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Study of WiMAX Physical Layer under Adaptive modulation Technique using Simulink

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ABSTRACT
IEEE 802.16e WIMAX (*Worldwide interoperable Microwave Access)* is the upcoming wireless system which can offer high speed voice, video and data service up to the customer end..It offers both LOS&N-LOS wireless communication. By using WIMAX Technology we can overcome the limitation of short coverage area, lack of security and low data rate. The aim of this paper is the performance evaluation of an WIMAX system under different combinations of digital modulation and different communication channels AWGN and fading channels. And the WIMAX system incorporates Reed-Solomon (RS) encoder with Convolutional encoder with ½ and 2⁄3 rated codes in FEC channel coding. Orthogonal frequency division multiple accesses use adaptive modulation technique such as(BPSK,QPSK,16-QAM,64-QAM) on the physical layer of WIMAX and it uses the concept of cyclic prefix that adds additional bits at the transmitter end. The signal is transmitted through the channel and it is received at the receiver end. Then the receiver removes these additional bits in order to minimize the inter symbol interference, to improve the bit error rate and to reduce the power spectrum. The simulation results of estimated Bit Error Rate (BER) displays that the implementation of interleaved RS code (255,239,8) with 2/3 rated Convolutional code under BPSK modulation technique is highly effective to combat in the WIMAX communication system.

Keyword: *OFDM, Block Coding, Convolution coding, Additive White Gaussian Noise, Fading Channel, orthogonal frequency division multiplexing (OFDM); Line-of-Sight (LoS); Physical (PHY) layer.*

I. INTRODUCTION
Conventional high-speed broadband solutions are based on wired-access technologies such as digital subscriber line (DSL). This type of solution is difficult to deploy in remote rural areas, and furthermore it lacks support for terminal mobility. Mobile Broadband Wireless Access (BWA) offers a flexible and cost-effective solution to these problems [1]-[5].The IEEE WIMAX/802.16 is a promising technology for broadband wireless metropolitan area networks(WMANs) as it can provide high data rates(upto100Mbps), extended coverage (up to 50 km) for fixed and mobile users(5-15 km), network scalability, security& support of quality of services. It provides a wireless backhaul network that enables high speed Internet access to residential, small and medium business customers, as well as Internet access for Wi-Fi hot spots and cellular base stations [5]-[9]. It supports both point-to-multipoint (P2MP) and multipoint-to multipoint (mesh) modes. In this way, WIMAX will connect rural areas in developing countries as well as underserved metropolitan areas. It can even be used to deliver backhaul for carrier structures, enterprise campus, and Wi-Fi hotspots. WIMAX offers a good solution for these challenges because it provides a cost-effective, rapidly deployable solution [9]-[11]. Additionally, WIMAX will represent a serious competitor to 3G cellular systems as high speed mobile data applications will be achieved with the 802.16e specification. Mobile WIMAX supports full mobility, nomadic and fixed systems [4]. In this paper, we focused on WIMAX and physical layer simulation. Initially, we analyzed the basic concept of WIMAX including its standards and relationship with other technologies. Then, it presents a model for simulating WIMAX physical layer using Simulink in Mat lab. Finally, performance of the system implementation with different SNR is tested and BER versus SNR curves are presented. WIMAX has its two closest competitors, WiFi and universal mobile telecommunications system (UMTS).

II. IEEE 802.16 WIMAX STANDARDS
WIMAX technology is based on the IEEE 802.16 standard, which is also called Wireless MAN. The IEEE

802.16 group was formed in 1998 to develop an air interface standard for wireless broadband. The group's initial focus was the development of a LoS-based point-to-multipoint wireless broadband system for operation in the 10–66GHz millimeter wave band. The first version of the standard IEEE802.16 was approved on December 2001 and it has gone through many amendments to accommodate new features and functionalities. The current version of the standard IEEE 802.16, approved on September 2004.In the IEEE 802.16e-2005, this layer has been modified to scalable OFDMA, where FFT sige is variable and can take any one of the value: 128,512,10,24& 2,048.

The variable FFT sige allow for optimum operation of the system over a wide range of channel bandwidths and radio conditions; this PHY layer has been accepted by WIMAX for mobile and portable operations and is also referred to as mobile WiMAX.

Major shortcomings of WiMAX: There are several major shortcomings of WiMAX which are still a headache to the engineers. Those are as follows:

Data Rates: Mobile WiMAX uses Customer Premises to fixed WiMAX Equipment (CPE) which is attached to computers (either desktop or laptop or PDA) and a lower gain omni-directional antenna is installed which is difficult to use compared

Bit Error Rate:

General concept of WiMAX is that, it provides high speed data rate within its maximum range (30 miles). If WiMAX operates the radio signals to its maximum range then the Bit Error Rate (BER) increases. So, it is better to use lower bit rates within short range to get higher data rates.

$$BER = \frac{Error\ Number}{Total\ Number\ of\ bits\ sent}$$

Feature of WIMAX:

i. OFDM Based physical laye
ii. High data rate
iii. WIMAX MAC layer is responsible for QoS. WIMAX MAC layer support real time, non real time and best effort data traffic and its high data rate, sub channelization, and flexible scheduling improve the QoS;
iv. Flexible architecture: WIMAX architecture is very flexible. It can support point to point and point to multipoint connection also support IP – based architecture.
v. Mobility support: WIMAX offer optimized handover which support full mobility application such as voice over internet protocol (VoIP). It has also the power saving mechanism which increases the battery life of handheld devices;
vi. Scalability: WIMAX offer scalable network architecture that support user roaming indifferent networks. It also enhances the broadband access capability, and (vii) Strong Security: WIMAX support extensible security feature for reliable data exchange. It use Advanced Encryption Standard (AES) encryption for secure transmission and for data integrity, it use data authentication mechanism.
vii. It is cost effective. (ix)It supports fixed, nomadic and mobile applications.

III. WIMAX PHYSICAL LAYER

Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. It also defines the type of modulation and demodulation as well as transmission power. WIMAX 802.16 PHY-layer considers two types of transmission techniques OFDM and OFDMA. Both of these techniques have frequency band below 11 GHz and use TDD and FDD as its duplexing technology. WIMAX physical layer is based on the orthogonal frequency division multiplexing (OFDM). OFDM is a good choice of high speed data transmission, multimedia communication and digital video services. It even can maintain very fast data rate in a non line of sight condition and multipath environment.

The modeling setup includes MATLAB 7.9.0 (R2009b), Simulink9 and Communications Block set 3 running on Windows XP SP2/Windows 7. MATLAB 7.9.0 (R2009b) Semolina includes all the mandatory function blocks as specified by the standard documents. The Model itself consists of three main components namely transmitter, receiver and channel. Transmitter and receiver component consist of channel coding and modulation subcomponents where as channel is modeled as AWGN

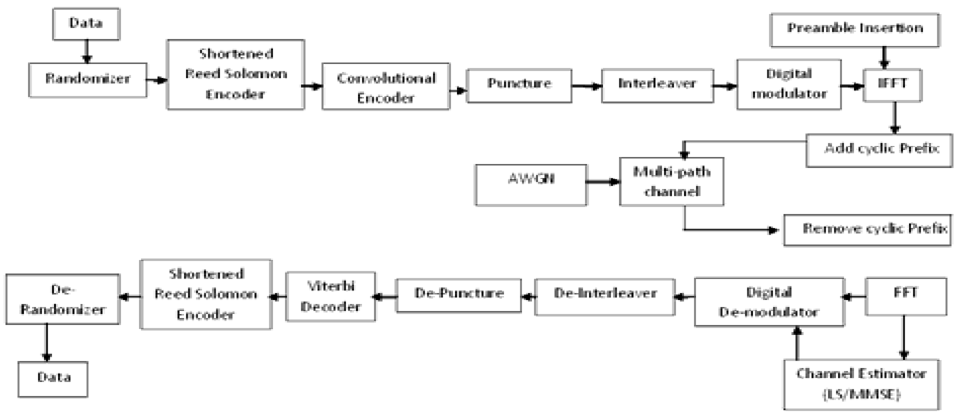

Fig.1. Physical layer of WIMAX

A. Randomizer

The Randomizer performs randomization of input data on each burst on each allocation to avoid long sequence of continuous ones and zeros. This is implemented with a Pseudo Random Binary Sequence (PRBS) generator which uses a 15stage shift register with a generator polynomial of with XOR gates in feedback configuration as shown in Fig.2.

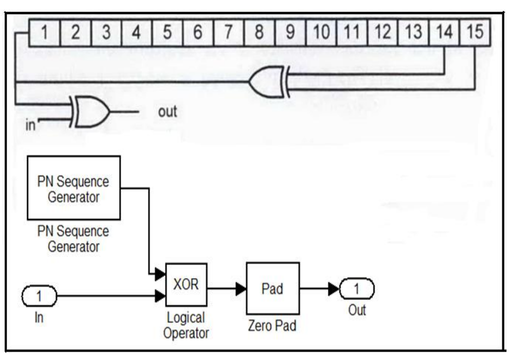

Fig.2 **Channel Encoder-Data Randomizer**

B. Reed-Solomon encoder

The encoding process for RS encoder is based on Galois Field Computations to do the calculations of the redundant bits. Galois Field is widely used to represent data in error control coding and is denoted by GF .WIMAX uses a fixed RS Encoding technique based on GF(2^8) which is denoted as RS(N = 255, K = 239, T = 8)

Where:

N = Number of Byte

K = Data Bytes

T = Number of bytes corrected

Eight tail bits are added to the data just before it is presented to the Reed Solomon Encoder stage. This stage requires two polynomials for its operation called code generator polynomial g(x) and field generator polynomial p(x). The code generator polynomial is used for generating the Galois Field Array whereas the field generator polynomial is used to calculate the redundant information bits which are appended at the start of the output data. These polynomials are defined by the standard [I] as below:

Code Generator Polynomial:

p(x)=x8+x4+x3+x2+1

Field Generator Polynomial:

$g(x) = (x + \lambda^0)\ (x + \lambda^1)\ (x + \lambda^2)\ (x + \lambda^3)$

The properties of Reed-Solomon codes make them suitable to applications where errors occur in bursts. Reed-Solomon error correction is a coding scheme which works by first constructing a polynomial from the data symbols to be transmitted, and then sending an oversampled version of the polynomial instead of the original symbols themselves. A Reed-Solomon code is specified as RS (n, k,t) with l-bit symbols. This means that the encoder takes k data symbols of l bits each and adds 2t parity symbols to construct an n- symbol codeword. Thus, n, k and t can be defined as: n: number of bytes after encoding; k: number of data bytes before encoding, and t: number of data bytes that can be corrected. The error correction ability of any RS code is determined by (n − k), the measure of redundancy in the block.

C. Convolutional Encoder

The outer RS encoded block is fed to inner binary Convolutional encoder. Convolutional codes are used to correct the random errors in the data transmission. A convolution code is a type of FEC code that is specified by CC(m, n, k), in which each m-bit information symbol to be encoded is transformed into an 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 the constraint length of the code . To encode data, start with k memory registers, each holding l input bit. All memory registers start with a value of 0. The encoder has n modulo-2 adders, and n generator polynomials, one for each adder.

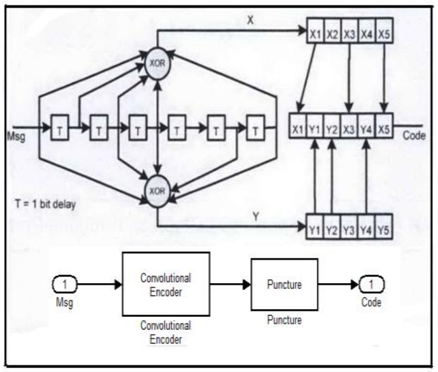

Fig 3.FEC Convolution and Puncture

D. Puncturing Process.

Puncturing is the process of systematically deleting bits from the output stream of a low-rate encoder in order to reduce the amount of data to be transmitted, thus forming a high-rate code. The process of puncturing is used to create the variable coding rates needed to provide various error protection levels to the users of the system. The different rates that can be used are rate 1/2, rate 2/3, rate 3/4, and rate 5/6. The puncturing vectors for these rates are given in Table II.

Table II: Puncture vectors for different convolutional coding rates:

Rate	Puncture vector
1/2	[1]
2/3	[1110]
3/4	[110110]
5/6	[1101100110]

E. Interleaver

RSCC encoded data are interleaved by a block interleaver. The size of the block is depended on the numbers of bit encoded per sub channel in one OFDM symbol, Ncbps. In IEEE 802.16, the interleaver is defined by two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers.

F. Modulation Scheme

Modulation depending their size and on the basis of different modulation schemes like BPSK,, Gray mapped QPSK The modulation has done on the basis of incoming bits by dividing among the groups of i. That is why there are 2i points. The total number of bits represented according to constellation mapped of different modulation techniques. The size for BPSK, QPSK, 16 QAM is 1, 2, 4 and 16 respectively.

Guard band, pilot carriers and DC carrier are inserted in the structure before using the IFFT to convert the frequency domain signals into time domain. These time domain signals are then transmitted through the channel

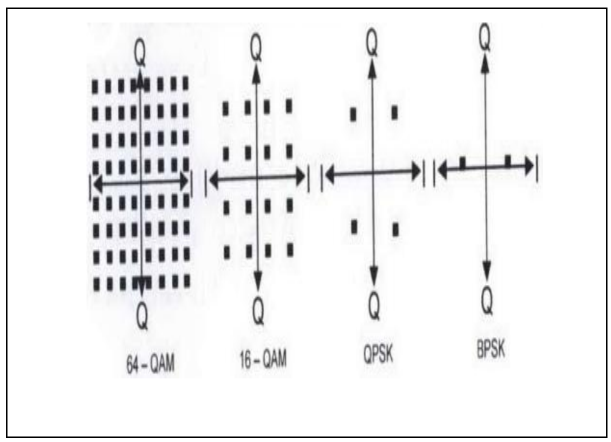

Fig.4.I Q. Mapper

G. Inverse FFT

The OFDM symbol threats the source symbols to perform frequency-domain into time domain. If we chose the N number of subcarriers for the system to evaluate the performance of WIMAX the basic function of IFFT receives the N number of sinusoidal and N symbols at a time.

H. Cyclic Prefix Insertion

To maintain the frequency orthogonality and reduce the delay due to multipath propagation, cyclic prefix is added in OFDM signals. To do so, before transmitting the signal, it is added at the beginning of the signal. In wireless transmission the transmitted signals might be distort by the effect of echo signals due to presence of multipath delay. The ISI is totally eliminated by the design when the CP length L is greater than multipath delay.

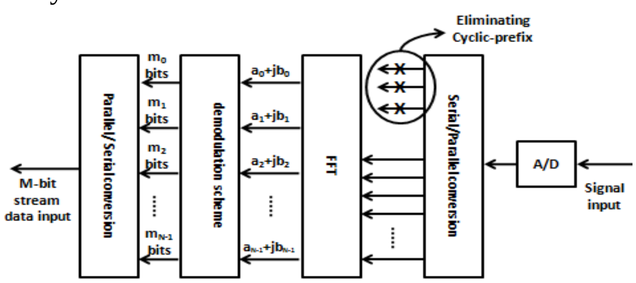

Fig.5 OFMD transmitter

The receiver blocks are basically the inverse of the transmitter blocks [10]. When communicating over a wireless radio channel the received signal cannot be simply modeled as a copy of the transmitted signal corrupted by noise. At the receiving side, a reverse process (including deinterleaving and decoding) is executed to obtain the original data bits. As the deinterleaving process only changes the order of received data, the error probability is intact. When passing through the CC Decoder and the RS-decoder, some errors may be corrected, which results in lower error rates.

IV. EXPERIMENTAL RESULTS

A. Simulation Parameters

In our MATLAB implementation of the physical layer, there are some parameters in which specified as ´OFDM_ params´ and some are specified as ´IEEE802.16 params´ which can be accessed globally. *OFDM Symbol Parameter:* There are two types of OFDM parameters (primitive and derived) that characterize OFDM symbol completely. The later one can be derived from the former one because of fixed relation between them. The used OFDM parameters are listed in Table V, and *IEEE802.16-e OFDM physical layer parameters:* The system supports four modulation schemes and two channel models, namely Additive White Gaussian Noise (AWGN) and Rayleigh fading. The channel coding part is composed of three steps randomization, FEC and i interleaving. The simulated coding, modulation schemes an in the present study are shown in Table.

B. Simulation Results

During this simulation process cyclic prefix was used to minimize the Inter symbol Interference (ISI) on the basis of following adaptive modulation techniques. This simulation was performed using MATLAB2009a on an Intel Core2Duo 2.93 GHz/2MB Cache processor using Windows-XP service package-2 operating system The performance of the simulated WiMAX network based on IEEE-802.16e was shown in the set of figures from Fig.6 to Fig.15.

V. CONCLUSION

This paper described current trends in WiMAX systems for achieving high speed mobile wireless access services and outlined the technologies supporting these systems. The performance of the WiMAX-PHY layer based on the IEEE 802.16e standard, was evaluated and rates; (iii) FEC coding schemes, and (iv) noise levels. As a result of the comparative study, it was found that: when channel conditions are poor, energy efficient schemes such as BPSK or QPSK were used and as the channel quality improves, 16-QAM or 64-QAM was used. It adjusts the modulation method almost instantaneously for optimum data transfer, thus making a most efficient use of the bandwidth and increasing the overall system capacity. Actually, this simulation phase was done a s a first step in implementing WiMAX networks using field programmable gate array (FPGA) systems.

Table III .Mandatory channel coding per modulation

Modulation	Uncoded Block Size (bytes)	Coded Block Size (bytes)	Overall coding rate	RS code	CC code rate
BPSK	12	24	1/2	(12,12,0)	1/2
QPSK	24	48	1/2	(32,24,4)	2/3
QPSK	36	48	3/4	(40,36,2)	5/6
16-QAM	48	96	1/2	(64,48,8)	2/3
16-QAM	72	96	3/4	(80,72,4)	5/6
64-QAM	96	144	2/3	(108,96,6)	3/4
64-QAM	108	144	3/4	(120,108,6)	5/6

Table IV Simulated Coding, Modulation Schemes and noisy channel.

Modulation	RS code	CC code rate	Noise Channels
BPSK QPSK 4-QAM 16-QAM	(255,239,8)	(1/2, 2/3)	AWGN Chnnel
BPSK QPSK 4-QAM 16-QAM	(255,239,8)	(1/2, 2/3)	Rayleigh Channel
BPSK QPSK 4-QAM 16-QAM	(255,239,8)	(1/2, 2/3)	Rician Channel

Table V AMC SCHEME TO SNR RANGE

AMC	Rayleigh channel	AWGN channel
BPSK	4 dB<SNR<9 dB	7 dB<SNR<11 dB
QPSK CC=1/2	9 dB<SNR<15 dB	11 dB<SNR<17 dB
QPSK , CC=3/4	15 dB<SNR<18 dB	17 dB<SNR<19 dB
16-QAM , CC=1/2	18 dB<SNR<23 dB	19dB<SNR<22 dB
16-QAM , CC=3/4	23 dB<SNR<28 dB	22dB<SNR<25 dB
64-QAM , CC=1/2	28 dB<SNR<40 dB	25 dB<SNR<29 dB
64-QAM , CC=3/4	SNR>40 dB	SNR>29 dB

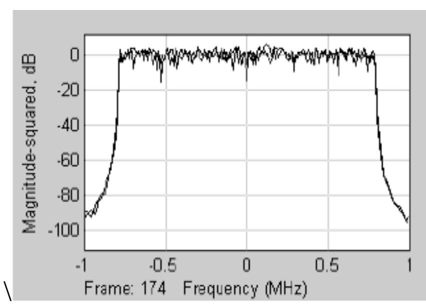

Fig.6.Transmitted signal

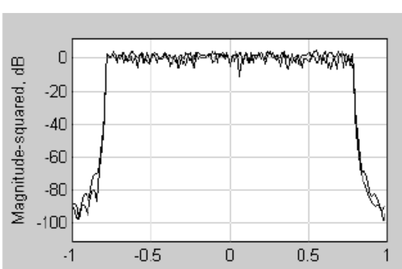

Fig.7. Received signal at 10

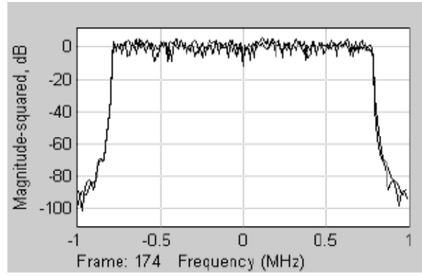

Fig.8. Received signal at 20

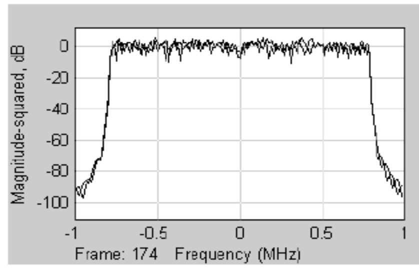

Fig.9 Received signal at 30

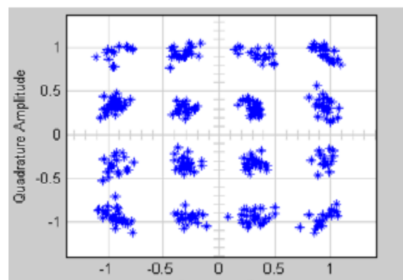

Fig 10 .Scatter plot for 16-QAM at S/N=30dB

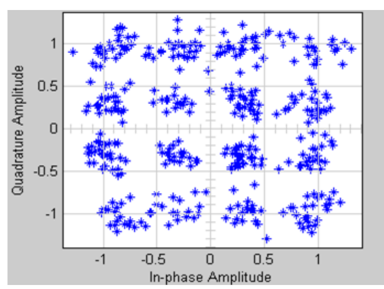

Fig.11 Scatter plot for 16-QAM at S/N=20dB

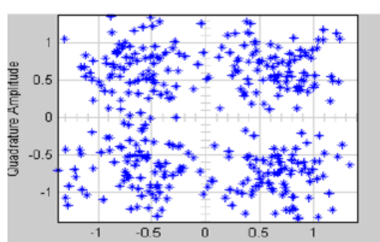

Fig.12.Scatter plot for 16-QAM at S/N=10dB

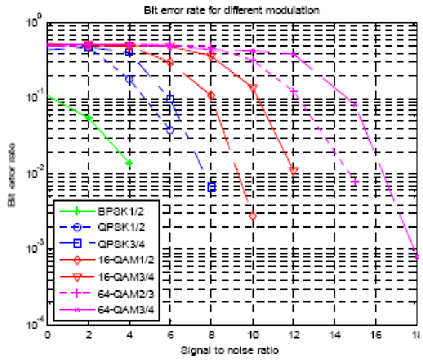

Fig.13 Performance at different modulation schemes for 1/2&3/4code rates in AWGN channel

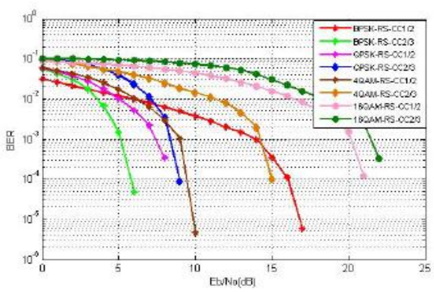

Fig.14. System performance under different modulation schemes for a convolution Encoder with a 1/2 and 2/3 code rates in Rayleigh channel.

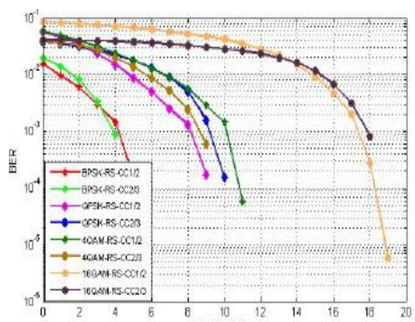

Fig.15.System performance under different modulation schemes for a convolution Encoder with a 1/2 and 2/3 code rates in Rician channel.

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