A
DISERTATION REPORT

ON

PERFORMANCE ANALYSIS OF OFDM SYSTEMS AND DIFFERENT PAPR

REDUCTION TECHNIQUES

For partial fulfillment of Master of Technology in Electronics and Communication Engineering

By

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(2017PEC5187)

UNDER THE GUIDANCE OF

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CERTIFICATE

This is to certify that the dissertation work entitled " **PERFORMANCE ANALYSIS OF OFDM SYSTEMS AND DIFFERENT PAPR REDUCTION TECHNIQUES",** submitted by **Kajal Shivraj Meena (2017PEC5187**) in partial fulfillment for the award of the degree of Master of Technology in **Electronics and Communication** , Malaviya Natinal Institute of Technology , Jaipur is a bonafide work done by her under my guidance and supervision . The work submitted, in my opinion has reached to a level required for being accepted for dissertation. The matters embodied in this project work, have not been submitted to any other University or Institute for the award of any degree or diploma to the best of my knowledge.

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CANDIDATE'S DECLARATION

I, **Kajal Shivraj Meena,** hereby declare that the dissertation report entitled "**PERFORMANCE ANALYSIS OF OFDM SYSTEMS AND DIFFERENT PAPR REDUCTION TECHNIQUES",** being submitted by me towards the partial fulfillment of the requirement of **Masters of Technology in the field of Electronics and Communication from Malaviya National Institute of Technology , Jaipur.** It is record of the work carried out by me under the supervision of **Dr. Ashish Kumar Ghunawat** and has not been submitted anywhere else.

Date : Kajal Shivraj Meena

Place : ID : 2017PEC5187

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Kajal Shivraj Meena

ABSTRACT

Mobile Communication is the most widely used segment in the communication industry. But there are several technical problems like Intersymbol interference, propagation loss, fading which degrades the system performance and that must be overcome for better results. There is always a greater demand of high capacity with a good quality of service.

OFDM is one of the efficient technology used in wireless Communication Systems which offers High Data Rates, Robust to Intersymbol Interference, Efficient use of Bandwidth, Simple Design etc. The currently used 4G mobile Communication uses OFDM technology and provide high data rate transmissions with high spectral efficiency, multipath delay speed tolerance, immunity to frequency selective fading channels and power efficiency. Multicarrier Modulation (MCM) Scheme is the basis of OFDM Technology. It splits the high data rate streams into lower data rate streams. An individual carrier is modulated by using each of the lower data streams. The overall data streams are re-assembled at the receiver side for further communication process. In OFDM Systems also all high data rate streams separated into lower data rate streams with closely spaced sub-carriers. Each data stream corresponds to single carrier and is modulated by conventional modulation schemes such as Phase shift Keying (PSK), Quadrature Amplitude modulation (QAM) or Binary Phase Shift Keying (BPSK). Subcarriers are orthogonal to each other and eliminates the Intersymbol Interference (ISI) or reduce the cross-talk and saves bandwidth.

As every System has some Disadvantages. In this Thesis we are dealing with one of the major problem i.e. high Peak to Average Power Ratio (PAPR). PAPR is one of the challenging issues in OFDM Systems as it degrades systems performance, Increases Bit Error Ratio and decreases Signal to Noise Ratio, Increases System Complexity, Lessens the battery lifetime in mobile applications, makes power amplifiers less performance oriented and thus makes it economically less feasible. Clipping and Filtering technique has been used in this research to minimize PAPR and is compared to several other techniques. Clipping and Filtering significantly decreases the PAPR of OFDM signals at the cost of introducing Distortions. The Compander, applying Mu-Law Compression and Expansion, is the other Effective method to reduce PAPR. Finally, the comparison of the PAPR values obtained from the Simulation Results gives us the better method of PAPR Reduction.

List of Abbreviation

OFDM	Orthogonal Frequency Division Multiplexing
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
3GPP	Third Generation Partnership Project
BER	Bit Error Ratio
SNR	Signal to Noise Ratio
CF	Clipping and Filtering
SLM	Selective Mapping
WiMAX	Wireless Interoperability for Microwave Access
PAPR	Peak to Average Power Ratio
CCDF	Complementary Cumulative Distribution Function
SQNR	Signal to Quantization Noise Ratio
TDD	Time Division Duplex
FDD	Frequency Division Duplex
WCDMA	Wideband Code Division Multiple Access
LTE	Long Term Evolution
AMPS	Advanced Mobile Phone System
GSM	Global System for Mobile Communication
VOIP	Voice Over Internet Protocol
HSDPA	High Speed Downlink Packet Access
MAC	Medium Access Control
BPSK	Binary Phase Shift Keying
QPSK	Quadrature Phase Shift Keying

QAM	Quadrature Amplitude Modulation
CP	Cyclic Prefix
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
IFFT	Inverse Fast Fourier Transform
FFT	Fast Fourier Transform
UE	User Equipment
IEEE	Institute of Electrical and Electronics Engineering
AWGN	Additive White Gaussian Noise
UMTS	Universal Mobile Telecommunication System
DSL	Digital Subscriber Line
ISI	Intersymbol Interference
ICI	Interchannel Interference
GPRS	General Packet Radio Service
NLOS	Non Line of Sight
HD	High Definition
ASK	Amplitude Shift Keying
PSK	Phase Shift Keying
DFT	Discrete Fourier Transform
CFO	Carrier Frequency Offset
ARQ	Automatic Repeat Request
DM	Delta Modulation
CN	Core Network
RAN	Radio access network

CS	Circuit Switched
PS	Packet Switched
RNC	Radio Network Controller
LAN	Local Area Network
FM	Frequency Modulation
PM	Phase Modulation
DSB-AM	Double Side Band Amplitude Modulation
DSB-SC	Double Side Band Supressed Carrier
SSB-SC	Single Side Band Supressed Carrier
MECT	Modified Exponential Companding Transform
OBI	Out-of-band interference

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CHAPTER 1 BACKGROUND AND MOTIVATION

1.1 Introduction

In this 21 st century which is full of new technologies, the use of mobile communications helds a great position in our life's. The demand of multimedia systems like mobiles, laptops, tab, palmtops etc has been tremendously increasing. And Wireless communication is the most demanding area of study with rapidly developing antenna's, or different efficient systems. Earlier we are using GSM, CDMA, AMPS, UMTS etc techniques in different generation of cellular network. But as the number of users are increasing, and there is a demand of highly efficient system without any complications with advanced features we need to design a system which provide more bandwidth with low BER for VOIP purpose.[1]

After several generations of mobile communication, LTE represents a major advancement in cellular technology. LTE is one step closer towards 4th generation (4G) which has increased capacity, faster communication than any other generation, less interference, low signal loss etc. This rapid advancement of technology need a high data transmission rates and as a result demands of OFDM, Orthogonal Frequency Division Multiplexing increases for higher data rate transmission and high mobility modulation techniques in 4G. OFDM has a significant role in wireless communications ranging from its use in DSL modem technology to IEEE 802.11 wifi wireless system.

OFDM is an advanced case of MCM technique. It splits the high data rate streams into lower data rate streams. An individual carrier is modulated by using each of the lower data streams. The overall data streams are re-assembled at the receiver side for further communication process. Multicarrier modulation technique is advantageous compared to single carrier system as it is less vulnerable to interference since only a small number of the carriers are prone to be corrupted. In OFDM Systems also all high data rate streams separated into lower data rate streams with closely spaced subcarriers. Each data stream corresponds to single carrier and is modulated by conventional modulation schemes such as Phase shift Keying (PSK), Quadrature Amplitude modulation (QAM) or Binary Phase Shift Keying (BPSK). Subcarriers follows the property of orthogonality and banish the Intersymbol Interference (ISI) or reduce the cross-talk and saves bandwidth.[2]

A major drawback of OFDM system is High PAPR (Peak to Average Power Ratio) that causes Distortions in the system (as we have limited linear range power amplifier and ADC, DAC converter) making Power amplifiers less efficient. To maintain efficiency, it is crucial to utilize a large dynamic range DAC & expensive linear range converters and this is an addition to Hardware Cost & Complexity. High PAPR lessens the Battery Lifetime in Mobile Applications. It is a problem in the Uplink on the grounds that Uplink Mobile terminal has Limited Power. It also introduce In-band and Out-band distortion. So it is important to reduce the problem of high PAPR to make the system more effective.[2]

1.2 Evolution of Mobile Technology

Mobile Communication technology brought a revolutionary change in the way of communication of people. Communication became easier and faster. Gradually, these technologies are improving and introducing a better ways of communication for people. Looking past, we can clearly observe the evolutionary paths that the wireless communication technology has followed. By the end of 2010, the subscription of mobile cellular network is four times than that of telephone lines. This drastic change in society demands a better and efficient system to provide telephonic service to the huge number of subscriptions.[3]

1.2.1 First Generation

First Generation (1G) cellular networks was first introduced in 1980's and came into action in 1990's. It was based on Analog Communication technique. First generation technology used FDMA (Frequency Division multiple access) and known as AMPS (Advanced mobile phone systems) which was started in USA. In this users can only make phone calls, sending and receiving text messages was not possible. 1G systems are Line of Sight (LOS).[3]

1.2.2 Second Generation

Second Generation (2G) cellular networks was started in 1990's. 2G networks are based on Digital Communication Technique instead of Analog transmission. Digital transmission systems are way more secure than analog systems. 2G provided the service of voice calls and introduced a new feature of communication i.e text messaging. Second Generation primarily used Global System for mobile positioning (GSM) system and circuit switching (sends information voice or data in ordered time slots) for data transmission. And further it has many stages with slightly improved version.

2.5 G used General packet radio service (GPRS) which could provide data rates from 56 kbit/s upto 115 kbit/s and users could also acess the internet service for sending mails and MMS multimedia messaging service.

2.75 G used Enhaced data rates for GSM evolution (EDGE) which is an evolution of GSM system with an increased speed upto 384 kbit/s for the fast transmission of data and information.

All these system used different techniques like TDMA, IS-95 CDMA. These are Non line of sight system (NLOS).[3]

1.2.3 Third Generation

Third generation (3G) was introduced in 2000's and still they are used, But only when the superior signal 4G fails. Universal Mobile Telecommunication system (UMTS) was introduced in 3G and used packet switching (sends out data as required in no special order, voice is digitized). 3G has higher bandwidth, have transfer speed upto 3Mbps ,enables several services like voice calls, broadband application, video conferencing ,upload and download E-mail messages. 3G has many standards like UMTS, CDMA2000, HSPDA etc.[3]

1.2.4 Fourth Generation

Currently, we are using 4G technology which is five times faster than 3G, provides speed upto 100 Mbps and users can experience higher quality voice calls without any call drop or disturbance, video conferencing with better latency, live streaming of videos with HD quality.

These services are accessible anywhere, anytime without any changes in their packages. 4G has several technologies like LTE (Long term evolution) Advanced, IEEE 802.11 wimax. It is the most secure form of communication nowadays.[3]

1.2.5 Fifth Generation

5G technology is yet to be released but it is highly expected that 5G may bring a revolutionary change in mobile industry, not only in the field of speed and security but can change the concept of connecting a mobile phone to internet and can help to make the smart cities.[3]

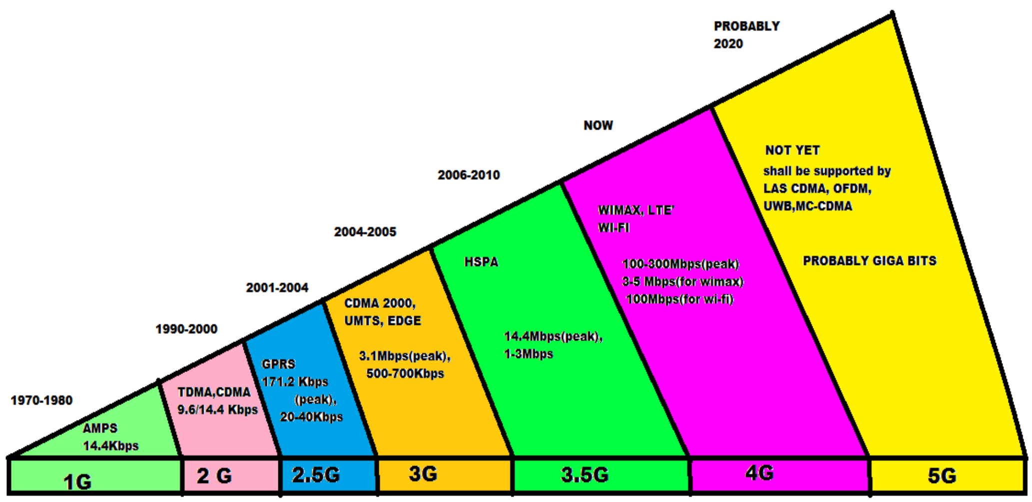

Fig 1.1 Evolution of Cellular Network

1.3 Evolution of LTE Advanced technology

LTE is a project started by 3GPP (third generation partnership project) in 2011. 3GPP is evolved from UMTS and UMTS is evolved from GSM. This is named as LTE (Long Term Evolution) because it represented the next step of technology. Further releases in LTE technology gives us the transition of 4G technologies. 4G technology drags LTE towards LTE Advanced. It includes WCDMA, WiMAX and CDMA 2000.

VOLTE (voice over LTE) is a advanced technology used in 4G in which users can place phone calls using data packets instead of typical phone call.[3]

1.3.1 Wideband Code Division Multiple Access (W-CDMA)

W-CDMA is a spread spectrum technique, both direct sequence and frequency hoped. It is a 3rd generation technique which is able to artificially increase the signals bandwidth. It is an ITU standards derived from CDMA and promises much higher data rates than CDMA. It works on both FDD and TDD.[4]

W-CDMA Network architecture consists of several nodes and interfaces.

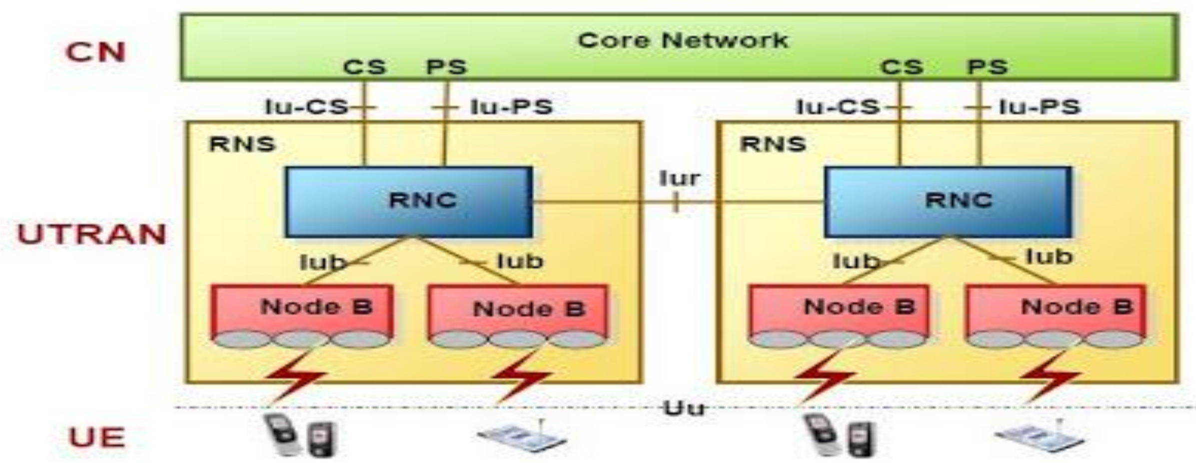

Fig 1.2. W-CDMA Network Architecture

W-CDMA has RAN and CN. RAN is utilized for radio related process, whereas CN is deployed to handle the voice calls and data connection with UMTS and execute the network of switching and routing. CN is consists of two parts CS domain and PS domain. UTRAN, CN, UE together known as UMTS system. RNS is consist of one RNC and one or many Node B's. RNC is responsible for managing a call setup and maintain the quality of service. Node B's are also known as Base station for the transmitting cells and responsible for transmission and reception for various different cells. There are several interfaces between RNC and Node or between RNC to RNC. ARQ (Automatic Repeat Request) are used by RNC for error correction, handling and retransmission. HSDPA is the advance technique than W-CDMA. It adds a MAC sub-layer in Node B that schedules, rate controls and operate a hybrid ARQ and affect the overall operation.

W-CDMA supports high data rate transmission of speed upto 384 kbps with wide coverage area, this system is highly secure than any other system as it follows a particular code for transmission and reception. [4]

1.3.2 Worldwide Interoperability for Microwave Access (WiMax)

WiMax standard also known as IEEE 802.16 standard. Today, WiMax is widely used in wireless networking. It is almost same as Wifi technology but Wifi is available for LAN whereas WiMax is used on much larger scale (i.e WAN) at faster speeds. WiMax provides 10 to 15 Mbps upload/download speed and coverage area is upto 10 km from base station. It is an IP based broadband technology that is integrated in both type wireless and wireline network to make it seamless anywhere , anytime. WiMax offers an ultra wideband ranging from 2 to 10 Ghz.[5]

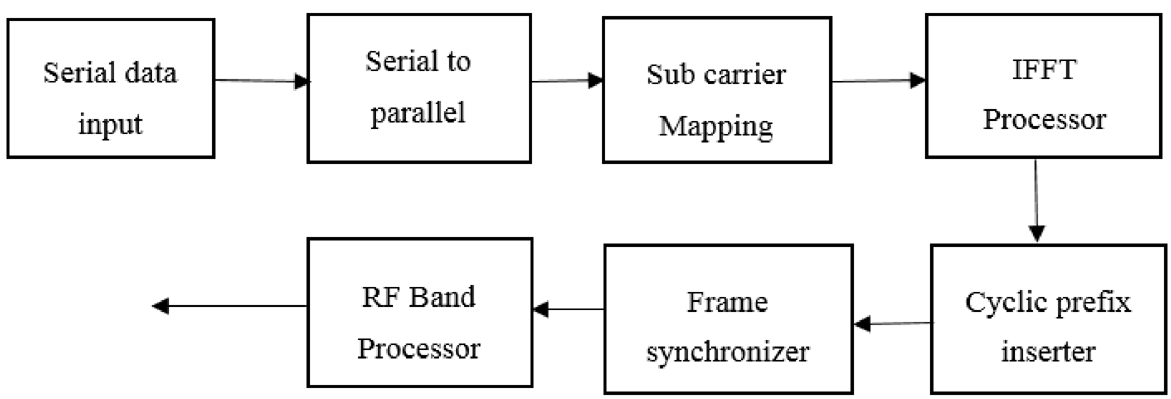

Fig 1.3. Block Diagram of WIMAX System

From fig 1.3 it consists of serial data input, serial to parallel converter, Sub carrier mapping, IFFT Processor, CP inserter, frame synchronizer and RF band processor at the transmitter side. WiMax uses OFDM technique for transmission and reception of information in 4G wireless technology which make communication process more feasible and efficient.

Serial to parallel converter converts the serial data input into parallel data output and mapped onto the corresponding subcarriers. Mapping of different coded bits use different modulation schemes like BPSK, QPSK, 16-QAM, 64-QAM, 128-QAM. IFFT is used to modulate the information and CP is used to provide a guard band between the streams of data. After that the data can be converted into analog form to detect the information.

By the use of OFDM technique we are able to communicate in Multipath environment, capable of handling different data rates, interference of signals are reduced. Due to all these reasons OFDM technique became widely popular for wireless communication. Now, we are using 4G technology which is based on OFDM.

1.4 Modulation Techniques in Communication System

Communication system is consist of two types of Modulation Techniques i.e Analog Modulation and Digital Modulation. In Analog modulation a baseband signal (low frequency) is transferred over a high frequency signal like Radio frequency. In Digital modulation discrete bits are modulated by the use of carrier signal. There are several ways to modulate a low frequency signal according to a carrier signal in both the modulation process.

1.4.1 Amplitude Modulation (AM)

AM is an analog modulation technique in which amplitude of the Message signal is diversify in accordance with carrier signal. AM is further divided into several techniques. There are more techniques of continuous modulation i.e FM, PM.

1.4.1.1 Double Side Band Amplitude Modulation (DSB-AM)

Consider an analog message signal m(t) which is transmitted using amplitude modulation (AM). m(t) is put down on the carrier signal to modulate the amplitude of the carrier signal.

Carrier signal = $A_c \cos(2\pi f_c t)$ fc = carrier signal frequency.

The transmitted signal = $A_c (A + m(t))\cos(2\pi f_c t)$, A= constant.

m(t) = $\cos(2\pi 40t)$ message to transmit via AM

c(t) = $\cos(2\pi 200t)$ carrier signal and have constant A = 1

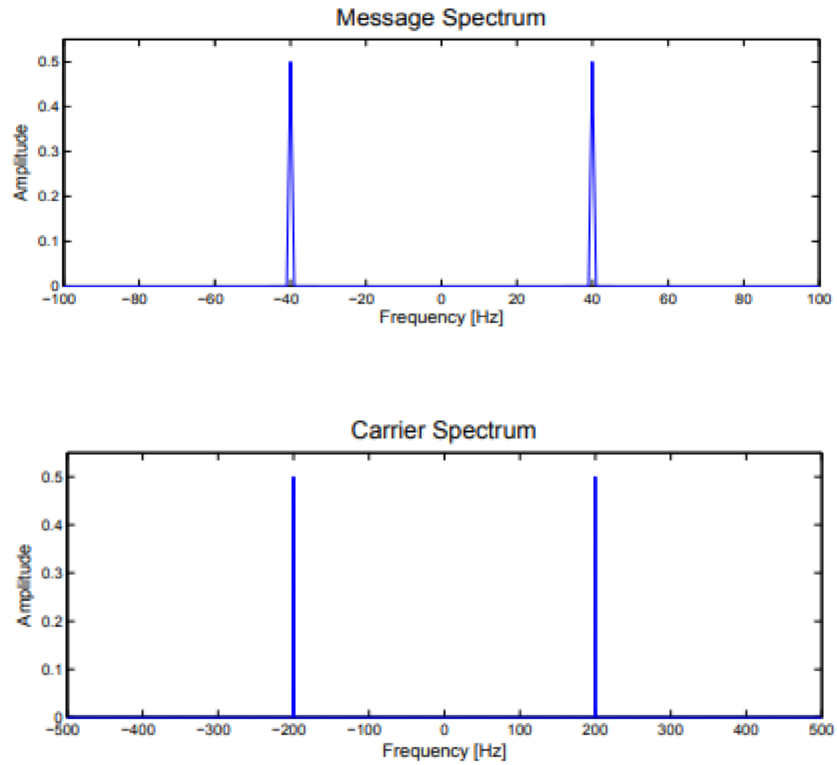

Figure 1.4. Message and carrier spectrum

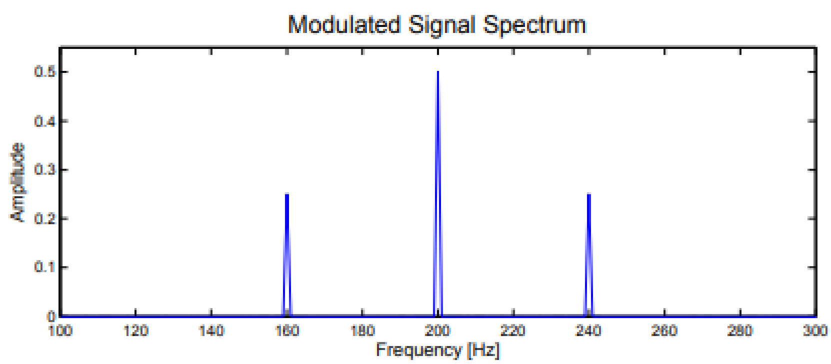

Figure 1.5. Modulated signal spectrum

Figure1. 4. represents the time and frequency spectrum of message and carrier.

The modulated signal x(t) $= [A + m(t)]c(t) = [1 + \cos(2\pi 40t)]\cos(2\pi 200t)$

Figure 1.5. represents time series and frequency spectrum.

This is called double side band full carrier , the carrier frequency is present in the spectrum as well as both side bands of the message.

1.4.1.2 Double Side Band Suppressed Carrier (DSB-SC)

In transmission of DSB-AM there is a wastage of power as the information lies only in side bands so by suppressing carrier part we can save power. So in previous method by setting A=0 we can suppress carrier and known as Double Side Band Suppressed carrier.

Carrier signal = $A_c \cos(2\pi f_c t)$, fc = carrier signal frequency.

The transmitted signal = $A_c\, m(t)\cos(2\pi f_c t)$

m(t) = $\cos(2\pi 40t)$ be the message to transmit via AM

c(t) = $\cos(2\pi 200t)$ be the carrier signal

The modulated signal x(t) = m(t) c(t) = $\cos(2\pi 40t)\cos(2\pi 200t)$

$$= \frac{1}{2}\cos 2\pi(200+40)t + \frac{1}{2}\cos 2\pi(200-40)t$$

$$= \frac{1}{2}\cos 2\pi 240t + \frac{1}{2}\cos 2\pi 160t$$

Figure 6. shows time series and frequency spectrum.

This is called double side band Suppressed carrier (DSB-SC).

Only side bands are present with full information available without any wastage of power for the transmission carrier signal.

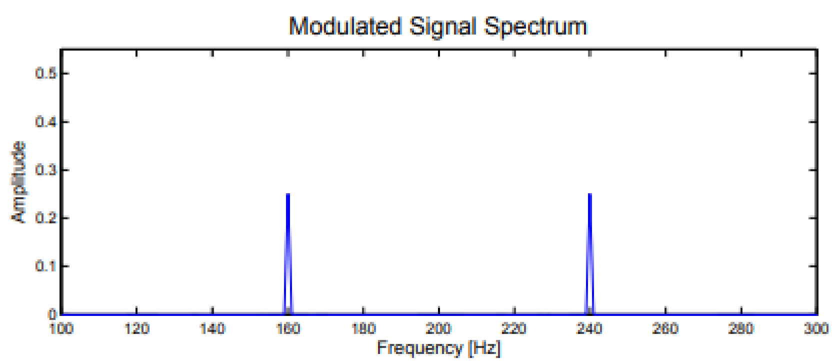

Figure 1.6. Modulated signal spectrum

1.4.1.3 Single Side Band Suppressed Carrier (SSB-SC)

In DSB-SC only side bands are transmitted but there is no need to transmit both of them as they both carry same information. By removing one side band we can save power and bandwidth that is called SSB-SC.

SSB-SC is represented as s(t) = $\frac{AcAm}{2}\cos 2\pi(fc \pm fm)t$

SSB-SC is used in voice transmission, radio communications, point to point communication.

1.4.2 Digital modulation

In digital modulation signals are in the form of pulse and modulated by using carrier wave. There are several types of pulse modulation like PCM, DPCM, DM, ADM, ASK, PSK BPSK, QAM etc few of them are discussed here.

1.4.2.1 Pulse Code Modulation (PCM)

In PCM a signal is transformed into a binary sequence, i.e., 1's and 0's and then transmitted. This technique is better than analog transmission in terms of interference, security, noise, distortion etc.

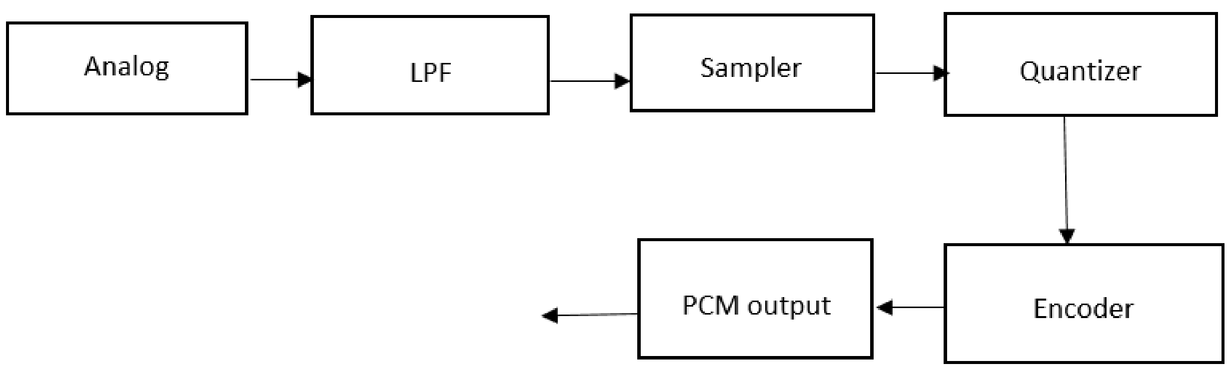

Figure 1.7. Block diagram of PCM Transmitter

PCM is appropriate for communication over long distances. PCM is characterized by high efficiency of transmitter and high immunity of noise. But it needs large bandwidth in comparison of analog system and it has a complex circuitry for data encoding and decoding. It has a great role in mobile communication, satellite systems and space communication also.

1.4.2.2 Phase Shift Keying (PSK)

In PSK the message is carried in the form of phase changes, while in AM the information is brought up in the form of amplitude. In PSK binary 1 is represented with actual carrier and binary 0 is reflects with 180˚phase shift. BPSK and QPSK are the two types of PSK.

In Binary PSK, sine wave consists of two phase reversals i.e 0° and 180°. In its principle, BPSK is fundamentally a DSBSC modulation scheme..

In Quadrature PSK (QPSK) the sine wave has four phase reversals such as 0°, 90°, 180°, and 270°. Depending on the requiremens, it can be extended to eight or sixteen values..

BPSK signal waveform is expressed as:

$$s(t) = \sqrt{\frac{2Es}{Ts}}\cos\left(2\pi fct + \frac{2\pi}{n}(k-1)\right) \quad 0 \le t \le Ts, 1 \le k \le n$$

where fc = carrier frequency

Es = symbol energy

Ts = symbol time

n = number of symbols.

BPSK is a form of PSK in which n = 2 and Es = Eb and Ts = Tb.

QPSK signal waveform is expressed as:

$$s(t) = \sqrt{\frac{2Es}{Ts}}\cos\left(2\pi fct + \frac{2k-1}{n}\pi\right) \quad 0 \le t \le Ts, 1 \le k \le n$$

QPSK is a form of PSK in which n = 4. Therefore, in QPSK Es = 2Eb, and Ts = 2Tb.

Higher data rates are achieved by using PSK, less susceptible to errors than ASK, since PSK carries data in an efficient way. However, it has lower bandwidth efficiency. Detection and recovery algorithms of binary data are very intricate. Multi-level PSK modulation schemes (QPSK, 16QAM etc.) are more responsive to variations in phase.

1.4.2.3 Quadrature Amplitude Modulation (QAM)

QAM is very popular way due to its spectral efficiency. QAM have both the components of amplitude and phase. In QAM the shifting of phase is 90°. They are named as quadrature due to 90° phase difference. The signal with no shifting is called In-phase or "I" signal, and signal with 90° phase difference is called quadrature or "Q" signal.

The transmitter efficiency increases due to the combined affect of Amplitude and Phase. However, due to the closeness of states, system got affected by noise. The other limitation is due to the amplitude component of signal. Linear amplifiers are not needed in the case of amplification of phase or frequency of a modulated signal. QAM contains an amplitude component, which make it necessary to use linear amplifier for maintaining linearity. This is a drawback as linear amplifiers are uneconomical and absorb additional power making them less enticing for mobile applications.

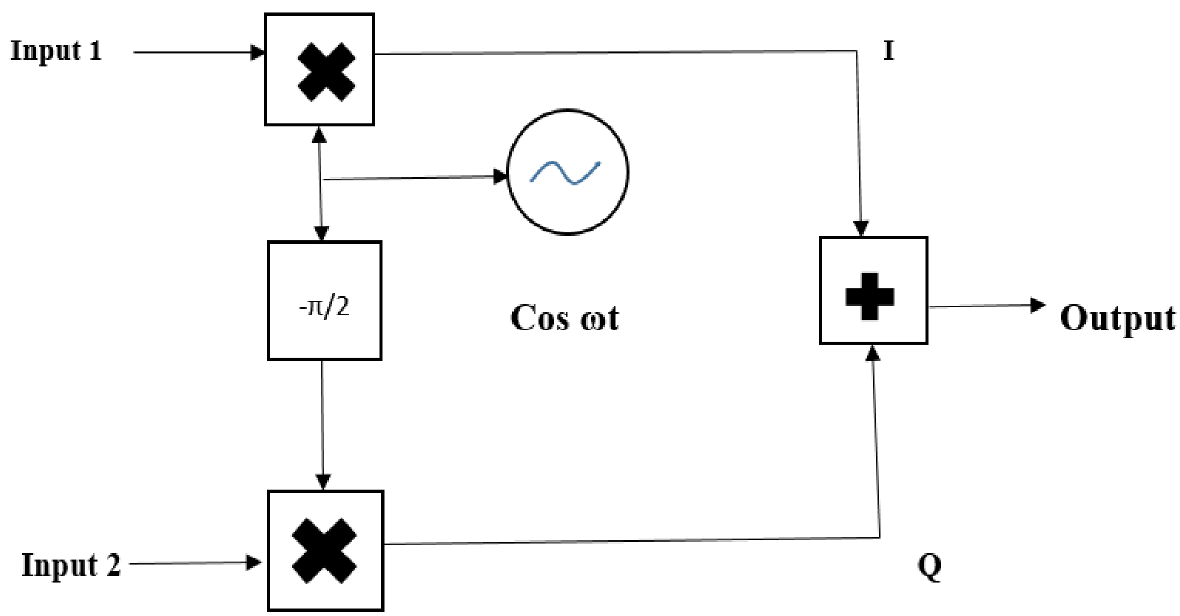

Figure 1.8. Block diagram of QAM Modulation

1.5 Literature Review

Digital communication technique plays a vital role in today's communication industry. Nowadays whole telephony system is based on digital technique. Digital revolution is the Third biggest revolution from mechanical and analog to digital systems. According to the data of 2016 about 62.9% of population uses Telephonic system for communication. Now in 2019 it is expected to pass 5 billion population that owns a mobile phone. In Mobile communication OFDM is the one technique that brought revolution in the field of communication as it reduces the problem of signal interference. There are several reasons due to which it is used at very large scale.

In 1996, Robert W. Chang introduced the very first technique for synthesizing a band limited signals for multi-channel transmission and lead to the development of OFDM technique which is capable in transmitting a signal at the same time with no ICI (Inter channel interference).[6] In 1967, Saltzberg follow the work of Chang and proposed that rather on concentrating about Multi-channel transmission we must discover a technique that can reduce the crosstalk and problem of ISI between adjacent channels.[7]

In 1971, Weinstein and Ebert work on the data transmission by using FDM technique utilizing DFT for the Modulation and Demodulation process which removes the repetitive use of oscillators and system become lighter. To solve the problem of ISI guard intervals are introduced. But this technique is not able to accomplish the ideal orthogonality principle between the sub-carriers.[8]
Further, to follow ideal orthogonality principle in 1980's Peled and Ruiz uses Cyclic prefix instead of guard interval that overcome the orthogonality issue. As a result they observed that cyclic prefix is better technique for removing ISI and ICI.[9]

ISI and ICI basically arises due to carrier frequency offset at the time of signal transmission to remove this different approaches are made. In 1994 Moose worked on CFO estimation technique and after that several work was proposed on CFO estimation and compensation. In 1997 Schmidl and Cox, 1999 Moreilli and Mengali, 2000 Lei and Tung-Sung, 2004 Hlaing Minn, 2006 Hlaing Minn and Xing S. this method provide low complexity, fast synchronization and reliable performance etc. There is one more approach used to cancel ICI but at the cost of data rate (1996 Zhao and Haggaman, 1999 Armstrong).

In 2010, S. Srikanth et al. worked on **"Orthogonal Frequency Division Multiple Access in WiMAX and LTE – A Comparison"**. OFDM Technique was used in Wimax and LTE , both system improves their performance due to subtle differences OFDM emerge as a advantageous technique.

In 2012, N. Shirisha et al. worked on **" A Simulation and Analysis of OFDM system for 4G communication"** and observed that ISI is eliminated by the use of Cyclic prefix and due to spectral efficiency and higher data rates OFDM system is the best possible technique for 4G network.

In 2012, Vineet Sharma et al. worked on **" BER performance of OFDM-BPSK, QPSK, QAM over AWGN channel using forward Error Correcting code."** And conclude that using error correcting code over AWGN channel improves the BER.

In 2012, Abhijyoti Ghosh et al. did a research entitled **" Comparative BER Performance of M-ary QAM-OFDM System in AWGN & Multipath Fading Channel".** They concluded that using error correcting codes to improve BER made the system complex and spectral efficiency decreased and results in lower data rates. To improve this one more experiment was performed to accomplish high data rate M-array modulation technique was used and it improves data transfer capability over the other techniques. In M-array as we increase the value of M then we get higher the value of data rate and speed. In this paper 64-QAM performs better but it also increases the system complexity and error in the system also increases.

In 2013, Usha S. M. et al. did a research entitled **"BER performance of Digital Modulation Technique Schemes with and without OFDM Model for AWGN, Rayleigh and Rician channels."** It was observed that conventional modulation techniques gives better results with OFDM systems in all the channels and more robust to noise, ISI. OFDM is used in various applications DAB, DVB and in 4G communication also.

In 2013, Sahasha Namdeol et al. did a research entitled **"Designing and Performance Evaluation of 64 QAM OFDM System."** To maximize the average throughput under the BER that is below the target value.

In 2015, Mohd Abuzer Khan et al. did a research entitled **"BER Performance of BPSK, QPSK & 16 QAM with and without using OFDM over AWGN, Rayleigh and Rician**

Fading Channel". This research revealed that lower order modulation technique was better than any other technique in communication, provided that the effects on spectral efficiency were neglected.

In 2015, Mranali Joshi et al. did a research entitled **"Analyzing various Fading Channels using different Modulation Techniques under IEEE 802.16 Standard".** The different modulation technique are tested in different channels Rayleigh, Rician, Nakagami and Lognormal shadowing channel and conclude that Nakagami channel is better technique at higher SNR value with different modulation technique..

In 2016, Kalaivani. P et al. did a research entitled **"Performance Evaluation of OFDM System for different Modulation Techniques on the basis of BER and PAPR."** Observed that orthogonal subcarrier minimizes interference and OFDM provides best performance with QPSK modulation, 8-QAM and 16-QAM. The PAPR values for M = 32, 64, and 128 are quite high. This high value of PAPR must be handled by proper subcarrier mapping in OFDM system.

In 2016, Pawan Kumar et al. did a research entitled **"BER Analysis of BPSK, QPSK, 16-QAM, 64-QAM, Based OFDM system over Rayleigh fading Channel."** On considering the performance of spectral efficiency, use higher order modulation techniques. For less BER performance lower order modulation technique are preferred. So they make the system performance better rather than higher order techniques.

There are some problems in OFDM system one of them is high PAPR which affects the system performance. To remove it, first companding technique is released in 1999 by Chang et.al. Companding technique is better than Clipping technique. In μ law companding schemes it compresses the large amplitude signal at transmitter side, maintains the average power of the signals and upgrades the system performance.

In 2005, Luqing Wang et al. did a research entitled **"A Simplified Clipping and Filtering Technique for PAPR Reduction in OFDM Systems."** CF is the effortless and efficient technique to reduce PAPR.

In 2007, Gang Yang et al. did a research entitled **"Using hyperbolic tangent sigmoid transfer function for companding transform in OFDM system."** By using hyperbolic tangent sigmoid transfer function with companding decreases the PAPR and improves the graph of BER performance.

In 2013, Xiaodong Zhu et al. did a research entitled **“Ultimate Performance of Clipping and Filtering Techniques for PAPR Reduction in OFDM systems.”** In this work an extra signal was added to the input signal. The achieved PAPR is caused by the distortion in the original signal due to the addition of the extra signal. For optimization problem CF technique is formulated.

In 2014, E. Singh et al. did a research entitled **“Novel companding technique for PAPR reduction in OFDM System.”** PAPR reduction technique using companding offers low complexity, higher efficiency etc. Companding adjusts the signal as low or high amplitude whatever is required to maintain the average power level.

In 2014, G. S. Toor et al. did a research entitled **“PAPR reduction and BER improvement by using logarithmic companding hybrid with SLM Technique in bit interleaved COFDM system.”** As we are increasing the compression parameters of companding scheme then it decreases the PAPR but degrades BER. So there is a kind of trade-off between PAPR and BER.

In 2014, E. Singh, M. Arif et al. did a research entitled **“Nonlinear companding technique for PAPR reduction in OFDM.”** using proper companding parameters BER performance gets improved.

In 2014, M. Hu et al. did a research entitled **“A piecewise linear companding transform for PAPR Reduction of OFDM signals with companding distortion Mitigation.”** This work used proper companding technique and gets improved BER performance.

In 2015, R. Yoshizawa et al. did a research entitled **“Energy efficient improvement of coded OFDM Systems based PAPR Reduction.”** Power amplifier is a power hungry device and plays an important role for communication systems.

In 2015, R.K. Singh et al. did a research entitled **“An efficient PAPR reduction scheme for OFDM system using peak windowing and clipping.”** This technique provide good results when the value of clipping ratio (CR= 2,1.8, 1.6,1.4,1.2).

In 2015, Shatrughna Prasad Yadav et al. did a research entitled **“PAPR Reduction using Clipping and Filtering Technique for Nonlinear Communication Systems.”** at different clipping ratio performance of BER and PAPR are observed.

In 2016, A. Kangapadden et al. did a research entitled **" Comparison between SLM-companding and Precoding- companding techniques in OFDM Systems."** In this SLM is observed under two types Reimann modified SLM and Hadamard modified SLM. In this Reimann is better than Hadamard as it decreases 3db of PAPR on comparing with original signal. After that precoding is observed which has 80% efficiency in reduction of PAPR. On combining precoding and non linear companding we observed that it is better than the combination of SLM modified and non linear companding technique.

In 2016, E. H. Krishna et al. did a research entitled **" Performance evaluation of different PAPR reduction methods in OFDM systems."** In this research study, a new MECT technique was used for PAPR reduction in OFDM systems and gives us the better simulation results in terms of BER and reduced OBI.

In 2016, Zhuo Wang et al. did a research entitled **"An overview of PAPR reduction technique for OFDM Signals."** This paper evaluated different PAPR reduction techniques and from them CF is the best and easiest method to reduce PAPR.

In 2016, K. Sultan et al. did a research entitled **"Joint SLM and modified clipping scheme for PAPR reduction."** the combination of SLM and clipping provides better results than traditional techniques.

In 2017, Manjula A. V et al. did a research entitled **"PAPR Reduction in OFDM systems using RCF and SLM techniques."** if the clipping ratio decreases the BER also decreases.

In 2017, Mamta Arora et al. did a research entitled **"PAPR Reduction in OFDM Systems using Higher Order Prediction Filter".** by using prediction filter PAPR is reduced upto a great extent as it is 7.4 db earlier and after the use of filter it become 3.55 db. So the use of prediction filter offers less PAPR than Weighted OFDM system and BER performance is also improved.

In 2017, Suseela Vappangi et al. did a research entitled **"Performance Analysis of Fast Optical OFDM for VLC".** This research work compared the channel estimation techniques for FOOFDM and DCO-OFDM over VLC channel. From the results, it was clear that FOOFDM is far better than DCO-OFDM when we are concentrating on power efficiency.

In 2018, Nilesh Kumar Jadav et al. did a research entitled **"A Survey on OFDM Interference Challenge to improve its BER".** This paper reflected the Study about wavelet transform and

STBC-OFDM which is a part of channel coding which may helps for better OFDM capable application.

In 2018, Zheng-rong Tong et al. did a research entitled "**PAPR reduction in CO-OFDM systems using IPTS and modified clipping and filtering.**" The simulation results showed that at CCDF of 10^{-4}, the PAPR is optimized by 1.86 dB and 2.13 dB compared with IPTS and CF schemes.

1.6 Thesis Objective

The objective of this thesis is to study the performance analysis of OFDM Systems and Compare several PAPR reduction techniques. Using different modulation technique BPSK, QPSK and M-QAM in AWGN channel.

Energy efficiency and information without distortion matters a lot in a mobile industry. OFDM is the one technique that can offers a lot but every coin has two sides merit and demerits. In OFDM there are several problems that can affect a communication system like carrier frequency offset, PAPR. PAPR is one the major issues in OFDM technique it degrades the systems performance, lessens the battery lifetime which is an important factor.

In this thesis, for PAPR reduction CF is compared with SLM technique. Mu- Law Companding + CF performance is also observed.

1.7 Thesis outline

The thesis consists of the following seven chapters:

Chapter 1 deals with the introduction of communication system and history about mobile industry. Also stated the problem in current scenario of mobile communication. About the evolution of different techniques in today's processing.

Chapter 2 is an introductory part for current mobile communication technique i.e OFDM System. Define the importance of orthogonality and cyclic prefix for removing ISI. It includes different modulation techniques which works with OFDM.

Chapter 3 it describes the problem of PAPR in OFDM Systems and the affect of different parameters on PAPR.

Chapter 4 discuss about the PAPR Reduction technique.

Chapter 5 describes the research methodology used in this work.

Chapter 6 shows the simulation results of PAPR reduction technique and efficiently working of this system.

Chapter 7 summarizes the work by giving the conclusion.

CHAPTER 2 OFDM SYSTEM

Extensive research has been conducted in the field of wireless communication. The insistence for high-quality communication services, anywhere, anytime, is spreading swiftly. System designers faces great challenges to improve the available system as they have to deal with many technical issues. The Modulation techniques in communication system have problems like ISI which occurs due to time dispersion, multipath fading, low spectral efficiency and the need of more transmitting power for high-bit rate. These difficulties can be resolved by utilizing OFDM techniques. OFDM is a very convincing modulation technique in which ISI and ICI are reduced. High data rate transmission can be attained by using OFDM Systems. These are the techniques that are used in 4G mobile industry, video broadcasting, audio broadcasting.

2.1 Orthogonal Frequency Division Multiplexing

Multicarrier Modulation Scheme (MCM) is the basis of OFDM Technology. It splits the high data rate streams into lower data rate streams. An individual carrier is modulated by using each of the lower data streams. The overall data streams are re-assembled at the receiver side for further communication process. Multicarrier modulation technique is advantageous compared to single carrier system as it is less vulnerable to interference since only a small number of the carriers are prone to be corrupted. OFDM works on MCM technique all high data streams are separated into lower rate data streams with closely spaced sub-carriers. Sub-carriers follows the property of orthonality and they are orthogonal to each other, thus no band gap is needed which improves the spectral efficiency. The use of IFFT and its inverse FFT for modulation and demodulation makes the system more efficient. Due to these design modulation OFDM get rid from number of oscillators which makes the system bulkier. Carrier power and modulation schemes are commanded seperately for each carrier to sustain the high spectral efficiency. Orthogonality must be maintained in OFDM System to eliminate ISI. Same data is designated to every sub-carrier for transmission. Different modulation scheme can be implemented by each sub-carrier such as BPSK, QPSK, 8PSK, 16QAM, 64QAM, etc. To avoid

ISI cyclic prefix must be utilized and serve as a guard band, the size of CP must be prominent than the delay spread.

2.2 OFDM System Model

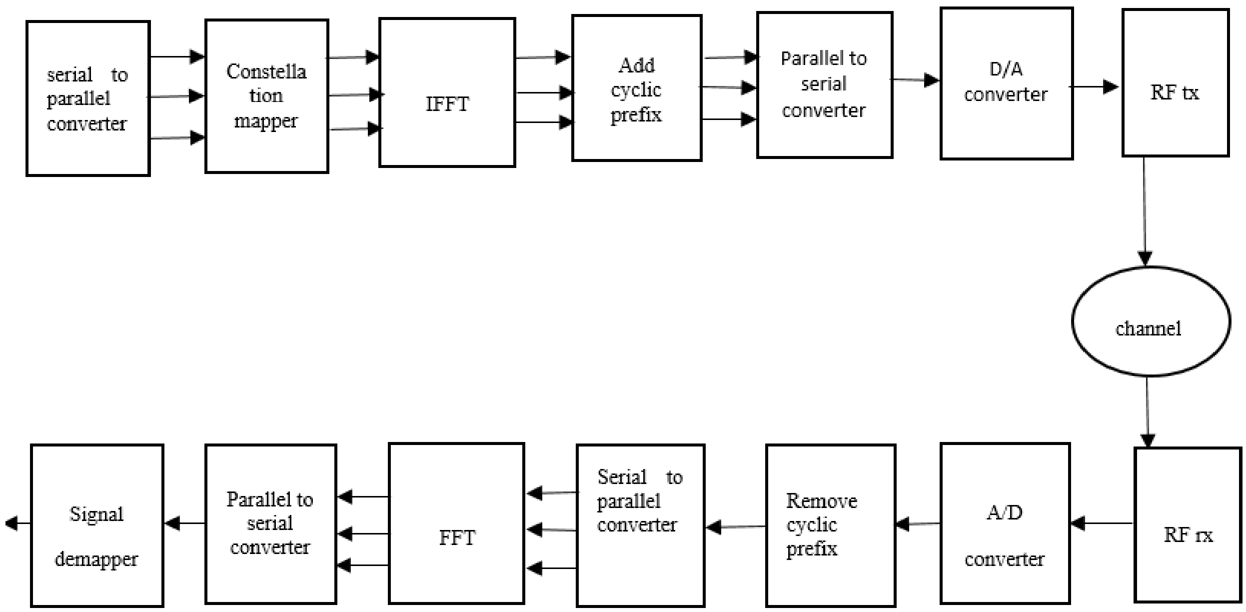

Fig. 2.1 Block diagram of OFDM system model

In OFDM Systems modulation and demodulation IFFT and FFT are used which make the system easy and light weight. Orthogonality is the basic property that must be followed by the system as it is an important factor to remove ISI. It is the property that allows multichannel transmission over one channel with successful detection. Two functions or signals are mutually independent to each other then they are orthogonal. If dot product is zero then they are known as orthogonal .Sine and cosine are best example of orthogonal signal. Orthogonality is vital criteria for the OFDM signal to be Interference Free. Orthogonal means having 90˚ phase shift between 2 signals. On performing integration operation on the wave, the total sum is Zero. Cyclic prefix is another method to remove ISI. It serves as a guard band in between the signals. CP is defined as the periodic extension of the later part of OFDM symbol which is added to the front of the sequence in the transmitter and removed at the receiver side before demodulation. Mathematically, the CP/Guard Interval converts the linear convolution into a cyclic convolution. This results in a diagonalised channel, free of interference. In this model the higher data streams are converted into lower data streams by using serial to parallel converter. After that different modulation schemes are mapped onto the signals like BPSK, QPSK, QAM and modulate them using IFFT, add cyclic prefix and then convert from parallel to serial for further transmission. Then signal is transmitted through different channels like AWGN, Rayleigh, Rician etc. as AWGN is only for additive noise and other suffers all types of noise at the transmitter and receiver. Then reverse process happens cyclic prefix is removed and demodulated by using FFT to receive the correct information.

2.3 Mathematical Description

ISI channel, described as $\mathrm{y(k) = h(0)x(k) + h(1)x(k-1) + v(k)}$= Received symbols at time k

x (k) =transmitted symbols at time k, $\mathrm{x(k-1)}$=transmitted symbols at time $\mathrm{(k-1)}$, $\mathrm{v(k)}$ is noise.

OFDM overcomes ISI with very low complexity and it is very efficient scheme

These are the symbols for transmission: $\mathrm{X(0), X(1), X(2), X(3)}$.

N=4 Symbols and similarly 4 Subcarriers.

X (l) is loaded on to the lth subcarrier.

N point IFFT is taken.

$$\mathrm{x(k)} = \frac{1}{N}\sum_{l=0}^{N-1}\left(\mathrm{X(l)}e^{\frac{j2\pi kl}{N}}\right) \tag{1}$$

Put N=4

$$\mathrm{x(l)} = \frac{1}{4}\sum_{l=0}^{3}\left(\mathrm{X(l)}e^{\frac{j2\pi kl}{4}}\right) \tag{2}$$

$\mathrm{x(0), x(1), x(2), x(3)}$

x(3) is periodically extended at the front of the symbol and known as cyclic prefix CP

Therefore,

$y(0) = h(0)x(0) + h(1)x(3) + v(0)$

$y(1) = h(0)x(1) + h(1)x(0) + v(1)$

$y(2) = h(0)x(2) + h(1)x(1) + v(2)$

$y(3) = h(0)x(3) + h(1)x(2) + v(3)$

This is circular shift of the channel taps or channel filter over sample x(0), x(1), x(2), x(3). Therefore output will be $y = h \otimes x + v$. Insertion of Cyclic prefix changes the condition mathemarically from linear convolution to circular convolution. In frequency domain circular convolution becomes product in FFT domain.

N point FFT at receiver

$$Y(l) = \sum_{k=0}^{N-1} \left(y(k) e^{-\frac{j2\pi kl}{N}} \right) \qquad (3)$$

Put N=4

$$Y(l) = \sum_{k=0}^{3} \left(y(k) e^{-\frac{j2\pi kl}{4}} \right) \qquad (4)$$

Received symbol across subcarrier L=2, [h(0), h(1),0,0 .] Which is known as padding with N-L zero's, N=4 and L=2. Channel coefficient across subcarrier L [H(0), H(1), H(2), H(3)]

Here number of subcarrier is N = 4. L=0,1,2,3

$Y(0) = H(0)*X(0) + V(0)$

$Y(1) = H(1)*X(1) + V(1)$

$Y(2) = H(2)*X(2) + V(2)$

$Y(3) = H(3)*X(3) + V(3)$

There is no ISI interface from previous symbol on each subcarrier, ISI has been removed in frequency domain.[7]

2.4 BER Performance of OFDM System

OFDM Signal of bit duration T_d, and time period of CP adder is T_{cp}, the total timeperiod of OFDM Signal is $T_d + T_{cp}$. Energy of OFDM Signal and bit energy E_b is expressed as:

$$E_b \times T_d = E_s (T_d + T_{cp}) \qquad (1)$$

Consider AWGN channel n, with a two sided noise spectral density is N_o, the variance is given by :

$$\text{Variance} = \frac{\text{No}}{2} \quad (2)$$

The OFDM Symbol energy is expressed as:

$$E_s = \log_2(M) \times R_c \times E_b \quad (3)$$

For QPSK M=4, BPSK M=2, 16 QAM M=16.

R_c = Code rate

Simplify equation (3) and divide it by N_o, the expression is given by:

$$\frac{E_b}{N_o} = \frac{E_s}{\log_2 M \times R_c \times N_o} \quad (4)$$

The relationship of Symbol energy and bit energy in terms of number of used subcarriers (n DSC) and FFT size (n FFT) is as follows:

$$\frac{E_s}{N_o} = \frac{E_b}{N_o} \times (\text{n DSC} \div \text{N FFT}) \times \left(\frac{T_d}{T_{cp} + T_d}\right) \quad (5)$$

This equation is used in MATLAB Coding to reflect the relation of Symbol energy and Bit energy.

2.5 Advantages of OFDM System

- Overlapping of spectrum orthogonally shows the efficient use of spectrum in OFDM System.
- On division of channel into narrowband flat fading sub-channels, OFDM becomes repellent to frequency selective fading than single carrier systems.
- ISI and ICI are neglected by the usage of cyclic prefix.
- OFDM Systems are less sensitive to sample timing offsets.
- Provides good protection against co-channel interference and impulsive parasitic noise.
- Using IFFT and FFT system overcome the heavy weight of the design.

2.6 Disadvantages of OFDM System

- OFDM suffers a problem of high peak to average power ratio.
- It is more sensible towards CFO and drift than single carrier systems.
- OFDM spectrum travels through multiple paths which require guard band to avoid ISI errors due to timing offsets.

CHAPTER 3 PAPR PROBLEM IN OFDM SYSTEM

High PAPR causes distortion in the system (as we have limited linear range power amplifier and ADC, DAC converter). It critically minimizes the efficiency of the power amplifiers. To maintain efficiency it is important to utilize large dynamic range DAC & expensive linear range converters & this is an addition to hardware cost & complexity. High PAPR lessens the battery lifetime in Mobile applications. It is a problem in the uplink on the grounds that uplink mobile terminal has limited power. It increases the systems complexity.

3.1 High PAPR

In OFDM Systems High Peak-to-Average Power Ratio has been acknowledged as one of the considerable practical problem. Data are transmitted using different modulation techniques number of bits are mapped onto modulation technique. These symbols are modulated using IFFT. On the summation of multiple sub-carriers or sinusoids High PAPR is observed as a problem. PAPR is defined as the ratio of the maximum instantaneous power and the average power i.e Maximum power occurring in the OFDM transmission to the average power of the OFDM transmission.

3.1.1 Definition of PAPR

OFDM systems have high PAPR which is one of its major adverse aspects as it reduces the Signal to Quantization Noise Ratio (SNR).
PAPR of Signal is expressed as following formula

$$\mathrm{PAPR} = \frac{\text{maximum power}}{\text{average power}}$$

$$\mathrm{PAPR(db)} = 10\log\left(\frac{\max[x(t)x*(t)]}{E[x(t)x*(t)]}\right)$$

Where ()* shows a complex operator

For single complex tone, following tone signal is considered:

$$x(t) = e^{-j2\pi ft}$$

Peak value of the signal with time period‘t’

$$\max[x(t)x*(t)] = \max\left[e^{j2\pi ft}.e^{-j2\pi ft}\right] = 1$$

Mean square value:

$$E[x(t)x*(t)] = E\left[e^{j2\pi ft}.e^{-j2\pi ft}\right] = 1$$

Thus, we have PAPR = 0 dB

For OFDM signal of K complex tone, following tone signal is considered:

$$x(t) = \sum_{0}^{k-1}\left(a_k e^{-j2\pi ft/T}\right)$$

Assume a_k=1 for any k .

Peak value is:

$$\max\,[x(t)x*(t)] = \max\,[\sum_{0}^{k-1}\left(a_k e^{j2\pi ft/T}\right)\sum_{0}^{k-1}(a*_k\, e^{-j2\pi ft/T})] = K^2$$

Mean square value is :

$$E\,[x(t)x*(t)] = E\,[\sum_{0}^{k-1}\left(a_k e^{j2\pi ft/T}\right)\sum_{0}^{k-1}(a*_k\, e^{-j2\pi ft/T})] = K$$

On calculating, PAPR obtained is K. Thus, OFDM signals having large PAPR leads a detrimental affect on the systems performance.

The PAPR of an OFDM Signal is defined in terms of CCDF and can be represented as:

$$P(PAPR > PAPR_{\circ}) = 1 - (1 - e^{PAPR_{\circ}})\,\hat{}2$$

Where $PAPR_{\circ}$ represents the clipping level. CCDF is the probability of getting high PAPR.

3.2 Factors affecting High PAPR

There are numerous factors that influence the PAPR some of them are given here. Each of them has there own advantages and disadvantages.

3.2.1 The order of Modulation

3.2.2 The number of sub-carriers

3.2.3 Pulse shape

3.2.4 Constellation shape

3.3 Identification of the PAPR Problem

Multicarrier technique is thought to be the real improvement in wireless communication system and in the midst of OFDM technique is being the essential one. The major drawback of OFDM is the high PAPR esteem brings about power efficiency going to be lessened. To beat the lower power efficiency it is important to utilize large dynamic range DAC as well as profoundly effective HPA and expensive linear range converters, results in the addition in the hardware cost and furthermore the complexity of the system and furthermore to reduce the hardware cost it has turned out to be basic to utilize effective PAPR reduction technique.

The drawback of utilizing extensive dynamic range is that it has impacts over the design of components. For example, length of the FFT/IFFT, mixer stage and the HPA , which is composed to handle the irregularity Noise ratio (SQNR) of ADC and DAC. The issue of PAPR is more impactful in uplink system on the grounds. In the uplink the mobile terminal has the limited battery power, so the effectiveness of power amplifier is basic in the uplink transmission. It is hard to design components having a satisfactorily extensive linear range brings about the saturation of the HPA. The saturation introduces both in-band distortion and out-band distortion, increased BER or spectral splatter brings about adjacent channel interference. To take care of the issue it is important to design such components that work within large linear range, however this is realistic as the components will be working improperly and cost turns out to be too high. This is particularly evident in the HPA where a high cost and 50% of the size of a transmitter lies.

3.3.1 Nonlinear HPA and DAC

Operating HPA's near the saturation region helps to obtain maximum output power efficiency. A high PAPR happens when the data on the subcarriers are add up in a constructive manner at the transmitter side. The composite transmit signal could be clipped through the DAC and power amplifier because of their bounded dynamic range. Due to clipping a significant amount of distortion occur in the output. So to remove the distortion in the output signal it is necessary to reduce the PAPR of an OFDM signal presents different undesirable results, for eg. Signal distortion and spectral regrowth. Clipping causes in band noise that outcome in BER performance degradation. Moreover, higher order harmonics that spill over into OOB spectrum also occurs due to signal clipping. To remove the spectral leakage from the system filtering is used after HPA. It's a waste of power, so it is an undesirable solution. Thus the dynamic range of DAC should be adequately broad to suit the largest peak signals. A high precise DAC support high PAPR having a commendable measure of quantization noise, but it is costly to a particular sampling rate of the system, yet a low precise DAC would be more affordable, yet the quantization noise will be more, which diminish the signal to noise ratio. The linear range of DAC is expanded to oblige high PAPR for the most part the DAC going to be saturated and clipping will happen. As the dynamic range of the DAC and power amplifier increases the cost is going to be increased.

3.4 Power Saving

HPA with dynamic range has low power efficiency. By reducing the PAPR value the power could save. The power efficiency is:

$$\eta = 0.5/PAPR$$

where $\eta = P_{out,avg}/P_{dc}$

η = HPA efficiency, $P_{out,avg}$ = the average of the output power, P_{dc} = a fixed amount of power regardless of their input power. The PAPR of OFDM system has to reduce for neglecting this level of power inefficiency.

3.5 The Parameters for the perception of the PAPR reduction in OFDM System

There are different strategies for PAPR diminishment. Every strategy has a few merits and demerits. Thus, there is always a trade-off between the PAPR lessening and different factors like bandwidth average power, computational complexity and some more. There are some characteristics given below for an ideal PAPR reduction technique. These factors play a important role for analyzing the performance of PAPR reduction technique in terms of CCDF and BER.

3.5.1 Bandwidth Expansion

The expansion in bandwidth is directly related to the information code rate loss because of side information, so the loss in bandwidth must be saved.

3.5.2 Spectral Spillage

Any PAPR decrease strategies can’t conquer OFDM captivating specialized features, for eg immunity to the multipath fading, so in PAPR lessening strategy the spectral spillage must be overlook.

3.5.3 Low Implementation Complexity

For PAPR reduction chooses such a method having both time and hardware imperatives for the PAPR reduction must be minimal. So due to this system becomes complex.

CHAPTER 4 PAPR REDUCTION TECHNIQUES

Numerous techniques have been developed to decrease PAPR of OFDM System over the years. Techniques used for PAPR reduction have been constantly innovated to meet the demands of the system. These techniques are dependent on numerous parameters like PAPR Spectral efficiency, reduction capacity, signal power increment, loss in data rate, complexity of computation and increase in the BER at the receiver end. These different parameters have to be considered prior to developing a PAPR Reduction technique for the system. Various methods have been instructed to reduce PAPR of the system. However, this techniques have varying success rates and complexness. Consequently bunch of techniques have been presented for the PAPR reduction. [8]

4.1 Clipping and filtering

Clipping is one of the basic technique utilized for PAPR reduction in OFDM systems. Clipping is mainly executed in transmitter side to limit the maximum of transmit signal to a pre-specified level as well as the parts of the signals that are outside the allowed region. In this technique we have to cut the peak of the signal above the threshold level to reduce the PAPR. But there are some demerit also as at the cost of reduced PAPR it introduces distortion in the system. As a result of in-band distortion it affects the BER performance and Spectral efficiency. Another demerit is it introduces out-band distortion also further which can be reduced by clipping technique at the transmitter but results in peak regrowth. In order to deal with these problem repetitive clipping and filtering technique is used. There are several techniques to deal with problem of PAPR but this is the simplest one and easy to design. Clipping is done at transmitter side. It is the most widely used technique and not expensive than any other technique.

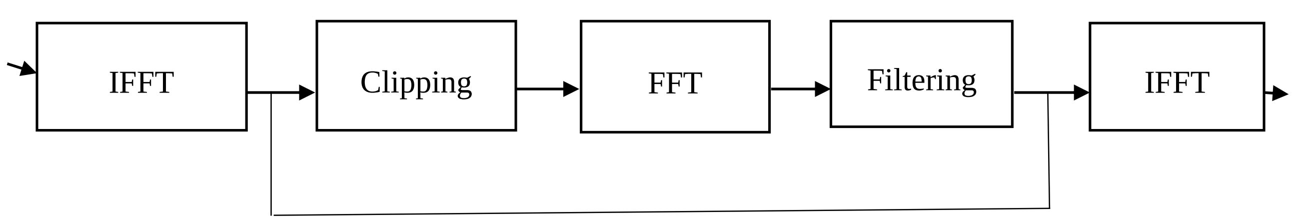

Fig. 4.1 Block diagram of Clipping and Filtering

4.2 Selective Mapping Technique (SLM)

In SLM method, from one input signal number of duplicate signals are generated that reflects the original information .This replica of signals are multiplied with some rotation factors. The multiplication factors are phase rotation factors and then signals are modulated using IFFT. After that signal with minimum PAPR is transmitted further .The rotation vectors acts as side information which helps in signal recovery. This is the main obstruction in classical SLM method as it increases one more component to get low PAPR. Amount of scrambling done by rotation factors on the original OFDM sequence and the length of SLM defines the efficiency of the system.[9]

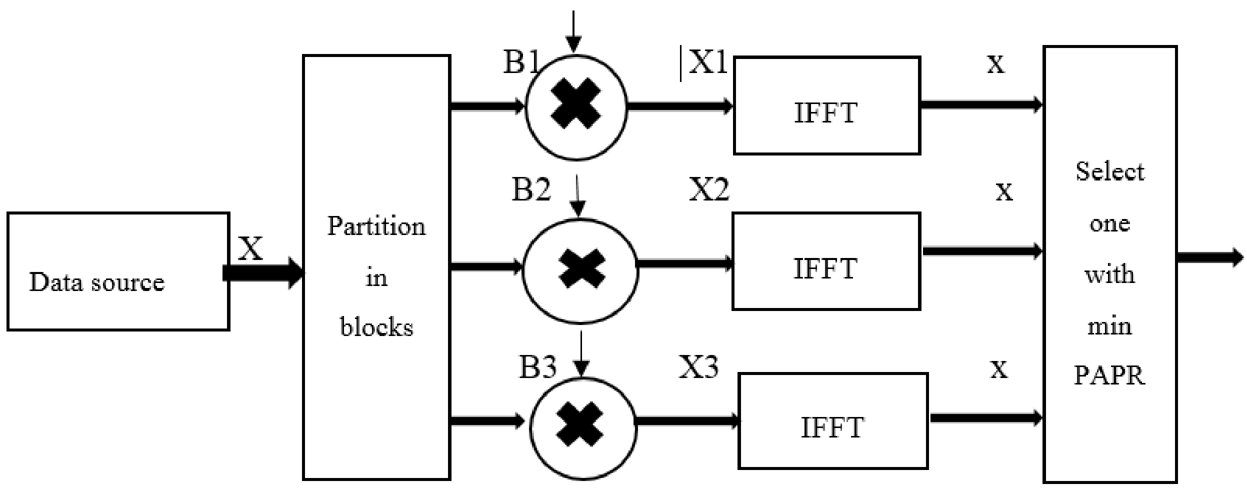

Fig. 4.2 Block diagram of SLM Technique

In this method, a number of duplicate signals are created to reflect the original information, and at the transmitter side signal having minimum PAPR is selected. The information about the selection of these duplicate signals need to be certainly transmitted along with the selected signal as side information. Selected mapping technique needs to transmit the information to receiver, with the selected signal, as side information to simplify the process of decoding at the receiver side. This technique can be enlist for larger number of sub-carriers with moderate complexity.

4.3 μ - Law Mapping

Distortions occurs in OFDM technique due to the usage of limited range of ADC and DAC. CF PAPR reduction technique also introduce distortion in this system. Companding techniques are developed to reduce PAPR without any introduction of distortion by decreasing the dynamic range of signal. Companding technique compresses the signal, making its distribution quasi-uniform, such that signal's maximum amplitude does not exceeds system's limitations and expands the low amplitude signal at receiver side. Thereby, no distortions will occur.

To obtain the original signal reciprocal of expanding is performed at receiver side. Absence of clipping noise in addition to improved BER performances makes Companding schemes a better alternative for PAPR Reduction than Clipping.

Mu-Law companding is of two types Compressor at transmitter side and Expander at receiver side. The generic form of μ-law compression is expressed by the following equation:

$$\acute{S}_n = \frac{\max(S_n)\ln\left(1+\frac{\mu|S_n|}{\max(S_n)}\right)}{\ln(1+\mu)}\,\mathrm{sgn}(S_n)$$

where, μ = μ law compressor coefficient

S_n = peak amplitude

Sgn = Sign function.

The generic form of μ-law expander is expressed by the following equation:

$$S_n = \frac{\max(S_n)}{\mu}\left(e^{|\acute{S}_n|\left(\frac{\ln(1+\mu)}{\max(S_n)}\right)} - 1\right)\mathrm{sgn}(\acute{S}_n)$$

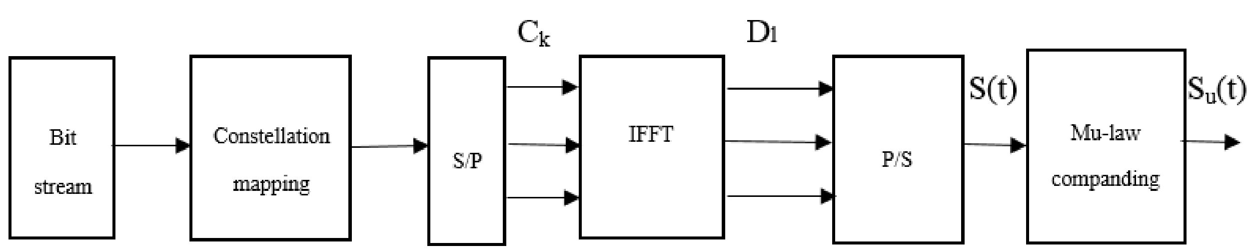

Fig 4.4 . Block diagram of μ-law mapping scheme at the OFDM transmitter

In fig. 4.4 C_k represents $[C_o, C_1, C_2\text{-----}C_{k-1}]^T$, C_k is the modulating symbol on data subcarriers, k. After signal constellation mapping has been done, the vector D_l is obtained by precoder process and mapping to N -points IFFT with N - L points zero padding is express as :

$$D = [d_0, d_1, d_2\text{----} d_{L-1}, 0\text{-----}0]^T$$

After the IFFT process, the complex signal in the time domain can be written as:

$$S(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} \left(d_n e^{\frac{j2\pi f t}{T}} \right), 0 \leq t \leq T$$

Where $f = n\Delta f, \Delta f = \frac{1}{T}$ and T is the OFDM symbol duration.

After that using μ- law

$$\acute{S}_n = \frac{\max(S_n) \ln\left(1 + \frac{\mu|S_n|}{\max(S_n)}\right)}{\ln(1+\mu)} sgn(S_n)$$

In the μ-law companding, piecewise compressor characteristics are obtained in which low level inputs are represented by the linear segment and high level inputs are represented by the logarithmic segment. From fig 4.5 it can be inferred that for higher values of μ, more compression occurs.

For μ=0, uniform quantization is reflected by a linear segment in which no compression takes place. As a result, zero value of μ is not preferred. The preferred value of μ that is common in practical terms is taken as 255. μ-law companding finds its applications in speech & music signals.

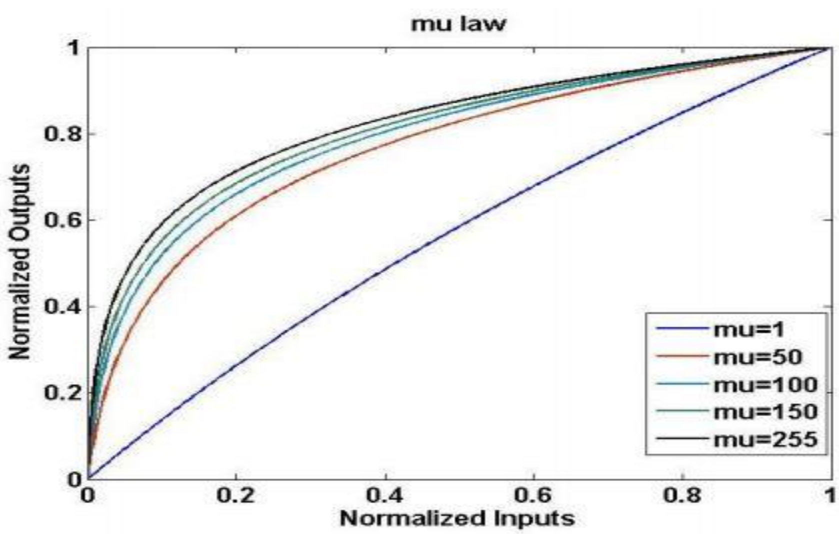

Fig. 4.5 Mu- Law Compressor Characteristics

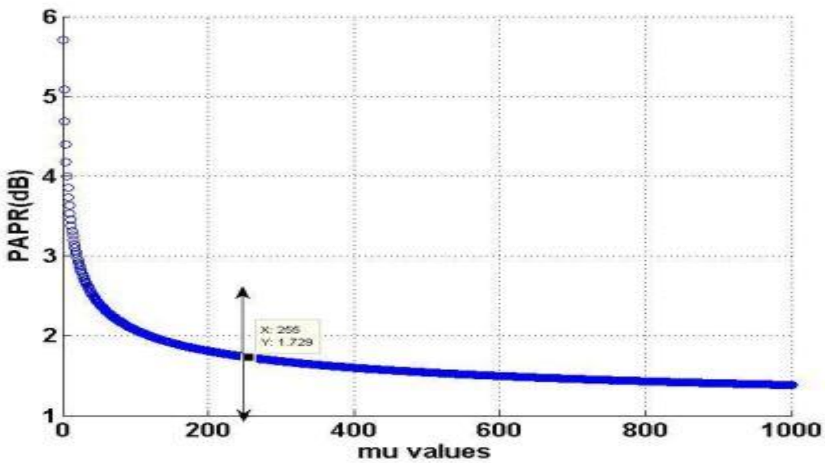

Fig. 4.6 PAPR for different μ values

Chapter 5 Research Methodology

The objective of this project is to evaluate the performance of OFDM System in terms of SNR vs BER. For this purpose we have used Matrix Laboratory (MATLAB) as a research tool.

5.1 Methodology used for the performance analysis of OFDM Systems

5.1.1 MATLAB as a tool

MATLAB is a language that combines a real time environment on our desktop using mathematical analysis. Execute the system by using array mathematics and get the real time observations. It allows an effective numerical computing environment with multiple data. It offers an optimized platform for solving scientific problems. MATLAB is basically a Matrix based language which is great at solving mathematical problems.

5.1.2 Procedure to plot results

Select the required parameters like number of subcarriers, duration of CP, symbol duration, channel, modulation technique. After selecting these write a code according to OFDM Procedure and after simulating that results are obtained which are reflected in the form of graphs. Matlab is a great software in handling up of large data as compared to other similar tools. We can have fine graphs by using MATLAB.

MATLAB by default provides the output values at every sample points taken within the iteration in tabular format while similar thing cannot be readily find into other tool.

CHAPTER 6 SIMULATION RESULTS AND ANALYSIS

6.1 Results of MATLAB Coding for BER Comparison of Different Modulation Techniques with or without OFDM Systems

This section shows the BER performance of BPSK, QPSK, 16-QAM modulation technique with Rayleigh fading channel and compare them with modulation technique on using in OFDM Systems over the same Rayleigh fading channel. This performance is observed by the help of MATLAB Coding and Simulink.

Table 6.1 Parameters to observe different Modulation technique in OFDM System with Rayleigh fading Channel

Number of Bits per symbol	52
Number of Symbol	10000
Length of FFT	64
Number of sub-carrier	52
Modulation Technique	BPSK, QPSK, 16-QAM
Channel	Rayleigh fading channel
Signal Frequency	8 Mhz
Sub-carrier frequency	0.125 Mhz
Cyclic Prefix	1/40
SNR	0-12

These are the required parameters used in to compare the performance of different modulation technique.

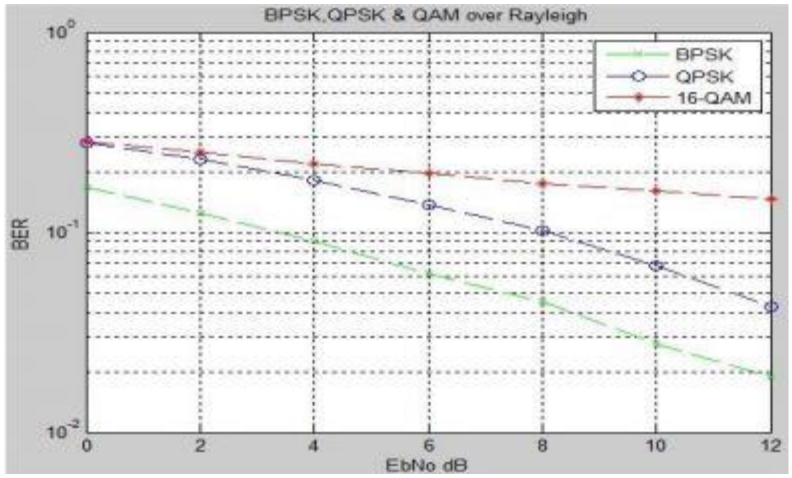

Fig. 6.1 Performance of modulation technique using Rayleigh fading Channel without OFDM System

In Fig. 6.1 observed the performance of modulation technique such as BPSK, QPSK and 16-QAM over Rayleigh fading channel. BER of BPSK is lower than QPSK and 16QAM. For example, at SNR=4, BER in BPSK is < 10^{-1} (0.1) whereas, in QPSK and 16-QAM is 0.2. At SNR=12 , BPSK=0.02 ,QPSK > 0.04 and 16 QAM-BER > 0.1

Now Comparison between modulation technique with OFDM Systems o the basis of BER.

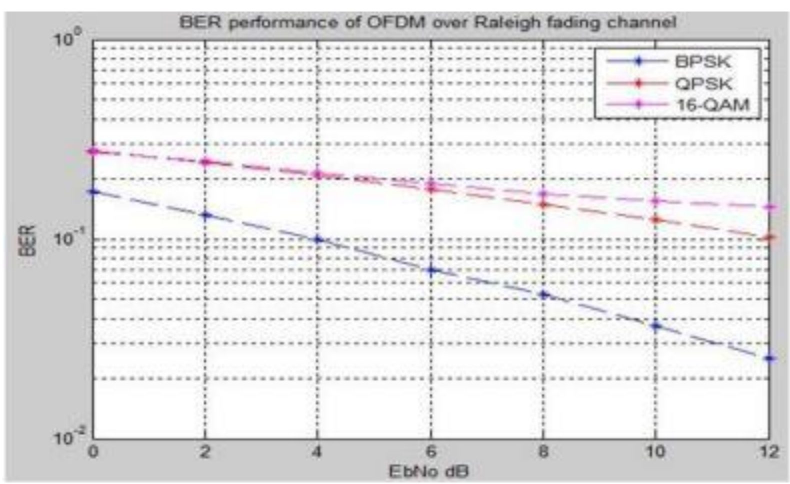

Fig. 6.2 BER Performance of modulation technique using Rayleigh fading Channel with OFDM System

Table 6.2 Obtained values of BER over Rayleigh fading channel with OFDM Systems

SNR(db)	BPSK(BER)	QPSK(BER)	16QAM(BER)
0	0.1711	0.2744	0.2736
2	0.1343	0.2417	0.2402
4	0.1001	0.2061	0.2107
6	0.0736	0.1765	0.1875
8	0.0511	0.1504	0.1705
10	0.0377	0.1241	0.1561

From the values of table 6.2 we observe that over Rayleigh fading channel there is very slightly difference between the BER values of QPSK and 16-QAM. In communication system to achieve high data rate at higher SNR we have to use higher order modulation technique. QAM technique provides good response at higher SNR values. So due to the need of high data rate nowadays QAM is used in 4G mobile communication.

6.2 Results obtained from MATLAB Coding for Clipping and Filtering (CF) for PAPR Reduction in OFDM System

These are the following parameters used in OFDM Systems to decrease the PAPR of the system.

- QAM modulation technique is used for mapping of the input bits
- FFT/IFFT blocks = 128
- Size of OFDM Symbol = 128
- Frequency Spacing = 15Khz
- Channel used = Rayleigh Fading channels
- Cyclic prefix length = 0.25*size of OFDM symbol
- Bandwidth = 1.5 Mhz
- Clipping ratio = 1, 2, 3, 4
- Sampling Frequency = 15KHz * 128

- Iteration = 1000

6.2.1 Using M-QAM where M= 16

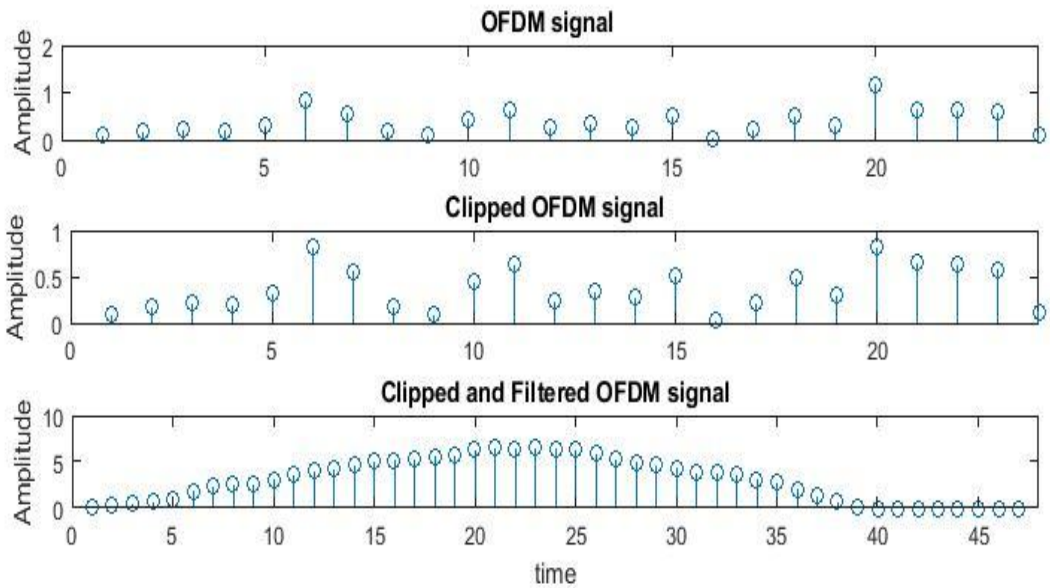

Fig 6.3 Clipping and Filtering , M = 16

6.2.2 Using M-QAM where M=64

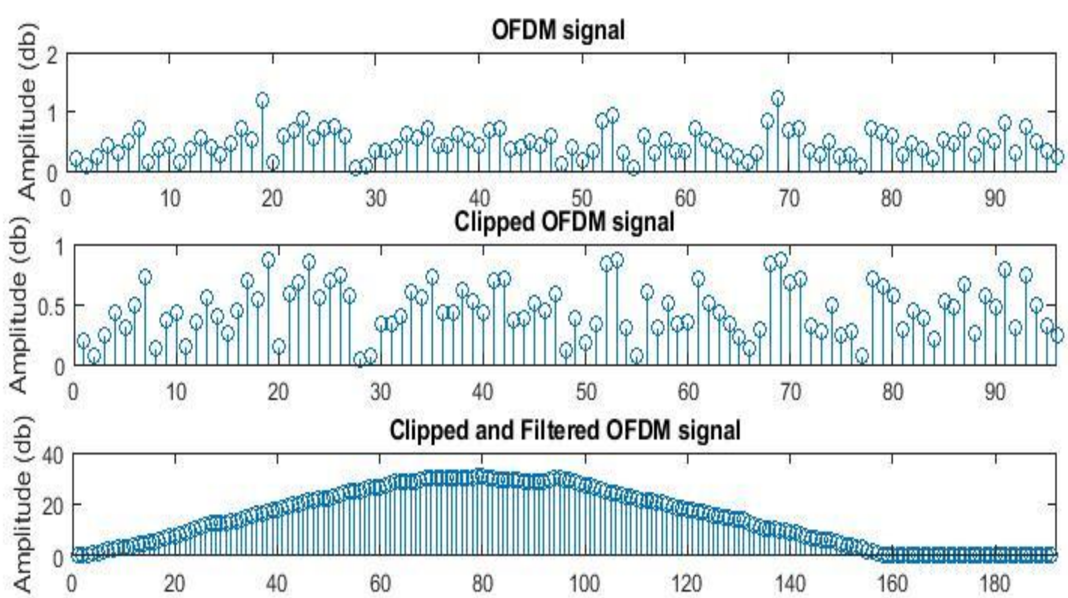

Fig. 6.4 Clipping and Filtering , M = 64

6.3 Results of MATLAB Coding for Selective Mapping (SLM) for PAPR reduction in OFDM System

6.3.1 Using M-QAM where M = 16

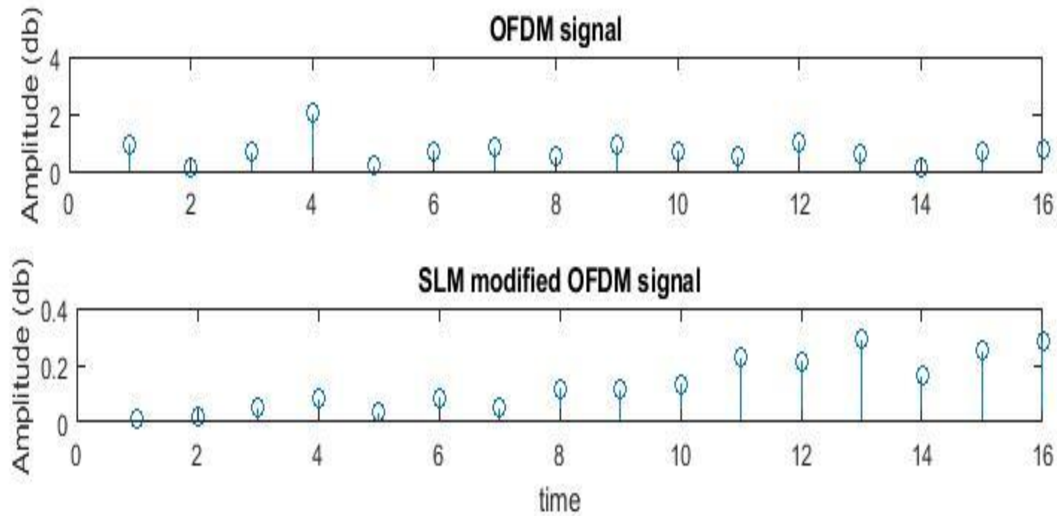

Fig. 6.5 SLM, M = 16

6.3.2 Using M-QAM , where M = 64

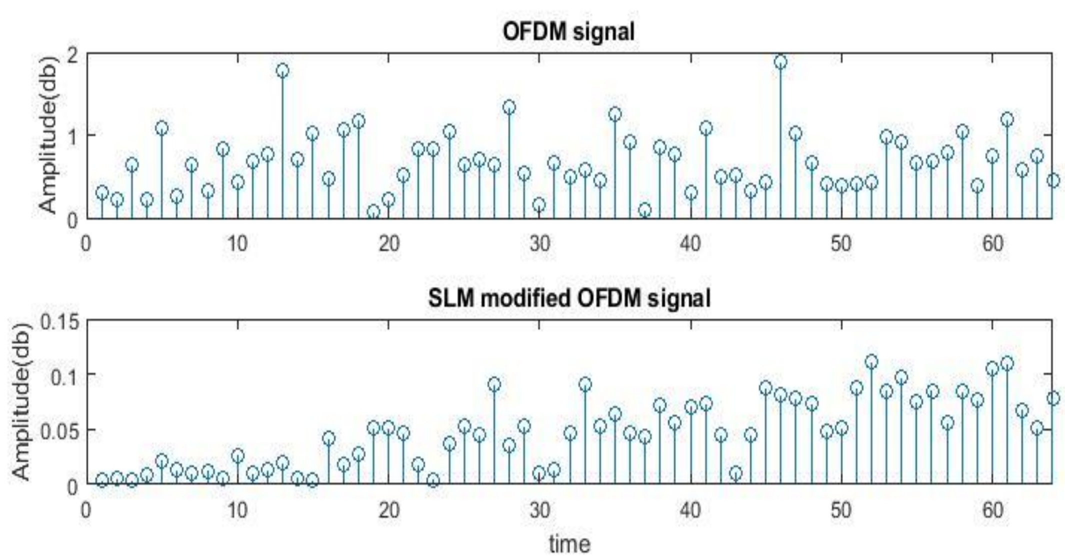

Fig. 6.6 SLM , M = 64

Table 6.3 Comparison of PAPR Values

PAPR	16 – QAM	64 – QAM
PAPR of OFDM Signal (db)	17.7594	17.6653
PAPR of CF Signal (db)	10.6508	9.3523
PAPR of SLM Signal (db)	11.9054	10.3894

Table 6.3 shows that Clipping and Filtering is better technique from both of them as it reduces more amount of PAPR than any other. Higher order techniques provides high bit rate and reduces slightly more amount of PAPR.

6.4 Results of MATLAB Coding for comparison of different techniques, where M = 64

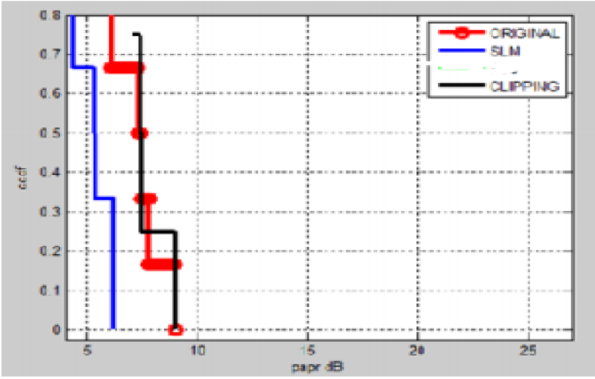

Fig. 6.7 Comparison of OFDM Signal after CF and SLM on the basis of PAPR

From figure 6.7 we observed that the Clipping and Filtering technique is better than the others as it reduces the most PAPR values. Many techniques are implemented for the reduction of PAPR on the basis of its own advantages and disadvantages.

As the efficiency of Clipping and filtering technique is 40.0273% and efficiency of SLM technique is 32.9626% on using QAM modulation technique so it is clearly visible that Clipping and Filtering is better than any other technique.

6.5 MATLAB Coding Results for Mu-Law Mapping + Clipping and Filtering for PAPR Reduction in OFDM System.

6.5.1 Using M-QAM where M = 16

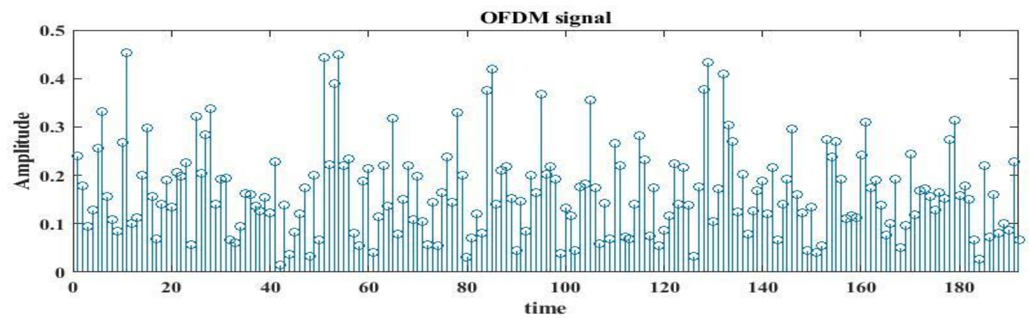

Fig. 6.8 OFDM signal

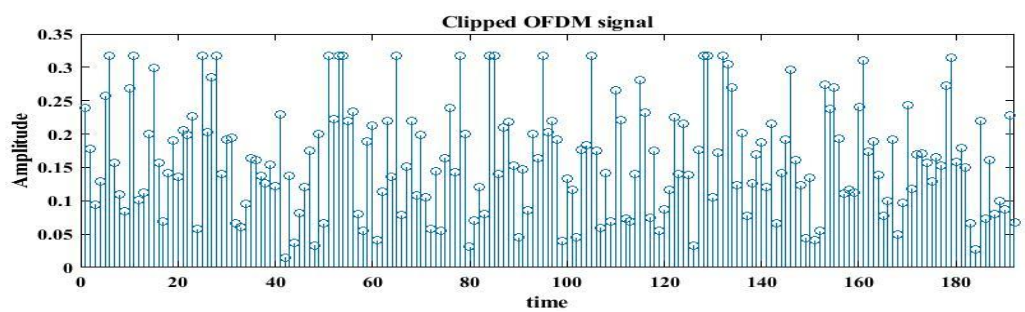

Fig. 6.9 Clipped OFDM signal

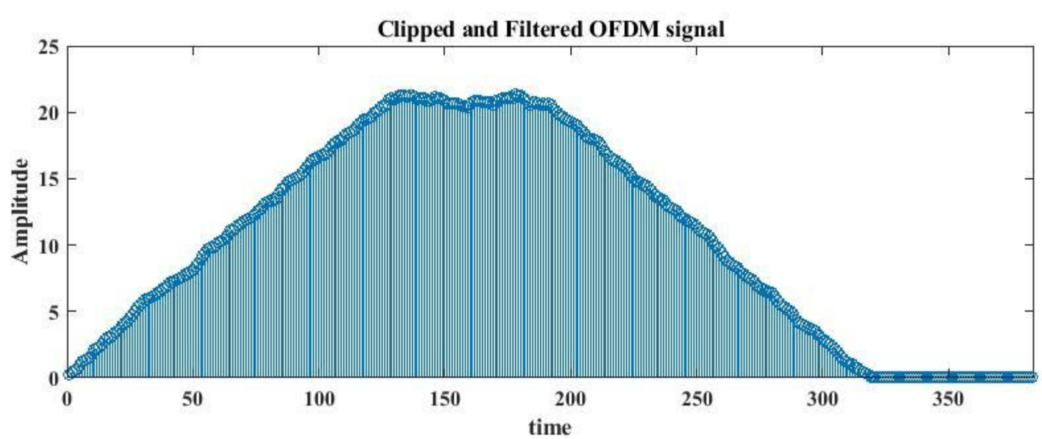

Fig. 6.10 Clipped and Filtered OFDM signal

After obtaining clipping and fitering OFDM signal in fig 6.10 apply mu-law on that signal using MATLAB coding and we get papr values with M =16. μ= 50, 100, 255, 500, 1000

Table 6.4 Comparison of different PAPR values

μ	PAPR of OFDM Signal (db)	PAPR of Clipped OFDM (db)	PAPR of μ law OFDM (db)	PAPR of μ law + CF OFDM(db)
50	15.2677	9.8705	3.2282	1.0779
100	17.3816	10.4989	3.3887	1.0781
255	18.0797	9.8404	2.8952	1.0266
500	20.7666	8.987	4.5036	1.0203
1000	22.3764	9.1132	4.5998	1.0213

From the above table we observe that mu-law + Clipping and Filtering is the best technique from all the other technique which are observed here. There is about improvement of 3.0 db between different values of μ.

CHAPTER 7 CONCLUSION AND FUTURE ASPECTS

7.1 Conclusion

In mobile industry there is a need of higher data rate which is possible with higher order modulation. OFDM technique shows a benchmark performance in reducing PAPR. The insertion of cyclic prefix act as a guard band between the symbols and BER gets reduced which decreases the ISI and increase the system performance. Instead of insertion of more cyclic prefix there is an alternative approach to maintain BER. This work conclude that higher order QAM technique performs better at high SNR values (SNR value greater than 15 db). In 4G communication OFDM system are used with high order of QAM modulation technique at high value of SNR.

The performance of Clipping and filtering and Selective Mapping technique is evaluated under 16-QAM and 64-QAM observed that CF is the better and efficient technique to reduce PAPR in OFDM Systems. The performance using mu-law with OFDM System is also observed to reduce PAPR there is a radical reduction in the value of PAPR value. And found that µ- law based reduction is more efficient than CF.

In this reduction an approach is made to reduce PAPR by combining µ-law and clipping and filtering which gives us about 3.0 db reduction in PAPR values.

7.2 Future Aspects

In this work clipping and filtering is combined with mu-law and observe a radical reduction in the PAPR values. So new techniques can be introduced by combining further techniques with each other.

1. Combination of different techniques can propose a new method to reduce PAPR.
2. Study the impact of these proposed techniques on bandwidth, noise, distortion and the ratio of power saving.
3. The proposed CF+Mu-law can be combined with other technique such as coding, interleaving etc.
4. These technique can also be implemented for other multicarrier system.

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