexing that enables WiMAX to work in NLOS conditions. It bolsters very high peak data rate upto 74 Mbps based on the spectrum used in the system. Depending on the channel conditions or per user and per frame basis, different types of modulation and forward error correction coding schemes can be used in WiMAX. BPSK, QPSK, 16-QAM and 64 QAM modulation schemes can be used in both uplink and downlink whereas 64-QAM is discretionary in the uplink.

II. DESCRIPTION OF WIMAX SYSTEM

WiMAX is the most well-known broadband wireless access (BWA) technology utilized for wireless metropolitan area networks (WMANs). It comprises of different blocks that work in conjunction with each other. The three main blocks of WiMAX Physical layer are transmitter, receiver and channel. Transmitter block consists of randomizer, FEC encoder, interleaver, modulator and OFDM multiplexer. Receiver block consists of De-randomizer, FEC decoder, De-interleaver, Demodulator and OFDM De-multiplexer. Channel is the medium that is used for transmitting the signal from transmitter to receiver. In this paper, AWGN (Additive White Gaussian Noise) is used as a channel for transmission. The block diagram of WiMAX physical layer is shown in Fig. 1.

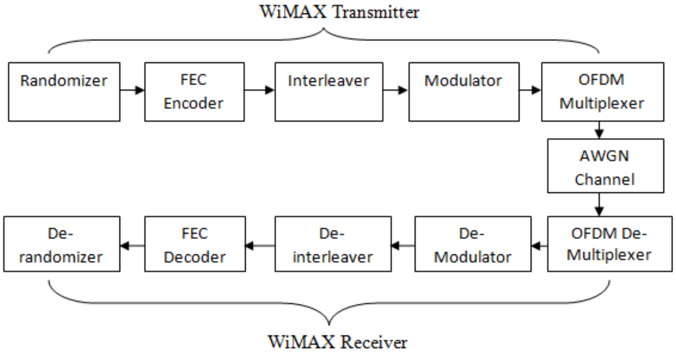

Fig. 1.Block diagram of WiMAX physical layer

A. Transmitter

Transmitter of WiMAX physical layer consists of randomizer, FEC encoder, interleaver, modulator and OFDM multiplexer. The function of randomizer is to subjectively change the arrangement of data which is done with the help of Pseudo Random Binary Sequence (PRBS) generator. PRBS generator consists of shift registers whose input bit is driven by the Exclusive-OR of some bits of the overall shift register value. In this paper, 15-stage shift register is used with generator polynomial of $X^{15}+X^{14}+1$ along with Exclusive-OR gate in the feedback configuration shown in Fig. 2.

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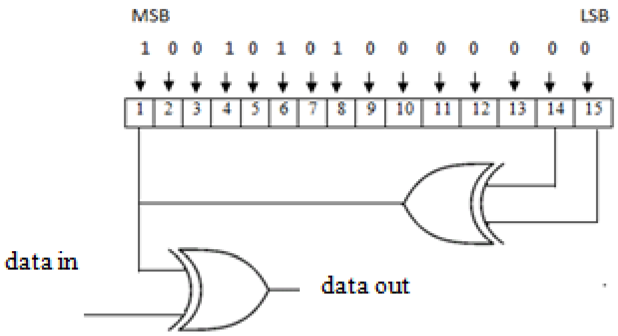

Fig. 2. Pseudo Random Sequence Generator

FEC encoder is error detection and error correction block that adds redundancy in a controlled way to increase the reliability of data. The FEC encoding process is shown in Fig.3.

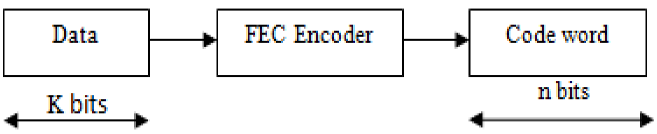

Fig. 3. .FEC encoding process

In this paper, Concatenated RS-CC (Reed Solomon-Convolutional code) encoder is used where Reed Solomon (RS) is the outer code and Convolutional code (CC) is the inner code shown in Fig.4.

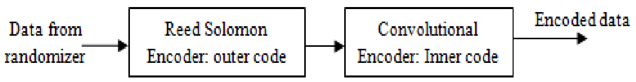

Fig. 4. Concatenated RS-CC Encoder

Interleaving is done on the encoded bits after channel coding to get over long sequences of random errors or burst errors. Interleaving is implemented using a two-step permutation process where the adjacent coded bits are mapped onto non-adjacent subcarriers in first permutation and the adjacent coded bits are mapped alternately onto less or more significant bits of the constellation in second permutation [1]. Modulation is the process toward superimposing the information contents of a modulating signal on a high frequency signal by changing the characteristic of high frequency signal according to the modulating signal .WiMAX has included advantage that we can utilize diverse order of modulation schemes. This is called as adaptive modulation where modulation changes relying on the channel condition. In this paper, we have used BPSK, QPSK, 16-QAM and 64 QAM. OFDM multiplexer is utilizing for orthogonal frequency division multiplexing that integrate between the modulator and the channel. The function of OFDM multiplexer is to separate carriers into sub-carriers which are orthogonal to each other with the goal that they don't cause inter-symbol interference (ISI). It is executed by utilizing IDFT (Inverse Discrete Fourier Transform) or IFFT (Inverse Fast Fourier Transform) at the transmitter. Guard intervals are also utilized between OFDM symbols with a specific end goal to wipe out ISI.

B. Channel

A communication channel or simply channel alludes to physical transmission medium imparting information from one location to another. In this paper, AWGN (additive White Gaussian noise) channel is used which adds white noise to the signal that is transmitted through it. Mathematically, AWGN channel is represented as

$$r(t) = s(t) + n(t) \qquad (1)$$

Where r (t) is the received signal,
s (t) is the transmitted signal and
n (t) is the background noise as shown in Fig.5.

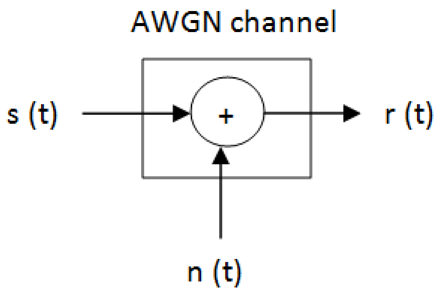

Fig. 5. AWGN channel model

C. Receiver

The blocks on the recipient side are the inverse blocks of those on the transmitter side. The blocks do precisely the reverse process of what is done by each blocks of the transmitter. The receiver of WiMAX physical layer consists of OFDM de-multiplexer, de-modulator, de-interleaver, FEC decoder, and de-randomizer. OFDM de-multiplexer is used for removing cyclic prefix as well as for converting the sub-channels into wideband channels by applying FFT (Fast Fourier Transform) or DFT (Discrete Fourier Transform) on the receiver side [2]. The signal from OFDM de-multiplexer is demodulated to digital form by demodulator. De-interleaver is used to undo the changes done by interleaver. FEC decoder is utilized to evacuate the redundancies that are added at the transmitter. It also detects the errors and corrects them to get the original data that was transmitted. The FEC decoding process is shown in Fig. 6.

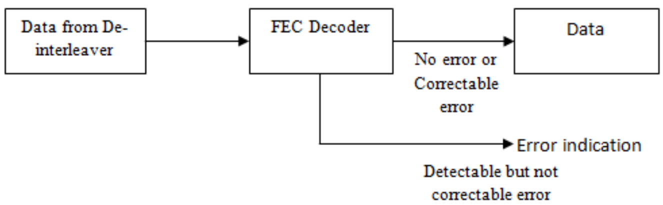

Fig. 6. FEC decoding process

The scrambled data is now descrambled by de-randomizer to get the same message as was delivered to the destination.

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III. RELATED WORK

khan et al. (2008) discusses the model building of the WiMAX Physical layer using Simulink in MATLAB. The model presented in this paper was processed by the Physical Layer using Convolutional Encoding Rate of 5/6 with QPSK modulation and transmitted with 256 carrier OFDM symbols [3]. O.Arafat et al. (2010) analysed the performance of physical layer of mobile WiMAX under SUI channel [4]. The results of simulation show that coding rate and modulation techniques had more prominent effect on the relative performance between the distinctive channel conditions. M.A. Mohamed et al. (2010) analysed the WiMAX physical layer under different combinations of digital modulation schemes and different communication channels [5]. The performance of the simulated system was evaluated using the bit-error-rate (BER). This paper concluded that when channel conditions are poor, energy efficient schemes such as BPSK or QPSK were used and when channel quality improves, higher M-ary modulation schemes such as 16-QAM or 64-QAM was used. A.R.Shankar et al. (2010) emphasis on the comparison of quality of service parameters between different channels in WiMAX physical Layer on the basis of Bit Error Rate, Signal to Noise Ratio, Power Spectral Density and Probability of Error [6]. He stated that as the probability of BER, Theoretical Values of BER, and Probability of Error decrease as SNR increases more in Rician channel compared to Rayleigh channel in PURE AWGN. BPSK has the lowest BER while 64-QAM has highest BER than others. Z.T. Sharef et al. (2012) analysed the performance of physical layer of WiMAX over AWGN and Rayleigh fading channel. The performance of QPSK modulation technique is evaluated and compared on the basis of bit error rate (BER) vs. bit energy-to-noise density ratio (E_b/N_o) curve [7]. The result of simulation shows that the performance of the system can be improved by utilizing channel estimator. H.Kaur et al. (2013) analysed the bit error rate for WiMAX based COFDM (Coded orthogonal frequency division multiplexing access) system with BPSK modulation technique under various channel conditions like AWGN, Rayleigh, Rician and Nakagami [8]. The results show that performance of Nakagami fading channel is better than other fading channels. D.R. Selvarani et al. (2014) provide an overview of Wi-Fi and WiMAX which includes the features, Specifications, architecture, advantages, limitations and security. WiMAX and Wi-Fi was compared and it is recommended that when Wi-Fi is synergized with WiMAX, it will give the best answer for last mile scope [9]. Ahmed et al. (2014) verified the performance of WiMAX system under various channels and number of modulation schemes on the basis of SNR and BER graph. The results state that WiMAX system works well in both AWGN and multipath fading channel [10]. A. Al-Kandari et al. (2014) discussed the capacity, efficiency, complexity and coverage features of WiMAX (Worldwide Interoperability for Microwave Access) and LTE (Long Term Evolution) with their advantages and disadvantages. M. Joshi et al. (2015) analysed the WiMAX system under distinctive channels like Rayleigh, Rician, Nakagami and Lognormal shadowing channel with different modulation techniques on the basis of bit error rate (BER).This paper concludes that Nakagami channel provide better performance using different modulation techniques at higher SNR. Y.M. Al-Moliki et al. (2015) compared the Concatenated Reed Solomon and Convolutional (RSCC) codes with Reed Solomon (RS) codes without concatenation [13]. The Simulation results show that the performance of concatenated RS-CC code is better and robust as compared to RS code without concatenation in terms of BER with various SNR. R.Pornima et al (2015) analysed the higher order modulation techniques like 16-QAM and 64-QAM for mobile WiMAX in OFDMA [14]. U.R.Mori et al (2015) compared the features of two advance technologies in physical layer and also gives performance analysis of different modulation schemes (BPSK, QPSK, and 16-QAM) in WiMAX & LTE technologies [15]. M.L.Singh et al (2016) analysed in terms of BER for ITU-R and Cost-207 channel model conditions for Typical Urban Area and Typical Rural Area. K.S.Pooja et al. (2016) concluded that the single convolutional coding and dual interleaving plays out the best under all ranges of Signal to Noise Ratio.

IV. RESULTS AND DISCUSSION

A. Simulation Parameters

The simulated modulation and coding used in this paper is shown in Table 1.

Table 1. Mandatory channel coding per modulation

Modulation	Overall coding rate	RS code	CC code rate
BPSK	½	(12,12,0)	1/2
QPSK	½	(32,24,4)	2/3
QPSK	¾	(40,36,2)	5/6
16-QAM	¾	(80,72,4)	5/6
64-QAM	2/3	(108,96,6)	3/4
64-QAM	¾	(120,108,6)	5/6

The OFDM parameters both primitive and derived that characterize OFDM symbol completely in WiMAX are listed in Table 2.

Table 2. OFDM parameters used in WiMAX

Parameters	Value	Description
BW	1.25,5,10,20	Bandwidth
N_{used}	72, 360,720,1440	used subcarriers
n	8/7, 28/25	Sampling factor
N_{fft}	128,512,1024,2048	FFT size
G	1/4, 1/8, 1/16, 1/32	Guard time ratio
F_s	Floor(n*BW/8000)*8000	Sampling frequency
Δf	F_s / N_{fft}	Frequency spacing
T_b	1/ Δf	Useful symbol time

The spectral efficiency of WiMAX based on diverse modulation techniques and code rates are listed in Table 3.

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Table 3. Spectral efficiency of WiMAX

Modulation and code rate	Maximum Spectral Efficiency(bps/Hz)
BPSK R1/2	0.5
QPSK R1/2	1.0
QPSK R3/4	2.0
16 QAM R3/4	3.0
64 QAM R2/3	4.0
64 QAM R3/4	4.5

B. Simulation Results

The simulation results consist of BER vs. SNR graph and Spectral Efficiency vs. SNR graph of WiMAX system over AWGN channel with diverse modulation schemes and Guard time intervals. The performance of a WiMAX system over AWGN channel using BPSK, QPSK, 16-QAM and 64-QAM is shown in Fig.7 to Fig. 17.

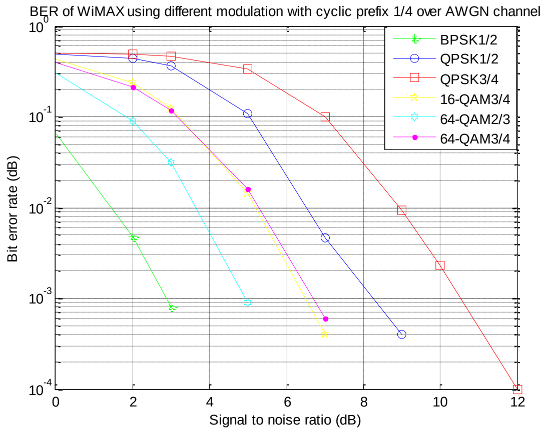

Fig. 7. BER of WiMAX using diverse modulations with cyclic prefix 1/4

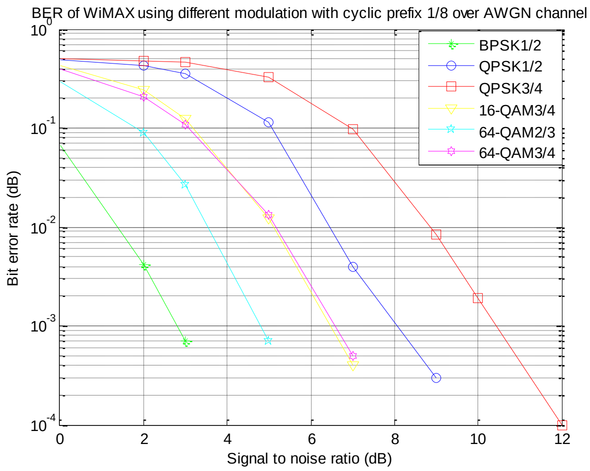

Fig. 8. BER of WiMAX using diverse modulations with cyclic prefix 1/8

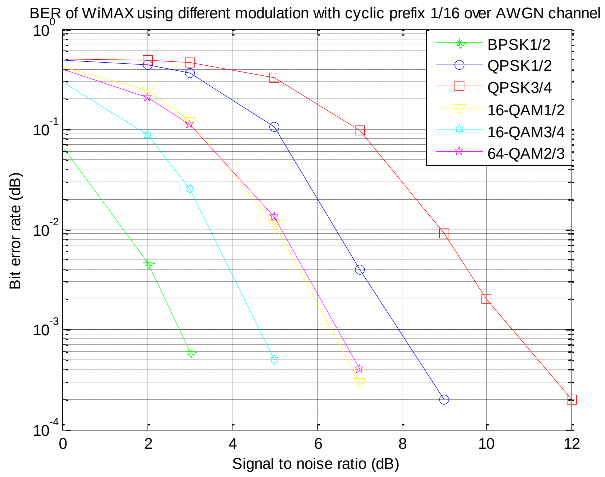

Fig. 9. BER of WiMAX using diverse modulations with cyclic prefix 1/16

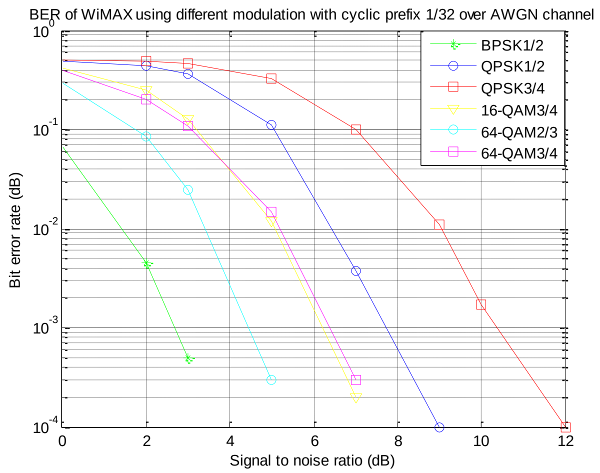

Fig. 10. BER of WiMAX using diverse modulations with cyclic prefix 1/32

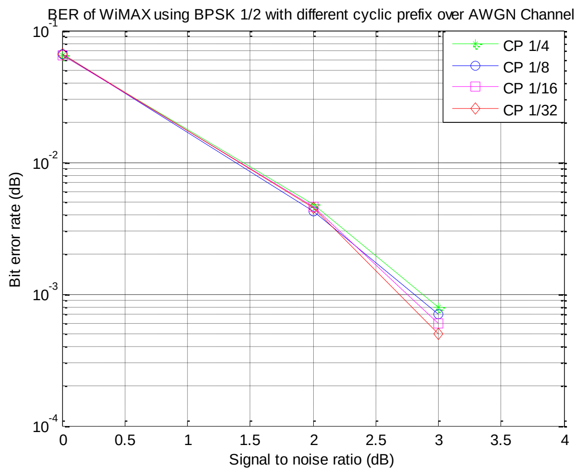

Fig. 11.BER of WiMAX using BPSK ½

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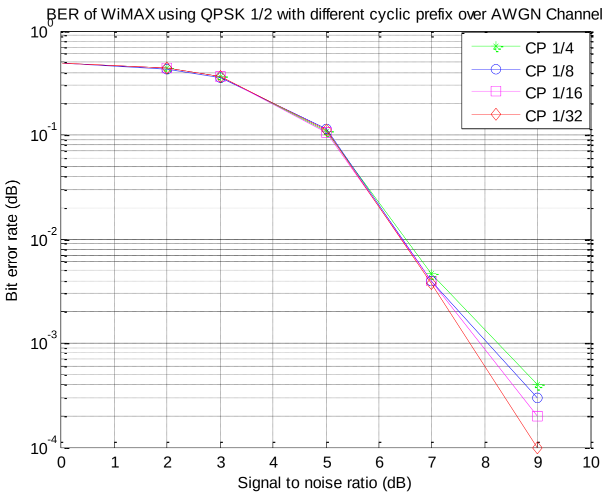

Fig. 12. BER of WiMAX using QPSK ½

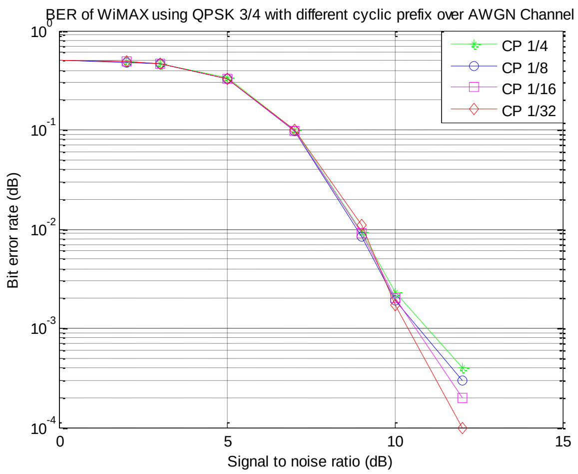

Fig. 13.BER of WiMAX using QPSK ¾

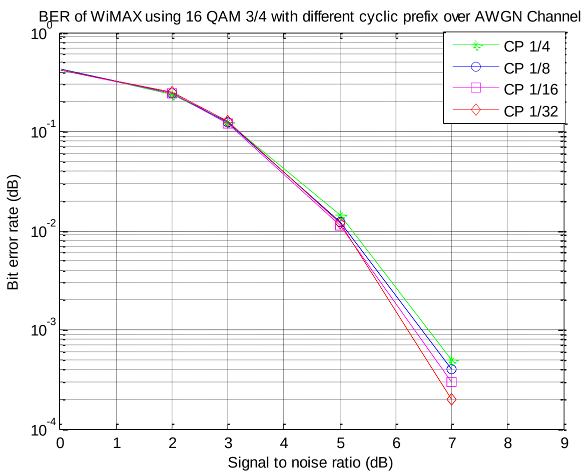

Fig. 14. BER of WiMAX using 16 QAM ¾

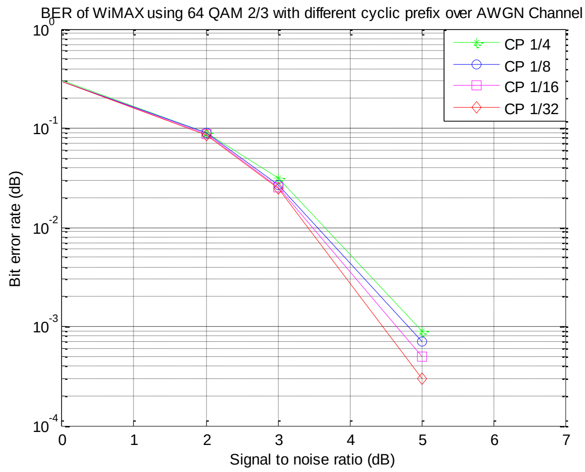

Fig. 15. BER of WiMAX using 64 QAM 2/3

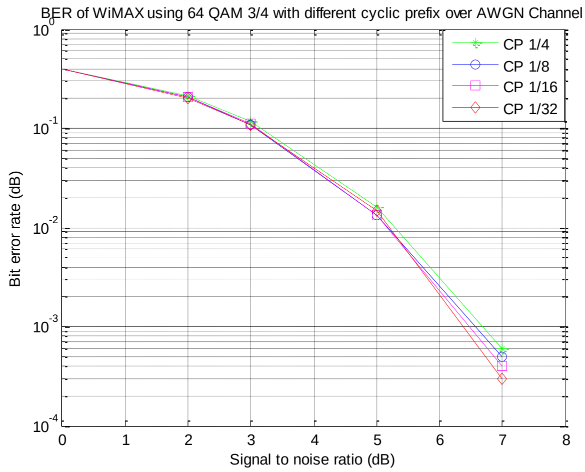

Fig. 16. BER of WiMAX using 64 QAM ¾

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Table 4.SNR requirement in WiMAX for diverse modulation techniques

Cyclic prefix	SNR(dB) required to achieve a BER of 10^{-3}					
	Modulation					
	BPSK ½	QPSK ½	QPSK ¾	16 QAM ¾	64 QAM 2/3	64 QAM ¾
1/4	2.87	8.25	10.95	6.58	4.94	6.69
1/8	2.80	8.07	10.69	6.46	4.80	6.57
1/16	2.74	7.91	10.60	6.33	4.64	6.47
1/32	2.68	7.72	10.37	6.21	4.45	6.38

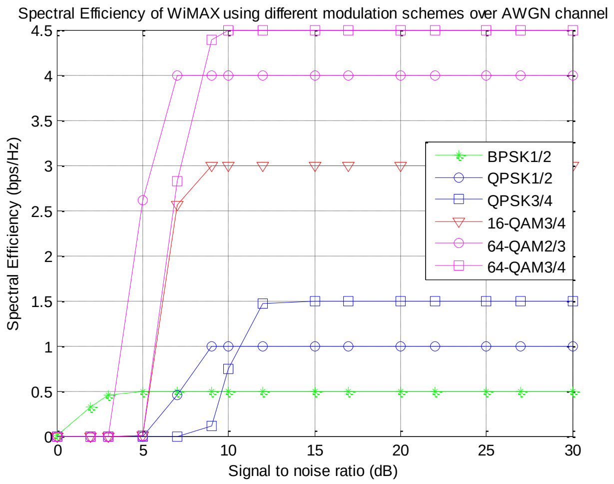

Fig. 17. Spectral Efficiency of WiMAX using diverse modulation scheme

V. CONCLUSION

In this paper, we have analysed the bit error rate and spectral efficiency of OFDM based WiMAX physical layer using different modulation schemes and guard time intervals over AWGN channel. We can conclude that the outcomes are distinctive by using different modulation techniques in WiMAX. Amid all the simulations, BPSK R1/2 has the most reduced BER and QPSK R3/4 has the most elevated BER than other modulation techniques so BPSK R1/2 is more power efficient thus require less bandwidth. The outcomes also uncover that the different modulations and coding rate give better execution with less SNR at guard time interval 1/32. The simulation outcomes of spectral efficiency reveals that 64 QAM R3/4 has the highest spectral efficiency and BPSK R1/2 has the lowest spectral efficiency so 64 QAM R3/4 can be used for transmitting maximum amount of information with lesser transmission error.

Table 5 . Spectral Efficiency of WiMAX using diverse modulation schemes

Spectral Efficiency						
Modulation	BPSK	QPSK	QPSK	16 QAM	64 QAM	64 QAM
Code rate	1/2	1/2	3/4	3/4	2/3	3/4
Bits/Symbol	1	2	2	4	6	6
Spectral Efficiency	0.5	1	2	3	4	4.5
SNR(dB)	From 5 onwards	From 9 onwards	From 15 onwards	From 9 onwards	From 7 onwards	From 10 onwards

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