Performance Evaluation of IEEE 802.16e (Mobile Wimax) In OFDM Physical Layer

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Abstract- *The next generation broadband wireless technology which offers high speed, sophisticate, secure, and last mile broadband services along with a cellular back haul and Wi-Fi hotspots is known as WiMAX. IEEE 802.16, also known as IEEE Wireless-MAN, explored both licensed and unlicensed band of 2-66 GHz which is standard of fixed wireless broadband and included mobile broadband application. Idea is to provide "very last mile" broadband connectivity to home or else business locations, also its data rates are analogous with Cable and Digital Subscriber line (DSL) rates happens in WiMAX. It has the capability which connects to the ISP (Internet Service Provider) even when you are roaming outside home or office. The WiMAX technology can give a cost-effective broadband access solution in areas beyond the reach of DSL and cable. In this paper work, we built a simulation model based on 802.16e OFDM-PHY baseband and demonstrated in different simulation scenarios with different modulation techniques such as BPSK, QPSK and QAM (8,16 and 64) to find out the best performance of physical layer for WiMAX Mobile. All the necessary conditions were implemented in the simulation according to the 802.16e OFDMA-PHY specification.*

Keywords- Worldwide Interoperability for Microwaves Access (WiMAX), Orthogonal Frequency Division Multiplexing (OFDM), Physical Layer (PHY). Coding data rate, Additive White Gaussian Noise (AWGN), Bit Error Rate (BER), Interliving, Modulation.

I. INTRODUCTION

WiMAX is known as the next generation broadband wireless skill which offers high speed, secure, sophisticate and very last mile broadband services alongside with a cellular back haul and Wi-Fi hotspots. The evolution of WiMAX began a few years ago when scientists and engineers felt the need of having a wireless Internet access along with other broadband services which works well all over the place especially the rural areas or in those areas where it is hard to establish wired infrastructure and economically not feasible. IEEE 802.16, also known as IEEE Wireless-MAN, explored both licensed and unlicensed band of 2-66 GHz which is standard of fixed wireless broadband and included mobile broadband application.

WiMAX forum, a confidential association was formed in June 2001 to coordinate the components as well as develop the equipment those will be compatible along with inter operable. After several years, in 2007, Mobile WiMAX equipment developed with the standard IEEE 802.16e got the certification and they announced to discharge the product in 2008, providing mobility and nomadic access. The IEEE 802.16e air interface based on Orthogonal Frequency Division Multiple Access (OFDMA) which most important aim is to give better performance in non-line-of-sight environments. IEEE 802.16e introduced bandwidth of scalable channel up to 20 MHz, Multiple Input Multiple Output (MIMO) as well as AMC enabled 802.16e technology to support peak Downlink (DL) data rates up to 63 Mbps in a 20 MHz channel through Scalable OFDMA (S-OFDMA) system [1]. IEEE 802.16e has physically powerful security architecture as it uses Extensible Authentication Protocol (EAP) for mutual authentication, a series of strong encryption algorithms, CMAC or HMAC based message protection and reduced key lifetime [2]. Cellular phone systems, WLAN, wide-area wireless data systems, ad-hoc wireless networks as well as satellite systems etc are wireless communication.

All emerged based on wireless technology to give higher throughput, longer range, immense mobility, robust backbone to thereat. The vision comprehensive a bit more by the engineers to provide smooth transmission of multimedia anywhere on the globe through variety of applications and strategy leading a novel idea of wireless communication which is cheap along with elastic to implement still in odd environment.

The wireless broadband connection is greatly easier to install, have long range of coverage, easier to access in addition to it is more flexible. This connectivity is really important for developing countries along with IEEE 802.16 family helps to resolve the previous mile connectivity problems with BWA connectivity. IEEE 802.16e can be able to operate in both Line-Of-Sight (LOS) as well as Non-Line-

Of-Sight (NLOS) environments. In NLOS, the PHY specification is extended to 211 GHz frequency band which intend is to fight with fading as well as multipath propagation. The OFDM physical layer based on IEEE 802.16 standard which is approximately identical to European Telecommunications Standard Institute's (ETSI) High performance Metropolitan Area Network (HiperMAN) as they oblige with each other [3].

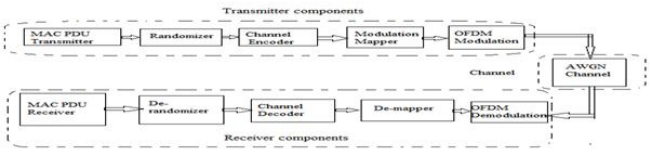

Figure 1: WiMAX System Model

II. WIMAX ARCHITECTURE

WiMAX design comprises of numerous components but the basic two components are BS as well as SS. Other components are MS, ASN, CSN and CSN-GW etc. The WiMAX Forum's Network Working Group (NWG) has developed a network reference model according to the IEEE 802.16e-2005 air interface to make sure the objectives of WiMAX are achieved. To sustain fixed, nomadic as well as mobile WiMAX network, the network reference model can be logically separated into three parts [4].

a)Mobile Station (MS)

It is for the end user to access the mobile network. It is a portable station able to move to wide areas and perform data and voice communication. It has the necessary user equipments such as an antenna, amplifier, transmitter, receiver and software needed to perform the wireless communication. GSM, FDMA, TDMA, CDMA and W-CDMA devices etc are the examples of Mobile station.

b)Access Service Network (ASN)

NAP is the owner of this, created with one or several base stations and ASN gateways (ASN-GW) which creates radio access network. It provides all the access services with full mobility and efficient scalability. Its ASN-GW controls the access in the network and coordinates between data and networking elements.

c) Connectivity Service Network (CSN):

It provides IP connectivity to the Internet or else other public or corporate networks. It moreover applies per user policy management, address management, location management between ASN, ensures QoS, roaming and security.

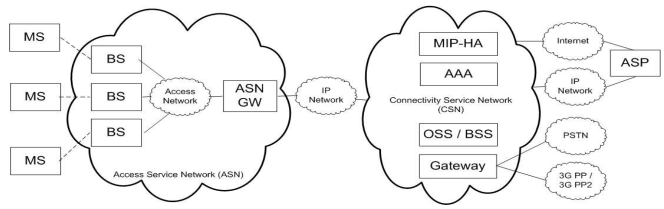

Figure 2: WiMAX Network Architecture based on IP [4]

Along with increase in data rate requirements, large bandwidths are needed to support it. Higher bandwidths (subcarriers) radically increase the BER. In this system model the chief blocks are channel encoder and decoder, modulation mapped as well as OFDM block. In the baseband transmission, depends on the 256 point FFT size to generate the data, the entire data is transmitted using the OFDM transmission technique, which converts the data into an OFDM symbol by performing the corresponding operations, which includes a frequency-time transformation and the additional of a guard period.

III. WIMAX PHYSICAL LAYER

The WiMAX physical layer (PHY) is planned to work with dissimilar specifications for licensed and unlicensed frequency bands. For example, one is based on a single carrier (SC) to support line of site with high data rates , others use orthogonal frequency division multiplexing (OFDM), and OFDMA to support both line of site(LOS) and none line of sight (NLOS) . [5][6][7][8]

OFDM /OFDMA:

OFDM is an efficient modulation schema used for transmitting large amount of data over radio waves. OFDM is a multi carrier transmission method that is based on dividing the frequency of a carrier into orthogonal frequency sub carriers each carrying different stream of data and is can be modulated and coded separately. Since OFDM selects the sub carriers such that they are orthogonal to each other over the time duration, it limits or eliminates overlapping and the sub carrier interference. OFDMA is the access method that is based on the OFDM modulation technique to divide the carriers among the users to form sub channels. Each sub channel is allocated a separate coding and modulation parameters to allow are adapted separately, allowing channel optimization on a smaller scale (rather than using the same parameters for the whole channel). This technique optimizes the use of spectrum resources and enhances indoor coverage by assigning a robust scheme (yet, with low rates) to vulnerable links. OFDMA is an option in 802.16 (for fixed access), but it's not required for certifying 802.16 products. However, OFDMA is necessary in 802.16e devices and is required for certification. SOFDMA is an enhancement of OFDMA that scales the number of sub carriers in a channel using the four set of scaling factors 128, 512, 1,024, and 2,048. OFDM is widely addressed as the way to mitigate multipath for broadband wireless. Multi-carrier modulation on OFDM is based on a program method, which divides a high bit stream into a number of low bit streams, which are each modulated by separate carriers called subcarriers or tones. The WiMAX RF signals utilize OFDM techniques as well as its signal bandwidth can range from 1.25 to 20 MHz. To continue orthogonality among the individual carriers the symbol period must be reciprocal of the carrier spacing.

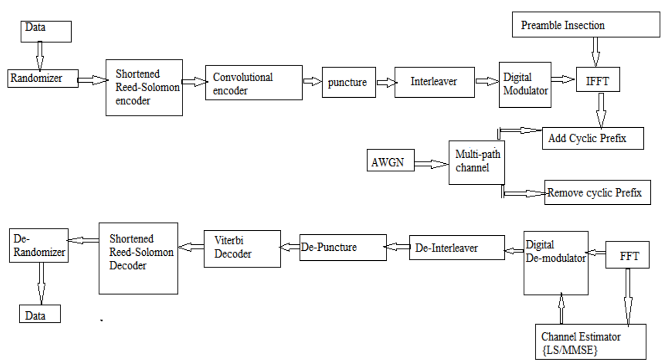

Figure 3: WiMAX Physical Layer

The different blocks of WiMAX Physical Layer are:

A. Randomization:

Previously the data packet is received from the higher layers; randomization is the first step to perform in the physical layer. The Randomizer operates on a bit by bit fashion and each burst in downlink and uplink is randomized. The whole implementation of this phase is done with a Pseudo Random Binary Sequence (PRBS) generator.

B. FEC (Forward Error Correction)

FEC is a method worn for controlling errors in data transmission over noisy communication channels. It is done on both the uplink and the downlink bursts and consists of concatenation of reed-Solomon outer code and a rate compatible convolution inner code.

C. Reed Solomon Outer Code:

Reed-Solomon error correction is a coding system which works by adding up redundancy to the data to deal with the block errors that occur during transmission of the signal. The encoding process for RS encoder is based on Galois Field Computations to perform the estimate of the redundant bits. Galois Field is extensively used to represent data in error control coding is denoted by GF (2m).

D. Convolution Coding:

A convolution code is a type of FEC code written by cc(m,n,k), wherever every m-bit information symbol to be encoded is transformed into n-bit symbol, where m/n is the code rate (n>m) and the transformation is a function of the last k information symbols, where k is constraint length of code. It mostly handles the random errors in data transmission.

E. Interleaving

Unlike Randomizer, Interleaving does not alter the state of the bits but works only with the position of bits. It aims at distributing transmitted bits in time or frequency domain or both to achieve desirable bit error distribution. The external data is randomized in two permutations wherever first permutation ensures that adjacent bits are mapped onto non-adjacent subcarriers while the second permutation maps the adjacent coded bits onto less or more significant bits of constellation thus avoiding long runs of less reliable bits.

The first permutation is defined by the formula:

$$mk = (Ncbps/12) * mod(k,12) + floor(k/12).$$

The second permutation is defined by the formula:

$$S = ceil (Ncpc/2)$$

$$Jk = s \times floor (mk/s) + (mk + Ncbps – floor(12\times mk/Ncbps))mod(s)$$

Where:

K = Index of coded bit before first permutation
mk = Index of coded bit after first permutation
jk = Index of coded bit after second permutation
Ncpc = Number of coded bits per carrier
Ncbps = Number of coded bits per symbol.
Index of bits represented by
jk is used during the modulation process.

F. Cyclic Prefix Insertion

A cyclic prefix is extra to the time domain samples to combat the effect of multipath. Four different duration of cyclic prefix are available in the standard. Being G the ratio of CP time to OFDM symbol time, this ratio can be equal to

1/32, 1/6, 1/8 and 1/4.AWGN (Additive white Gaussian noise) Channel AWGN channel block adds white Gaussian noise to real or complex input signal. It adds real Gaussian noise when the input signal is real and produces a real output signal. Additive white Gaussian noise is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. The AWGN channel capacity is expressed as following equation

Cawgn = W log2 (1+P'/NoW) bits/Hz

Where the average received power is P'[w] and the noise power spectral density is No [W/Hz] And P'/NoW is received signal-to-noise ratio (SNR)

G. Rayleigh Fading Channel

It is a statistical model for propagation environment on the radio signal used by wireless networks. It assumes that the power of a signal passing through a transmission medium will vary randomly which is modelled as Rayleigh distribution. It is a sensible reproduction for troposphere and ionosphere signal propagation. This channel is most applicable when there is no line-of-sight between the transmitter and receiver.

IV. SIMULATION RESULTS ANALYSIS

During our simulation we used cyclic prefix to minimize the Inter Symbol Interference (ISI) on the basis of following adaptive modulation techniques through MATLAB.

- Phase Shift Keying (PSK)
- Binary Phase Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- 16-Quadrature Amplitude Modulation (16-QAM)
- 64-Quadrature Amplitude Modulation (64-QAM)

With the help of above modulation techniques we got the following parameters,

- Scattering Points of QPSK
- Scattering Points of QAM
- Bit Error Rate (BER)
- Signal to Noise Ratio (SNR)
- Probability of Error (Pe)

Bit Error Rate (BER)

Bit Error Rate (BER) is when number of bits error occur within one second in transmitted signal. In another sentence Bit Error rate is one type of parameter which used to access the system that can transmit digital signal from one end to other end. We can define BER as follows,

BER = (Error Number)/(Total Number of bits sent)

If transmitter as well as receiver's intermediate are good in a particular time and Signal-to-Noise Ratio is high, then Bit Error rate is very low. In our paper simulation we generated random signal when noise occurs after that we got the value of Bit error rate.

Eb/N0

Energy per bit to noise power spectral density ratio is important role especially in simulation. Whenever we are simulating and comparing the Bit Error rate (BER) performance of adaptive modulation technique is very necessary Eb/N0. The normalized form of Eb/N0 is Signal-to-Noise Ratio (SNR). In telecommunication, Signal-to-Noise ratio is the form of power ratio between a signal and background noise,

$$SNR = \frac{P_{signal}}{P_{Noise}}$$

Here P is mean power. In this case the signal and the background noise are measured at the same point of view if the measurement will take across the same impedance then SNR would be obtained by measuring the square of the amplitude ratio.

$$SNR = \frac{P_{signal}}{P_{Noise}} = \left(\frac{A_{Signal}}{A_{Noise}}\right)^2$$

BER Vs Eb/No

The Bit Error Rate (BER) defined as the probability of error (Pe). On the other hand Signal-to-Noise is the term of power ratio between a signal and background noise. There are three variables like,

- The error function (erf)
- The energy per bit (Eb)
- The noise power spectral density (N0)

Each and every modulation system has its own value for the error function. That is why each modulation scheme performs in different manner due to the presence of background noise. For instance, the higher modulation scheme

(64-QAM) is not robust but it carries higher data rate. On the different, the lower modulation scheme (BPSK) is more healthy but carries lower data rate. The energy per bit, Eb defined by dividing the carrier power and measured of energy with the unit of Joules. Noise power spectral density (N0) is power per hertz with the unit of Joules per second. So, it is clear that the dimension of SNR is cancelled out. So we can agree on that point that, the probability of error is proportional to Eb/No.

Physical layer performance results

The fundamental objective of this thesis is to analyze the performance of WiMAX OFDM physical layer based on the simulation results. In order to analyze, firstly we focused on the scattering points of Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) using channel equalizer. Secondly, we investigated the BER Vs SNR plot by using AWGN and Rician fading and finally, we investigated Probability of Error Rate.

BER Vs SNR Plot

We set various theoretical values in our simulation to find out Bit Error Rate alongside Signal-to-Noise Ratio for all modulation techniques using AWGN and Rayleigh Fading respectively. The results are shown in figure 4

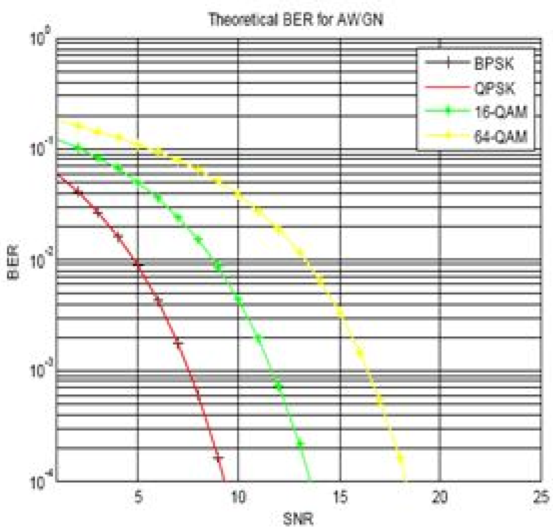

Fig 4: Theoretical Value used for BER Vs SNR under AWGN channel

Adaptive modulation of Probability of Error (Pe)

Probability of Error (Pe) is important to find out the error rate in a system because it affects fading and noise in a channel at transmitting and receiving end. From the following formula Probability of Error for M-array PSK has been calculated.

$$P_e \cong erfc\left(\sqrt{\frac{E_S}{N_0}}\sin\left(\frac{\pi}{M}\right)\right)$$

Probability of Error for M-array QAM has been calculated through this formula which is as follows,

$$P_e \cong 2\left(1-\frac{1}{\sqrt{M}}\right)erfc\left(\sqrt{\frac{3E_s}{2(M-1)N_0}}\right)$$

Probability of Error (Pe)

Due to fading as well as Doppler shift achieve, the Probability of Error of the system increased resulting the physical layer performance degrades.

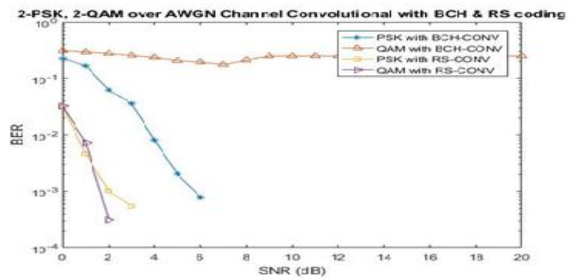

Fig 5. PSK,2-QAM over AWGN channel Convolution with BCH & RS coding

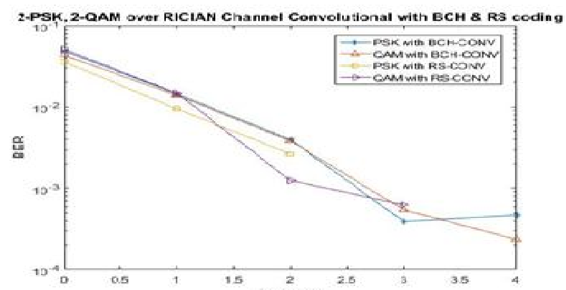

Fig 6.: 2-PSK,2-QAM over Rician channel Convolution with BCH & RS coding

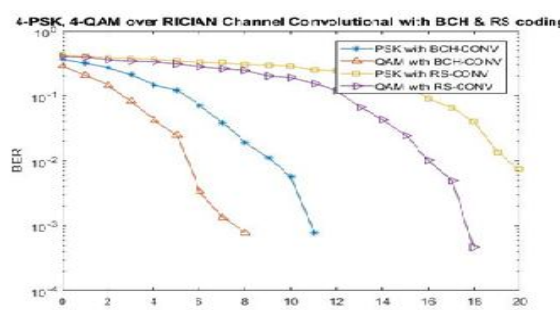

Fig 7: 4-PSK,4-QAM over Rician channel Convolution with BCH & RS coding

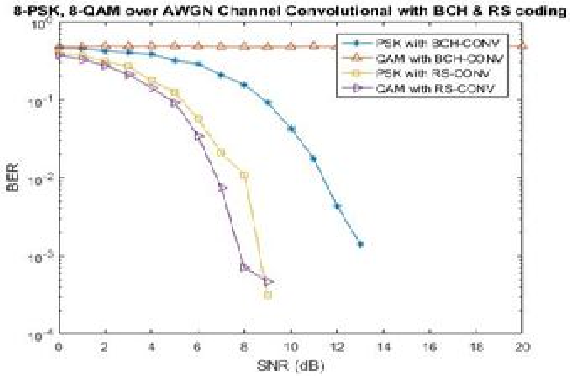

Fig 8: 8-PSK,8-QAM over AWGN channel Convolution with BCH & RS coding

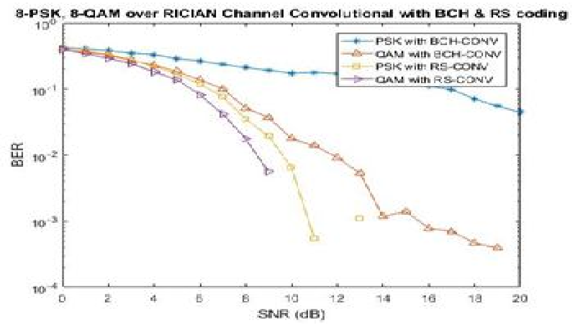

Fig 9: 8-PSK,8-QAM over RICIAN channel Convolution with BCH & RS coding

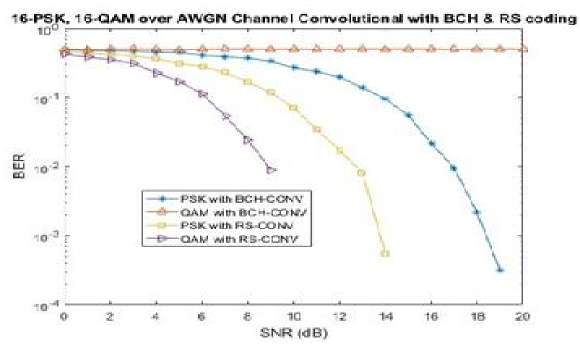

Fig 10 : 16-PSK,16-QAM over AWGN channel Convolution with BCH & RS coding

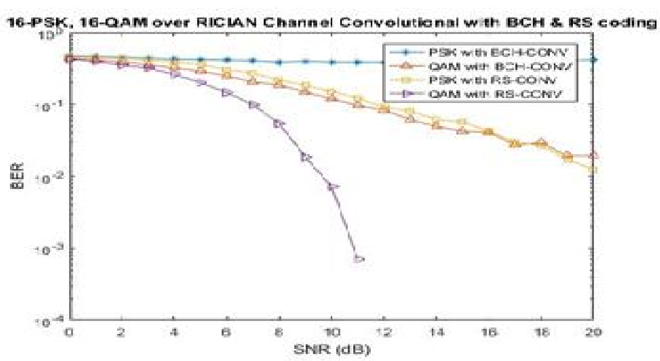

Fig 11: 16-PSK,16-QAM over RICIAN channel Convolution with BCH & RS coding

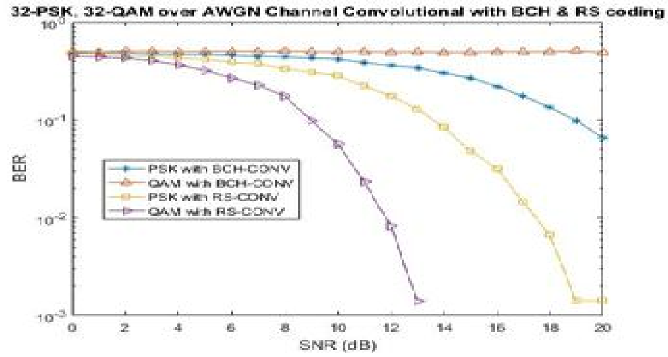

Fig 12: 32-PSK,32-QAM over AWGN channel Convolution with BCH & RS coding

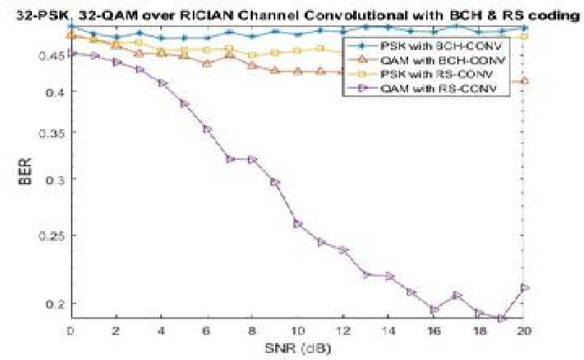

Fig 13: 32-PSK,32-QAM over RICIAN channel Convolution with BCH & RS coding

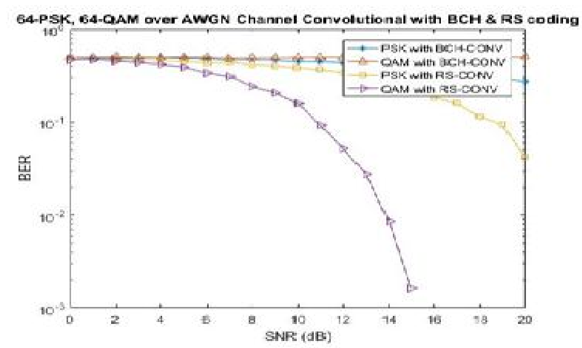

Fig 14: 64-PSK,64 -QAM over AWGN channel Convolution with BCH & RS coding

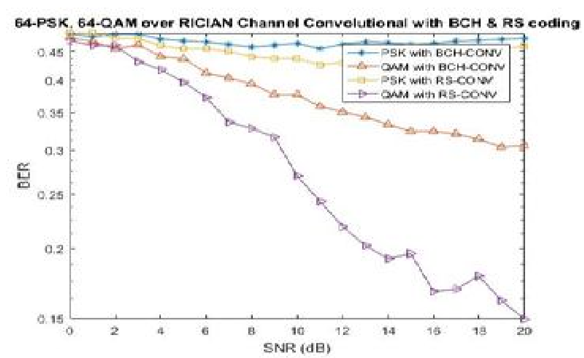

Fig 15: 64-PSK,64 -QAM over RICIAN channel Convolution with BCH & RS coding

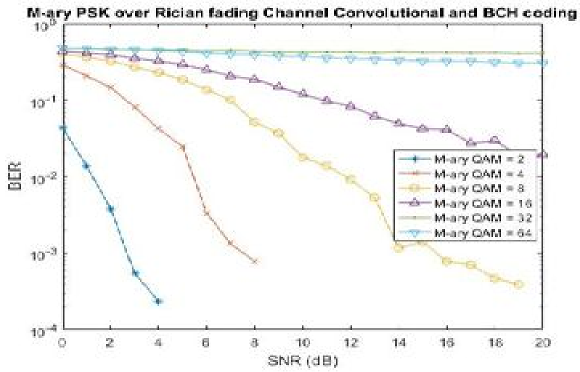

Fig 16: M-ary QAM over Rician Fading Channel Convolutional and RS coding

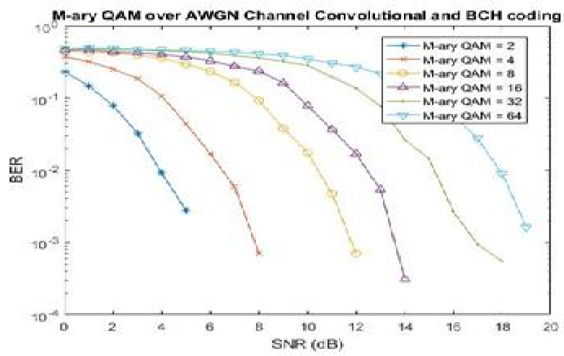

Fig 17: M-ary QAM over AWGN channel convolutional and BCH coding

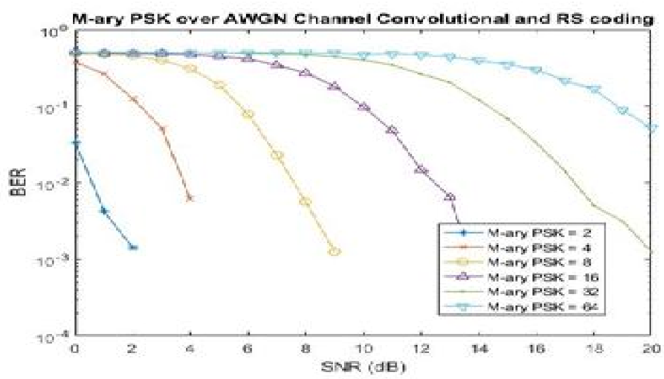

Fig 18: M-ary PSK over AWGN channel convolutional and BCH coding

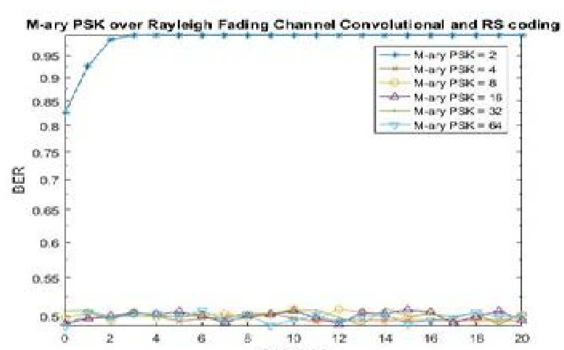

Fig 19: M-ary PSK over Rayleigh Fading channel convolutional and BCH coding

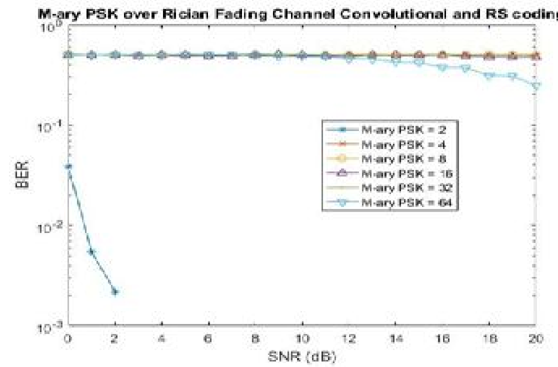

Fig 20: M-ary PSK over Rician Fading channel convolutional and BCH coding

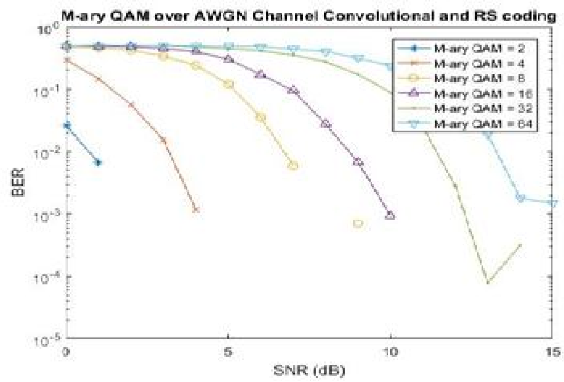

Fig 21 : M-ary QAM over AWGN channel convolutional and BCH coding

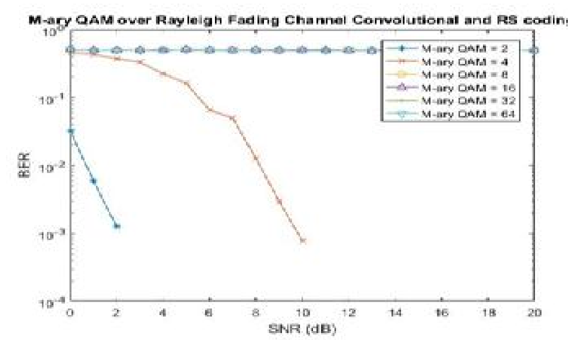

Fig 22 : M-ary QAM over Rayleigh Fading channel convolutional and BCH coding

Table 1: Comparison of BCH & RS encoder with PSK and QAM modulator over AWGN channel

System		2	4	8	16	32	64
BCH-conv-AWGN-PSK	SNR	5	8	12	14	18	19
	BER	7.816 e^{-04}	4.6897 e^{-04}	0.0014	3.1265 e^{-04}	0.0653	0.2717
BCH-conv-AWGN-QAM	SNR	5	8	12	14	18	19
	BER	0.0027	7.0345 e^{-04}	7.0345 e^{-04}	3.126 e^{-04}	5.4713 e^{-04}	0.0016
RS-conv-AWGN-PSK	SNR	3	5	9	14	20	20
	BER	5.4705 e^{-04}	4.6890 e^{-04}	3.1260 e^{-04}	5.4705 e^{-04}	0.0014	0.0417
RS-conv-AWGN-QAM	SNR	2	4	9	9	13	15
	BER	3.1260 e^{-04}	0.0020	4.6890 e^{-04}	0.0089	0.0014	0.0016

Table 2: QAM Modulator over Rician Fadding Channel Modulation order

System		2	4	8	16	32	64
RS-conv-Rician-PSK	SNR	2	20	13	20	20	20
	BER	0.0027	0.0074	0.0011	0.0124	0.4719	0.4593
RS-conv-Rician-QAM	SNR	3	18	9	11	20	20
	BER	$6.2520e^{-04}$	$4.6890e^{-04}$	0.0056	$7.0334e^{-04}$	0.2108	0.1497
BCH-conv-Rician-PSK	SNR	4	11	20	20	20	20
	BER	$4.6897\ e^{-04}$	$7.8162\ e^{-04}$	0.00445	0.4159	0.4923	0.4747
BCH-conv-Rician-QAM	SNR	4	8	19	20	20	20
	BER	$2.3452\ e^{-04}$	$7.8174\ e^{-04}$	$3.9087\ e^{-04}$	0.0195	0.4137	0.3057

Table 3: Comparison of BCH & RS encoder with PSK & QAM modulator over Rician Fadding Channel

System/Modulation order		2	4	8	16	32	64
RS-conv-Rician-PSK	SNR	2	20	13	20	20	20
	BER	0.0024	0.0074	0.0011	0.0124	0.4779	0.4593
RS-conv-Rician-QAM	SNR	3	18	9	11	20	20
	BER	$6.2520\ e^{-04}$	$4.6890\ e^{-04}$	0.0056	$7.0334\ e^{-04}$	0.2103	0.1497
BCH-conv-Rician-PSK	SNR	4	11	20	20	20	20
	BER	$4.6897\ e^{-04}$	$7.8162\ e^{-04}$	0.00445	0.4159	0.4923	0.4747
BCH-conv-Rician-QAM	SNR	4	8	19	20	20	20
	BER	$2.3452\ e^{-04}$	$7.8174\ e^{-04}$	$3.9087\ e^{-04}$	0.0195	0.4137	0.3057

From the figures and tables above, the performance of the system is with RS convolution and BCH convolution with Rician QAM and PSK. Various values obtained in the above mentioned 3 tables. SNR and BER values of various system obtained with various modulation order.

V.CONCLUSION

Finally , we can conclude the performance of Mobile WiMAX as, Binary Phase Shift Keying (BPSK) is extra power efficient and needs fewer bandwidth in adaptive modulation method On the other hand 64-Qadrature Amplitude Modulation (64-QAM) has higher bandwidth with very good output. In an additional casing, Quadrature Phase Shift Keying (QPSK) as well as 16-QAM modulation techniques are in central point of those two (BPSK as well as 64-QAM) and they requires higher bandwidth. QPSK and 16-QAM are less power efficient than BPSK. During all simulations we got, BPSK has the lowest BER and 64-QAM has the highest BER than other modulation techniques.

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