PAPR REDUCTION USING DIFFERENT TRANSFORMS IN WIMAX (IEEE 802.16e)

DISSERTATION-II

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By

Madhav Prasad Khanal

Under the Guidance of

Mr. Lavish Kansal

Assistant Professor

SECE

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINNERING

LOVELY PROFESSIONAL UNIVERSITY

Phagwara-144002, Punjab (India)

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DECLARATION

I, Madhav Prasad Khanal, student of B.Tech.-M.Tech .(Dual Degree) under Department of Electronics and Communication, Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This dissertation does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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Reg. No.11000240

CERTIFICATE

This is to certify that the Dissertation titled "**PAPR Reduction Using Different Transforms in WiMAX (802.16e)**" that is being submitted by "***Madhav Prasad Khanal***" is in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY DEGREE, is a record of bonafide work done under my guidance. The contents of this Dissertation, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mr. Lavish Kansal
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MADHAV PRASAD KHANAL

ABSTRACT

Worldwide Interoperability for Microwave Access (WiMAX) is also known as the IEEE 802.16 wireless metropolitan area network. Along with the development of mobile communication, WiMAX has become the highly interested area for global telecom operators and manufacturers. Since January 2007, the working group of WiMAX is working on IEEE802.16m to meet the requirement of 4G. WiMAX adapts orthogonal frequency division multiplexing (OFDM) technique for multiple transmissions. 802.16 working group was formed by the Institute of Electrical and Electronics Engineers (IEEE) in 1998. Responsibility of 802.16 working group is to develop the specifications of broadband wireless access technology. Delivering the Internet throughout the world and connect the long distance of broadband wireless connectivity services are promises of WiMAX.

This Dissertation is a technical and application analysis of WiMAX, and it is easily understandable and useful to readers who want to know about functions and technical particulars. This Dissertation will help to understand the OFDM based WiMAX physical layer and its advantages and mere disadvantages. After discussing all disadvantages of OFDM based WiMAX, the main drawback, Peak to average power ratio (PAPR) will be discussed. Further all the Literature about WiMAX, OFDM and PAPR are presented. By understanding the effects of PAPR, all the PAPR reduction like linear and nonlinear techniques are discussed. by using linear precoding techniques like DST, DCT and CZT, WiMAX physical layer is analyzed to find the best precoding technique for higher reduction of PAPR and CZT is found to be the most promising transform technique. According to the demand of advance digital communication field there should be lower bit error rate (BER) in communication process and the good news is CZT can decrease the BER and that improves the performance of WiMAX.

Later, in this Dissertation some Hybrid techniques are generated by the combination of linear precoding technique and nonlinear techniques like selective mapping, partial transmit sequence and clipping for the further reduction in PAPR. The research process of this dissertation is concluded by analyzing all the hybrid techniques to reduce PAPR. Any technique can be practically used as per the requirements of users.

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LIST OF ABBREVIATIONS

A	
AP	Access Point
ASK	Amplitude-Shift Keying
AWGN	Additive White Gaussian Noise
B	
BER	Bit Error Rate
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
BS	Base Station
BSS	Basic Service Set
BTS	Base Transceiver Station
BWA	Wireless Broadband Access
C	
CC	Convolution Encoder
CP	Cyclic Prefix
D	
DFT	Discrete Fourier Transform
DL	Downlink
F	
FCC	Forward Control Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FFT	Fast Fourier Transform
FSK	Frequency-Shift Keying
G	
GSM	Global system of mobile communication
GPRS	General Packet Radio

I

ICI	Inter Carrier Interference
IEEE	Institute of Electrical and Electronic Engineers
IFFT	Inverse Fast Fourier Transformation
ISI	Inter Symbol Interference
ITU	International Telecommunication Union

L

LAN	Local Area Network
LOS	Line Of Sight
LTE	Long Term Evaluation

M

MAC	Medium Access Control
MAN	Metropolitan Area Network
Mbps	Megabits per Second
MBWA	Mobile Broad Band Wireless Access
MIMO	Multiple Input, Multiple Output
MS	Mobile Station
MSS	Mobile Subscriber Station

N

NLOS	Non Line Of Sight
NSS	Network Switching Subsystem

O

OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access

P

PAR	Peak to Average Ratio
PAPR	Peak to Average Power Ratio
PSK	Phase-Shift Keying
PTS	Partial transmit sequence

Q

QAM	Quadrature Amplitude Modulation
QoS	Quality of Service

QPSK	Quadrature Phase Shift Keying
R	
RF	Radio Frequency
S	
SNR	Signal to Noise
SLM	Selective Mapping
T	
TDD	Time Division Duplex
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
U	
UL	Uplink
W	
WBA	Wireless Broadband Access
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide interoperability for Microwave Access

CHAPTER 1: INTRODUCTION

In the far-off areas the access to data is really very difficult. We will find a technology which can reach in such areas. The transfer rates of high data rete to the users to the range of many kilometrs can only be achieved by this innovation of technology. Now a day, huge amount of information is exchanged between people of society. In daily routine, you need wireless communication technology in many ways. In the morning, you might surface the internet on a coffee shop with your laptop via Wi-Fi technology. When you are on a bus, you might want to check your email via your 3G cell phone. In the office, you might need to do video conference with your customers somewhere all over the world. Therefore, Wireless communication seems to be a promising that satisfying our need. We want the next generation wireless communication systems to support mobility, simplicity, flexibility, and global accessibility. Among all the next generation system, Worldwide Interoperability for Microwave Access (WiMAX) seems to be one of the most gifted techniques.

1.1 INTRODUCTION TO WiMAX

WiMAX (World interoperability Microwave Access, Global Microwave Access Interoperability) technology is based upon IEEE802.16 protocol. It is a metropolitan area network technology (MAN). Range of the frequency provided for WiMAX technology is from 2GHz to 66 GHz. Its frequency section can be separated by non-line of sight frequency and line of sight frequency. 75 Mbps is maximum rate of transfer that can be achieved in WiMAX. Bandwidth of the channel lies between 1.25MHz to 20MHz. WiMAX can provide wireless broadband access wth in range of 50 Km by using macro cells to cover far away areas. Same access can be provided in 5-15 km range if the user is mobile [5]. WiMAX is based upon OFDM system and that has various advantages with some notable disadvantages.

1.1.1 Advantages of OFDM Based WiMAX System

- The frequency spectrum is rectangular for increasing number of subcarriers that gives high spectral efficiency.
- FFT provides simple digital vision.

- Less problem of ISI due to cyclic prefix.
- Different subcarriers can be modulated differently which changes the condition of transmission of each subcarrier.

1.1.2 Disadvantages of OFDM Based WiMAX System

- More number of subcarriers can affect the system in the basis of Doplar shift.
- Synchronization in time and frequency needed.
- Cyclic prefix (CP) creates problem in spectral efficiency.
- OFDM signals generally linear amplifiers for the high peaks so PAPR in one of the major problem of OFDM based WiMAX.

1.2 WiMAX STANDARDS

WiMAX standards are widely used OFDM based WiMAX standards where the band and the frequency is already defined for the system. Spectrum range for the WiMAX system is 11- 66 GHz. 2- 11GHz is taken as line of sight frequency and 11-66 GHz is taken as the non-line of sight frequency. WiMAX provide bit rate of upto 75 Mbps and modulation techniques used in WiMAX are mainly BPSK, QPSK, 16-QAM and 64-QAM.

Table 1.1: Standards of WiMAX

	IEEE 802.16	IEEE 802.16d	IEEE 802.16e
Spectrum	11-66 GHz	2-11 GHz	2-6 GHz
Application	Backhaul	Wireless DSL and Backhaul	Mobile Internet
Channel Conditions	Line of sight	Non line of sight	Non line of sight
Bit Rate	32-134 Mbps	Up to 75 Mbps	Up to 15 Mbps
Modulation	QPSK, 16 QAM, 64QAM	QPSK, 16 QAM, 64QAM, OFDM 256	QPSK, 16 QAM, 64QAM, OFDM 256
Bandwidth	20, 25 & 28 MHz	1.5-20 MHz	1.5-20MHz

FFT is used for multicarrier transmission and it is useful to face fading in the system without any equalizer used at the receiver side of the system. Size of FFT defines the how optimum the system can be. Generally used bandwidth in WiMAX is 1.5 – 20 MHz.

Following are the major problem in WiMAX engineering are facing to make the system flexible.

Data Rates: Use of portable device to laptop is originated by omnidirectional antenna used to make the system useful but it is found that the installation of that type of antenna is not easy.

Bit Error Rate: Generally it is taken in mind that the WiMAX system provide high speed data rate to the user in far range but the problem is as the range increases the BER of the system also increase so to avoid this problem we can shorten the range.

1.3 FEATURE OF WiMAX

- Physical layer is OFDM based.
- Data rate is high.
- MAC layer of WiMAX gives QOS.
- Flexible architecture.
- Mobility.
- Scalability.
- It is cost effective as compared to other similar techniques.
- It supports static, roaming and mobile applications.

1.4 WiMAX MODEL

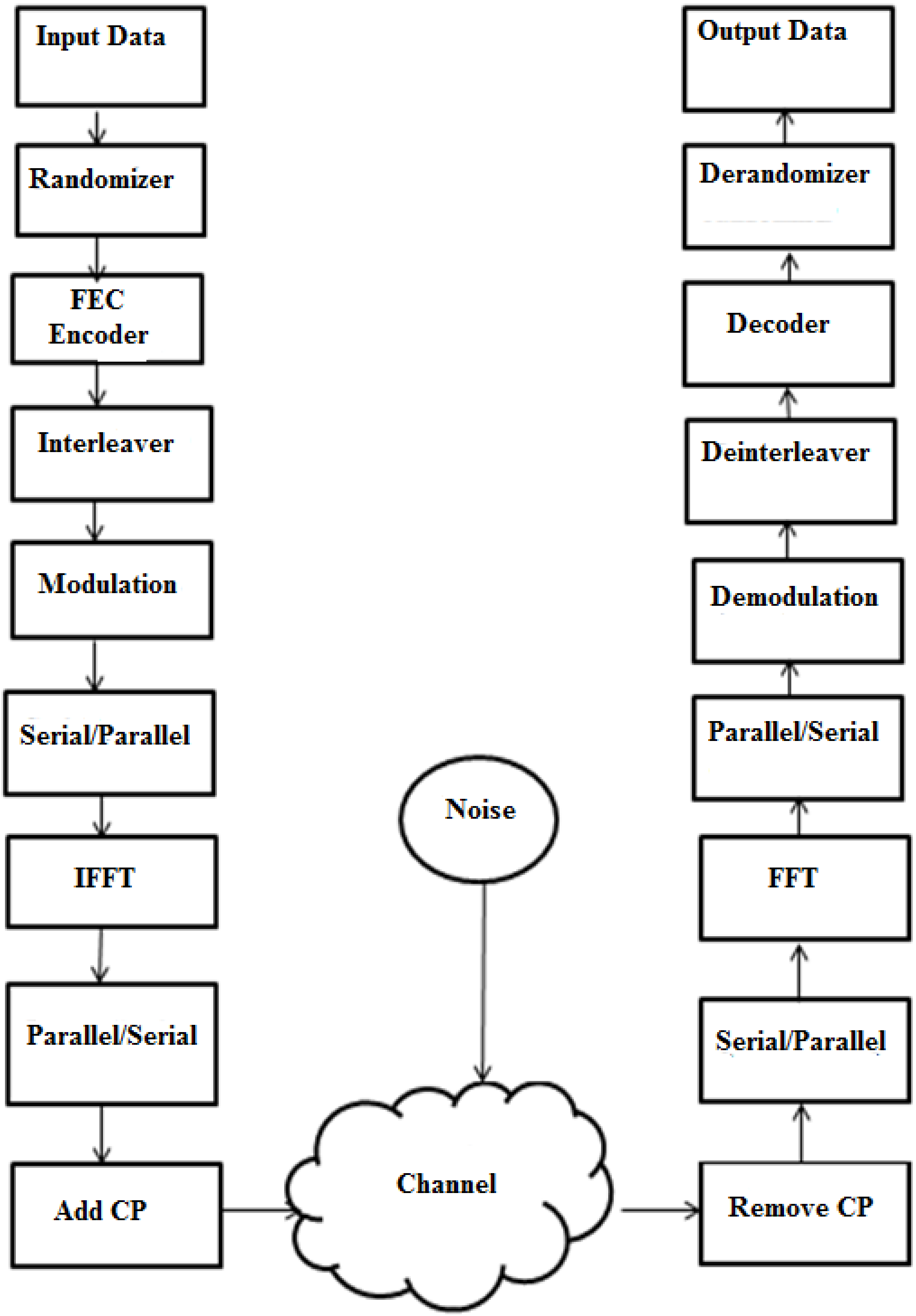

Fig 1.1: WiMAX Physical Layer Model

1.5 TRANSMITTER

The transmitter section does mapping of subcarrier into amplitude and phase. Then the frequency domain signal is converted to time domain signal by using IFFT. The Inverse Fast Fourier Transform (IFFT) performs as IDFT with more efficiency in term of computation and it is used broadly in all practical systems. The time domain signal is assorted up with required frequency in order to transmit [1].

1.5.1 RANDOMIZATION

The data into the physical layer from higher layer comes in the form of digits and randomization is the first process carried out in WiMAX. In transmitter and receiver of WiMAX every data symbol is randomized, operates in bit by bit basis. Converting long sequence of type of same bit is major task of randomization to improvement coding operation occurs in WiMAX. PN Sequence code generator is main component of randomizer formed using Linear Feedback Shift Register (LFSR). To overcome all the fading that system faces during the transmission creates bit error rate in the data and that can be eliminated by channel coding techniques. The data is coded by the formation of sequence and changing the characteristics of sequences. The coded sequences are filled with redundant bits at transmitter and removed at receiver to perform error correction. System with coding is more immune to errors. Randomization, Forward Error Correction and Interleaving are overall process of channel coding technique.

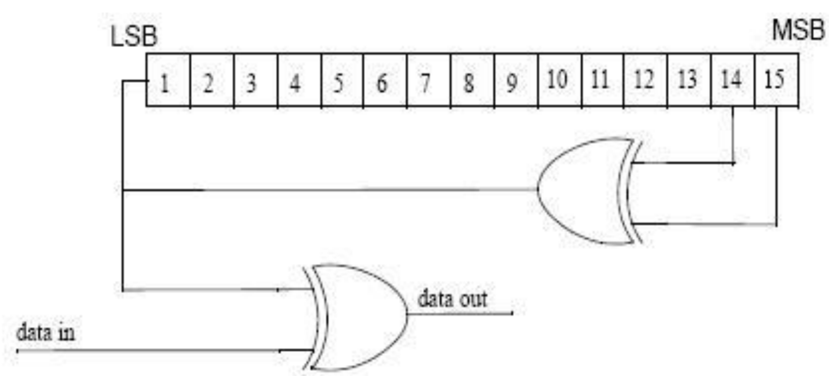

Fig 1.2: Randomization Process Using PN Sequence

The generator defined for the randomizer is given by Equation (1.1)

$$1 + x^{14} + x^{15} = \text{out} \tag{1.1}$$

1.5.2 FORWARD ERROR CORRECTION (FEC)

Both the transmitter side data and the receiver side data are passed through FEC and consists of combination of Reed- Solomon Code and Convolutional Inner Code. FEC in WIMAX is dual coding technique where RS coding act as outer coding and Convolutional coding act as inner coding.

- **Reed Solomon Encoding:** Addition of redundancy into the symbol of data taken from randomization is task of Reed Solomon coding. The redundant bits added to the symbol help at the receiver side to take the decision of correction of data which may be faulted by the characteristic of channel. Calculation and encoding process is done by using Galois Field and it is denoted by (2^m).

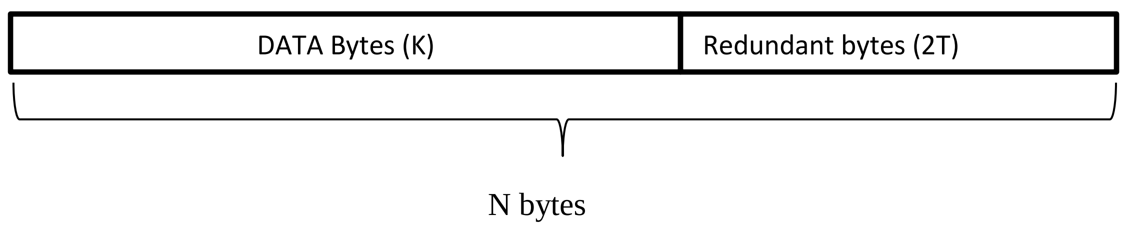

Fig 1.3: Reed Solomon Coding

Standard RS Encoding technique is used in WiMAX which is based on GF (2) denoted by:

RS (N= 255, K = 239, T =8)

Where, N = Coded Bytes

K = Data Bytes

T = Capability of correcting number of bytes

N= K+2T

For generating the Galois Field Array the polynomials of code generator are used and Field is used to calculate the number of redundant bits to be added in the data. These polynomials are defined by the standard as below:

Code Generator Polynomial:

$$G(x) = (x+a^0)\ (x+a^1)\ (x+a^2)\ (x+a^3)\ldots\ldots.\ (x+a^{2T-1}) \tag{1.2}$$

Field Generator Polynomial:

$$P(x) = x^8+x^4+x^3+x^2+1 \tag{1.3}$$

- **Convolutional Encoding:** Correcting errors occurs during the communication process occurs in WiMAX through the channel is the task of Convolutional codes. Convolutional code is an outer coding type of FEC code denoted by CC (m, n, k). Here each m bit data is transformed into n bit coded data where n is greater than m and n divided m is known to be code rate [2]. n numbers modulo-2 adders with n generator polynomials are used in convolutional coding.

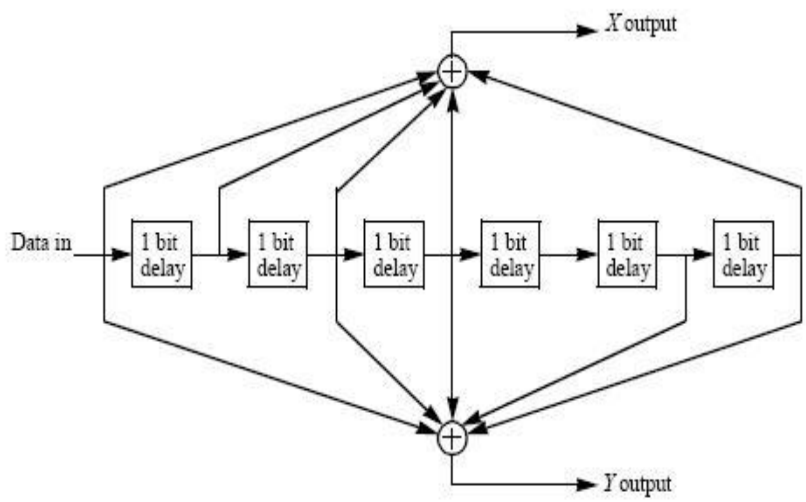

Fig 1.4: Convolution Coding Technique

A = 171 octal = 1111001 binary for X (1.4)

B = 133 octal = 1011011 binary for Y (1.5)

1.5.3 INERLEAVING

Interleaver in its most basic form can be known as a randomizer. Randomizer works on the state of the data bits but interleaver works on the state of the data bits. Interleaving is done before modulation. It ensures that side bits will not be mapped into side subcarriers and it also ensures that long run of unwanted data will be avoided [3].

The first permutation is defined by the formula:

$$c= (b/ 12) * \text{mod} (k, 12) + \text{floor}(k/ 12) \quad (1.6)$$

The second permutation is defined by the formula:

$$s = \text{ceil} (a/12) \quad (1.7)$$

$$d = s \times \text{floor} (mk / s) + (c + b - \text{floor} (12 * mk / b))\text{mod}(s) \quad (1.8)$$

Where,

a=Number of coded bits per carrier.

b= Number of coded bits per symbol.

K= index of coded bits before first permutation.

c= Index of coded bits after first permutation.

d= Index of coded bits after second permutation.

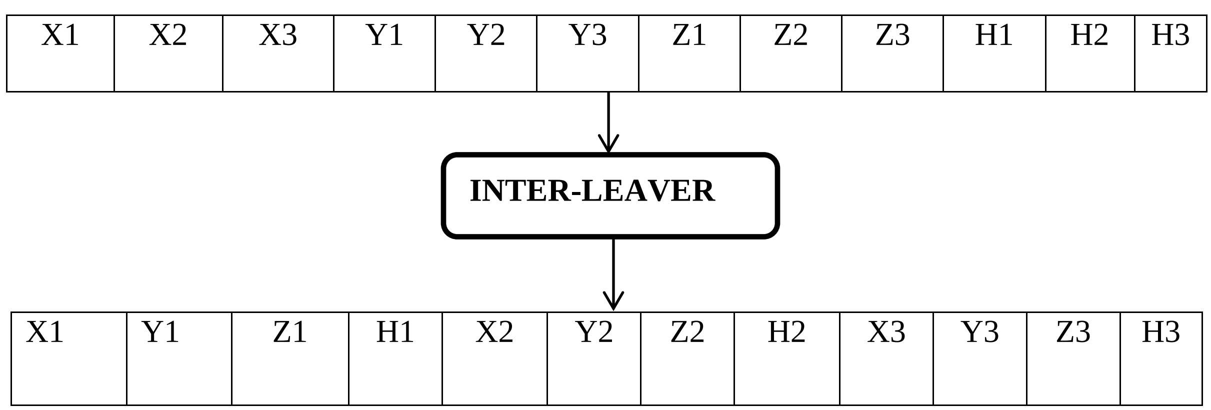

Fig 1.5: Interleaving Process

1.5.4 MODULATION

Modulation is mapping of input sequence to match the characteristics of transmitting data with characteristics of channel. Modulation is generally mapping of input sequence in different frequency range or different phase to avoid the loss of data [3]. M-PSK and X-QAM are generally used modulation techniques in WiMAX where (M= 2, 4) and (X= 16, 64) [3]. The number of bit taken at a time for the modulation is $\log_2 M$ and $\log_2 X$ respectively for M-PSK and X-QAM. Guard band and pilot carriers are inserted in the data modulated.

$$Z_i(t) = \sqrt{\frac{2Es}{T}} \cos(2\pi f_c t + \frac{2\pi i}{M}) \tag{1.9}$$

Z is phase shift keying of n^{th} sequence of bits from M number of sequence.

Modulated data is given to IFFT to convert the frequency domain signals into time domain signal for multicarrier transmission. Converted signal is passed through CP addition and transmitted. The modulated data is passed through S/P conversion. If M is total number of modulated data Z, data will be given to IFFT after converting its formation from serial to parallel because IFFT deals with parallel form of data.

$$X = [Z_0, Z_1, Z_2, Z_3 \ldots\ldots Z_{M-1}]^T \tag{1.10}$$

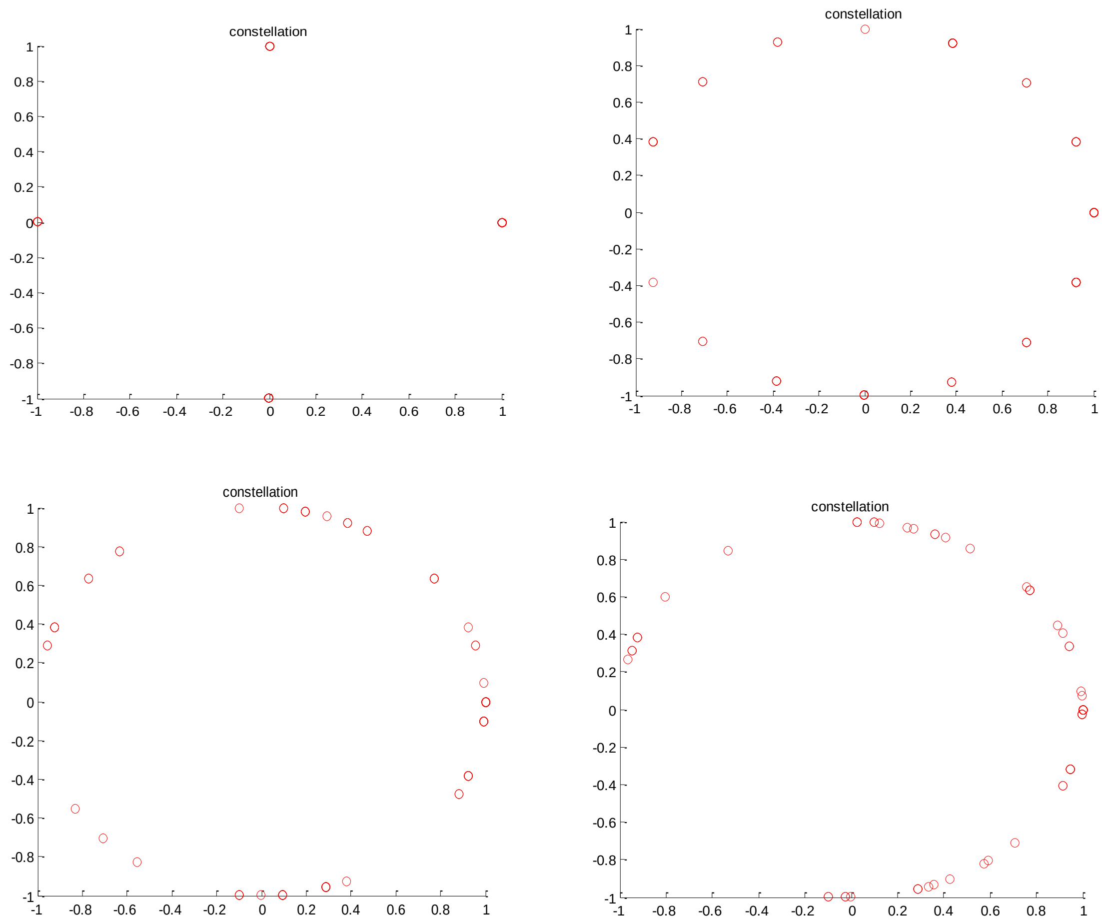

Fig 1.6: Constellation Diagram of Different Modulation Techniques (QPSK, 16-PSK, 64-PSK and 256-PSK)

1.5.5 INVERSE FFT

At the transmitter side of WiMAX the modulated data is found in the domain of frequency and it is necessary to convert the data into domain of time to overcome all the fading characteristics. Each symbol is assigned to each carrier and modulation will take place within assigned area. Modulation can be done by different PSK and QAM. OFDM symbol for i^{th} symbol in N-subcarrier system can be generated by:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X(i).e^{(j2\pi.i.n/N)}; 0 \le n \le N-1 \qquad (1.11)$$

Where X(i) is subcarrier mapping and j= $\sqrt{-1}$.

1.5.6 CYCLIC PREFIX (CP) ADDITION

For the optimum transmission of data in OFDM there need to be orthogonality of signal and there should be no delay problem in symbols. To overcome these both problems and find zero ISI we need to add cyclic prefix of certain length to the symbol. The length of cyclic prefix should be greater than delay occurs to save overlapping of data symbols.

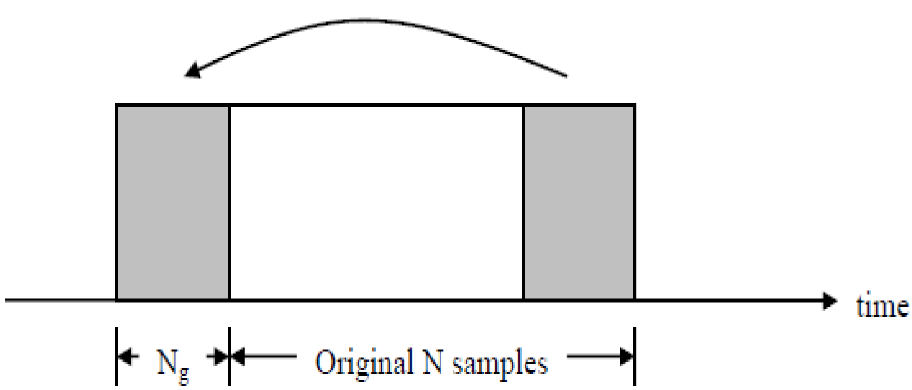

Fig 1.7: CP Addition in Transmitter

Inter symbol interference (ISI) is major drawback of wireless communication. To overcome ISI cyclic prefix is added to the data. The addition of cyclic prefix changes the data segment and bandwidth. If Ns is the length samples and Ng is the length of guard band, N becomes the total number of samples available to transmit which is sum of Ns and Ng. The output from IFFT is x(n) and it is converted to x(t) by adding cyclic prefix.

1.6 COMMUNICATION CHANNEL

Communication channels are path of carrying data in the communication between sender and receiver. There are wireless and wired channels available for communication. WiMAX is wireless communication based system so Wireless channels are used. Fading channels can be divided into fast and slow. In fast fading impulse response changes with each symbol but in case of slow fading impulse response does not changes with every symbol or we can say that it will change after number of symbols. Additive White Gaussian Noise (AWGN) channel is representation of channel with specific noise. Bit Error Rate for the system is calculated with respect to signal to noise ratio (SNR) of signal transmitted through AWGN channel. Other wireless channels are Rayleigh channel, Racian channel etc.

1.7 RECEIVER

The inverse task of the transmitter is done in the side of receiver. The carrier on the pathway between sender and receiver is open and full of noise. As the data is received at the receiver side through the pathway, the data may be found with lots of noise component added to it by environment so this data cannot be taken as original data. At the receiving side, a reverse process like removing cyclic prefix, multicarrier receiver FFT, Demodulation depends on Modulation, Deinterleaving, Decoding and Derandomization are taken place to obtain actual data. The base band signal is mixed with RF signal for processing of data. The guard period is removed later. By using Fast Fourier Transform (FFT) the time domain signal is again converted to frequency domain signal. The amplitude and phase components are used to decide the demodulation process. Then interleaved and coded data was deinterleaved and decoded to reference data. As the deinterleaving process only changes the order of received data, the error probability is unharmed. By applying digital data through Convolution Decoder and RS decoder some errors can be corrected which gives less error rate. The digital bits sent at the transmitter side are compared with the digital data received at the receiver side and number of errors occurred calculated.

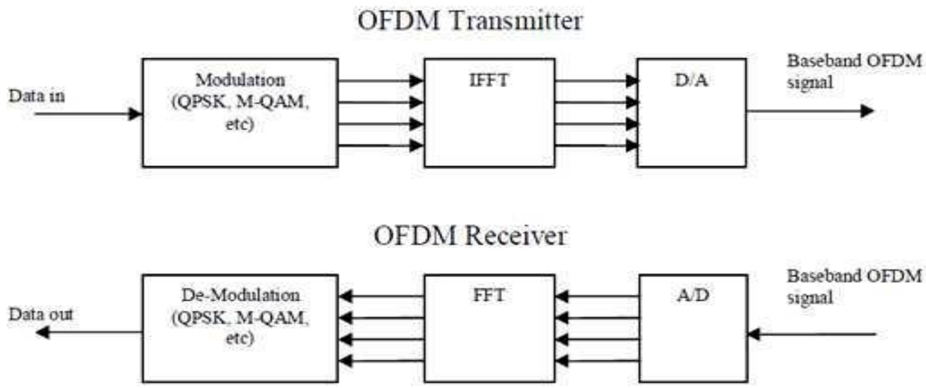

Fig 1.8: OFDM based WiMAX transmitter and receiver

1.8 PEAK TO AVERAGE POWER RATIO IN OFDM BASED WIMAX

The OFDM system has lot of advantages such as good spectral efficiency, no loss due to fading, No need of use equalizer and safety of interference of impulse but as the no system can be full of advantages only the OFDM system also has the main problem of PAPR. PAPR is peak to average value ration of power of signal. OFDM signal consist of lots of peak valued signals occurse due to independently modulated subcarriers. According to the nature of the IFFT which sums N sinusoids through superposition, some of the combinations of those sinusoids create large peaks. The transmitted signal has envelope which are not constant and shows peaks whose power exceeds the mean power and to avoid distortion the transmitting amplifiers need to work linearly. So, power amplifiers with a large range are required which are expensive. To overcome high expense of OFDM systems PAPR should be as low as it can be. The drawback of PAPR is so much important for communication engineer because as the power level of the signal increases and passed through the amplifiers it can be seen that the power level effect the components having less power tendency [6]. It can be said that as the components burn out the signal cannot be fully transmitted and the distortion occurs.

The signal generated after IFFT of a perfectly Modulated (mapped) bits is:

$$x(t) = \sum_{n=0}^{N-1} x(n) \exp(j2\pi tfn) \tag{1.12}$$

The PAPR of the generated signal (t) will be:

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \tag{1.13}$$

Orthogonal Frequency Division Multiplexing (OFDM) is most commonly used technique of multicarrier modulation and become vastly used in wireless communication but the major disadvantage of OFDM transmission is its high peaks in signal and can be computed as PAPR. Operating power must lies below the available power of amplifier to work in its linear region. Lots of algorithms have been developed to reduce PAPR. Partial Transmit Sequence (PTS), Selected Mapping (SLM) technique, clipping techniques are mostly used nonlinear techniques and precoding technique is mostly used linear technique.

PTS technique is modified technique of SLM technique. PTS adapts optimization process to avoid sending side information but it is lot more complex than SLM. SLM is good technique to minimize PAPR but the problem is we have to send side information with data that also minimize spectral efficiency. Clipping technique is very old techniques to reduce PAPR but it has disadvantage of BER degradation. Linear precoding is most promising technique because it has no problem of bandwidth increasing and BER degradation. For the further reduction of PAPR precoding can be used as an added technique with any of the nonlinear technique to form hybrid technique.

1.9 MOTIVATION OF STUDY

The study of WiMAX provided the important knowledge about digital communication system. WiMAX is the system based on OFDM radio channel. Studied about the basic block diagram of WiMAX this has very important role in the future for the revolution in communication system which will be distance independent for the best connectivity. From the Randomization process data are regenerated using information bits and dual coding technique of RS code as outer code and Convolution code as an inner code are used for the better error correction capability. PAPR is dependent on the subcarriers numbers used and it is found that that more number of subcarriers also increases the PAPR. Any OFDM base system will have more PAPR if the number of subcarriers used in the system is more.

The formation or installation of ADC and DAC in the route of high PAPR is extremely harmful. A large PAPR degrade system efficiency if components used for transmitting data do not operate properly. It has an effect on the lifetime of battery. So in communication system it is found that all the advantages of multicarrier transmission can be out weighted because of high PAPR.

1.10 OBJECTIVES OF STUDY

- To understand the basic characteristics of WiMAX in wireless communication, can be the revolutionary technique in future.
- To understand the radio channel of WiMAX which is OFDM and to study the importance of multicarrier transmission in OFDM for better transmission.
- To study the reason of high PAPR, effect on system due to high PAPR.
- To be known of the techniques used for the reduction of PAPR and find out the best technique (by taking spectrum efficiency and BER in consideration).
- To establish a new technique for the reduction of PAPR that can be help in wireless communication system and will be useful in future.

CHAPTER 2: LITERATURE REVIEW

As the growth in demand of this generation the speed communication need has become a greatest priority. To fulfill these demands of the new generation; few highly used techniques like Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) are used. Orthogonal Frequency Division Multiplexing is a multiplexing of frequency division scheme used as a digital multicarrier modulation. Closely spaced orthogonal subcarriers in large numbers are used to carry data during transmission process.

2.1 WiMAX TECHNIQUE

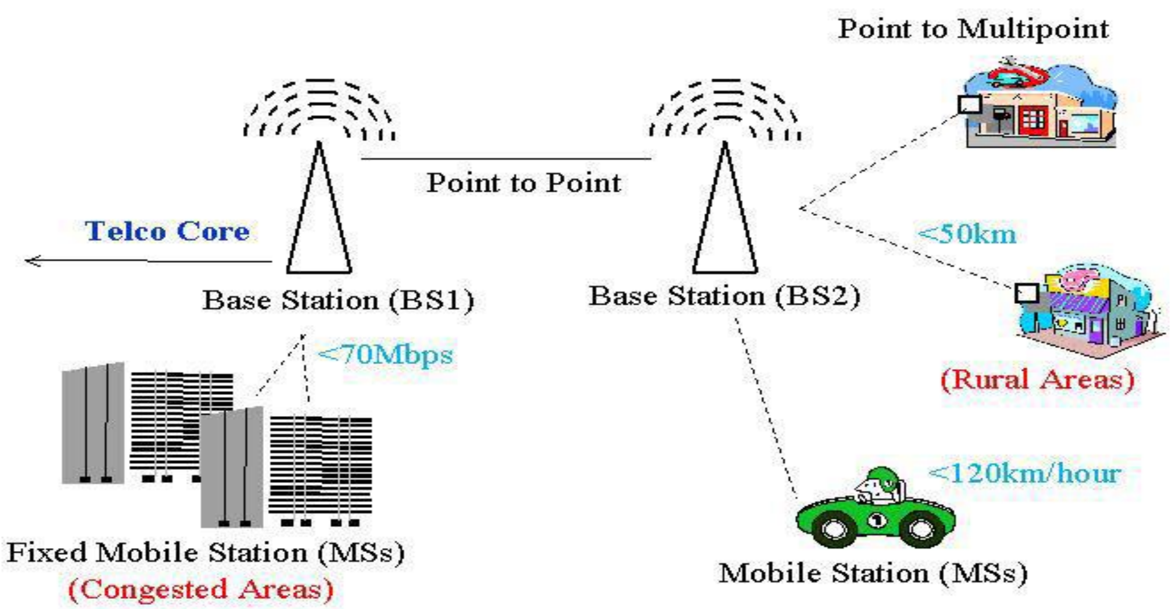

Fig 2.1: WiMAX Deployment Scenarios

M. N. Khan et.al [7] states WiMAX became the most interesting area for the students' users and researcher because of its revolutionary technique. The important services provide by the WiMAX system are discussed and explained about the physical layer of the WiMAX and block by block task of physical layer. The implementation process of physical layer of WiMAX using WiMAX is being discussed. MATLAB tool is very useful source to analyze the research done by students and higher authorities. The implementation process by block to block representation motivates researchers from all fields to works in the field of WiMAX.

IEEE 802.16e WiMAX is the next generation wireless system that can provide us high speed voice, video and data pack service to the user as the demand of environment. Both LOS and N-LOS wireless communication is provided to customers by WiMAX in the different frequency range of carrier. WiMAX Technology will make us forget about the limitation of area of coverage, security of transmission. The performance discussion concludes that the WiMAX physical layer is based on the IEEE 802.16e standard. Modulation techniques are used to fulfill the channel conditions as Abdul Rehman et.al [8] defined.

The error occurs during the transmission of information bits can be eliminated by using different channel coding techniques. Reed-solomon coding and convolution coding are used to check the capability of error correction and found very much effective for low BER on WiMAX system. Later dual coding technique is used in WiMAX for better results and glad to know that it was very much successful. Reed-solomon coding is used as outer coding and convolution coding is used as inner coding technique as explained by Md. Ashraful Islam et.al [9]. Different modulation scheme like QPSK, 16QAM and 64QAM are also discussed for the perfect mapping.

Chakchai So-In et.al [10] state that the value of WiMAX is increasing daya by day because of its qualities like high data rates up to the far away areas which also support same service to the moving equipments which a normal LAN cannot provide. It is also giving light on the topics like WiMAX deployment and discussed for improving knowledge.

2.2 OFDM TECHNIQUE

R. Prasad et.al [11] explained about how the OFDM became mostly used technique in the field of wireless communication. The various advantages like high spectral efficiency and security issues are discussed and its merit on fading channels found to be the most impressive technique. Different type of techniques to resemble with WiMAX are discussed and found that WiMAX is all the way revolution in wireless communication. The addition of CP in OFDM technique is to eliminate ISI from the system.

Olalekan Bello et.al [12] explained the need of high speed internet service in modern world and presented WiMAX can be the technique to fulfill all the desires we expect from the service provider. OFDM based WiMAX system found to be the perfect combination of emergence of demand of user in practical form. Different number of subcarriers can be used in this technique and performance of system and found effective and possibility of 512 and 1024 OFDM in WiMAX emerged.

WiMAX, the Worldwide Interoperability for Microwave Access is a new technology which is working for limitation of data over long distance using wireless communication method in many different ways are explained by M. Seyedzadegan et.al [13]. IEEE 802.16 WiMAX is taken as an alternative broadband rather than cable LANs. Quick technical overview of relative factor of WiMAX regarding cost, QOS, Network is provided and that shows WiMAX as an out of the box technique in wireless communication.

Nick LaSorte et.al [14] illustrates the development process of OFDM based WiMAX in the form of historical emergence. Major problems occurred during the formation of OFDM are discussed and IFFT technique for the multicarrier transmission of data is explained. ISI problem and solution by adding CP is discussed and PAPR for OFDM signals is found to be the most challenging prospective of WiMAX.

The bandwidth consumption by OFDM symbol and subcarrier modulation technique is found to be the major advantage as ststed by M. Bhardwaj et.al [15]. The parallel transmission technique used in OFDM is for getting high throughput. The higher the range higher BER is discussed and concluded that we can reduce number of error bits by limiting the range of system.

Helmut Bolcskei et.al [16] explained about the capacity of OFDM that can be increased by using spatial multiplexing. Fading is the major problem in wireless transmission and OFDM is immune to that. It can be used in single input single output and multiple input multiple output system. Single input single output gets more fading in data compared to MIMO.

The analysis of OFDM systems by post coding technique is discussed by S. F. A. Shah et.al [17]. Post coding technique found to be more effective on symbol recovery but the precoding technique had major advantage of minimizing PAPR too. To reduce cost of the system and make it more efficient the precoding technique can help in OFDM.

2.4 PAPR REDUCTION IN OFDM AND WiMAX

Introduction of peak to average power ratio has been discussed by Dae Woon Lim et.al [18]. A general description of OFDM including advantages and disadvantages reshaped the concept over the technique we are using now a days and it is found that with lot of advantages provide by OFDM there is a major disadvantage that creates sort of degradation in BER of data. The problem is high PAPR and it will destroy all the hard work of the system and makes the system non-linear.

A coding technique which will reduce PAPR of the system with better error correction was described by I. Shakeel et.al [19]. This technique of use block codes to provide security to data over the process can keep peaks down to minimize PAPR and ADC and DAC work properly means PAPR can save further degradation in BER. This technique was first invented for the minimization of BER but we got added advantage of minimizing PAPR.

Reduction of PAPR using all proposed techniques of an OFDM signal is derived by Malhar Chauhan et.al [20]. All the Proposed technique shows better performance for reduction in PAPR any technique can be used according to performance required. SLM and PTS are taken as nonlinear techniques to reduce PAPR but they may degrade the BER performance. Signal scrambling and clipping techniques are derived to conclude that these are the standard techniques having disadvantage of high complexity.

Md. Ibrahim Abdullah et.al [21] described different PAPR reduction techniques. Selected mapping technique (SLM) which is a most efficient technique for PAPR minimization needs more bandwidth because it sends side information with actual data to get original data. The degradation in spectral efficiency makes SLM less used technique but it depends upon the need of user.

Tao Jiang et.al [22] showed the analysis of different techniques like linear and non-linear techniques to minimize the PAPR in the basis of spectral use, complexity and performance of the system. It is analyzed that we cannot put BER on danger for concerning PAPR. A technique which can minimize PAPR without affecting bandwidth consumption and BER can be the best technique to reduce PAPR.

M. Khan [23] said new modulation technique can be used for WiMAX system and strength of cancelling ISI and ICI makes OFDM a perfect technique to get spectral efficiency. It is discussed that the precoding technique is one of the most efficient method for reduction of high PAPR. Precoding techniques like WHT and DCT are discussed to show the reduction on PAPR without effecting BER of OFDM.

Imran Baig et.al [25] explained ZCT gives minimum PAPR as compared to WHT and DHT precoded WiMAX. The precoding technique was used with pulse shaping technique to form a hybrid technique to reduce more PAPR. The formation of ZC matrix is complex but as the data is gained we can get high reduction in PAPR.

Beamforming in OFDM system is implemented and the phase shift for different antenna can help reducing PAPR as explained by S. Khademi et.al [26]. As in SLM technique the phase shift done for different beamformed antenna can reduce PAPR. Optimization of phase recover the original data but makes the system complex.

Imran Baig et.al [27] derived a novel DST precoding based RI-OFDMA transmitter for high minimization in PAPR. The precoding technique is used before IFFT and after IFFT pulse shaping technique is used for higher reduction. DST precoded technique is compared with WHT precoded and ZCT precoded technique and found that DST is most impressive transform technique to minimize PAPR.

As linear precoding is not fully dependable technique for high reduction in PAPR, the combined techniques of nonlinear techniques like PTS, SLM or clipping and linear techniques can be more efficient for high reduction in PAPR. Nonlinear techniques (SLM, PTS or Clipping) with DCT, WHT or ZCMT precoding can be formed for high reduction of PAPR in mobile WiMAX AS explained by I. Baig et.al [28].

Y. Rong et.al [29] explained that the linear precoding technique is most efficient technique to reduce PAPR upto the certain level of amplitude. The Precoding technique based OFDM is taken as the least disturbed technique because of no degradation in BER of the system. PAPR gives minimum cutoff rate to reduce the complexity of transmitter that may reduce the cost of the system.

CHAPTER 3: RESEARCH METHODOLOGY

A large PAPR increases the complexity of the system and degrade the efficiency of the power amplifier. Regulatory and application limited can be implemented to reduce the peak transmitted power which also reduces the multi carrier transmission range. It causes prevention of spectral growth and the transmitter power amplifier is no longer limited to linear region in which it should be operating. Lifetime of battery decreases as a result. To reduce the PAPR and make a system efficient as it is discovered to be some of the major PAPR reduction techniques have been generated. These techniques are firstly classified into linear and nonlinear techniques and nonlinear techniques further can be classified into signal scrambling techniques and signal distortion techniques. Precoding technique is only linear technique in action. Selective mapping techniques, partial transmit sequence, interleaving technique, Tone reservation technique and Tone rejection technique are signal scrambling techniques. Clipping is signal distortion technique and Different transform techniques can be used as linear precoding technique.

Techniques used to overcome PAPR are:

- Signal scrambling techniques
- Signal distortion techniques
- Precoding techniques

3.1 SIGNAL SCRAMBLING TECHNIQUES

Signal scrambling techniques works by sending side information which minimized the efficiency of bandwidth consumption. These techniques are effective on PAPR reduction but the major disadvantage of these techniques is bandwidth capturing of side information because of that spectral efficiency will be less.

3.1.1 Selective Mapping (SLM)

Bauml has proposed Selective Mapping (SLM) in 1965. Peak to average power minimization of the system with selected mapping has been done by this method. All subset signals are generated signifying the same information in selected mapping, and then the signal with minimum PAPR is selected as a signal to be transmitted. In the SLM, for transmission the input data structure is multiplied by random series and resultant series with the lowest PAPR is chosen [15]. The multiplying sequence is sent as side information to allow receiver get the exact data to be received. The reduction in the PAPR problem can be possible by one of the preliminary probabilistic method that is with help of SLM method. Major advantage of selected mapping method is that it does not eliminate the peaks, and can handle any number of subcarriers. Major drawback of this method is side information needs to be sent to the receiver of the system in order to recover original data. In this method a signal is partitioned into number of blocks and converted to parallel form from serial form and each data block is phase shifted by different combination of phases B (n) where n can be 1, 2, 3, 4……N . N is total number of phase combination available. The phase is sent as side information to regain the actual data in receiver side. Then each data from each block X(n) is passed through multicarrier transmission (IFFT) to get the data x(n). Now N numbers of data are compared in term of lowest PAPR. The data with lowest PAPR is selected as data to be transmitted.

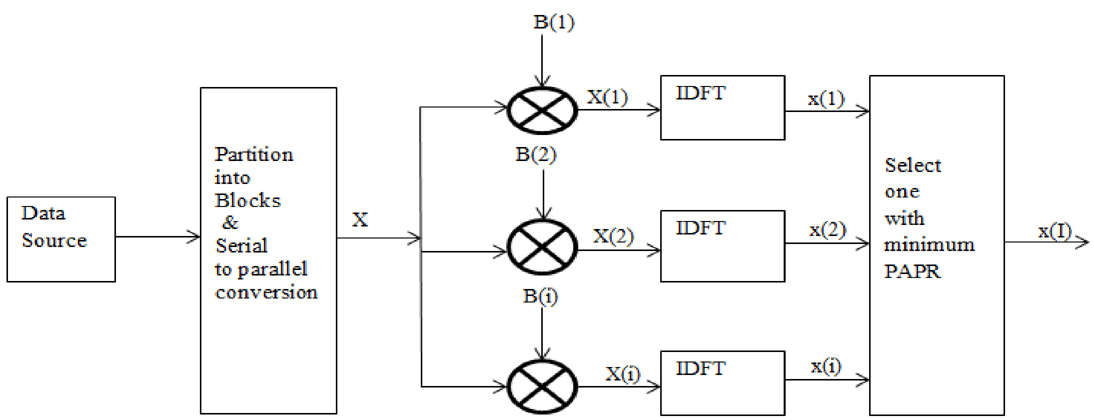

Fig 3.1: SLM Technique

3.1.2 Partial Transmit Sequence (PTS)

Partial Transmit Sequence (PTS) technique has been proposed by Muller. PTS technique id advanced form of SLM technique but it is found that it becomes more complex than SLM. The OFDM system becomes flexible and effective by this method. The input data frame is divided into sub blocks as done in SLM. Main purpose behind this method is each sub block is phase shifted by a certain constant factor to reduce PAPR. Reduction in the PAPR problem is done by probabilistic method of PTS. SLM method works poor than the PTS method [15].

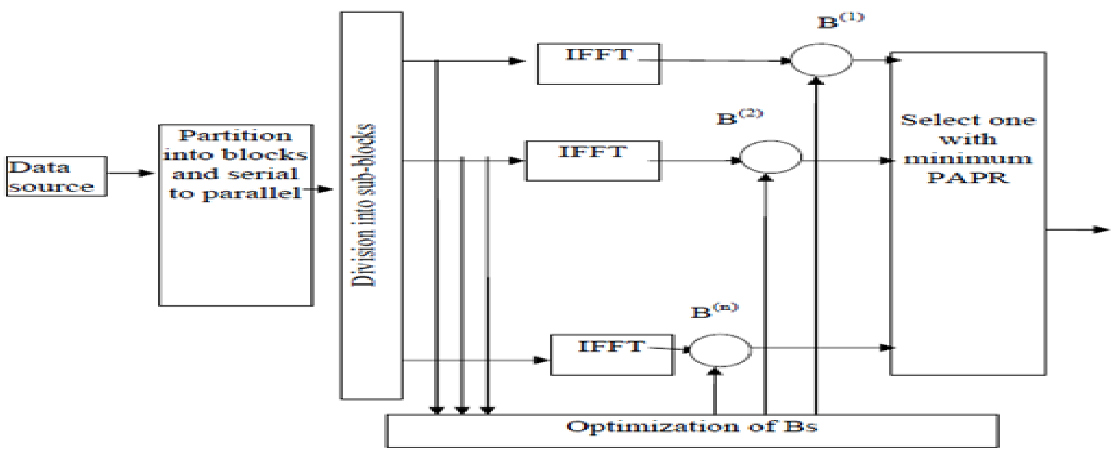

Fig 3.2: PTS Technique

The major different in work of PTS than SLM is there is optimization process of all the constant phases so there will be no need to send phase with each data as a side information. Optimization process of each data block is taken to action after FFT to help recovering actual data. Now N numbers of data are compared for lowest PAPR and the signal having lowest PAPR is selected as signal to be transmitted. In this method, no need to send any side information to the receiver of the system. This is the main advantage of this method. No effect is created on redundancy as no more information than input information is sent through the spectrum. The major advantage is no spectrum loss.

3.1.3 Interleaving Technique

For reduction of peak to average power ratio (PAPR) of an OFDM transmission, interleaving technique was proposed by Jayalath and Tellambura . The idea of if long correlation pattern is broken down, highly correlated data structures have large reduction in PAPR can be done. The adaptive interleaving is to set up initial threshold value of PAPR. Total number of interleaving sequence will have different PAPR value and the interleaving sequence having minimum PAPR can be set as threshold sequence. This method cannot be used as major technique for PAPR reduction. In this situation, higher order PAPR reduction method can be used in addition to this method.

3.2 SIGNAL DISTORTION TECHNIQUES

Signal distortion technique is lately invented technique to reduce the power level of signal by adjusting the signal level to limited power level. The power level adjusted can be known as threshold amplitude level. Reduction of amplitude level by changing the characteristic of signal provides a decent move to remove the complexity in converters. It can be used in hybrid techniques.

3.2.1 Clipping And Filtering

PAPR is one of the major problems in OFDM. High PAPR creates problems in the system like it makes the system complex because of the converters. Converters generally loose efficiency and amplifiers became unsupportive for high peaks. The most easily done technique to cutting down the peaks is clipping technique where the signal having more peak than threshold peak will be shortens down to threshold level.

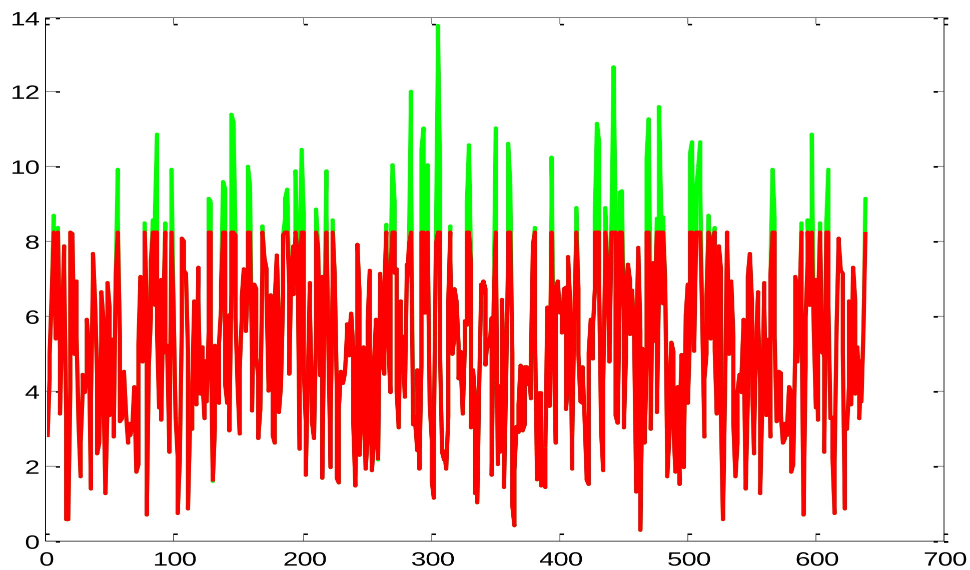

Fig 3.4: Effect of Clipping in OFDM based WiMAX System

$$X_k [n] = \{-A \; ; X [n] => -A\} \tag{3.1}$$

$$X_k [n] = \{X[n] \; ;-A<|X [n]| < A\} \tag{3.2}$$

$$X_k [n]= \{A \; ; X [n] >= A\} \tag{3.3}$$

Here A is the clipping level.

Clipping is nonlinear signal distortion PAPR reduction process. Clipping and filtering technique is effective for the problem of expanding spectrum. Filtering can prevent growth of spectrum and can eliminate the radiation which are outside the band, but the use of filtering after clipping cause regrowth of signal that will of course make signal exceed clipping level. The technique of clipping and filtering reduces the PAPR but does not expand the bandwidth but this technique also has a major problem of time consumption and computation complexity [30].

3.3 PRECODING TECHNIQUE

Precoding in OFDM based systems is multiplying the modulated data of each OFDM block by a precoding matrix before IFFT and transmission. A precoding matrix which is predefined is used in the OFDM based systems so no connection is needed between the sender and the receiver. Same precoding technique for all OFDM symbols will also avoid all the processing needed in block based optimization methods needed in nonlinear signal scrambling techniques.

Linear precoding is already used techniques like Orthogonal frequency multiplexing (OFDM), coded OFDM (COFDM), discrete multi-tone (DMT), time division multiple access (TDMA), frequency division multiple access and code division multiple access transmission systems. All the communication techniques use precoding idea with different precoding matrix say *F*. PAPR reduction can also be handled more intelligently using the precoder matrices in OFDM based systems hence as a result efficiency and quality of the transmission process increases [29]. Precoding technique is PAPR reduction technique used in OFDM based system for maintaining perfect calibration on transmission. Precoding technique is applied in frequency domain signal which is further converted to time domain using IFFT. Precoding technique is used to maintain the low power level of signal by using frequency domain transforms. The PAPR reduction techniques must compensate the nonlinearities of HPA. Precoding is found to be the only linear technique to reduce high PAPR in WiMAX. It is possible to reduce the PAPR of OFDM signals by precoding without affecting properties of the OFDM block by using any band efficient modulation like BPSK, QPSK etc. Precoding technique is a linear transformation, can reduce the PAPR to the level of PAPR of single carrier systems [9].

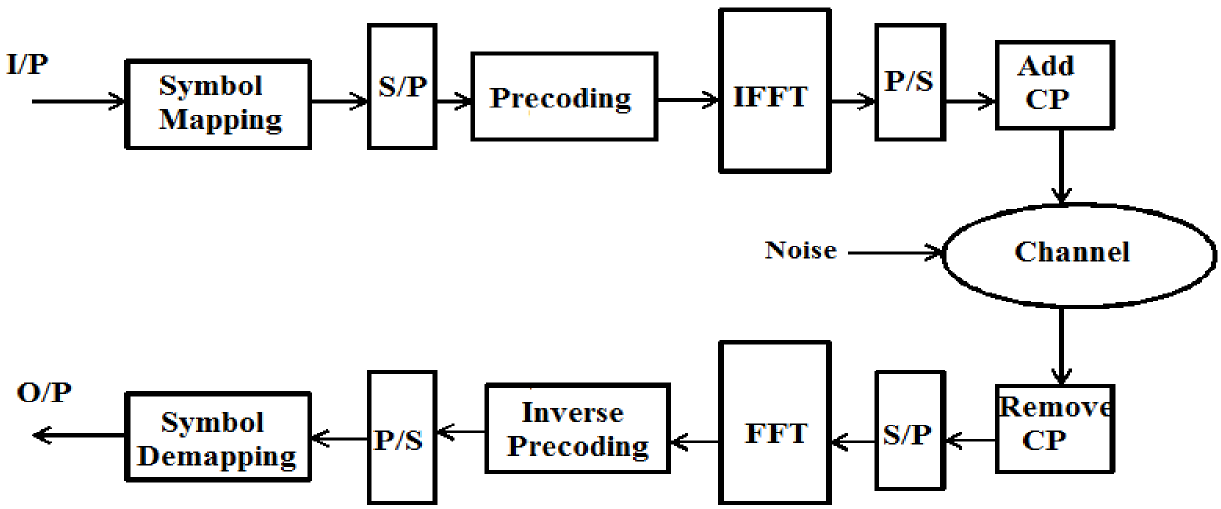

Fig 3.5: Precoding technique used in WiMAX

Precoding technique is a linear transformation technique where information carrying bit sequence blocks s(n); $0 \leq n \leq M\text{-}1$ is mapped to signal sequence u(n); $0 \leq n < P\text{-}1$with a transformation matrix F i.e. u(n) =Fs(n). Here P is greater than M. Hence some redundancy is introduced into the data sequence before the transmission. It is similar to the error correcting coding. If the channel is known the data vector is multiplied by a unitary matrix to generate a transmit vector that can be sent over the channel. Error correcting codes are introduced to correct the bits that have errors if any differences arise during the communication over channels.

The signal with N subcarriers can be written as:

$$X(n) = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} k(m).e^{j2\pi m \frac{n}{N}}, n = 0,1,2,.....,N-1 \qquad (3.4)$$

Let C, denoted $C = [c_0,c_1,c_2..........c_{k-1}]^T$ is modulating symbols on K data subcarriers after the process of signal constellation mapping. The vector D is obtained by precoder process and will be mapped to N –points using IFFT. The length of precoded data will be as same as modulated data to avoid redundancy.

$$D = [d_0, d_1, d_2 \ldots\ldots\ldots\ldots d_{k-1}]^T \qquad (3.5)$$

The precoded signal in time domain can be written as:

$$X(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} d(n).e^{j2\pi k \frac{n}{N}}, k = 0,1,2,\ldots.., N-1 \qquad (3.6)$$

The major advantages of linear precoding based techniques are no bandwidth expansion, no power increase, no data rate loss, no BER degradation because of zero distortion. The precoding has been considered as a best among nonlinear and linear techniques as it improves PAPR without increasing complexity of system and by maintaining orthogonality between subcarriers. Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Hilbert Transform (HT) and Zadoff-Chu Transform (ZCT) are various frequency domain transform techniques that are used as precoding techniques to reduce PAPR of a system. Although the OFDM systems can successfully overcome the ISI effect, but the signals with large peaks causes high PAPR. Sum of a number of independently modulated subcarriers causes large difference between the average signal power and the maximum signal power that will degrade performance of the system that causes more complex converters and power amplifiers. The large output initiates the power amplifiers in nonlinear regions which cause distortion to degrade the performance. This problem can also be overcome by adding a proper precoder in the transmitter and the corresponding inverse precoder in the receiver.

Basic Precoding techniques used are:

- Discrete Cosine Transform
- Discrete Sine Transform
- Chirp-Z Transform

3.3.1 Discrete Cosine Transform

DCT conveys a finite sequence of data in terms of a sum of cosine functions oscillating at different frequencies and discrete problem is so natural and almost unavoidable. Each continuous problem may have many approximations in discrete form so discrete case has a new level of variety and complexity. Each discrete cosine transforms (DCT) uses N real basis vectors whose components are in cosine form and these vectors are orthogonal and the transform is extremely useful in many applications. DCT basis contains the eigenvectors of a symmetric second difference matrix. DCT is a Fourier related transform similar to the discrete Fourier transform (DFT) but it uses only real numbers [30]. DCTs are equivalent to twice length of DFTs and it is a real transform that uses only real valued cosine functions with better computational efficiency than DFT which is a complex transform.

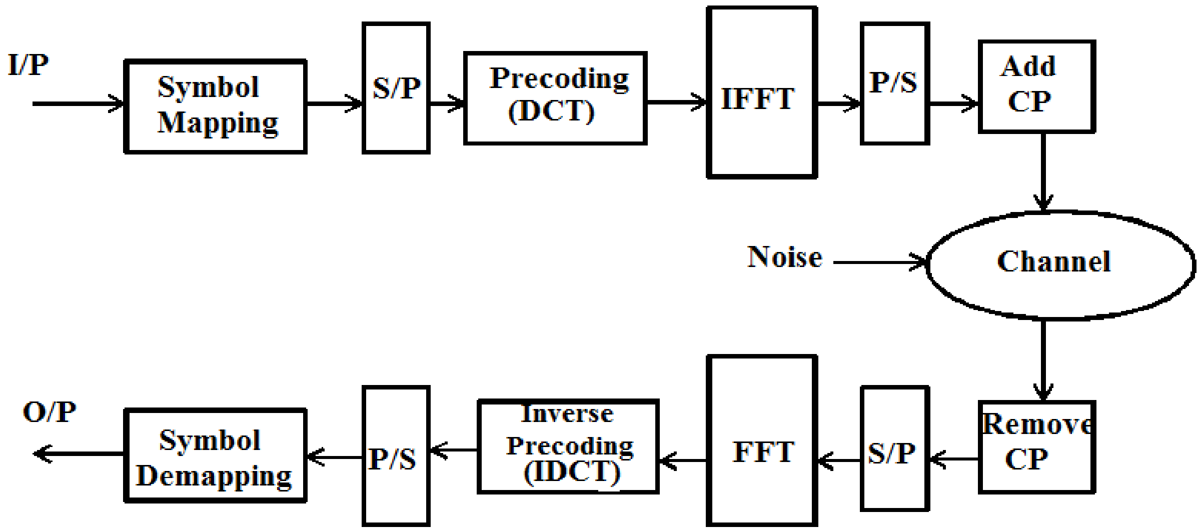

Fig 3.6: DCT precoding technique used in WiMAX

The discrete cosine Transform (DCT) can be used as precoding technique in WiMAX system. The DCT's energy compaction properties are useful for applications on communication of data. Mathematically, the unitary DCT of a Modulated sequence z is

$$y(k) = w(k)\sum_{n=0}^{N-1} z(n)\cos(\frac{\pi(2n-1)(k-1)}{2N});1 \le k \le N\ , \qquad (3.7)$$

Where,

$$w(k)=1/\sqrt{N}, \quad \text{for } k=1 \qquad (3.8)$$

$$w(k)=\sqrt{2/N}, \quad \text{for } 2\le k \le N \qquad (3.9)$$

After IFFT we get,

$$x(n) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} y(k).e^{(j2\pi.i.n/N)};0 \le n \le N-1 \qquad (3.10)$$

The addition of Cyclic Prefix provide x(t) from x(n) to calculate PAPR for DCT precoding based WiMAX system.

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \tag{3.11}$$

3.3.2 Discrete Sine Transform

The Discrete Sine Transform (DST) is similar to the Discrete Fourier Transform (DFT), but DST uses a real matrix. DST is computationally equal to the imaginary parts of a DFT and having doubled the length. DST operates on real data with odd symmetry, when the speech signal corrupted by noise then the signal is processed using different transforms like the DFT, DCT, and DST. Comparison on every system proves that the Discrete Sine Transform (DST) is most effective for eliminating noise from speech to provide original speech [29]. Discrete sine transform coefficients at the low frequency regions are mostly speech and at the high frequency regions are mostly noise. So it is an advantage of using DST as a precoder. Energy distribution throughout the segment of speech is uniform in DST. Ability of DST is not stronger than DCT but there is no need to be stronger to be best. In the processing of White noise also DST is far better than DCT.

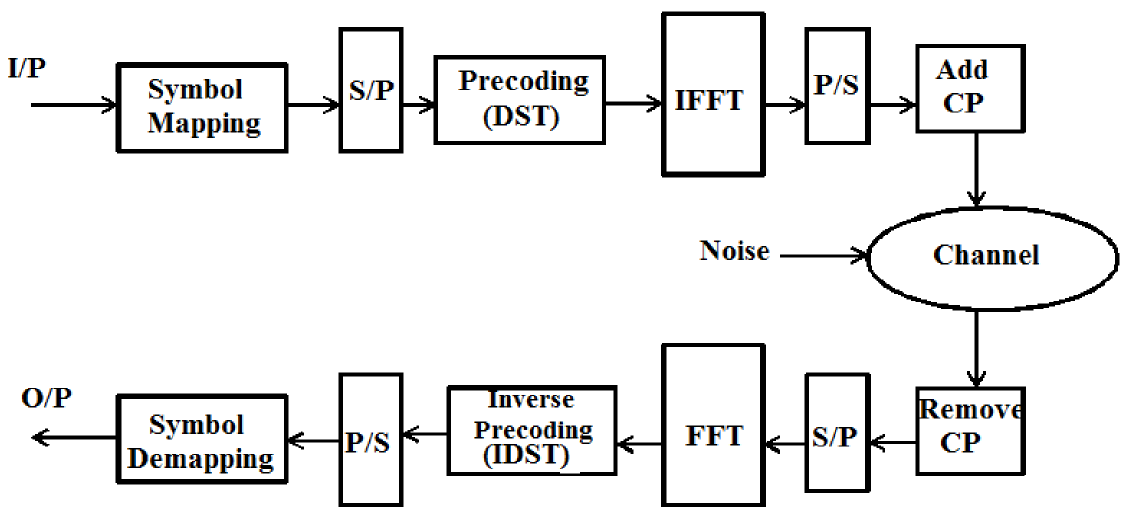

Fig 3.7: DST Precoding technique used in WiMAX

Mathematically, the DST of modulated data z is

$$y(k) = \sum_{n=1}^{N} z(n)\sin(\frac{\pi kn}{N+1});1 \le k \le N \quad (3.12)$$

After IFFT we get,

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} y(k).e^{(j2\pi.i.n/N)}; 0 \le n \le N-1 \quad (3.13)$$

The addition of Cyclic Prefix provide x(t) from x(n) to calculate PAPR for DST precoding based WiMAX system.

$$PAPR = \frac{\max|x(t)|^2}{E|x(t)|^2} \quad (3.14)$$

3.3.3 Chirp-Z Transform

For analysing frequency rage, such as recording frequency response measurements, matching voice patterns, or displaying spectrum information on the face of an amateur radio FFT is found to be the mostly preferred technique but lesser known technique Chirp Z transform (CZT) is lesser known technique can do all the above mentioned task with additional flexibility to identify both spectral analysis bandwidth and the resolution within that same spectrum and provides real and imaginary outputs. By which spectral magnitude and phase can be calculated.

CZT not only calculate spectrum on the unit circle but also can calculate the z-transform along circles point or on the z-plane spiral. Sampling frequency is taken as reference on the unit circle to determine start and stop bands located. Determination of resolution is done dividing the sampling frequency bandwidth by the total number input samples. CZT is much more flexible compared to DFT. By sampling rate and number of samples the resolution can be calculated using CZT. FFT is faster than CZT but CZT is much more efficient than FFT. CZT is also capable recording frequency response measurements by analyzing range of frequencies. CZT can be used to match voice patterns and display spectrum information. The need of more resolution and flexibility than the computational load and time delay can make Chirp Z Transform a revolutionary precoding technique in OFDM based WiMAX system.

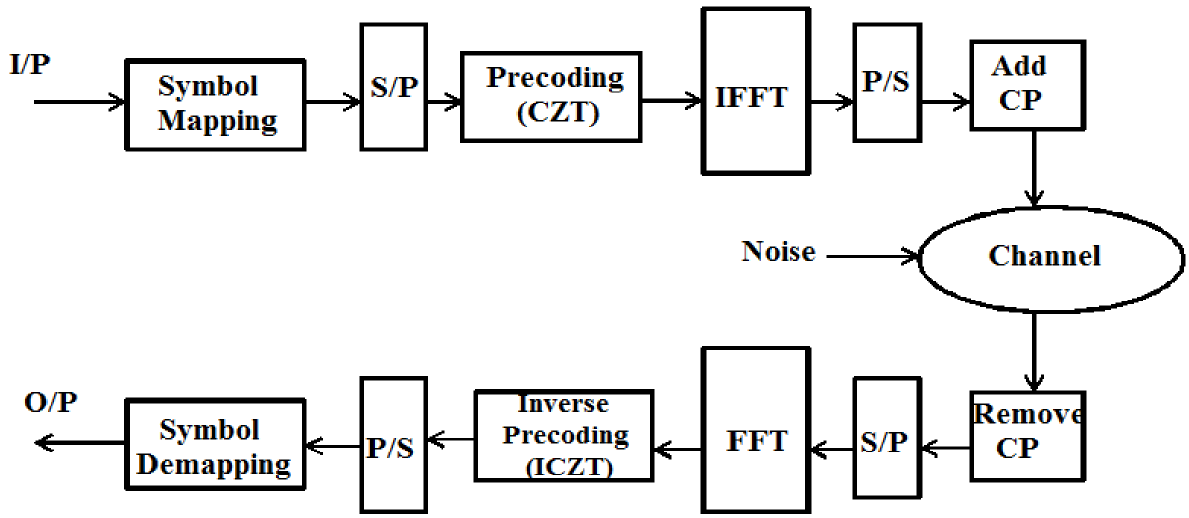

Fig 3.8: Chirp-Z Transform Precoding technique used in WiMAX

Chirp-Z Transform can be defined as Fast Fourier Transform (FFT) mathematically. FFT cancel out IFFT to provide low power subcarriers and independently modulated carriers are canceled out. Additional flexibility of CZT is to specify spectral analysis bandwidth and the resolution within bandwidth. CZT is more efficient and flexible technique than FFT. Mathematically, the chirp-Z transform of an input sequence z is

$$y(k) = \sum_{i=0}^{N-1} z(i).e^{(j2\pi.k.n/N)}; 0 \le k \le N-1 \tag{3.15}$$

IFFT for the output of CZT can be obtained by (14)

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} y(k).e^{(j2\pi.i.n/N)}; 0 \le n \le N-1 \tag{3.16}$$

The addition of Cyclic Prefix provide x(t) from x(n) to calculate PAPR for CZT precoding based WiMAX system.

$$PAPR = \frac{\max|x(t)|^2}{E|x(t)|^2} \tag{3.17}$$

3.4 HYBRID TECHNIQUES

The linear precoding technique is used with Non-linear techniques to form a hybrid technique that will help in further reduction of high PAPR. Chirp Z transform, the most efficient precoding technique, can be used with clipping, SLM and PTS to form hybrid technique. Precoding technique is used after the modulation of data and before the use of IFFT [29]. IFFT is used for multicarrier transmission of data. Precoding does not effect on Bit Error Rate of the system so there will be no effect on BER because of hybrid techniques [28]. The use of Hybrid technique is no more complex than a simple nonlinear PAPR reduction technique. Precoding technique is used in modulated data and nonlinear techniques like SLM, PTS and clipping are used with IFFT.

3.4.1 Precoding and Clipping

Precoding is used before IFFT and after the modulation to reduce independently modulated carriers. Chirp Z transform (CZT) is used as precoding technique and clipping of signal up to the certain level of amplitude is done after IFFT. Clipping is nonlinear signal distortion PAPR reduction process and distortion with in band and outside the band will degrade the performance of system[21]. X(t) is the output signal used to calculate PAPR. This technique will reduce PAPR by clipping as well as precoding technique.

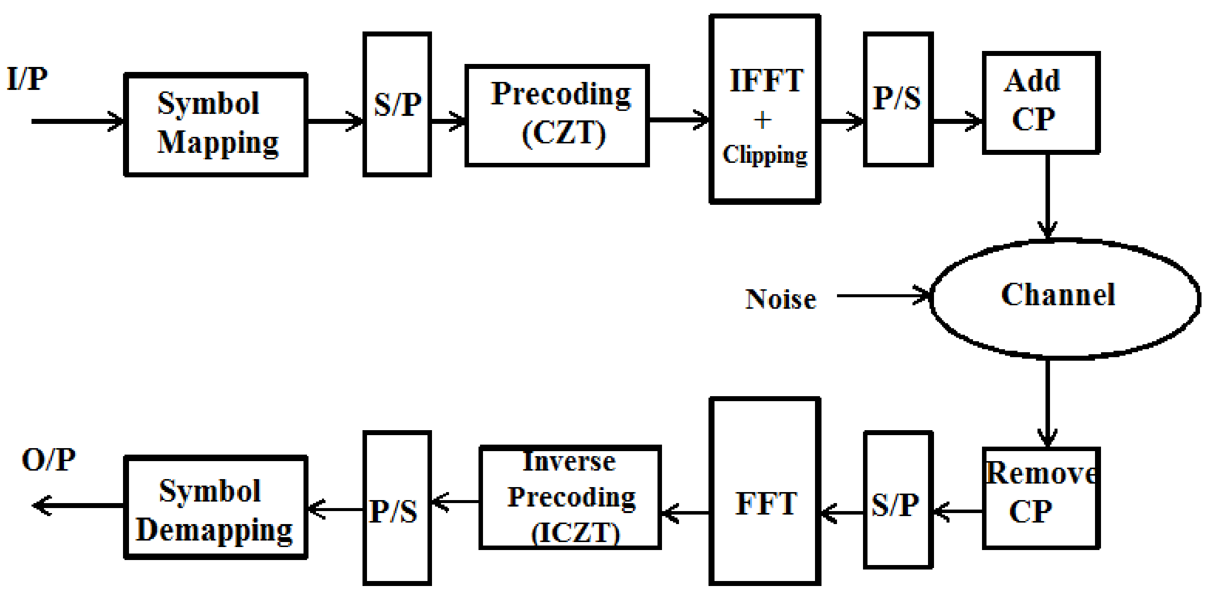

Fig 3.9: Chirp-Z precoding and clipping based WiMAX

There is no need of De clipping or increasing the amplitude of data because that will degrade BER.

$$X_k[t] = \{-A;\ X[t] => -A\} \tag{3.18}$$

$$X_k[t] = \{X[t];\ -A<|X[t]| < A\} \tag{3.19}$$

$$X_k[t] = \{A;\ X[t] >= A\} \tag{3.20}$$

Here A is the clipping level.

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \tag{3.21}$$

3.4.2 Precoding and SLM

A complete subset signals are generated with different information type in different block and one block of data is selected by calculating minimum PAPR and transmitted. CZT precoded signal is provided to SLM technique. IFFT is used within SLM technique for multicarrier modulation and transmission of data. The data having minimum PAPR is always selected in SLM for transmission to keep PAPR as lower as possible [22].

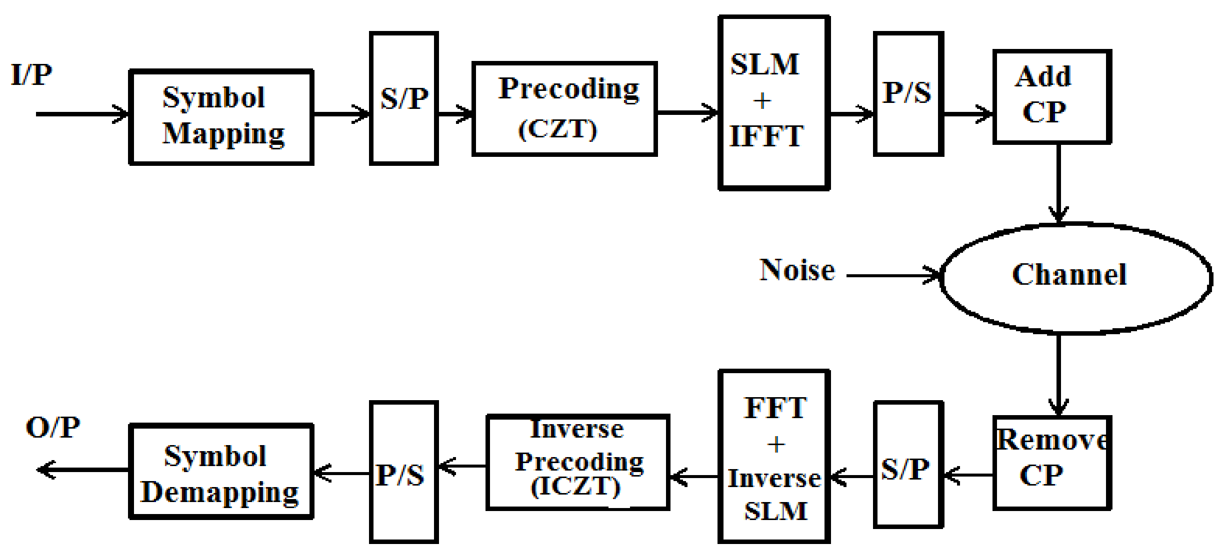

Fig 3.9: Chirp-Z precoding and SLM based WiMAX

SLM technique consists of IFFT in itself after the phase convolution with the block of data. The data blocks done with IFFT $X_k(t)$; k=1, 2, 3, ….N are taken individually to calculate PAPR of each block data and the data block with the minimum PAPR will be taken as the data to be transmitted where N is number of data blocks. The selected data block is sent with the side information of phase shift that may degrade the spectral efficiency of the system. The K^{th} data block selected is taken as x(t) to calculate the actual PAPR of information signal. Inverse SLM at the receiver side will multiply the side information with data to find actual data to proceed.

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \tag{3.22}$$

3.4.3 Precoding and PTS

The input data frame is divided into non-overlapping sub blocks, which is main purpose behind this method and each sub block is phase shifted by a constant factor to reduce PAPR. Reduction in the PAPR problem is done by probabilistic method of PTS. CZT precoded signal is provided to PTS technique. IFFT is done within the PTS technique. This technique is advanced version of SLM technique with the advantage of no need to send side information with data. This advantage of PTS makes it more powerful technique than SLM and save spectral efficiency degradation [21]. The signal with minimum PAPR is taken as the transmitting signal. Precoding is always done on modulated data and works on frequency domain signal.

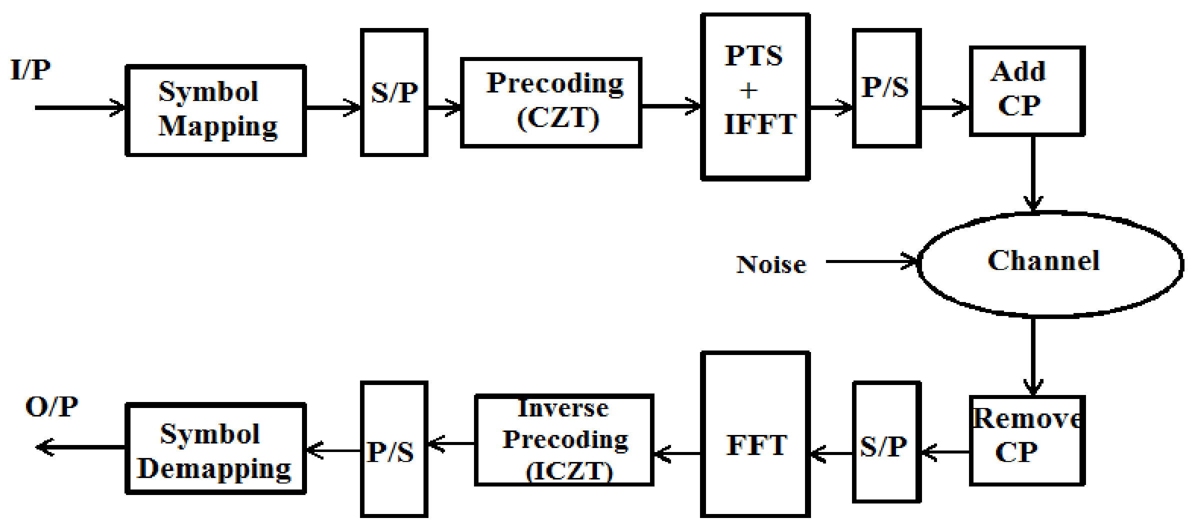

Fig 3.10: Chirp-Z precoding and PTS based WIMAX

The improvement in spectral efficiency and no BER degradation makes Precoding cum PTs technique a revolutionary technique. The precoded data is phase shifted in each block of data and IFFT is done. After IFFT the optimization of phase will return the actual form of data and each data $X_k(t)$; k=1, 2, 3, ….N are taken individually to calculate PAPR of each block data and the data block with the minimum PAPR will be taken as the data to be transmitted where N is number of data blocks [28]. The selected data block can be taken as x(t) to calculate the PAPR of transmitting signal.

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \quad (3.23)$$

3.5 PROPOSED WORK PLAN

- The confirmed physical layer of WiMAX is studied and the function of each block of transmitter. The implementation processes need some standards followed earlier so that we can get actual results. Randomization, interleaving, coding and modulation are completed that results the constellation diagram for M-PSK modulation.
- As the implementation of transmitter of physical layer up to modulation was already completed we were left with IFFT and CP insertion so we completed the whole transmitter part of WiMAX physical layer and started studying about PAPR calculation using pre-coding technique. Techniques used like DCT, DST are used and found that the PAPR reduction is possible by high margin by using Pre-coding technique.
- As the research is for the further more reduction in PAPR, the search of new precoding technique is started and found that chirp-Z transform is unused transformed techniques as Precoding techniques in WiMAX. As the PAPR calculation is started it was a successful approach that chirp-Z transform was providing less PAPR than other precoding techniques.
- The study of PAPR and reduction was successful up to the point but the major question was whether CZT can improve BER or not. To know this, performance analysis of CZT precoding based WiMAX has been done and it was successful research to have a technique that can reduce both PAPR and BER.

- As the CZT precoding based WiMAX was successful on PAPR reduction and BER minimization, CZT precoding with nonlinear techniques like clipping, PTS and SLM are proposed and analyzed that we can reduce more PAPR by these techniques.

CHAPTER 4: RESULT AND DISCUSSION

This chapter is devoted to the graphical and simulation results comparison of the WiMAX system with different precoding schemes and other PAPR reduction techniques. The MATLAB simulation of PAPR and BER calculation are presented for proposed model of WiMAX by using different modulation schemes. Simulation has been carried out to evaluate the effect of different linear precoding techniques discrete cosine transform precoding, discrete sine transform precoding and chirp-Z transform precoding on the PAPR of signal. PAPR is evaluated statistically by using CCDF. To show the PAPR analysis of different systems, data is generated randomly and modulated by QPSK or X-QAM (where X=16, 64) respectively. Performance analysis of WiMAX system can be done by analyzing the PAPR and BER for AWGN channel of the system.

4.1 PAPR ANALYSIS OF CONVENTIONAL WIMAX SYSTEM WITH PRECODED WiMAX SYSTEM

Figure [4.1-4.6] describe the CCDF comparison of PAPR of conventional WiMAX system with different precoding (DCT, DST and CZT) based WiMAX system. X axis denote threshold for the PAPR and Y axis denote the probability to exceed the threshold level. It is seen that for CCDF= 10^{-1}, the PAPR of CZT Precoded WiMAX system is less than DCT Precoded, DST Precoded and conventional WiMAX system. It can be analyzed that the probability of peak for CZT Precoded WiMAX system is as small as 10^{-1} at PAPR values shown in simulations. It is seen that CZT Precoded WiMAX system has low PAPR compared to DST precoded, DCT precoded and conventional WiMAX system for different modulation schemes.

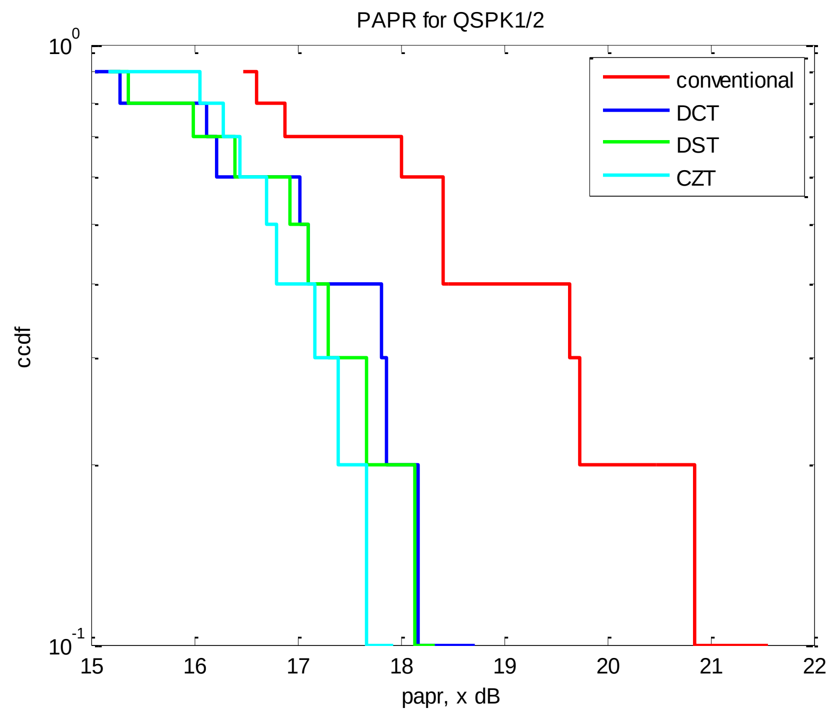

Fig 4.1: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for QPSK 1/2 modulation.

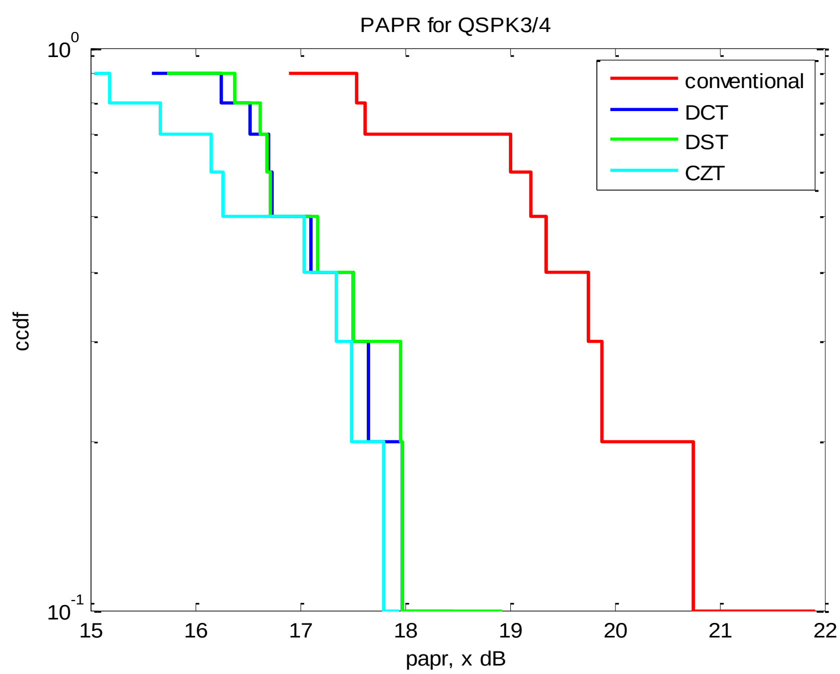

Fig 4.2: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for QPSK 3/4 modulation.

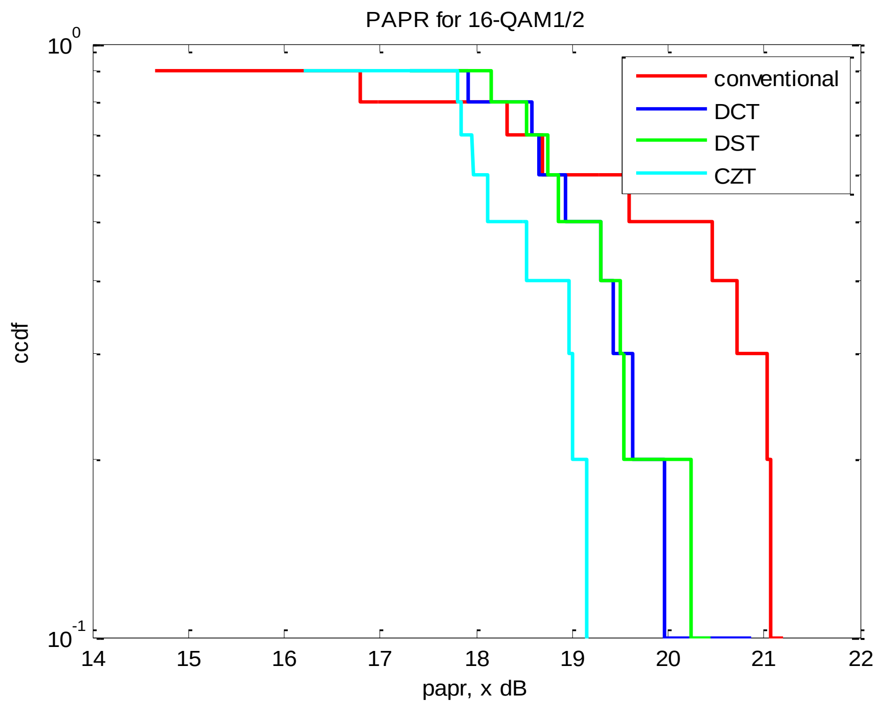

Fig 4.3: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for 16-QAM 1/2 modulation.

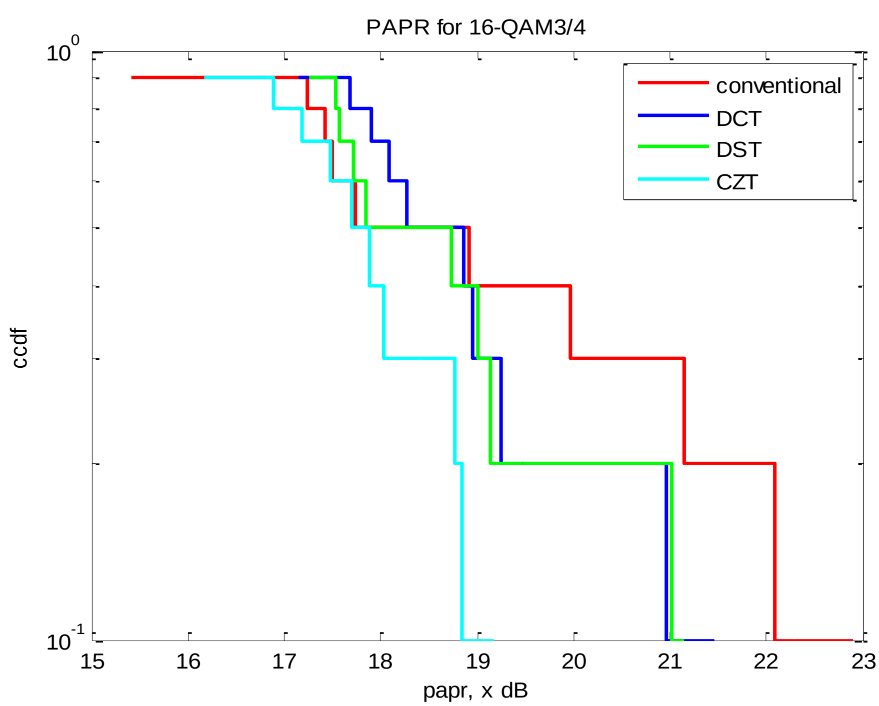

Fig 4.4: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for 16-QAM3/4 modulation.

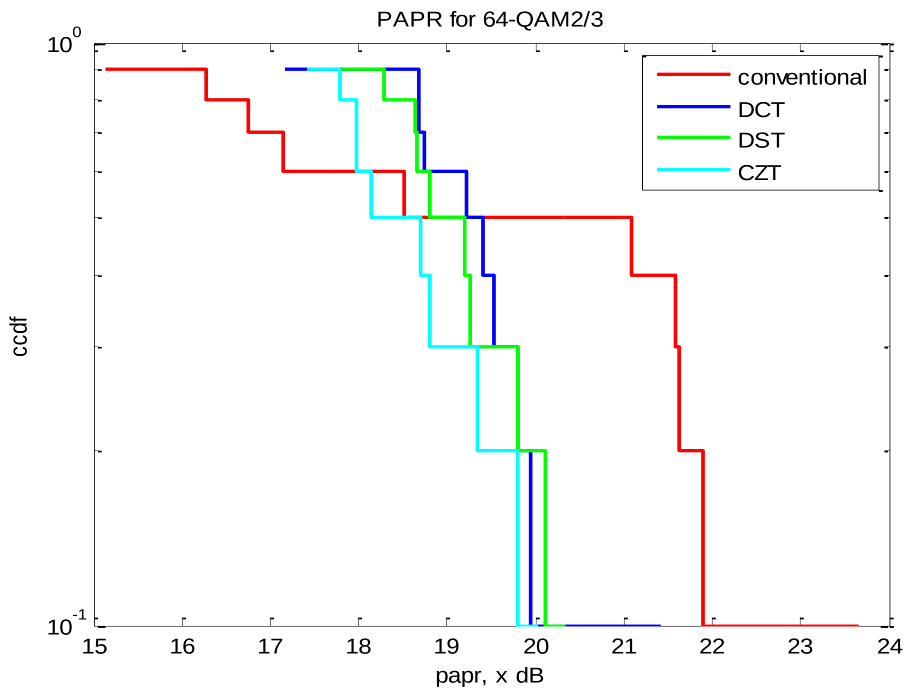

Fig 4.5: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for 64-QAM2/3 modulation.

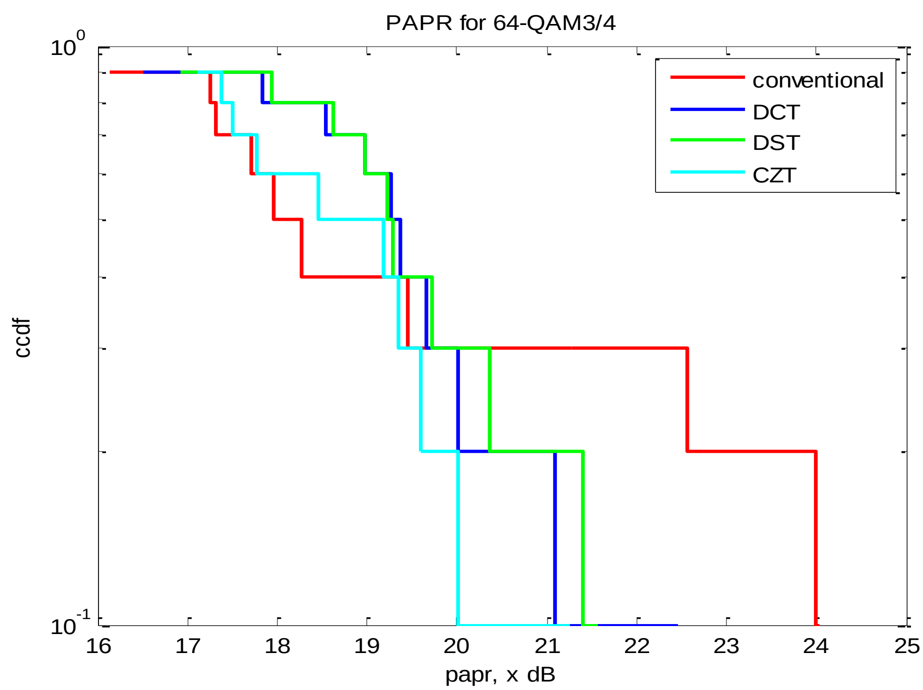

Fig 4.6: CCDF vs PAPR plot of different Precoding Techniques and conventional OFDM based WiMAX system for 64-QAM 3/4 modulation.

4.2 BER ANALYSIS OF CONVENTIONAL WIMAX SYSTEM WITH PRECODED WiMAX SYSTEM

Figure [4.7-4.12] shows SNR vs BER simulation of WiMAX system with and without Precoding techniques for QPSK or X-QAM (where x=16, 64). Analyzing the simulations gives the result that CZT precoded WiMAX system has less BER compare to DCT precoded, DST Precoded and conventional WiMAX system. As the BER is analyzed at particular SNR value, the difference in BER for CZT precoded WiMAX system to others techniques is clearly visible. The improvement in Bit Error Rate as well as PAPR makes CZT a revolutionary precoding technique for the WiMAX system.

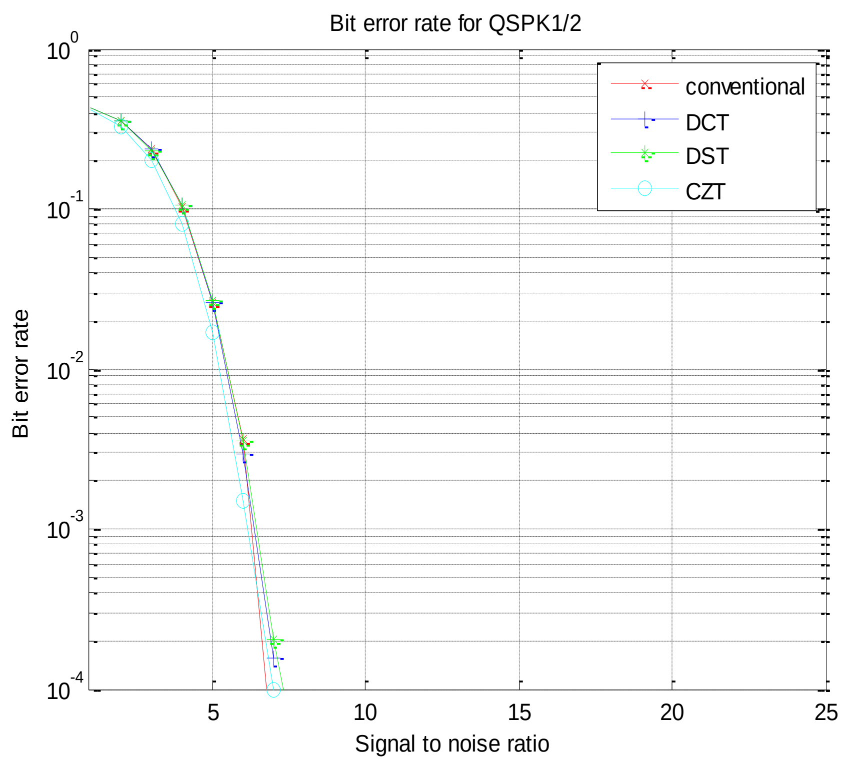

Fig 4.7: BER performance comparison of conventional WiMAX with Precoded WiMAX for QPSK 1/2 modulation.

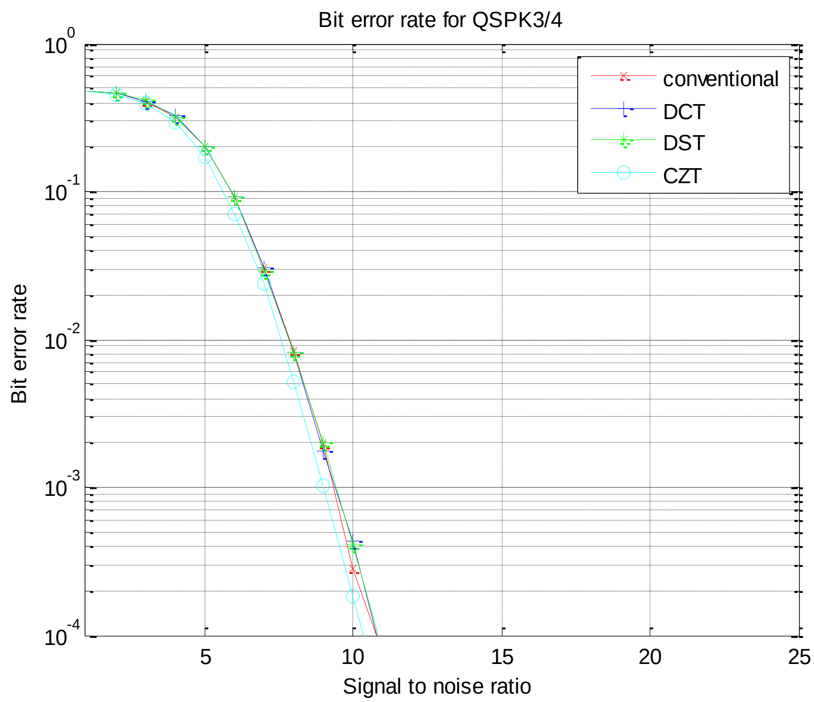

Fig 4.8: BER performance comparison of conventional WiMAX with Precoded WiMAX for QPSK 3/4 modulation.

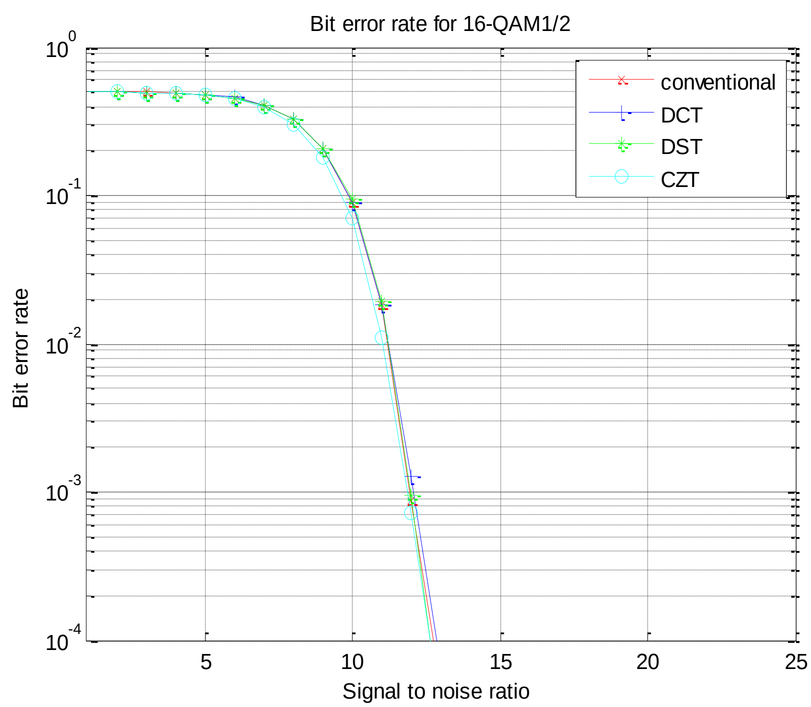

Fig 4.9: BER performance comparison of conventional WiMAX with Precoded WiMAX for 16-QAM 1/2 modulation.

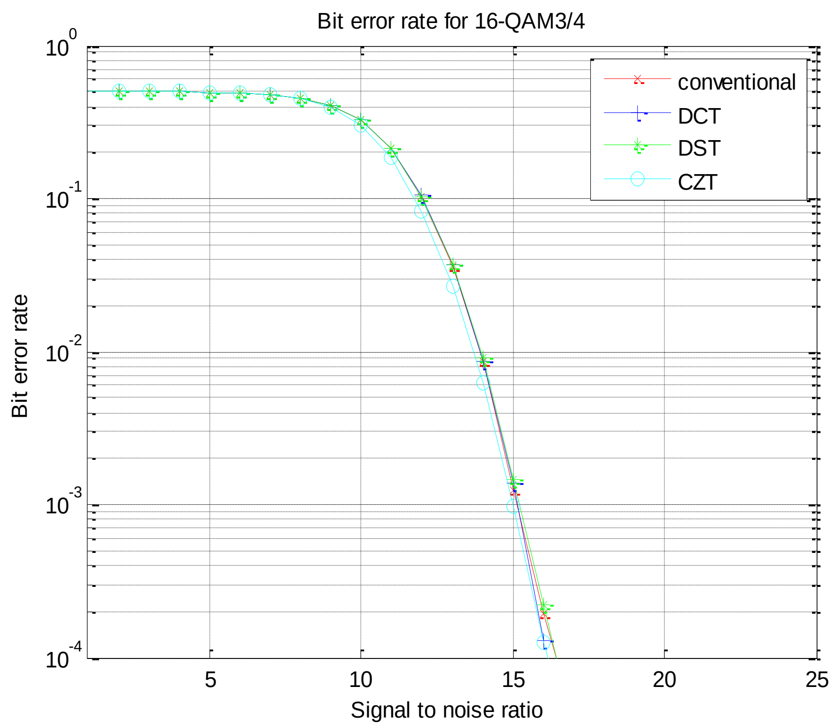

Fig 4.10: BER performance comparison of conventional WiMAX with Precoded WiMAX for 16-QAM 3/4 modulation.

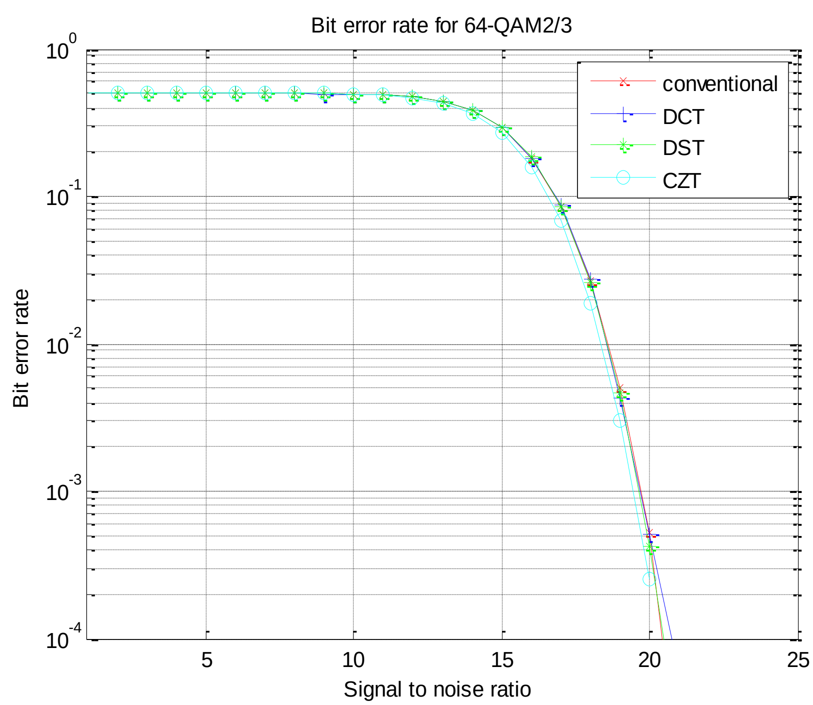

Fig 4.11: BER performance comparison of conventional WiMAX with Precoded WiMAX for 64-QAM 2/3 modulation.

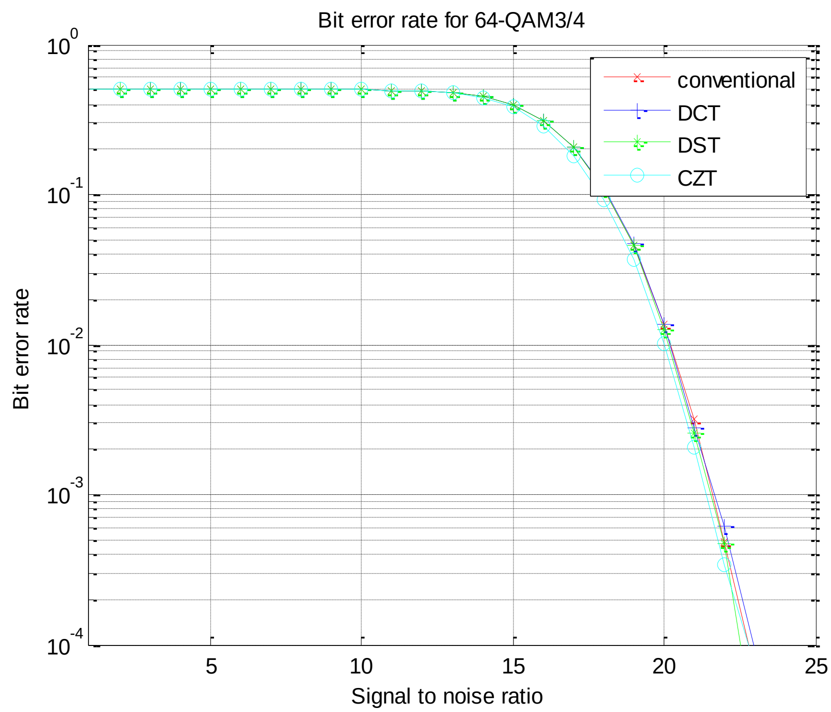

Fig 4.12: BER performance comparison of conventional WiMAX with Precoded WiMAX for 64-QAM3/4 modulation.

4.3 PAPR ANALYSIS OF CONVENTIONAL WIMAX SYSTEM WITH CLIPPED, PRECODED AND CLIPPING WITH PRECODING BASED WiMAX SYSTEM

Figure [4.13-4.18] describes the CCDF comparison of PAPR of conventional WiMAX system with different PAPR reduction techniques based WiMAX system. X axis denote threshold for the PAPR and Y axis denote the probability to exceed the threshold level. It is seen that for CCDF= 10^{-2} , the PAPR of CZT Precoding with clipping based WiMAX system is less than CZT Precoded, clipping and conventional WiMAX system. It can be analyzed that the probability of peak for CZT Precoding with clipping based WiMAX system is as small as 10^{-2} at PAPR values shown in simulations.

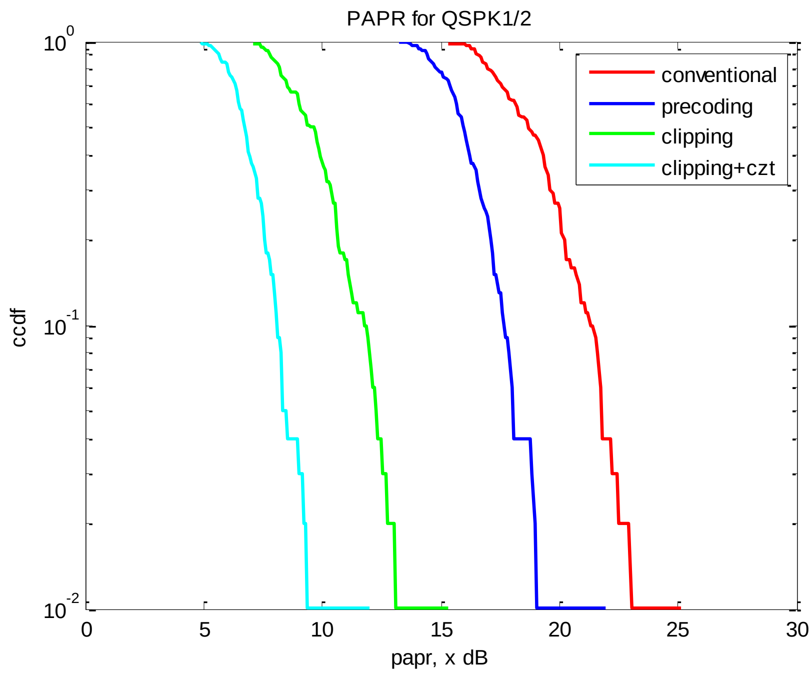

Fig 4.13: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK 1/2 modulation.

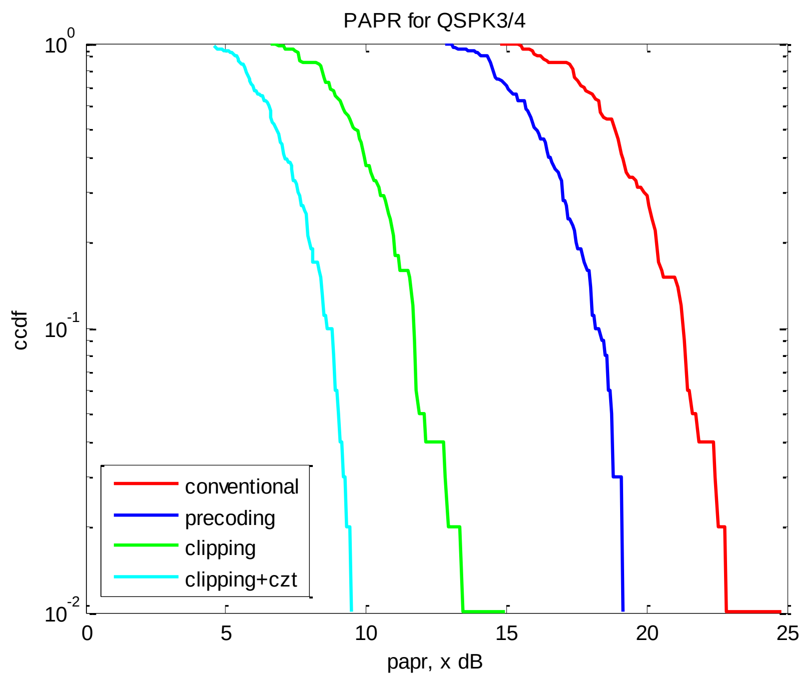

Fig 4.14: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK3/4 modulation.

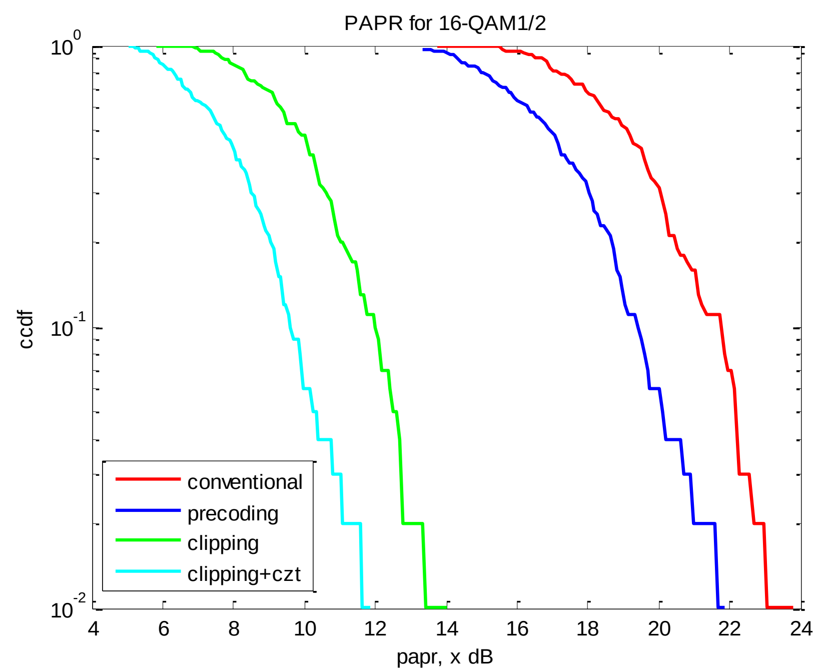

Fig 4.15: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM 1/2 modulation.

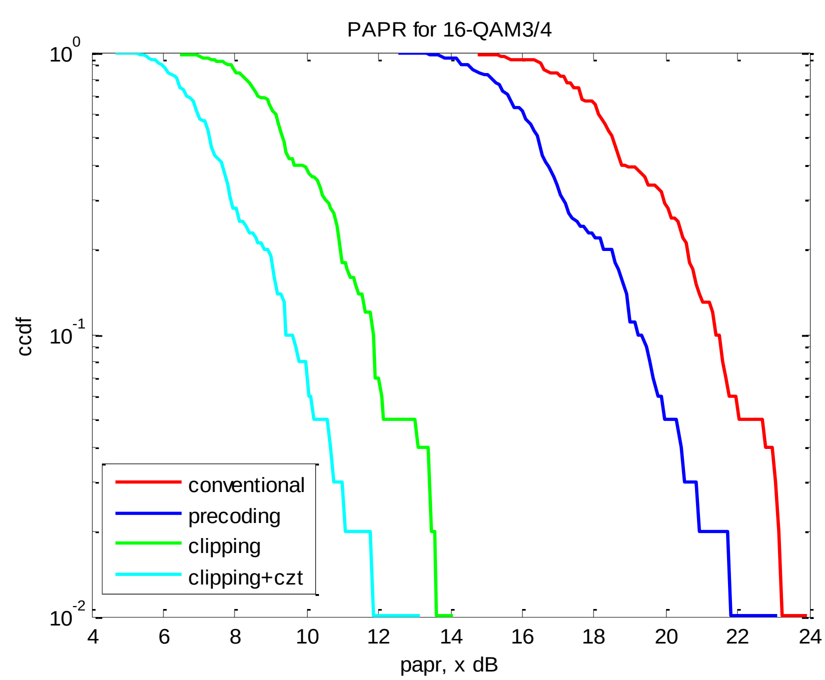

Fig 4.16: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM3/4 modulation.

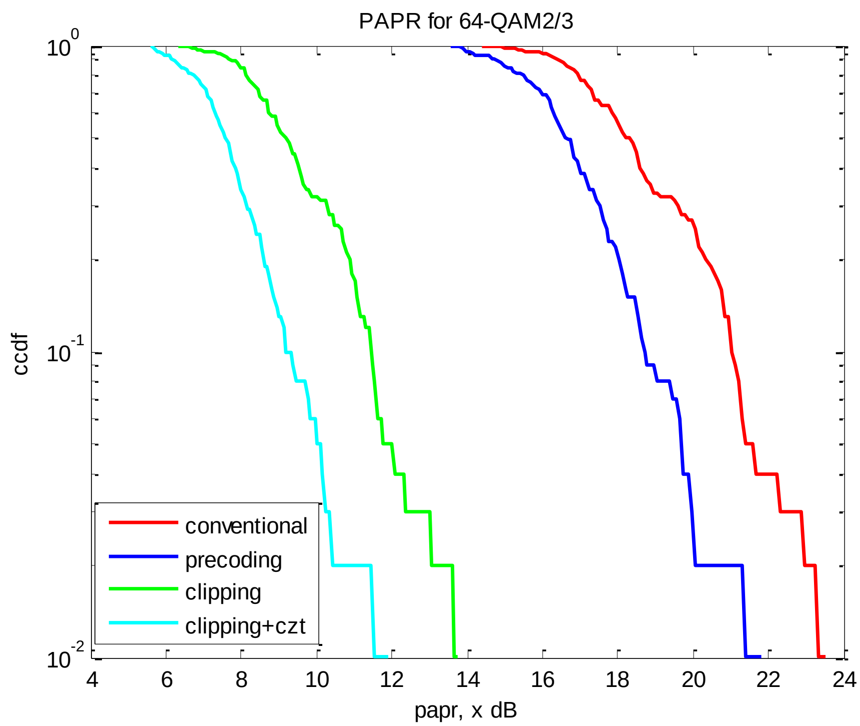

Fig 4.17: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM 2/3 modulation.

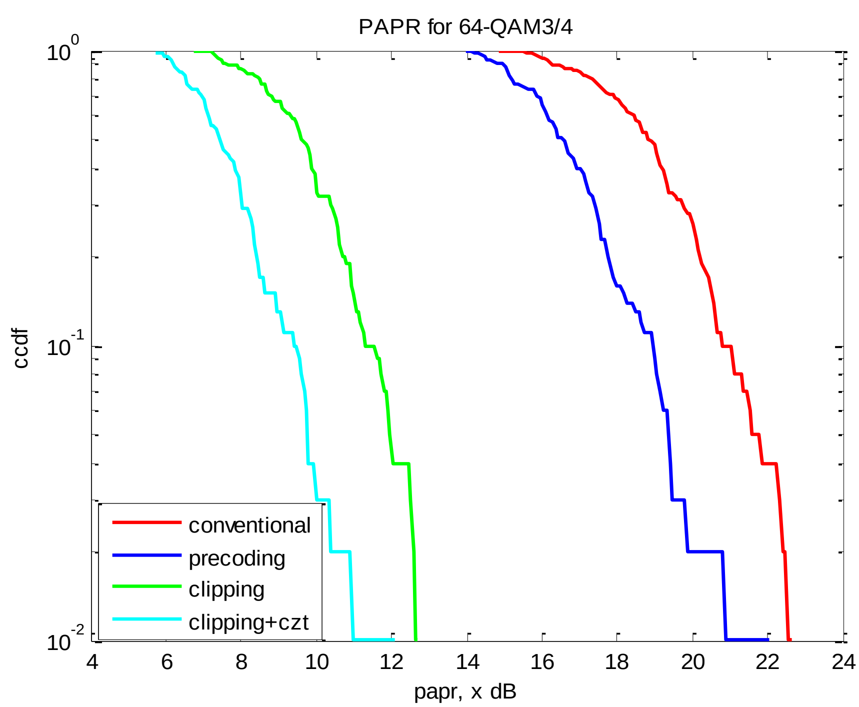

Fig 4.18: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM3/4 modulation.

4.4 PAPR ANALYSIS OF CONVENTIONAL WIMAX SYSTEM WITH PTS, PRECODED AND PTS WITH PRECODING BASED WiMAX SYSTEM

Figure [4.19-4.24] describes the CCDF comparison of PAPR of conventional WiMAX system with different PAPR reduction techniques based WiMAX system. X axis denote threshold for the PAPR and Y axis denote the probability to exceed the threshold level. It is seen that for CCDF= 10^{-2} , the PAPR of CZT Precoding with PTS based WiMAX system is less than CZT Precoded, PTS and conventional WiMAX system. It can be analyzed that the probability of peak for CZT Precoding with PTS based WiMAX system is as small as 10^{-2} at PAPR values shown in simulations.

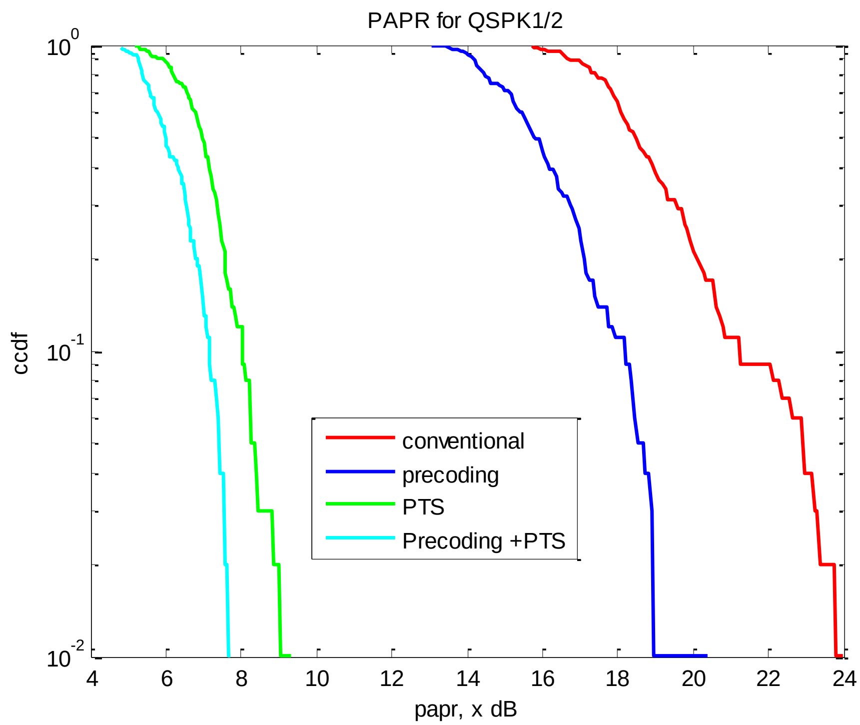

Fig 4.19: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK 3/4 modulation.

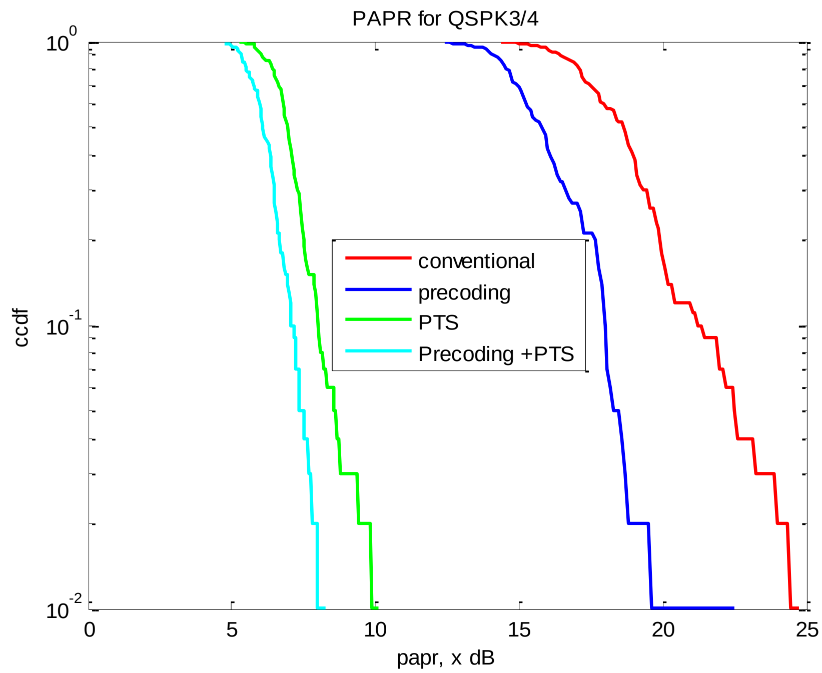

Fig 4.20: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK 3/4 modulation.

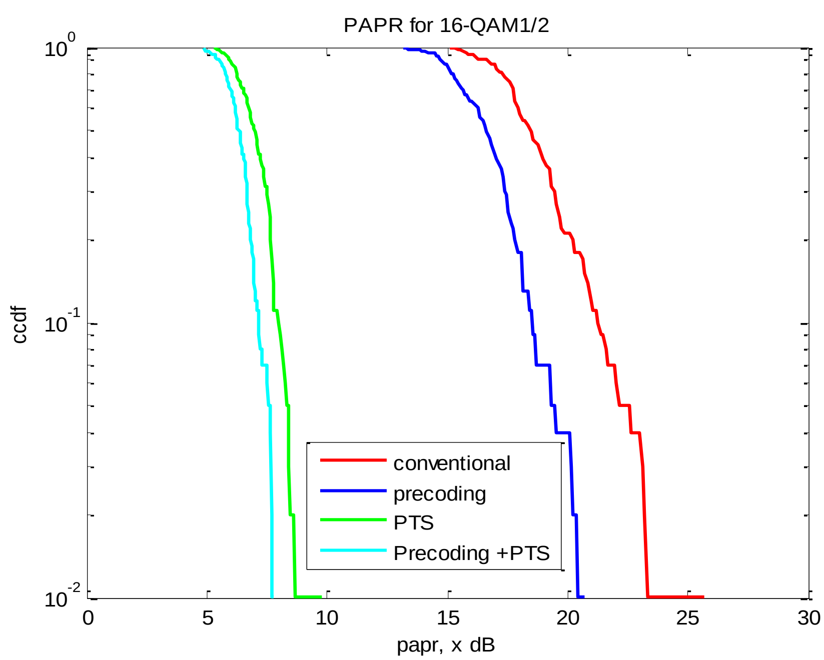

Fig 4.21: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM 1/2 modulation.

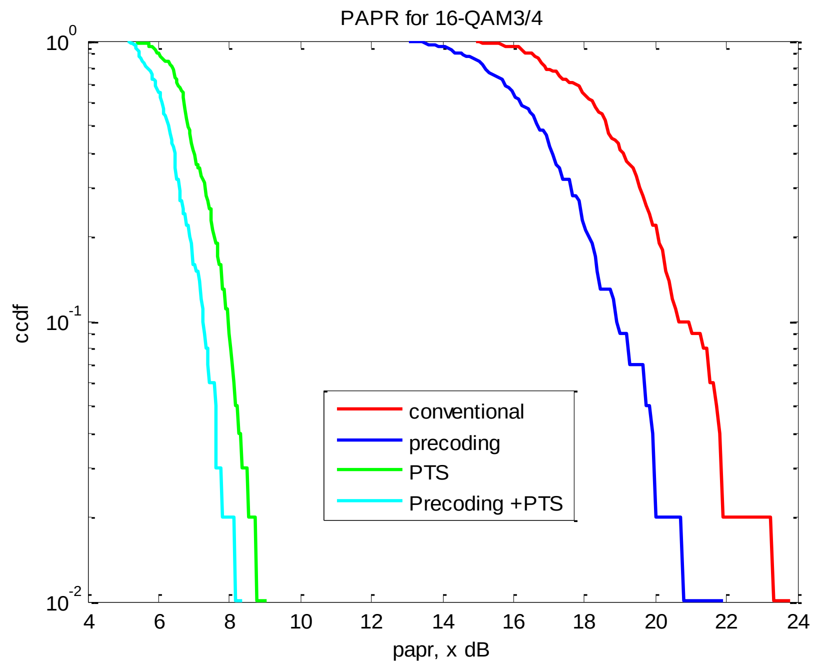

Fig 4.22: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM 3/4 modulation.

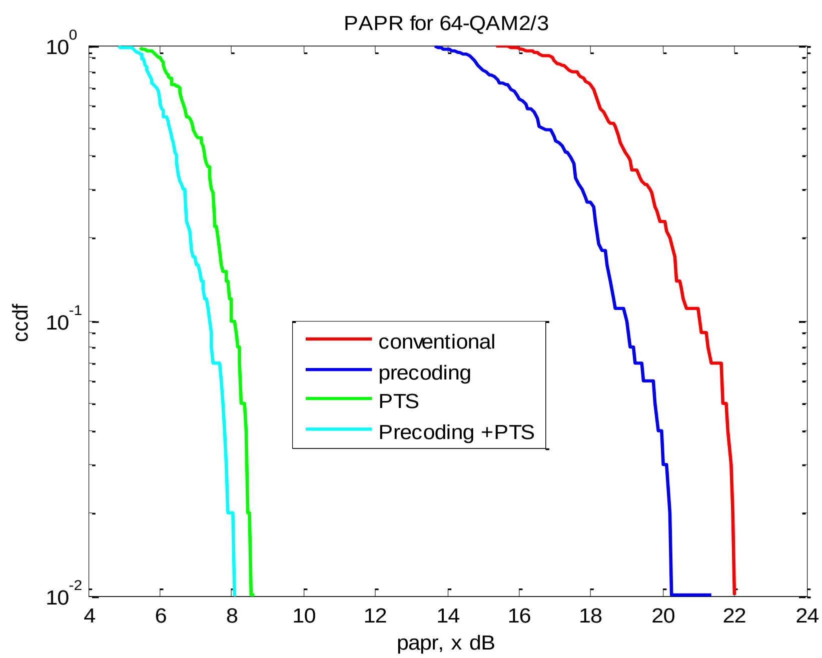

Fig 4.23: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM 2/3 modulation.

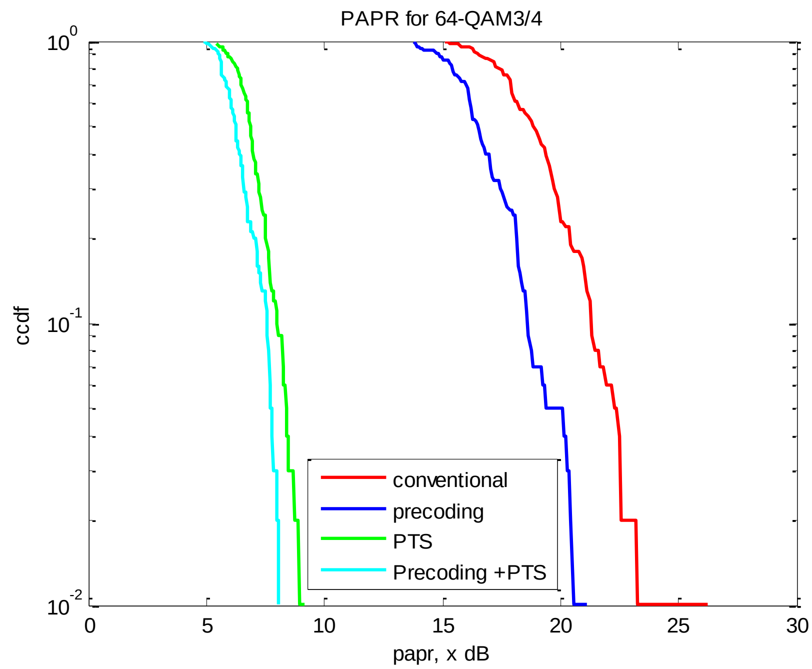

Fig 4.24: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM 3/4 modulation.

4.5 PAPR ANALYSIS OF CONVENTIONAL WIMAX SYSTEM WITH SLM, PRECODED AND SLM WITH PRECODING BASED WiMAX SYSTEM

Figure [4.25-4.30] describes the CCDF comparison of PAPR of conventional WiMAX system with different PAPR reduction techniques based WiMAX system. X axis denote threshold for the PAPR and Y axis denote the probability to exceed the threshold level. It is seen that for CCDF= 10^{-2} , the PAPR of CZT Precoding with SLM based WiMAX system is less than CZT Precoded, SLM and conventional WiMAX system. It can be analyzed that the probability of peak for CZT Precoding with SLM based WiMAX system is as small as 10^{-2} at PAPR values shown in simulations.

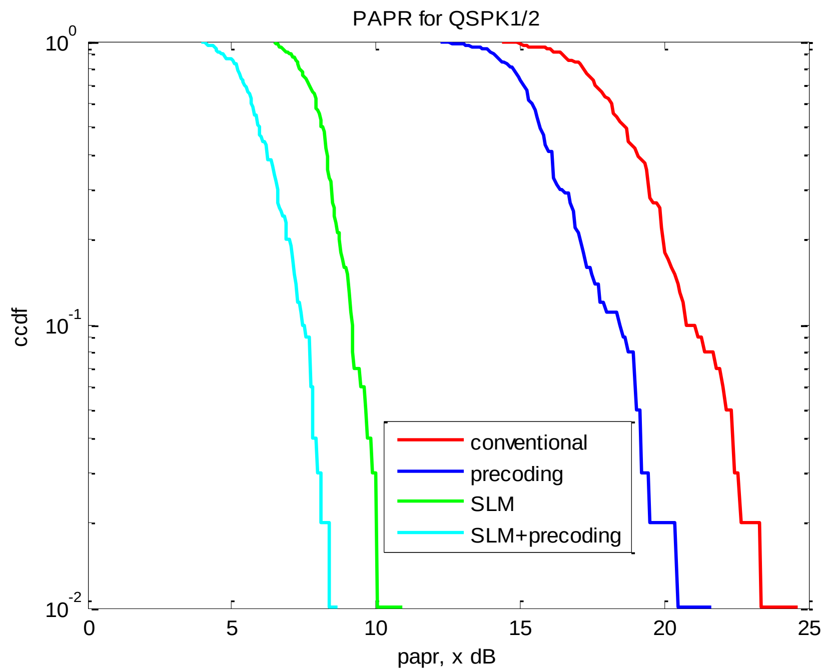

Fig 4.25: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK 1/2 modulation.

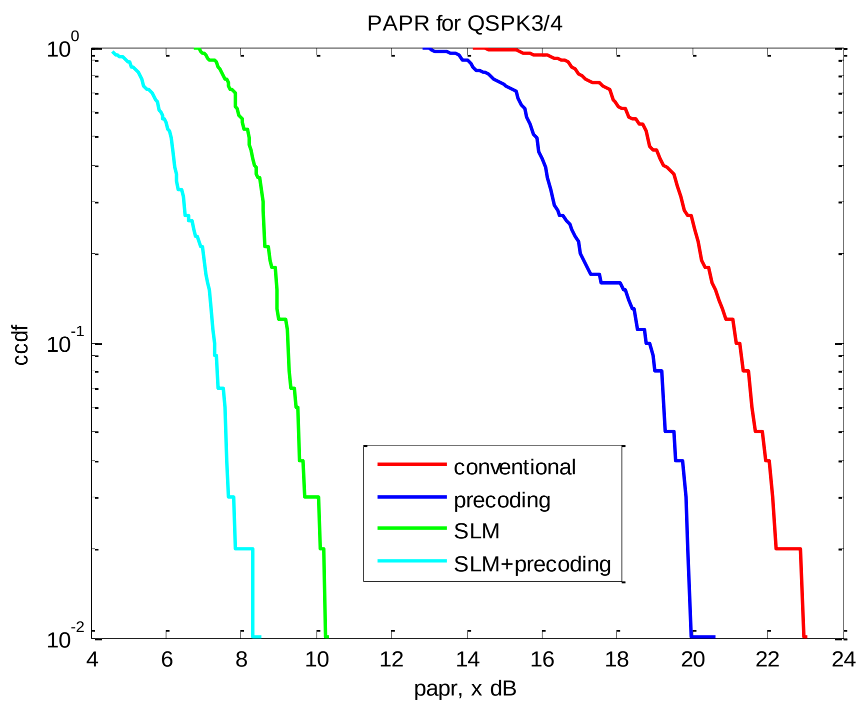

Fig 4.26: CCDF vs PAPR plot of different techniques and conventional WiMAX system for QPSK 3/4 modulation.

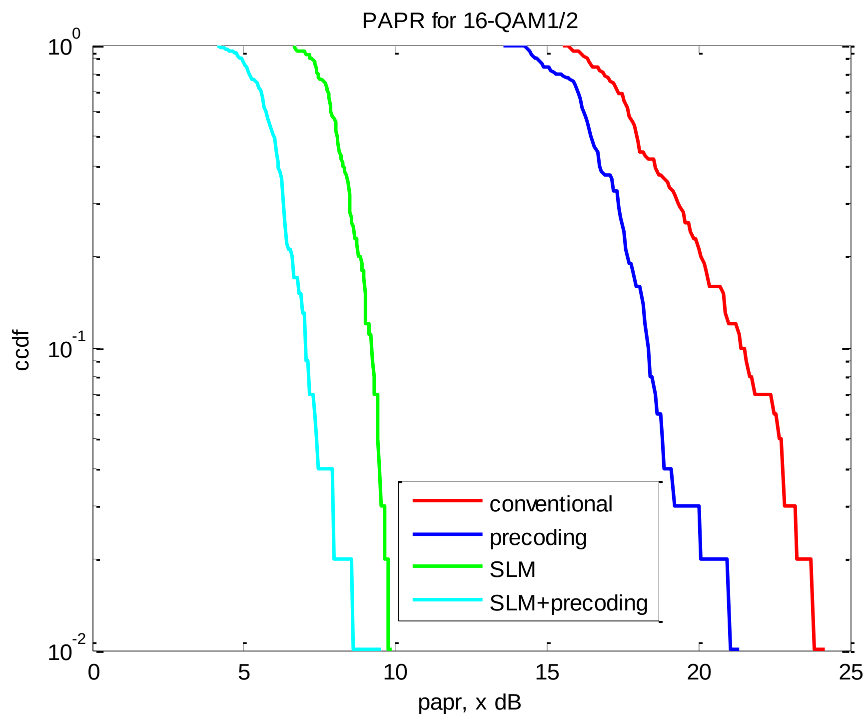

Fig 4.27: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM1/2 modulation.

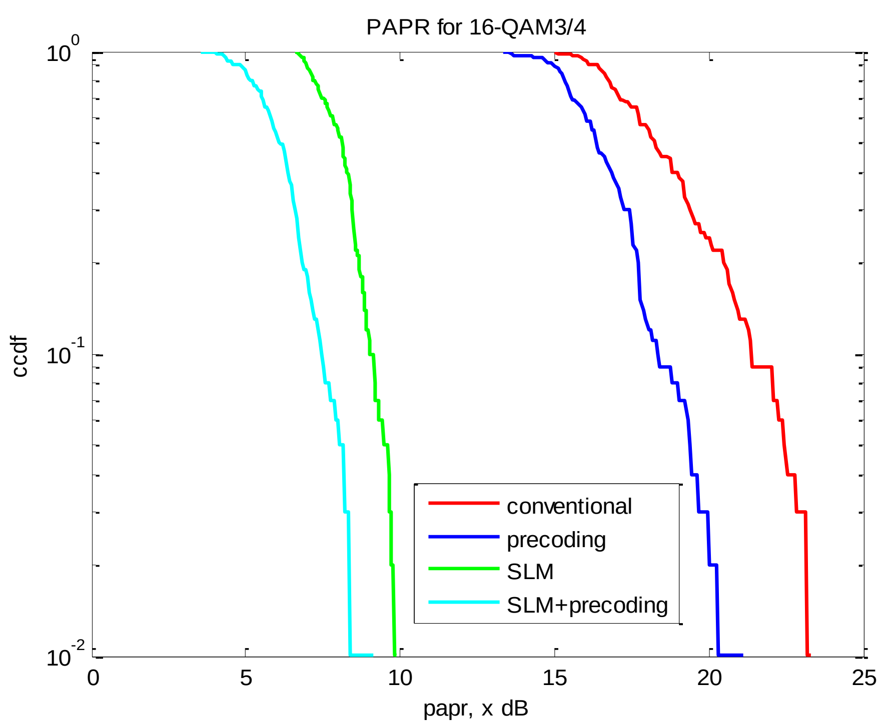

Fig 4.28: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 16-QAM 3/4 modulation.

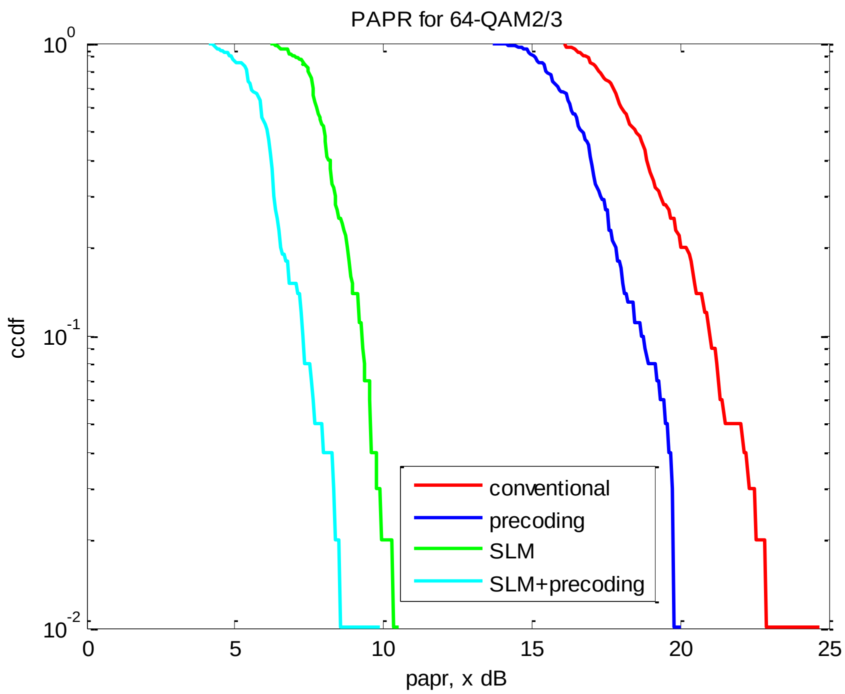

Fig 4.29: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM 2/3 modulation.

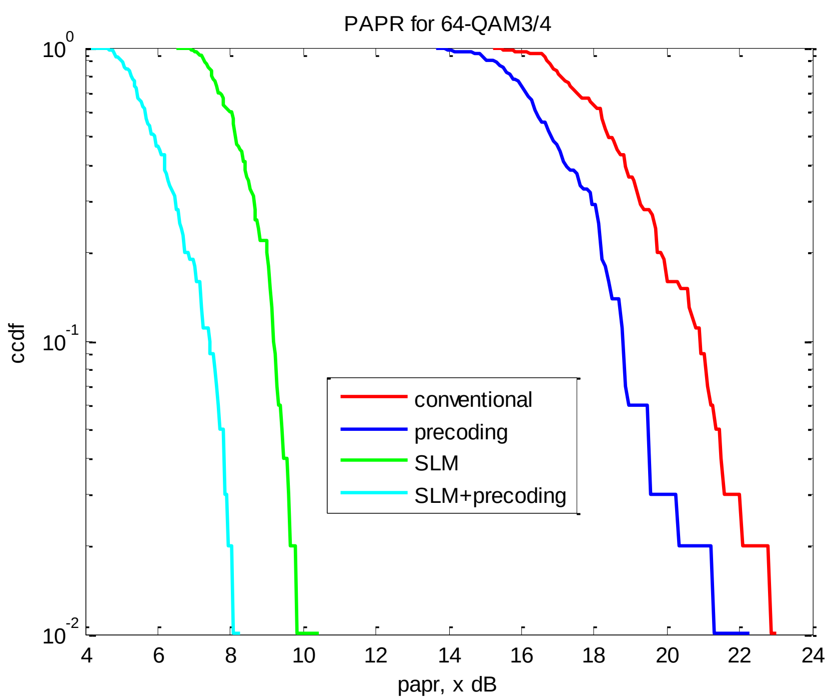

Fig 4.30: CCDF vs PAPR plot of different techniques and conventional WiMAX system for 64-QAM 3/4 modulation.

4.6 STANDARDS USED

Table 4.1: Techniques and parameters used for research

PARAMETERS	TECHNIQUES
FEC	Reed Solomon(outer)/convolution(inner)
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
IFFT Size	512
Cyclic Prefix	¼
Reduction tech.	Precoding, clipping, PTS, SLM and Hybrid
Transform	DCT,DST and CZT
Pre-Coding size	Modulation Dependent

CHAPTER 5: CONCLUSION AND FUTURE SCOPE

In the present work the brief of advance digital communication from WiMAX point of view is studied and found that it becomes the revolutionary technique in the fiend of wireless communication. OFDM based WiMAX gives addition to advantages in the system. The major disadvantage in WiMAX is analyzed and found that the PAPR can degrade the performance of system and make it costly. Different precoding techniques have been used to analyze the PAPR performance of the system and BER reaction for the respective technique. We came to know that wireless communication is very vast field and research cannot be faded in this field. Every time we will try for something new we will achieve it. CZT is found to be the technique with minimum PAPR during the research process so CZT has been taken as the proposed precoding technique to continue the research. PAPR and BER for proposed technique for WiMAX 802.16e PHY layer has been simulated through Matlab R2013a. CZT precoding based WiMAX system has been proposed for high PAPR reduction with improved BER. Simulation shows that, the PAPR of the CZT precoded WiMAX system has low PAPR as compared to the DCT precoded, DST precoded and conventional WiMAX system after that CZT precoding with selecting mapping technique, clipping technique and partial transmission technique has been proposed to form hybrid techniques for high PAPR reduction. Simulation shows that, the hybrid techniques based WiMAX system has low PAPR as compared to linear precoded and conventional WiMAX system. Proposed precoding system is also efficient, signal independent, distortion less and does not require complex optimization with additional flexibility to specify spectral analysis bandwidth and the resolution within bandwidth. The proposed CZT precoded hybrid techniques based WiMAX system is more effective on PAPR reduction. This improvement in performance with respect to PAPR and BER offered by the precoding technique and PAPR reduction through hybrid technique based system can help reduce the cost and complexity of the WiMAX transceiver.

5.1 FUTURE WORK

CZT precoding based WiMAX system is proposed to reduce the PAPR and BER of the system and CZT precoding with nonlinear techniques is proposed for the further reduction in PAPR. Simulations showed the smoothness of the research. BER for the different precoding and convention WiMAX is analyzed for AWGN channel and it can be assured that BER can be further analyzed for other other fading channel like racian, Rayleigh and nakagami. Other least known transform techniques can be analyzed as a precoding technique and that may reduce more PAPR because research in wireless communication cannot be faded. Precoding techniques can be used with other nonlinear techniques like tone injection and tone rejection to reduce PAPR. The demand of the user will vary the use of technique and that will give birth to adaptive techniques all around the wireless communication arena. The proposed technique can be used in MIMO system to analyze the performance.

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