OFDM SYSTEM CYCLIC PREFIX CHARACTERISTIC ANALAYSIS FOR WIMAX TECHNOLOGY

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ABSTRACT

In the modern world, Wireless Communication System are involved in every part of life. Worldwide Interoperability for Microwave Access (WIMAX) system based on Orthogonal Frequency Division Multiplexing (OFDM) with different adaptive modulation techniques is currently the topic of discussion.WIMAX is the next generation of broadband wireless technology which offers a greater range and bandwidth compared to the other available broadband wireless access technologies such as Wireless Fidelity (Wi-Fi) and Ultra Wideband (UWB) Family of standards. This research is focus on Orthogonal Frequency Division Multiplexing (OFDM) using adaptive modulation technique on the physical layer of WIMAX using the concept of cyclic prefix that adds additional bits at the transmitter end. The purpose of the cyclic prefix is to minimize the inter symbol interference and to improve the bit error rate. The MATLAB software is used to develop the OFDM model with cyclic prefix and analysis the performance of the WIMAX system. The performance of this system is compared between the models with one cyclic prefix, two cyclic prefix and without cyclic prefixed. The performance analysis is based on the Bit Error Rate (BER), Signal to Noise Ratio (SNR) and probability of error. The simulation results shows that modulation BPSK and QPSK have the low bit error rate while 64-QAM has the highest bit error rate equal to $BER = 10^{-3}$ at low SNR equal to 14 dB. For the probability of error, between $p_e = 10^{-1}$ and $p_e = 10^{-4}$ the modulation scheme SNR between 2dB to 345dB.

ABSTRAK

Dalam dunia moden, Sistem Komunikasi Tanpa Wayar adalah terlibat di dalam setiap bahagian hidup. Interoperability Seluruh Dunia bagi Akses Gelombang Mikro (WiMAX) sistem berdasarkan ortogon Bahagian Frekuensi pemultipleksan (OFDM) dengan teknik modulasi penyesuaian berbeza WIMAX adalah generasi akan datang teknologi jalur lebar tanpa wayar yang menawarkan pelbagai yang lebih besar dan jalur lebar berbanding dengan yang lain jalur lebar teknologi akses tanpa wayar seperti wireless Fidelity (Wi-Fi) dan Ultra Wideband (UWB) Keluarga standard. Fokus penyelidikan mengenai Frekuensi ortogon Division Multiplexing (OFDM) menggunakan teknik modulasi penyesuaian pada lapisan fizikal WIMAX dengan menggunakan konsep awalan berkitar yang menambah bit tambahan pada akhir pemancar. Tujuan awalan berkitar adalah untuk meminimumkan gangguan simbol inter dan untuk meningkatkan kadar ralat bit. Perisian MATLAB digunakan untuk membangunkan model OFDM dengan awalan berkitar dan analisis prestasi sistem WIMAX itu. Prestasi sistem ini dibandingkan antara model dengan satu awalan berkitar, dua awalan berkitar dan tanpa awalan berkitar. Analisis prestasi adalah berdasarkan Kadar Ralat Bit (BER), Signal kepada Nisbah Bunyi (SNR) dan kesilapan probabilityof. Keputusan simulasi menunjukkan bahawa modulasi BPSK dan QPSK mempunyai kadar ralat bit yang lebih rendah manakala 64- QAM mempunyai kadar bit ralat sama dengan BER = $BER = 10^{-3}$ di SNR rendah sama dengan 14 dB. Untuk kebarangkalian ralat, skim modulasi perintah yang lebih rendah juga mempunyai BER yang lebih rendah di SNR rendah.

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LIST OF SYMBOLS AND ABBREVIATIONS

WIMAX	Worldwide Interoperability for Microwave Access
RRM	Radio Resource Management
GSM	Global System for Mobile Communication
UMTS	Universal Mobile Telecommunication System
WLAN	Wireless Local Area Network
QoS	Quality of Service
AMPS	Advance Mobile Phone Systems
GPRS	General Packet radio Service
SMS	Short Messaging Services
OFDM	Orthogonal Frequency Division Multiplexing
2G	Second Generation
3G	Third Generations
MAC	Media Access Control
IP	Internet Protocol
OFDMA	Orthogonal Frequency Division Multiple Access
LOS	Line of Sight
TDD	Time Division Duplex
FDD	Frequency Division Duplex
ISI	Inter Symbol Interference

FFT	Fast Fourier Transform
MPDU	MAC Protocol Data Units
ATM	Time Division Multiplexing
MS	Mobile Station
BS	Base Station
SFID	Service Flow Identifier
FEC	Forward Error Correction
ARQ	Automatic Repeat Request
CRC	Cyclic Redundancy Check
SNR	Signal to Noise Ratio
CSN	Connection Service Network
DHCP	Dynamic Host Control Protocol
BSC	Base Station Controller
DSL	Digital Subscriber Line
PSTN	Public switched Telecommunication Networks
ITU	International Telecommunication Union
WCDMA	Wideband Code Division Multiple Access
CDMA	Code Division Multiple Access
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
BPSK	Binary Phase Shift keying
QPSK	Quadrature Phase Shift keying
QAM	Quadrature Amplitude Modulation

MIMO	Multiple Input Multiple Output
VOIP	Voice over Internet Protocol
RAN	Radio Access Network
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPL	Broadband over Power Line
ETSI	European Telecommunication Standard Institute
FSK	Frequency-Shift Keying
Hz	Hertz or Cycles per Second
ICI	Inter Carrier Interference
IEEE	Institute of Electric and Electronic Engineers
IFFT	Inverse Fast Fourier Transform
PTP	Point-to-Point
RF	Radio Frequency
SC	Single Carrier
CC	Convolutional Encode
ASK	Amplitude-Shift Keying
dB	Decibel
Eb/No	Energy per Bit to Noise Ratio
Mbps	Megabits per Second
MBWA	Mobile Broad Band Wireless Access
MCM	Multi Carrier Modulation
MIMO	Multiple Input, Multiple Output

MSR	maximum Sum Rate
NIC	Network Interface Card
NLOS	Non or Near Line of Sight
PM	Phase Modulation
PSTN	Public switch telephone Network
VDSL	Very high data rate Digital Subscriber Line
W-CDMA	Wideband Code Division Multiple Access

CHAPTER 1

INTRODUCTION

1.1 Introduction

WIMAX (Worldwide Interoperability for Microwave Access) system [1, 2] is a new wireless technology that provides high throughput broadband connection over long distances based on IEEE.802.16 wireless MAN air interface standard. It is designed to accommodate both fixed and mobile broadband applications. It can be used for many applications, including "last mile" broadband connections, cellular backhaul, and high-speed enterprise connectivity for business, due to its high spectrum efficiency and robustness in multipath propagation. The WIMAX Broadband Wireless Access Technology based on the IEEE 802.16 standard, is at the origin of great promises for many different markets covering fixed wireless Internet Access, Backhauling and Mobile cellular networks and provide for the transmission of multimedia services (voice, Internet, email, games and others) at high data rates (of the order of MB/s per user), which can offer high speed voice, video and data service up to the customer end. This is a technology that enables anywhere and anytime access to information and applications at low cost and with a small investment. This technology can reach a theoretical 30 mile coverage radius and achieve data rates up to 75 Mbps [3]. The WIMAX Wireless communication technique uses orthogonal frequency division multiplexing technique that has a higher sensitivity to frequency offsets and noise pulses. An orthogonal frequency division multiplexing is used by WIMAX. As soon as the orthogonal frequency division multiplexing use adaptive modulation technique such as (BPSK, QPSK, 16-QAM and 64-QAM) 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.

1.2 Problem Statement

WIMAX (stands for Worldwide Interoperability for Microwave Access) provides data rates up to 40-Mbits/s and 2011 version can support data rate up to 1 Gbit/s for fixed stations [4]. Hence the investigation of the performance of OFDM, in WIMAX system using Bit Error Rate analysis of WIMAX has been carried out for different modulation techniques like BPSK, QPSK, 16-QAM, and 64-QAM. The advantages of OFDM that have made this technique popular in wireless systems are sometimes counterbalanced by one major problem, which significantly reduces the average power at the output of the high-power amplifier (HPA) used at the transmitter. This research purpose is to study how to use cyclic prefix to minimize the inter symbol interference and to improve the bit error rate by a cyclic prefix which is added to each symbol period. The analysis is based on the Bit Error Rate (BER), Signal to Noise Ratio (SNR) and probability of error.

1.3 Objectives

The objectives of this project are:

I. To design an OFDM transmitter system without cyclic prefix, with cyclic prefix and with two cyclic prefixes using MATLAB software.

II. To analyze the OFDM model based on Bit Error Rate (BER), Signal to Noise Ratio and (SNR), Power spectral density (PSD) and Probability error (P_e).

1.4 Project Scope

The project scope will be focusing on three major components which are represented as follows:

I. To study and analyze OFDM model with cyclic prefix and without cyclic prefix using the adaptive modulation technique of WIMAX which uses modulating and demodulating signal (BPSK), (QPSK), (16-QAM) and (64-QAM).

II. To investigate the effects of cyclic prefix using adaptive modulation techniques and compare the performance of OFDM symbols in terms of BER and SNR.

III. To study the effect of Bit Error Rate when cyclic prefix is increase and analyze the effect of that on transmitted power and SNR.

1.5 Thesis Outline

Chapter 1 gives an overview of the project design. It covers the introduction orthogonal frequency division multiplexing is used by WIMAX, problem statement, objectives, significant and the scope of work in this project.

Chapter 2 focuses on literature review about the basic concepts of OFDM design transmitter and receiver . These include the review on design OFDM for WIMAX System Model and Cyclic Prefix in OFDM .

Chapter 3 discuss the methodology of designing OFDM without cyclic prefix ,one cyclic prefix and two cyclic prefix .

Chapter 4 presents the results obtained from the analysis of the simulation results using MATLAB simulator.

Chapter 5 briefly concludes the whole project including the improvement and development that can be made in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Orthogonal Frequency Division Multiplexing (OFDM) is developed to support high data rate that can handle multi carrier signals. Its specialty is that, it can minimize the Inter Symbol Interference (ISI) much more compared to other multiplexing schemes. It is more likely an improved Frequency Division Multiplexing (FDM) as OFDM uses cyclic prefix to minimize interference between different frequencies and wastes lots of bandwidth, but OFDM does not contain inter-carrier guard band which can handle the interference more efficiently than FDM. So, this is the perfect choice for WIMAX as it can help to satisfy the requirements of efficient use of spectrum and minimize the transmission cost. On top of that, OFDM handles the multipath effect by converting serial data to several parallel data using Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT).

2.2 Broadband Communication

In 1985 the Federal Communications (FCC) enabled the commercial development of wireless communication. Today it is used in satellite transmission, broadcasting, radio, television channels and cellular networks. There has been tremendous advancement in the transmission and reception of voice and data through wireless communication.

2.2.1 Mobile Phone of Generations

The first generation of mobile telephony (written 1G) operated using analogue communications and portable devices that were relatively large. It used primarily the following standards [5].

- AMPS (Advanced Mobile Phone System)
- TACS (Total Access Communication System)
- ETACS (Etended Total Access Communication System)

Wireless communication used in military applications before 1977 and research in satellite communication. The evolution of Advanced Mobile Phone System (AMPS) Mobile phones were first introduced in the early 1980s. In the succeeding years, the underlying technology has gone through three phases, known as generations. The first generation (1G) phones used analogue communication techniques was the initial and the turning point in wireless communication by offering a two way communication (Full Duplex Mode). Details of other generations of mobile phone are shown in Table 2.1.

In a telecommunication system, 4G is the fourth generation of technology standards. It is a successor to the third generation (3G) standard. A 4G system provides mobile ultra-broadband, Internet access for example to laptops with USB, wireless modems, smart phones, and to other devices. Conceivable applications include amended mobile web access, IP telephony, gaming services, high- definition mobile TV, video conferencing, 3D television [6].

Table 2.1: Mobile Phone Generations [5]

Generation	Standard	Multiple Access	Frequency Band	Throughput
2 G	GSM	TDMA/FDMA	890-960 (MHZ) 1710-1880 (MHZ)	9.6 Kbps
2.5 G	GPRS	TDMA/FDMA	890-960 (MHZ) 1710-1880 (MHZ)	171 Kbps
2.75 G	EDGE	TDMA/FDMA	890-960 (MHZ) 1710-1880 (MHZ) 1885-2025 (MHZ)	384 Kbps
3 G	UMTS	W-CDMA	2110-2200 (MHZ)	2Mbps

Two 4G candidate systems are commercially deployed: the Mobile WIMAX standard (first used in South Korea in 2006), and the first-release Long Term Evolution (LTE) standard (in Oslo, Norway and Stockholm, Sweden since 2009). It has however been debated if these first-release versions should be considered to be 4G or not. The 4th Generation of mobile phone system is under research with an objective of fully Internet Protocol (IP) based integrated system. The 3G provides an IP based for data, voice and multimedia services, the users are always connected to the network with good and reliable data connectivity, where ever they go and whatever the time is [6]. The generations that came after the 2.5th generation are referred as the broadband generations because these generations have high data rates and provide multimedia services to their subscribers.

2.2.2 What is Broadband?

Broadband or high-speed Internet access allows users to access the Internet and Internet-related services at significantly higher speeds than those available through “dial-up” Internet access services. Broadband speeds vary significantly depending on the particular type and level of service ordered and may range from as low as 200 kilobits per second (kbps), or 200,000 bits per second, to 30 megabits per second (Mbps), or 30,000,000 bits per second [2]. Some recent offerings even include 50 to 100 Mbps. Broadband services for residential consumers typically provide faster downstream speeds (from the Internet to your computer) than upstream speeds (from your computer to the Internet).

Broadband allows users to access information via the Internet using one of several high-speed transmission technologies. Transmission is digital, meaning that text, images, and sound are all transmitted as “bits” of data. The transmission technologies that make broadband possible move these bits much quicker than traditional telephone or wireless connections, including traditional dial-up Internet access connections.

2.3 Types of Broadband connections

The broadband technologies are divided into fixed and wireless broadband.The fixed broadband technologies are Digital Subscriber Line (DSL), cable modem, optical fiber and Broadband over Power lines (BPL).In the meantime,Wi-Fi and WIMAX are examples of wireless broadband communication [7].

2.3.1 Fixed Broadband Technologies

2.3.1.1 Digital Subscriber Line (DSL)

DSL is a wire line transmission technology that transmits data faster over traditional copper telephone lines already installed in homes and businesses. DSL-based broadband provides transmission speeds ranging from several hundred Kbps to millions of bits per second (Mbps). The availability and speed of your DSL service may depend on the distance from your home or business to the closest telephone company facility.

The following are types of DSL transmission technologies:

- **Asymmetrical Digital Subscriber Line (ADSL) –** Used primarily by residential customers, such as Internet surfers, who receive a lot of data but do not send much. ADSL typically provides faster speed in the downstream direction than the upstream direction. ADSL allows faster downstream data transmission over the same line used to provide voice service, without disrupting regular telephone calls on that line.

- **Symmetrical Digital Subscriber Line (SDSL) –** Used typically by businesses For services such as video conferencing, which need significant bandwidth both

  Upstream and downstream.

The ADSL system provides more speed in the downstream direction as compared to the upstream direction. The SDSL is suitable for businesses and offices that offer services like video conferencing, which require a significant amount of bandwidth in both upstream and downstream directions.

Now-a-days, other faster forms of DSL are also available, typically for large business organizations and offices. These are High data rate Digital Subscriber Line (HDSL) and Very high data rate Digital Subscriber Line (VDSL).

2.3.1.2 Cable Modem

Cable Modem is a type of modem that provides broadband connectivity to subscribers over cable television coaxial cables. It is used to deliver sound and pictures to the subscriber’s TV set. Cable modem enables the users to connect their PC to a local cable TV line and enjoy transmission speeds of 1.5 Mbps or more. Cable modem is an external device with two connections; one is for the TV cable wall outlets while the other one is for the PC.

2.3.1.3 Fiber

Fiber optic technology converts electrical signals carrying data to light and sends the light through transparent glass fibers about the diameter of a human hair. Fiber transmits data at speeds far exceeding current DSL or cable modem speeds, typically by tens or even hundreds of Mbps. Telecommunications providers sometimes offer fiber broadband in limited areas and have announced plans to expand their fiber networks and offer bundled voice, Internet access, and video services

The optical fiber cable can be classified into single mode fiber and multi-mode fiber cables. The single mode fiber is used for transmission over longer distances, while the multi-mode fiber is used for shorter distances (up to 500 meters). The transmitting speed in optical fiber communication is much higher than current DSL and cable modem speed. It is typically in the range of tens or even hundreds of Mbps.

2.3.1.4 Broadband over Power line (BPL)

On 14 October 2004, the U.S. Federal Communications Commission adopted rules to facilitate the deployment Power Digital Subscriber Line (PDSL) and uses Power Line Carrier (PLC) between a sending and receiving radio signals over the existing electric power distribution network. PDSL can transmit data using PLC modems in medium and high frequencies, in the range of 1.6 MHz to 80 MHz electrical carriers. The modem has a speed range of 256 Kbps to 2.7 Mbps, whereas the use of repeaters speeds up the data rates to 45 Mbps.

2.3.2 Wireless Broadband Technologies

Wireless broadband is high-speed Internet and data service delivered through a wireless local area network (WLAN) or wide area network (WWAN), Wireless service, wireless broadband may be either fixed or mobile.

2.3.2.1 Fixed Wireless Service

Fixed wireless service provides wireless Internet for devices in relative permanent locations, such as homes and offices. Fixed wireless broadband technologies include LMDS (Local Multipoint Distribution System) and MMDS (Multichannel Multipoint Distribution Service) systems for broadband microwave wireless transmission direct from a local antenna to homes and businesses within a line-of-sight radius. The service is similar to that provided through digital subscriber lines (DSL) or cable modem, but the method of transmission is wireless.

2.3.2.2 Mobile Broadband Service

Mobile broadband service provides connectivity to users who may be in temporary locations, such as coffee shops. Mobile broadband works through a variety of devices, including portable modems and mobile phones, and a variety of technologies including WIMAX, GPRS, and LTE. Mobile broadband does not rely on a clear line of sight because connectivity is through the mobile phone infrastructure. Mobile devices can connect from any location within the area of coverage. WIMAX supporting both fixed and mobile wireless, and is often predicted to become the standard for wireless broadband.

The term nomad city can be defined as “Ability to establish the connection with the network from different locations via different base stations” while mobility is “the ability to keep ongoing connections engaged and active while moving at vehicular speeds”. Examples of wireless broadband technologies are Satellite communication, Wireless LAN and WIMAX.

2.3.2.3 Wireless LAN

Wireless Local Area Network (WLAN) is a wireless technique that has replaced wired networks. It connects the number of devices or computers through radio waves. Wireless local area networks (LAN) are groups of wireless networking nodes within a limited geographic area, such as an office building or building campus, that are capable of radio communication. Wireless LANs are usually implemented as extensions to existing wired local area networks to Provide enhanced user mobility and network access. This enables organizations to offer its employees the mobility to move around within a broad coverage area and still be connected to the network.

The most widely implemented wireless LAN technologies are based on the IEEE 802.11 standard and its amendments. The original 802.11 standard was published in June 1997 as IEEE Std. 802.11-1997, and it is often referred to as 802.11 Prime because it was the first WLAN standard. Wireless LAN offers a quick and effective extension of a wired network or standard LAN. Installing a wireless LAN is easy and eliminates the need to pull wires, cables through walls and ceilings.

There are two types of modes in WLAN:

- Access Points (APs): They are base stations for the wireless network. They transmit and receive radio frequencies for wireless clients to communicate with.

- Wireless Clients: Wireless clients can be any computing related equipment device such as laptops, personal digital assistants, and IP phones, or fixed devices such as desktops and workstations that are equipped with a Wireless Network Interface Card (WNIC). A wireless LAN can be configured infrastructure mode Figure 2.1 or in either ad-hoc mode Figure 2.2 [8].

Infrastructure Mode

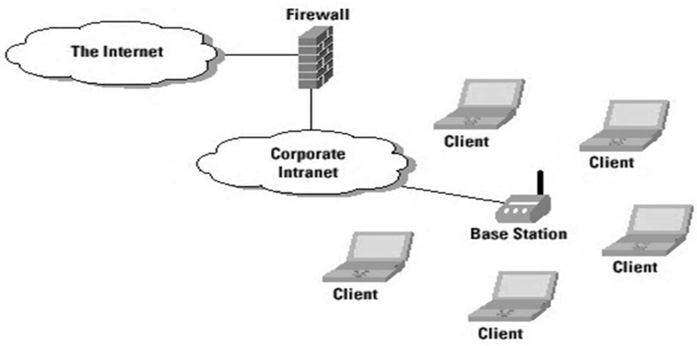

Figure 2.1: Wireless LAN Infrastructure Mode [8]

Adhoc Mode

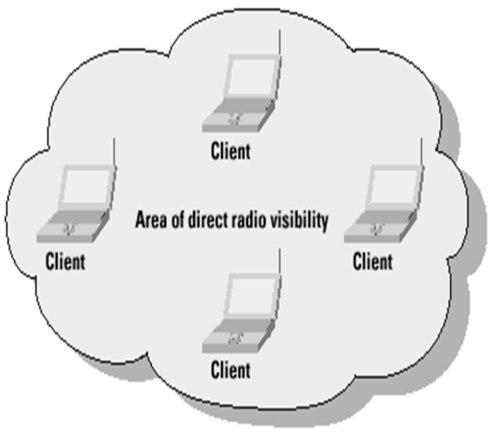

Figure 2.2: Wireless LAN Adhoc Mode [8]

2.3 What is WIMAX?

WIMAX is short for Worldwide Interoperability for Microwave Access. WIMAX is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings. It is a metropolitan wireless standard created by the companies Intel and Alvarion in 2002 and ratified by the IEEE (Institute of Electrical and Electronics Engineers) under the name IEEE-802.16. More precisely, WIMAX is one of the hottest broadband wireless technologies around today. WIMAX systems are expected to deliver broadband access services to residential and enterprise customers in an economical way, Based on Wireless MAN technology, a wireless technology optimized for the delivery of IP centric services over a wide area, a scale able wireless platform for constructing alternative and complementary broadband networks and certification that denotes interoperability of equipment built to the IEEE 802.16 or compatible standard. The IEEE 802.16 Working Group develops standards that address two types of usage models [9].

- **Fixed WIMAX (IEEE 802.16-2004)**

  The Fixed WIMAX provides for a fixed-line connection with an antenna mounted on a rooftop, like a TV antenna. Fixed WIMAX operates in the 2.5 GHz and 3.5 GHz frequency bands, which require a license, as well as the license-free 5.8 GHz band [10].

- **Mobile WIMAX (IEEE 802.16e).**

  Mobile WIMAX allows mobile client machines to be connected to the Internet. Mobile WIMAX opens the doors to mobile phone use over IP, and even high-speed mobile services.

2.4.1 Goals of WIMAX

The goal of WIMAX is to provide high-speed Internet access with a coverage range several kilometers in radius. In theory, WIMAX provides for speeds around 70 Mbps with a range of 50 kilometers. The WIMAX standard has the advantage of allowing wireless connections between a base transceiver station (BTS) and thousands of subscribers without requiring that they be in a direct line of sight (LOS) with that station. This technology is called NLOS for non-line-of-sight. In reality, WIMAX can only bypass small obstructions like trees or a house but is not able to cross hills or large buildings. When obstructions are present, the actual throughput might be under 20 Mbps.

The standard used by the Wireless LAN is IEEE 802.11. It uses 5 GHz and 2.4 GHz spectrum bands and can further be classified as:

- IEEE 802.11a: Uses 5 GHz frequency and 54 Mbps throughput.
- IEEE 802.11b: Uses 2.4 GHz frequency and 11 Mbps throughput.
- IEEE 802.11g: Uses 2.4 GHz frequencies and 54 Mbps throughput.
- IEEE 802.11n: Uses 2.4 and 5 GHz frequency and 600 Mbps throughput.

2.4.2 How WIMAX Works

The working of a WIMAX tower is similar to that of a cell-phone tower. A range up to 3000 square miles can be covered by a single WIMAX tower as shown in figure 2.3.

The system profiles of IEEE 802.16e-2005 scalable OFDM PHY are known as mobile system profiles. The details of operating frequencies, channel bandwidth, modulation and multiplexing techniques [11].

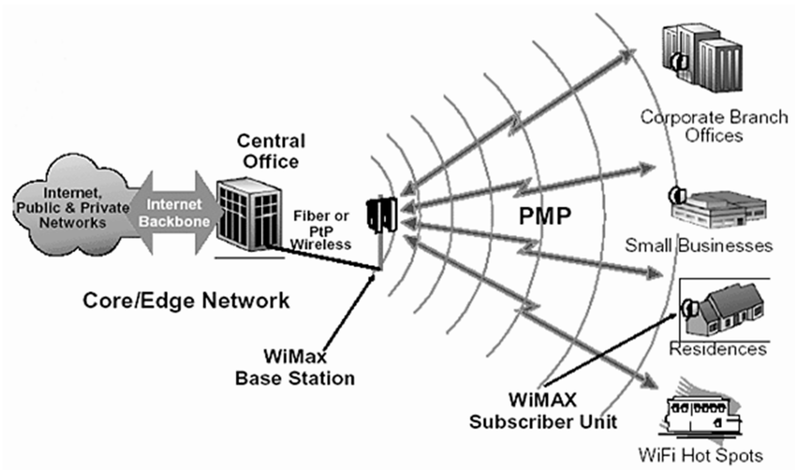

Figure 2.3: WIMAX Overview [11]

2.4.3 Development of WIMAX

The specification of wireless MAN Air Interface for a wireless metropolitan area network is given by IEEE std 802.16.

Table 2.2: WIMAX Standards

Standard	**Frequency**	**Status**	**Range**
IEEE std 802.16	Defines wireless metropolitan area networks (WMANs) on frequency bands higher than 10 GHz.	October 2002	Obsolete
IEEE std 802.16a	Defines wireless metropolitan area networks on frequency bands from 2 to 11 GHz inclusive.	October 9, 2003	Obsolete
IEEE 802.16b	Defines wireless metropolitan area networks on frequency bands from 10 to 60 GHz inclusive.		Merged with 802.16a (Obsolete)
IEEE std 802.16c	Defines options (profiles) for wireless metropolitan area networks in unlicensed frequency bands.		July 2003
IEEE 802.16d (IEEE std 802.16-2004)	Revision incorporating the 802.16, 802.16a, and 802.16c standards.	October 1st, 2004	Active
IEEE std 802.16e	Allows wireless metropolitan area networks to be used by mobile clients.	December 2005	Not approved

IEEE std 802.16f	Allows wireless mesh networks to be used.		Not approved
802.16h	Improved Coexistence Mechanisms for License Exempt Operation	2010	
802.16m	Advanced Air Interface with data rates of 100 Mbit/s fixed. Also known as Mobile WiMAX Release 2 or Wireless MAN- Advanced. Aiming the ITU-RIMT- Advanced requirements for 4G systems.		Current

2.4.4 Network Architecture of WIMAX

The network architecture of WIMAX is based on the IP network service model and supports fixed, and mobile standards of WIMAX as shown in Figure 2.4, in fact, most of IEEE 802.16e and WIMAX specifications deal with those aspects. But from a standpoint of delivering broadband wireless services to end users, there are several other aspects and challenges that require consideration. The network architecture of WIMAX is logically divided among three parts [11].

2.4.4.1 Base Stations (BS)

The BS is responsible for providing the air interface to the mobile station. Additional functions that may be part of the BS are micro mobility management functions, such as handoff triggering and tunnel establishment, radio resource management, QoS policy enforcement, traffic classification, DHCP (Dynamic Host Control Protocol) proxy, key management, session management, and multicast group management.

2.4.4.2 Access service network gateway (ASN-GW)

The ASN gateway typically acts as a layer 2 traffic aggregation point within an ASN. Additional functions that may be part of the ASN gateway include intra-ASN location management and paging, radio resource management, and admission control, caching of subscriber profiles, and encryption keys, AAA client functionality, establishment, and management of mobility tunnel with base stations, QoS and policy enforcement, foreign agent functionality for mobile IP, and routing to the selected CSN.

2.4.4.3 Connectivity service network (CSN)

The CSN provides connectivity to the Internet, ASP, other public networks, and corporate networks. The CSN is owned by the NSP and includes AAA servers that support authentication for the devices, users, and specific services. The CSN also provides per user policy management of QoS and security. The CSN is also responsible for IP address management, support for roaming between different NSPs, location management between ASNs, and mobility and roaming between ASNs as shown in figure 2.4[13].

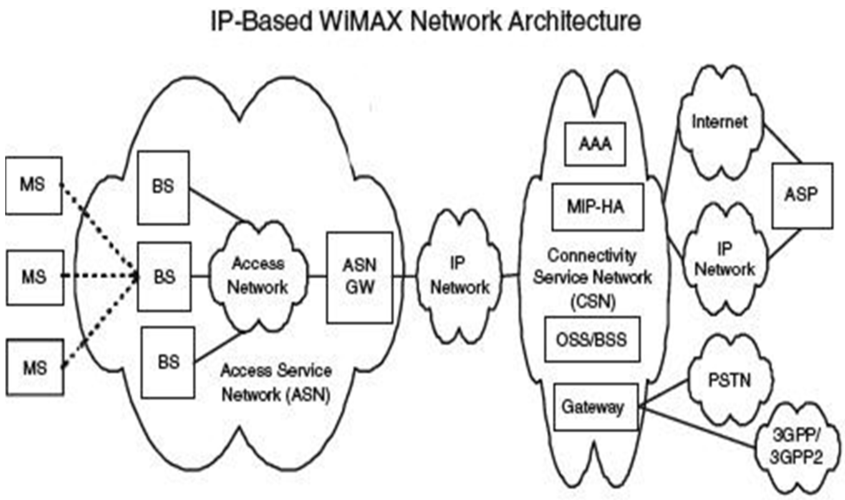

Figure 2.4: WIMAX Network IP based Architecture [13]

2.4.5 WIMAX Advantages and Drawbacks

Advantages:

- Single station can serve hundreds of users.
- Much faster deployment of new users compared to the wired network.
- Speed of 10Mbps at 10 kilometers with line of sight.
- It is standardized, and same frequency equipment should work together.
- OFDM Based physical layer.
- High data rate
- 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

Drawbacks

- Line of site is needed for longer connections
- Weather conditions like rain could interrupt the signal.
- Other wireless equipment could cause interference.
- Multiple frequencies are used.
- WIMAX is very power intensive technology and requires strong electrical support.

2.5 WIMAX Uses OFDM

Mobile WIMAX uses Orthogonal frequency division multiple access (OFDM) as a multiple-access technique, whereby different users can be allocated different subsets of the OFDM tones OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers, often called subcarriers or tones.

Multicarrier modulation schemes eliminate or minimize inter symbol interference (ISI) by making the symbol time large enough so that the channel-induced delays, delay spread being a good measure of this in wireless channels are an insignificant (typically, < 10 percent) fraction of the symbol duration. Therefore, in high-data-rate systems in which the symbol duration is small, being inversely proportional to the data rate splitting the data stream into many parallel streams increases the symbol duration of each stream such that the delay spread is only a small fraction of the symbol duration.

OFDM is a spectrally efficient version of multicarrier modulation, where the subcarriers are selected such that they are all orthogonal to one another over the symbol duration, thereby avoiding the need to have no overlapping subcarrier channels to eliminate intermarries interference [14].

2.5.1 Design of OFDM for WIMAX System Model

The purpose of implementation model of WIMAX using an AWGN channel has been employed for transmission. The implementation model is composed of a transmitter, AWGN communication channel and receiver as shown in Figure 2.5. Transmitter consists of data generator, convolution encoder, interleaver, bit to symbol mapper, modulator, serial to parallel converter, pilot carrier insertion, an inverse Fourier transform and cyclic prefix addition block. The data generator is used as , random data generating and fed into the transmitter in the form of binary pulses [15]. The data essentially needs to be digital in nature. The convolution 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 convolution ally encoded data is then fed to the interleave which arranges the data in non-contiguous way to improve the performance. 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. The symbols obtained are passed into the modulator. The serial to parallel converts a serial bit stream into parallel form to be transmitted as OFDM symbol. 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 AWGN channel. This noise has a uniform spectral density (making it white), and a Gaussian distribution in amplitude. At the receiver end the exact reverse process takes place to recover the data with the help of FFT in which it converts the signal into the frequency domain it then demodulated [15].

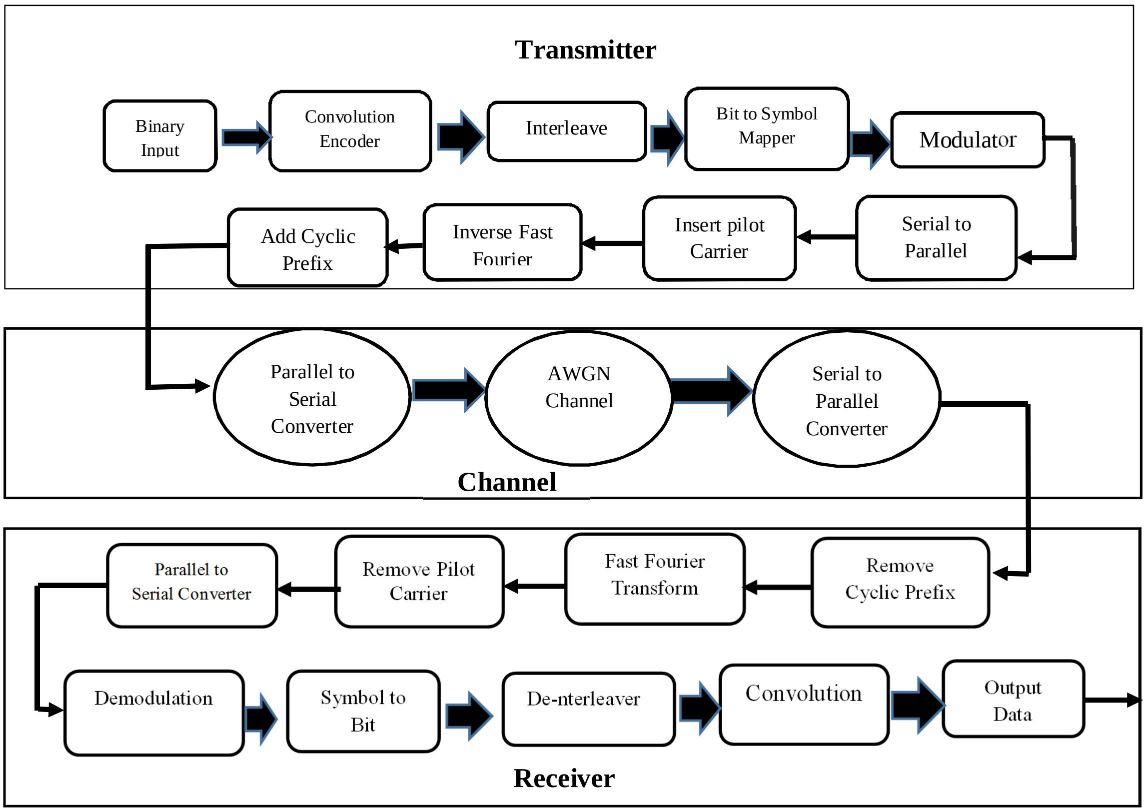

Figure 2.5: OFDM for WIMAX system model [16]

Then the initially added cyclic prefix is removed and original signal is extracted for further processing of FFT. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum.The pilot carrier is removed to use the retrieved signal for further processing.The output obtained after removal of pilot carrier is in parallel form. The next step is demodulation, where is needed to be converted into a serial bit stream. This serial bit stream is further passed on to the demodulator. The data obtained at the output of the demodulator is in the form of symbols. Then it is converted to original bits. The interleaved data is recovered in the form of its original order, the output of demodulator received in the form of symbols. Therefore it is converted into original bits. The interleaved data also regain in its original order and the deinterleaved data is further passed on to Viterbi decoder [16].

2.6 OFDM

OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers often called subcarriers, or tones. Multicarrier modulation schemes eliminate or minimize inter symbol interference (ISI) by making the symbol time large enough so that the channel-induced delays delay spread being a good measure of this in wireless channels are an insignificant (typically, <10 %) fraction of the symbol duration. Therefore, in high-data-rate systems in which the symbol duration is small, being inversely proportional to the data rate, splitting the data stream into many parallel streams increases the symbol duration of each stream such that the delay spread is only a small fraction of the symbol duration.

OFDM is very effective for communication over channels with frequency selective fading (different frequency components of the signal experience different fading). It is very difficult to handle frequency selective fading in the receiver, because the design of the receiver is complex. Instead of trying to mitigate frequency selective fading as a whole (which occurs when a huge bandwidth is allocated for the data transmission over a frequency selective fading channel), OFDM mitigates the problem by converting the entire frequency selective fading channel into small flat fading channels (as seen by the individual subcarriers).

Flat fading is easier to combat (compared to frequency selective fading) by employing simple error correction and equalization schemes [17].

Why use Orthogonal Frequency Division Multiplexing (OFDM)?

- Two main advantages:

  - ❖ Highest spectral efficiency
  - ❖ Lower multi-path distortion

2.6.1 How Does OFDM Work?

The broadband data at a slow symbol rate sounds contradictory at first; however, the trick to OFDM is to transmit multiple symbols in parallel using many carriers. Thus, we can keep the symbol rate low on each individual carrier and achieve high bandwidth by having many thousands of carriers. For example, mobile WIMAX (Worldwide Interoperability for Microwave Access) can have in excess of 2,000 carriers. This explains the "frequency division multiplex" part of OFDM. However, the "orthogonal" part is the real key to how the system works. If the carrier spacing is made equal to the symbol rate, this can significantly reduce the cross-carrier interface and allow for the modulation of many carriers, called sub-carriers, in a relatively small bandwidth. For example, WLAN 802.11g has 52 sub-carriers, spaced at 312.5 kHz, with an overall bandwidth of 16.25 MHz OFDM is derived from the Frequency Division Multiplexing (FDM), and extends the concept of single carrier modulation.

A single carrier spectrum modulation technique modulates all the information using a single carrier in terms of frequency, amplitude or phase adjustment of the carrier. In the case of digital communication single carrier is used. If there is an increase in the bandwidth of the system, then the duration of one symbol decreases. This causes the system to be more susceptible from noise, reflection, refraction, scattering and other impairments that introduce errors in the system. The block diagram of the single carrier modulation.

2.6.2 Designing of OFDM Transmitter and Receiver

Consider that in order to send the following data bits using OFDM, the first thing that should be considered in designing the OFDM transmitter is the number of subcarriers required to send the given data. As a generic case, let's assume that we have N subcarriers. Each subcarriers are centered at frequencies that are orthogonal to each other (usually multiples of frequencies),as shown in Figure 2.6.

The second design parameter is the modulation format, that is virtual for OFDM system use. An OFDM signal can be constructed using any one of the following digital modulation techniques, namely BPSK, QPSK, QAM and etc.

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier. $s[n]$ is a serial stream of binary digits, and by using inverse multiplexing, these are first data demultiplexed into N parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, therefore some streams may carry a higher bit-rate than others. An inverse FFT is computed for each set of symbols, giving a set of complex time- domain samples. These samples are then quadrature-mixed to pass band in the standard way. The real and (DACs), the analogue signals are then used to imaginary components are first converted to the analogue domain using a digital-to-analogue converters modulate cosine and sine waves at the carrier frequency f_c, respectively. These signals are then summed to give the transmission signal $s(t)$. This returns N parallel streams, each of which is converted to a binary stream using an appropriate

REFERENCE

[1] Gazi, O. and A. Ozg¨ ¨ ur Yılmaz, "Turbo product codes based on convolutional codes," ETRI Journal, Vol. 28, No. 4, August 2010.

[2] Vadaliya Savan Rameshbhai, Appana Manikanta Sitaram "Overview of WiMAX Technology Broad Band Access to the Last Mile", Prentic Hall Communication Engineering and Emerging Series, Nov-Dec 2012.

[3] 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" International Journal of Computer Science and Mobile Computing Vol.2 Issue. 9, September- 2013, pg. 178-183.

[4] "Performance Enhancement of WiMAX System using Adaptive Equalizer", Journal of Emerging Trends in Computing and Information Sciences, April 2012, pg 561-564.

[5] "Wireless Networks", International Journal of Innovative Research in Technology, June 12, 2014,

[6] Frank H. P. Fitzek, Hassan," mobile peer to peer (p2p): A Tutorial Guide ", edition Published @2009 John Wiley& Sons, ltd, pg 7-9.

[7] A, Kumar, "Mobile Broadcasting with WiMAX: Principles, Technology, and Applications". Focal Press, Page 89-96, 2009.

[8] Engelstad, P E, Do T V, Jønvik, T E. "Name Resolution in Mobile Ad-hoc Networks.

Proceedings", of 10th Int. Conf. on Telecom. 2003 (ICT 2003). Paper-for-ICT2003.pd, pg, 171.

[9] "Wireless communication systems. Broadband communication systems". I. auther, Title. Arunabha. II. Muhamed, Rias. III. TK5103.2.A56, 2007.

[10] "WIMAX: a wireless technology revolution", G.S.V.Radah KRISHNA Rao and G.Radhmani.2008, pg. 50 -56.

[11] Jeffrey G. Andrews, Arunabha Ghosh, Rias Muhamed, **"**Fundamentals of WiMAX: Understanding Broadband Wireless Networking", @2007, pg 57-61.

[12] Johnson I. Agbinya, Mari Carmen Aguayo-Torres, Ryszard Klempous, "4G Wireless Communication Networks: Design Planning and Applications"@2013, pg212-220.

[13] N. Quoc-Thinh.F.Lionel Fiat, and A.Nazim, "architecture for UMTS-WiMAX First Internetworking", International IEEE workshop, University of Evry, France, April 2009.

[14] "Wireless communication and networks second edition "William Stallings. 2002, pg 342.

[15] Michael Rice." Digital Communications: A Discrete-Time Approach". Pearson/Prentice Hall, 2009.

[16] "Wireless OFDM systems: how to make them work"? Copyright @2002 by kuuweer Academic pubilishers, pp 308- 311.

[17] **S**. Mohapatra, S. Das, "WiMAX Security and Quality of Service: An End-to-End Perspective"this edition first @ 2010 john wiley &Sons Ltd, pp 97- 99.

[18] H. Taub, D. L. Schilling, G. Saha,Taub's "Principles of Communication Systems": McGraw Hill, 2008.

[19] "An Extensive Review on WiMAX IEEE 802.16". Yogendra Patel, Prof. K. Suresh International Journal of Scientific Progress and Research (IJSPR) ISSN: Volume-

02, Number -01, Aug, 2014.

[20]]” T. S. Rappaport,” Wireless Communications, Chs. 3 and 4”, Upper Saddle River, NJ: Prentice Hall, 1996.

[21] “Performance Comparison of Multiple Modulation Schemes in Rayleigh Faded Channels using Adaptive Beam forming” (ITEEE) ISSN 2319 – 2577, Vol-1, Issue2, 2012.

[22] V. Erceg, K.V.S. Hari, M.S. Smith, D.S. Baum et al, “Channel Models for Fixed Wireless Applications”, IEEE 802.16.3 Task Group Contributions, Feb 2011.

[23] “Analysis of Effect of Cyclic Prefix on Data Rates in OFDM Modulation Techniques”, International Journal of Advanced Computer and Mathematical Sciences, ISSN 2230-9624. Vol 3, Issue 4, 2012, pg 465-470.

[24] “Performance Comparison of MIMO-OFDM Transceiver Wireless Communication System using QAM and QPSK Modulation Schemes “,] International Journal of Advances in Engineering Science and Technology Vol 3, Issue 4, 2012.

[25] Cristina Ciochina, Fabien Buda “An Analysis of OFDM Peak Power Reduction Techniques for WiMAX Systems”, IEEE@2009, Pg 4677- 4681.

[26] Z.Becvar, J.Zelenka, R Bestak,” comparison of handovers in UMTS and WiMAX”, Czech Technical university in Prague, department of telecommunication Engineering.

[27] Heikki Kaaranen, Ari Ahtiainen, Lauri Laitinen, Siamäk Naghian,Valtteri Niemi: UMTS Networks Architecture, Mobility and Services, John Wiley & Sons, Ltd 2009.

[28] Ghosh, A.; Wolter, D.R.; Andrews, J.G.; Chen, R., “Broadband wireless access with WIMAX/802.16: current performance benchmarks and future potential”, Communications Magazine, IEEE, Vol.43, Iss.2, Feb. 2010, Pages: 129136.

[29] G. Santella and F. Mazzenga, A Hybrid Analytical-Simulation Procedure for Performance Evaluation in M-QAM-OFDM Schemes in Presence of Nonlinear

Distortions," IEEE T r ans. V eh. Technol., vol. 47, no. 1, pp. 142{151}, Feb 2010.

[30] "Effect of Cyclic Prefix on Data Rates in WiMAX System with Variation in Delay Vector", Gain Vector, Signal to Noise Ratio and Coding Rates for Different Modulation Techniques, ISBN: 978-1-4673-5613-8©2013 IEEE, pp 538-542.

[31] "Multi-Carrier and Spread Spectrum Systems from OFDM and MC-CDMA to LTE and WiMAX," Second Edition K. Fazel Ericsson GmbH, Germany, 2008 John Wiley & Sons, Ltd, pp 149-170.

[32] Abhijyoti Ghosh "Comparative BER Performance of M-arry QAM-OFDM System in AWGN & Multipath Fading Channel", International Journal on Computer Science and Engineering (IJCSE), Vol.4No.06.June2012.

[33] M. S. Islam, G. R. Barai, and A. Mahmood, "Performance analysis of different Fundamental schemes using OFDM techniques in Rayleigh fading channel," International Journal of Physics Science, Vol. 1, No. 1, pp. 22-27, June, 2011.

[34] " Performance Analysis of OFDMA in LTE", International Journal of Current Engineering and Technology, Vol.4, No.3 (June 2014).

[35] "3G Evolution HSPA and LTE for Mobile Broadband", Erik Dahlman, Stefan Parkvall, Johan Ltd. Sköld and Per Beming. Published by Elsevier, Copyright © 2007.

[36] International Journal of Advanced Computer and Mathematical Sciences, "Analysis of Effect of cyclic prefix on data rates in OFDM modulation techniques", ISSN 2230-9624. Vol 3, Issue 4, 2012, pp 465-470.

[37] "Cyclic Prefix Optimization of OFDM System", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Ver. V (May - Jun. 2014), PP 79-82.

[38] "IEEE performance analysis of physical layer of wimax system using Simulink", Volume2, Issue 2, April 2013.

[39] Jeffery G. Andrews, Arunabha Ghosh, Rias Muhamed, "Fundamentals of WiMAX: Understanding Broadband Wireless Networking", Prentice Hall, 2007.

[40] "WiMAX Solutions Division - Intel. Mobility Group", Kuo-Hui Li, IEEE 802.16e-2005 air interface overview, 2009.

[41] H. Holma and A. Toskala," LTE for UMTS: OFDMA and SC-FDMA based radio Access", John Wiley & Sons Inc, 2009.

[42] J. T ubbax, B. Come, L. V. der Perre, L. Deneire, S. Donnay , and M. Engels, "OFDM verses Single Carrier with Cyclic Pre x: A System-Based Comparison," in Some Conference, 2012.

[43]] J. T ubbax, B. Come, L. V. der Perre, S. Donnay , M. Engels, H. D. Man, and M. Moonen, "Compensation of IQ Imbalance and Phase Noise in OFDM Systems," IEEE T r Ans. Wireless Commun., vol. 4, no. 3, pp. 872{877}Jun 2011.

[44] William Stallings, "Wireless: Communications and Networks", Page 139-146, Pearson Education, 2002.

[45] Wasan K. Saad, Mahamod Ismail and Rosdiadee Nordin," Survey of Adaptive Modulation Scheme in MIMO Transmission", Journal of Communications, Vol. 7, No. 12, December 2012.

[46] Anita Garhwal, ParthaPratim Bhattachary "Performance Enhancement of WiMAX System using Adaptive Equalizer", Department of Electronics and Communication Engineering, Faculty of Engineering and Technology Mody Institute of Technology & Science (Deemed University). Accessed: Nov 13, 2010.

[47] Jeffrey G. Andrews, Arunabha Ghosh, Rias Muhamed p. cm." Fundamentals of WiMAX : understanding broadband wireless networking",2007 ,Ch4 ,pg 181- 124.

[48] International Journal of Engineering Research and Applications "Design And Implementation Of An Efficient OFDM Trans receiver Chain For Wimax",