# A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR in OFDM

Dissertation-II

*Submitted in partial fulfillment of the requirement for*

*the award of the degree of*

**MASTER OF TECHNOLOGY**

In

Electronics and Communication Engineering

*By*


***Henna Bhatti***

*(Reg. No. 11301389)*

*Under the Guidance of*

**Mr. Surjeet Kumar**

Assistant Professor

Supervisor

LOVELY PROFESSIONAL UNIVERSITY

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA (DISTT. KAPURTHALA), PUNJAB

**School of Electronics and Communication Engineering**

**Lovely Professional University, Jalandhar-Delhi G.T. Road (NH-1),**

**Phagwara, Punjab, India-144411**


**(April 2015)**

# CERTIFICATE

This is to certify that the Dissertation-II titled "**A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR**" that is being submitted by **Ms. Henna Bhatti** in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY, is a record of bonafide work done under my guidance. The contents of this Dissertation-II, 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. Surjeet Kumar
(Assistant Professor)
LPU, Punjab.

Objective of the Dissertation-II is satisfactory / unsatisfactory

Examiner I

Examiner II

## ACKNOWLEDGEMENT

With great pleasure and deep sense of gratitude, I express my indebtedness to my supervisor Mr. Surjeet Kumar for his invaluable guidance and constant encouragement at each and every step of my thesis work. He exposed me to the intricacies of relevant topic through proper counseling and discussions and always showed great interest in providing timely support and suitable suggestions. I am greatly indebted to my head of department Mr. Shakti Raj Chopra for inspiring and motivating me to develop new ideas and implementing them. I am grateful to him for his invaluable guidance and encouragement throughout this work. I would like to take this opportunity to express my sincere and profound gratitude to him for the pains he has taken to accomplish this project.

I also extend my sincere thanks to all other faculty members of Electronics and Communication Department and my friends and colleagues for their support and encouragement.

Place: LPU, Jalandhar Henna Bhatti

Date: February, 2015 Reg. No: 11301389

# DECLARATION

I hereby certify that the work, which is being presented in the report, entitled **A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR in OFDM** in partial fulfilment of the requirement for the award of the Degree of Master of Technology and submitted to the Department of Electronics and communication Engineering of Lovely Professional University, Punjab, institution is an authentic record of my own work carried out during the period between *Jan-April,2015* under the supervision of Mr Surjeet Kumar. I also cited the reference about the text(s)/figure(s)/table(s) from where they have been taken.

The matter presented in this thesis as not been submitted elsewhere for the award of any other degree of diploma from any Institutions.

Date: Signature of the Candidate

This is to certify that the above statement made by the candidate is correct to the best of my /our knowledge.

Date: Signature of the Research Supervisor

# ABSTRACT

According to the demand of advance communication system, there should be high data rate with the both power efficiency and lower bit error rate. This demand of high data rate can be fulfilled by the single carrier modulation with compromising the trade off between the power efficiency and bit error rate. Again in the presence of frequency selective fading environment, it is difficult to achieve high data rate for this single carrier modulation with a lower bit error rate performance. With the consideration of an advance step towards the multi carrier modulation scheme it is possible to get high data rate in this multipath fading channel without degrading the bit error rate performance. To achieve better performance using multi carrier modulation we should make the subcarriers to be orthogonal to each other i.e. known as the Orthogonal Frequency Division Multiplexing (OFDM) technique. But the great disadvantage of the OFDM technique is its high Peak to Average Power Ratio (PAPR). As we are using the linear power amplifier at the transmitter side so it's operating point will go to the saturation region due to the high PAPR which leads to in-band distortion and out-band radiation. This can be avoided with increasing the dynamic range of power amplifier which leads to high cost and high consumption of power at the base station. The techniques are also associated with the cost and bandwidth. This report presents an efficient technique known A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR reduce PAPR in OFDM .This technique can provide the reduction in OFDM to 2.5 dB which is a significant reduction. Moreover due to cancellation of clipping noise, BER is improved. We get the reduced PAPR with reduction in BER.

# TABLE OF CONTENTS

| Contents | Page No |
|---|---|

# LIST OF FIGURES

# LIST OF TABLES

**Table No.** **Titles** **Page No.**

# LIST OF ABBREVIATIONS

| | |
|---|---|
| BER | Bit Error Rate |
| CCDF | Complementary Cumulative Distribution Function |
| FFT | Fast Fourier Transform |
| FDM | Frequency Division Multiplexing |
| ICI | Inter Carrier Interference |
| IEEE | Institute of Electrical and Electronics Engineers |
| IFFT | Inverse Fast Fourier Transform |
| ISI | Inter Symbol Interference |
| LTE | Long Term Evolution |
| OFDM | Orthogonal Frequency Division Multiplexing |
| PAPR | Peak to Average Power Ratio |
| MCM | Multicarrier Modulation |
| SNR | Signal to Noise Ratio |
| WiMAX | Worldwide Interoperability for Microwave access |
| 3G | Third Generation |
| 4G | Fourth Generation |

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

Today is the requirement of high data rate because of the increasing demand of wireless communication day to day very rapidly. We know that the transmission of data involve both wired as well as wireless medium. Frequently these services require very reliable data transmission over very callous environment [1, 2]. These transmission systems experience a large degradation such as there is large attenuation of signal during transmission, multipath interference, addition of noise, nonlinearities, time variance and this causes the signal to get faded. The transmission system must get together the finite constraints like cost and power limitation. So we necessitate the new modulation techniques which can meet the current day requirements. There are many rising multicarrier modulation techniques which can make agreement with these impairments. One of the techniques that is most usually used and can fulfil the requirements is Orthogonal Frequency Division Multiplexing (OFDM). It has been recently become very admired in wireless communication [3]. It is leading contender of 4G owing to its properties.

The chief disadvantage of OFDM is PAPR in which there is fluctuation in envelop. As we are using power amplifier at the transmitter side, so it's operating point must lie below the available power so as to function in a perfectly linear region. PAPR makes decrease in signal to quantise noise ratio of ADC and DAC whereas it degrades the efficiency at transmitter of power amplifier. A lot of algorithms have been proposed to get the reduction of PAPR but the algorithms still consist of advantages as well as disadvantages.

The Clipping and Filtering is the fundamental technique in which some part of the signal is clipped to a certain value. Also there is a technique known as coding technique but it cause the reduction in data rate which is undesirable. Another technique is Tone Reservation which again decrease the data rate with increase in power. Furthermore, there are multiple signal representation methods, such as selected mapping (SLM) and partial transmit sequence (PTS) are also renowned methods that can reduce the problem of PAPR to an extent by changing the phase of sub carriers [3]. To recover the original symbols, the phase weights are sending as side information to the receiver [1]. In with various scheme of reduction of PAPR, the clipping technique has been considered as the on the whole as a widely used and practical solution because its bandwidth do not expand and there is simplicity in implementation of technique, low computational complexity without receiver assistance [7, 8].

This technique neither requires more power nor additional bandwidth whereas providing equal or better PAPR reduction when compared to existing methods when they are compared to the existing methods [11]. This algorithm focuses on the clipping and filtering operation to achieve significant PAPR reduction. We consider PAPR reduction techniques which necessitate less complexity and bandwidth [14]. The combination of Clipping and the SLM technique can jointly prove to provide better PAPR.

### 1.2 Multicarrier Technique

Single carrier systems experience Inter Symbol Interference. When the bandwidth of signal is less than the coherence bandwidth, ISI takes place or in other way when the symbol duration is less than delay spread. Multicarrier techniques have been proposed to fight the problem of ISI. Multicarrier techniques divide the full bandwidth into large number of narrow band orthogonal subcarriers [13]. Figure 1.1 shows the spectrum of multicarrier signal and single carrier system. Consequently signal bandwidth becomes less when compared to coherence bandwidth which provide no ISI in time domain and provide in frequency domain flat fading. The multicarrier communication system like OFDM (Orthogonal Frequency Division Multiplexing) and MC-CDMA (Multi Carrier Code Division Multiple Access) are recognised as capable technologies for 4G.

Fourth-Generation communication systems, is a word used to describe the next pace in wireless communications. A 4G system will be able to give a high data rates than previous generations.

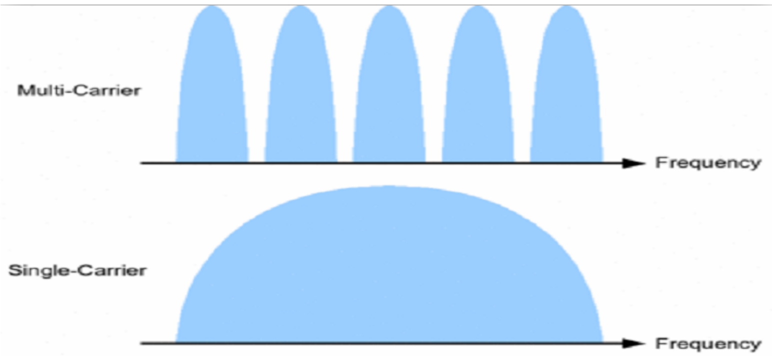


Figure 1.1 Conventional spectrum of multicarrier and single carrier system

### 1.2.1 Multi-carrier modulation (MCM)

Multi-carrier modulation (MCM) is a method by which data is transmitted by dividing it into a number of components and then sending each of these components over different carrier signals.

The advantages of MCM consist of relative resistance to fading that is caused by the signals which are transmitted and multiple copies of signal are received at a time which is known as multipath fading and furthermore, MCM has less susceptibility to interference that is caused by impulse noise when it is compared to single carrier system.

Analog military communications first used it in  in the year 1950 and recently MCM has its wide role in communication. This technology is used in digital television and is used as a method of acquiring high data rate in Asymmetric Digital Subscriber line (ADSL) systems. Local area networks (WLAN) also use MCM. MC modulation can be efficiently implemented digitally using the FFT (Fast Fourier Transform) techniques, forming the so-called orthogonal frequency division multiplexing (OFDM) which is the lately used modulation technique.

### 1.2.2 OFDM

The concept of OFDM has derived from multicarrier in which the multicarrier are used and made orthogonal to each other. Orthogonality implies that the signals are entirely independent to each other. It is achieved by making sure that the carriers are exactly placed to each other at nulls in the modulation spectra.  Thus, OFDM is a multicarrier modulation Scheme.

When the transmission is through single carrier, the performance will degrade soon in the occurrence of multipath. The parallel transmission scheme was preferred before the development of equalizer for high data rate though it has high bandwidth inefficiency and cost because it uses several modulators and demodulators.

Table compares serial transmission with parallel transmission scheme.

| Transmission method | Parallel | Serial |
|---|---|---|
| Symbol time | Ts | Ts/N |
| Rate | 1/ Ts | N/Ts |
| Total BW required | 2*N/ Ts + N*0.1/ Ts (Assume Guard band=0.1/Ts) | 2*N/Ts |
| Susceptibility to ISI | Less | More |

Table 1.1 Comparison of parallel transmission scheme with the serial transmission.

### 1 .3 Peak to Average Power Ratio (PAPR)

There are many independently modulated subcarriers in OFDM and they are mostly in hundreds and due to large number which can present a high PAPR when coherently added up. There is a peak power of N times the average power of the signal when these N signals are added with the same phase. So a very large PAPR occur in OFDM signals, which has very sensitiveness to make the power amplifier to work in a linear region. In OFDM, a block of $N$ symbols $[X_k, k = 0,1,........,N-1$ ], is formed with each symbol modulating one of a set of subcarriers, $[f_k, k = 0,1,.........,N-1]$[2]. The $N$ subcarriers are to selected to be orthogonal, that is, $f_k = k\Delta f$, where $\Delta f = 1/_{NT}$ and $T$ is the original time period. The resulting signal is given as [1]

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_n e^{j2n\Delta f t} \quad , 0 \leq t \leq T \qquad (1.1)$$

PAPR is defined as the large variation or ratio between the maximum power and the average power [1, 2].

$$PAPR = \frac{max|x(t)|^2}{1/_T \int_0^T |x(t)|^2 \, dt} \qquad (1.2)$$

### 1.3.1. Effects of high PAPR

The Q-point of the linear amplifier must lie in the linear and because of high PAPR the Q-point moves into the saturation part [3]. This needed a large dynamic range for the system devices such as A/D converters and D/A and power amplifier. A series of interference is present if this is not satisfied. If the peak signal moves into the non linear region of the device at the transmitter side, it causes high out-of-band radiation and inter-modulation distortions. It also consequence on the receive signal in rotation, and offset and attenuation. The large dynamic range of the power amplifier reduces its efficiency and increases the cost [3]. Hence there is a trade off exists between efficiency and non linearity of amplifiers [3, 5]. As a communication engineer our aim must be to reduce this drawback.

In OFDM system with N subcarriers and when all of subcarrier components are summed together with same phase, the maximum power will occur [3]. In an OFDM signal, there are 128 subcarriers that are having normalised power of 1w then maximum PAPR is 128 or 21db.

The following are the main two events that are caused by OFDM

- Inter-modulation of carriers
- Out-of-band radiation due to spectral leakage

### 1.3.3 CCDF for PAPR

The most usually used performance measurement for PAPR is known as Complementary Cumulative Distribution Function (CCDF). It gives the probability that the PAPR of a data-block crossed a given threshold is determined by CCDF [2]. If the CCDF graph is plotted against the threshold values, the better is the PAPR reduction performance if the graph is vertical [4]. OFDM signals can be regarded as Gaussian noise like signals their variable amplitude is approximately Rayleigh-distributed when the number of sub-carriers in an OFDM system is high, and the power distribution has a cumulative distribution function given by[3]

$$F(z) = 1 - e^{-z} \qquad (1.3)$$

Considering the samples of OFDM symbol are mutually uncorrelated, the probability of PAPR is below some threshold which can be specified as [1].

$$P(PAPR \leq z) = F(Z)^N = (1 - e^{-z})^N \tag{1.4}$$

Where N is the number of subcarriers

## 1.4 Motivation:

The 4th generation wireless communication technology has been achievable due to the OFDM technology. The existing world is in the need of high data rate and efficient bandwidth utilization as number of users has been tremendously increasing day by day which can be well offered by OFDM. Like other multicarrier signal, the OFDM has a chief worry of PAPR and from the last few decades researchers have been trying to develop a technique to reduce the drawback of OFDM and the technique must meet the requirement of low complexity and cost. Some techniques show less complexity while high distortion while some shows more complexity. There is a transaction among various such factors and therefore a optimize technique is requisite to reduce high PAPR. Such research works give motivation from for the betterment of the technique to reduce PAPR and to tackle the drawbacks in a novel approach.

## 1.5 Scope of Study

The prevailing one of major problems of OFDM systems is high peak-to-average-power ratio (PAPR) of signal which is transmitted and so many PAPR reduction techniques and combined schemes with individual techniques have currently been developed. The various techniques show that the clipping technique has been generally used as a practical scheme because of its simplicity in implementation and its slow computational complexity and [10]. In the method of clipping for PAPR reduction the amplitude of signal can be clipped to reduce peak power to a needed level before amplification. Out of band radiation and in band distortion are the results of Clipping. Filtering after clipping can trim down out of band radiation to maximum extent, but also give rise to some peak re growth in the filtered signal. Forward Error Correcting codes and band pass filtering with clipping are the techniques which can decrease BER and provide spectral efficiency [6]. The combination of the Clipping and Filtering with other technique can appreciably reduce PAPR and improve BER. So the performance can be enhanced of OFDM system. The clipping and Filtering is combined with the SLM technique to decrease the PAPR of OFDM which tackle the problem in an efficient manner.

### 1.6 Organization of the Thesis

This thesis gives overview of some of the existing techniques through investigation. The literature reviews have recommended the effect of individual scheme to reduce PAPR which has become the major problem of OFDM. We require a technique that is provide less simulation and efficient. This thesis proposes an efficient technique by combining Clipping and Filtering with SLM which is having low operation complexity which has the potential to reduce PAPR with low BER. This thesis is organized as follows:

This chapter 1 includes the introduction of the thesis. Here multicarrier technique, OFDM and its drawback that is PAPR is explained. The effects of PAPR in OFDM are also illustrated.

This chapter 2 includes the introduction generation and reception of OFDM, with its advantages, applications and major limitation which is peak-to-average power ratio (PAPR). Orthogonal Frequency Division Multiplexing (OFDM) as a transmission technique is known to acquire a lot of effectiveness when compared to any other transmission technique. It provide the advantage such as high spectral efficiency, have toughness to the channel fading and resistant to interference and it also illustrates some of the existing techniques. The description of literature survey of papers is also given in this chapter. The whole literature survey is based on the papers taken from various organizations such as IEEE.

In this chapter 3 we represent about the clipping and Filtering Technique to reduce PAPR in OFDM. Also the information of SLM technique is described.

In chapter 4 a hybrid technique to reduce PAPR is introduced which is an efficient technique to reduce peak to average power ratio is given in this chapter. With a proper selection of technique like SLM with clipping significant improvement in PAPR reduction can be achieved.

In the chapter 5 research methodology has been described which shows the way in which research is preceded.

In chapter 6 simulation study has been done to implement this technique by incorporating the Hybrid approach using CF and SLM to reduce PAPR. The result shows the reduction of PAPR. The result is shown by matlab simulations to reduce PAPR.

This chapter describe the final conclusion and future works.

# CHAPTER 2

# LITERATURE SURVEY

## 2.1 Introduction

In this chapter, it consists of description about OFDM. The different techniques have been proposed for the reduction of the drawback of OFDM that is to reduce OFDM. OFDM is a technique that fights against the environment factors which cause fading of signal. It has become the basis for 4G and description of main papers is given in this chapter. The whole literature survey is based on the papers taken from various organizations like IEEE.

## 2.2 Fourth Generation (4G)

4G is short for fourth generation is the fourth generation system. It provides high data rate. It is the next pace in wireless communication after 3G. A 4G system will be able to provide a broad internet protocol solution where the data, voice and multimedia messages can be specified to the subscriber at anytime and anywhere and moreover it provide high data rate when it is compared to previous generations. Mobile phones based on 4G are endow with data transfer rates of 100Mbit/s to 1Gbit/s.

Two 4G systems that are commercially used are WiMAX and LTE. WiMAX is using OFDMA in and in the uplink and in the downlink. For the LTE, OFDMA is used for the downlink and in contrary; SCFDM is used for the uplink because of PAPR in OFDMA as it marks in nonlinear operation of amplifiers. Moreover, IFDMA generates less power fluctuation and thus requires energy-inefficient linear amplifiers. Likewise MC-CDMA is in the suggestion for the IEEE802.20 standard.

The OFDM technique provides promising base to the 4G standard. The figure 2.1 shows the history of mobile communication as the adoption for radio access technique.

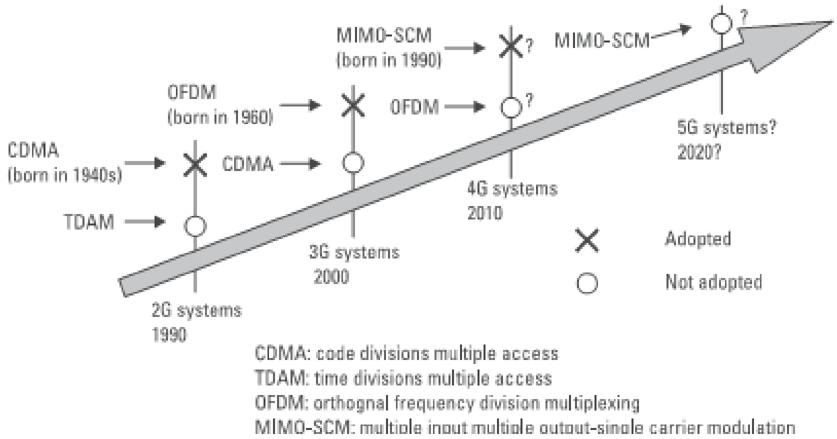


Figure 2.1: History of mobile communications systems

## 2.3 OFDM

Orthogonal Frequency Division Multiplexing (OFDM) has become an admired and efficient communication technique for high speed communication in the last few decades. OFDM is a multicarrier modulation technique [4] which depends on the principle of FDM where the bandwidth is divided in terms of frequency and transmitted simultaneously over the large number of subcarriers. Thus, in this high rate data block get divided into a number of lower small data streams which are sent simultaneously over a number of orthogonal subcarriers [2]. The evolution of OFDM can be divided into three parts that involve Multicarrier Communication (MC), Orthogonal Frequency Division Multiplexing and Frequency Division Multiplexing (FDM).

From the long time Frequency Division Multiplexing (FDM) has been used to carry the multiple signals over the telephone lines. FDM has the concept of dividing the bandwidth in small regions in frequency and then transmitting the signals in the small regions. Each small region has a frequency known as central frequency. To make sure that the one signal does not interfere with the adjacent signal, a guard band is kept between the adjacent signals. In MC, the signal is divided into various signals then modulation process of signal is carried out and then the signals with different frequency are multiplexed together like FDM.

OFDM is derived from the concept of multicarrier where the carriers used are made orthogonal to each other. Orthogonal in this way implies that the signals are totally Independent to each other [4].

It is make possible by making sure that the various carriers are positioned exactly at the nulls in the modulation spectrum of each other.

R.W. Chang in 1966 introduced the idea of OFDM which was later patented in 1970. Military communication used OFDM but it remained limited to it only due to lack of integrated circuits and broadband application to bear the necessary complex computation. In 1990, OFDM come into light after the advent of broadband digital applications and wonderful growth in VLSI design and process technology. Digital Audio Broadcasting (DAB) standard was the initial commercial OFDM which was based on wireless system in 1995 [2]. The expansion in the field of OFDM sustained in analogous to all other simultaneously existing technologies till the major 21st century wireless standards like WiMAX, WLAN and LTE taking place using OFDM in one manner or the other manner. The primary advantage of OFDM is its aptitude to adapt with strict channel conditions, for example narrowband interference and multipath without complex equalization filters.

**Principle:**

The basic principal of OFDM is orthogonality. Two signals are said to be orthogonal if the integral of the product for their common period is zero [15]. Since all the carriers are sine wave or cosine wave and the area under than one period of a sine or cosine wave is zero.

Let us take a sine wave of frequency o and then multiply it by a sinusoid of a frequency p where both m and n are integers. The integral of the area under this product is given by

$$f(t) = \sin owt * \sin pwt$$

This is equal to sinusoids of frequencies (p - o) and (p + o) by applying the trigonometric relationship

$$= ½ \cos( p + o ) + 1/2\cos(p - o)$$

These two components are each of sinusoidal so, the integral is equal to zero over one period.

$$\int 1/2\cos(p + o) + \int 1/2\cos(p - o)$$

$$= 0\text{-}0$$

So when we multiply a frequency p by sinusoid of frequency o/p the area under the product is zero. All the integers like o and p, sin(ox), cos(ox), cos(px) are orthogonal to each other. These frequencies are harmonics. This permit transmission of a lot of sub carriers simultaneously in a close frequency space without making interference with each other.

The orthogonality of the carriers implies that each carrier has cycles which are of integer in number over a symbol period. Because of this integer number of cycles that marks in no interference between the carriers, permitting them to be spaced as much close as possible. The Frequency Division Multiplexing (FDM) has the difficulty in controlling large carriers which can be improved in OFDM. As a consequence this multicarrier transmission scheme permits the overlapping of subcarriers which give bandwidth efficiency [4].

### 2.3.1 Transmission Scheme of OFDM

The main aim behind the OFDM is that the modulation which is of low rate are less delicate to to interference because of multipath, the best way is to transmit a number of small data blocks in parallel than transmitting one data block of high rate. Frequency spectrum is divided into narrow sub-bands short enough that the channel are constant (flat) over a given sub-band. The separate data is transmitted in each band using different sub carriers. Power and rate of transmission in each band depends on the reply of the channel in that band[3]. There will be no inter symbol interference since each sub band is narrow and flat. A classical IQ (In phase Quadrature phase) modulation (BPSK, QPSK, M-QAM, etc) is used over the sub band [2][16] . If properly design, the signal at the receiver is treated as flat faded due to the division of signal in flat and narrow region.

*Block diagram of OFDM:*

The block diagram for OFDM transmission is shown in Figure 2.2. A large number of subcarriers which are very near to each other are used to transmit data. They are spaced apart at precise at precise frequencies. The spacing frequency is such that it is reciprocal of the symbol duration. The spacing help to provide the orthogonality in this technique which protect the demodulator from detecting frequencies which are not its own frequencies. The modulation of each carrier is done with the modulation technique like Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK) at a low symbol rate which will convert the data into parallel data and IFFT is then accomplished on the transformed signal which is in process further by transmitting it in parallel to serial converter. The data transfer takes place through the channel.

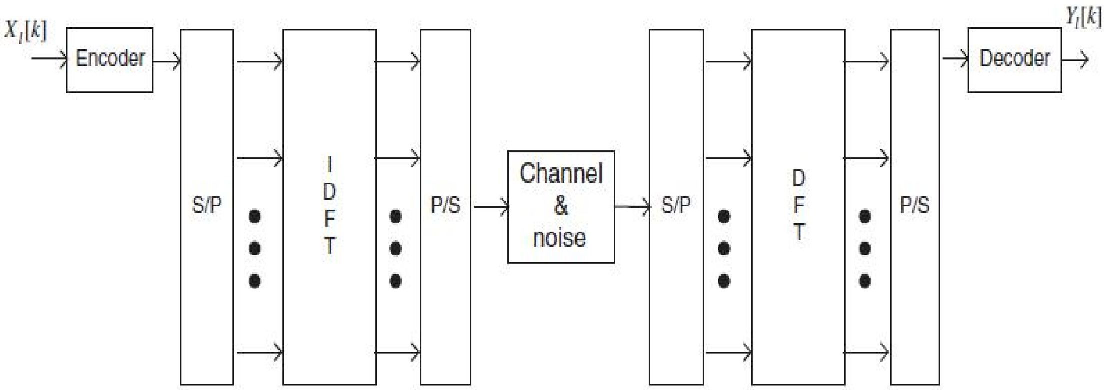


Figure.2.2: Block Diagram of OFDM transmission

The process which recovers the original information at the receiver side is known as demodulation. The signal is passed through serial to parallel converter which is then applied to FFT. The entire data rate is to be kept similar to that of the usual single carrier modulation scheme with the identical bandwidth.

The spectra of sub carriers are overlapped to get bandwidth efficiency. The spectrum of The sum of frequency shifted sinc function represents the spectrum of OFDM signal in frequency domain, where overlapped neighbouring sinc function are spaced apart by 1/T where T is the symbol duration. It is cleared from Figure 2.3 that the two lobes main lobe and side lobe are comparable to each other in the spectrum. So we have some guard band at outer subcarriers which are known as virtual carriers (VCs). They are kept around the frequency band to reduce out of band radiation. OFDM also uses guard intervals in time domain which is known as cyclic prefix which helps in mitigating ISI between the OFDM symbols.

Thus we are able to absolutely demodulate each sub-carrier in the transmitted signal and get back the transmitted symbol sequence.

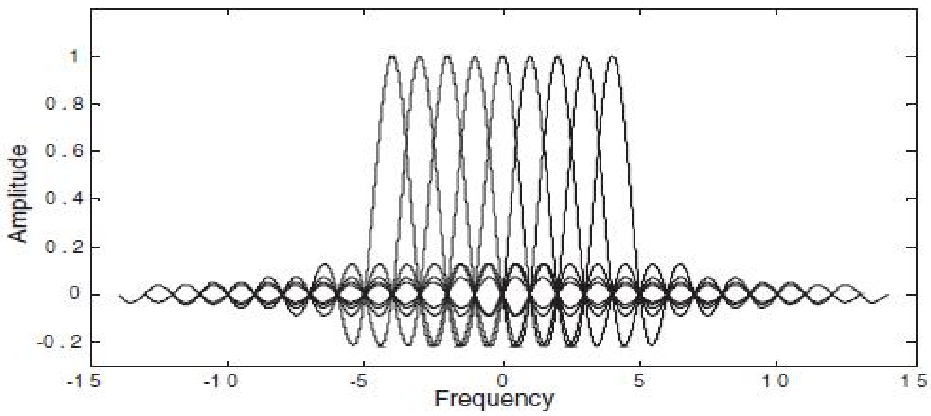


Figure 2.3 Frequency Spectrum of OFDM

**OFDM Modulation as IFFT**

The number of sub-carriers let be represented as ‘$N$’ in OFDM systems are usually of the order of hundreds; it implies that the transmitter and receiver blocks become very massive and high-priced to build and moreover the oscillators used for generating the carrier frequencies have temperature unsteadiness. In [6], the Discrete Fourier Transform (IDFT) is used to solve the modulation and demodulation in OFDM as discussed above. The modulation process can be achieved by the IFFT operation as given below.

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X[k]\, e^{\frac{i2\pi kn}{N}}; \quad 0 \le n \le N-1$$

The OFDM modulation and demodulation can be accomplished using the computationally efficient operations- IFFT and FFT respectively.

**2.3.2 Multipath Fading**

The signals which we transmit face various obstacles and due to these obstacles like reflection, diffraction, we get the multiple copies of the received signals from the same source at same times [2].This lead to the creation of echoes which affect the signals which arrive at the receiver. This is known as multipath fading. Fading means fluctuation in amplitude and phase of signal. It is shown in Figure 2.4. Dielectric constants, conductivity, permeability and width are the main factors affecting the system.

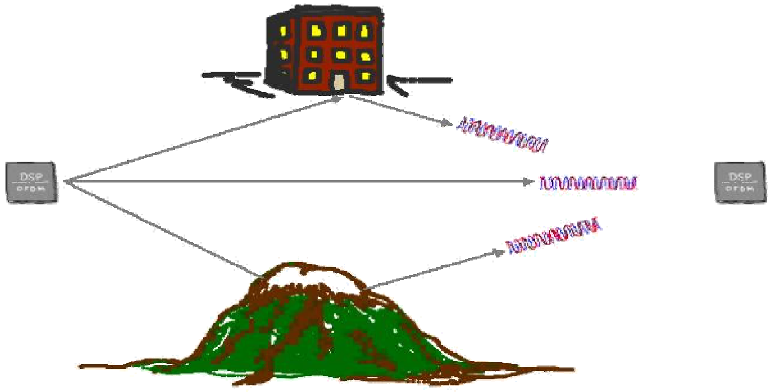


Figure.2.4 Representation of Multipath Fading

### 2.3.3 Inter Symbol Interference

Inter Symbol interference (ISI) is the form of alteration of a signal in which one sign interferes with its consequent symbols. This is an unnecessary phenomena which can makes the communication an unreliable communication. It is usually caused by the inherent nonlinear frequency response of a channel or multipath propagation causing successive symbols to blur together. Error in the decision device at the output of receiver is introduced due to the occurrence of ISI in the system. As a result, the purpose of the transmitting and receiving filters is to reduce the effects of ISI and in this manner make delivery of the digital data with the error rate as small as possible at the destination.

### 2.3.4 Inter Carrier Interference

There occurs a frequency and phase offsets and Doppler shifts in OFDM system due to which there is a loss of orthogonality in the sub-carriers. As a result of which interference is observed between the sub-carriers. This process is called as inter - carrier interference (ICI).

### 2.3.5 Cyclic Prefix

To permit a performance of OFDM and to deal with ISI effect over the multipath channel there must be guard intervals since the orthogonality cannot stay on over the whole duration of each OFDM symbol. In The Cyclic Prefix or Guard Interval, there is a periodic addition in the front of the symbols of the last part of an OFDM during transmission and is separated before demodulation at the receiver side. After the parallel to serial conversion, accumulation of Cyclic Prefix (CP) takes place and is being isolated at the receiver side before the operation of DFT takes place. Cyclic Prefix with OFDM symbol is shown in Figure 2.5.

Since OFDM signal is a linear combination, so we can append cyclic prefix just once to the multiple OFDM signal. The prefix range is about 10% to 25% of symbol time.

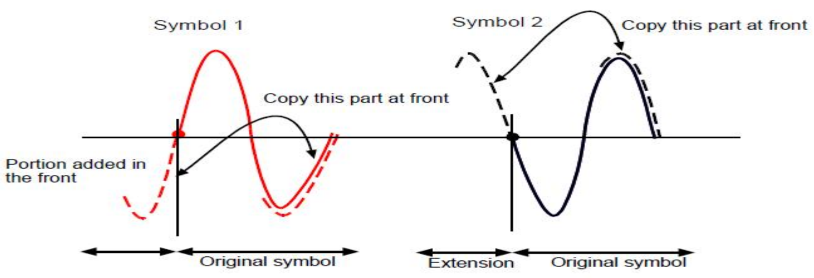


Figure 2.5 Cyclic Prefix

**2.3.6Applications:**

OFDM has numerous applications in wired and wireless domain. The first ever commercial OFDM system was based on Digital Audio Broadcasting (DAB) standards which were developed in 1995. Then OFDM has been accepted as the promising technology for some of the most potential standards of wireless industry [3]. The European Digital Video Broadcasting (DVB) standards came up immediately after the development of DAB standards which employed OFDM as the main technology. Following these standards, OFDM was taken up as the wireless standard for Local Area Network (LAN) with the protocol IEEE 802.11a being established. It has been recently become standardized for the IEEE fixed broadband wireless access standard 802.16. The IEEE 802.16 standard usually known as WiMAX employing OFDM coupling with MIMO system. Similarly standards like IEEE 802.15.3a, also called as wireless PAN uses a new version of OFDM [8].

Due to its high data rate services, OFDM has been recognized as leading candidate for the physical layer of fourth generation ( 4G) wireless services in which data rate upto 2GBPS is posiible[5]. OFDMA is an extension of OFDM where users are provided access in a multiplexed way. Therefore the present wireless and mobile industry is widely based on OFDM and its variables [3].

**2.3.7 Advantages**

High Spectral Efficiency:

High spectral efficiency can be obtained by OFDM by permitting the sub-carriers to partly cover in frequency domain. Altogether, it makes to reduce inter-carrier interference by orthogonal sub carriers. Due to this bandwidth efficiency modulation scheme has the advantage of justifying ISI in frequency selective fading channels.

*Immunity to Frequency Selective Fading:*

The complete bandwidth that is used by an OFDM symbol is usually greater than the coherent bandwidth of the channel. This results in frequency selective vanishing of the signal. The frequency response of a multichannel is as shown in Figure 2.6.

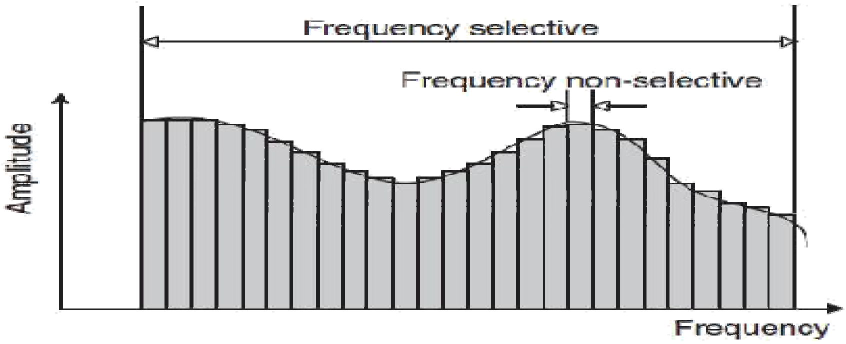


Figure 2.6 Frequency response of the multichannel transmission system

Each of the sub-carrier can prevail over the upshot of frequency selective fading because OFDM symbol consists of multiple sub-carriers with narrow-band spectra,. By using the adequate channel coding and interleaving, the symbols which are vanished can be recovered with the help of frequency selectivity of channel and hence the symbols are immune to such channel effects. It gives OFDM robustness against channel dispersion, so this makes it highly immune to multipath problem in high frequency wireless communication.

*Ease of phase and channel estimation*

The opinion of phase and channel parameters is hard in a time-varying environment. But in OFDM, the conclusion is supported by the information which is already carried by the sub-carriers due to the orthogonality of sub-carriers.

*Ease of VLSI Implementation:*

OFDM is computationally proficient by using FFT techniques to use the modulation and demodulation techniques. Due to the use of processes like IFFT/FFT, it has become easier to employ OFDM reception and transmission in VLSI also. This allows larger number of sub-carriers to be used without much remarkable increase in hardware requirement and hence effectively improves the data-rate as well as spectral efficiency. The requirement for extremely high frequency stable oscillators can be eliminated by performing the modulation and demodulation in the digital domain.

*Environment tolerance:*

OFDM has tolerance in environment for high RF interface. OFDM provides greater resistant to multipath fading as well as impulse noise.

### 2.3.8 Disadvantages of OFDM

With many multiple and important advantages, OFDM suffers from some limitations which desires to be handled with an extra care for OFDM reception transmission and. The drawbacks or disadvantages are as given below [2].

*High PAPR value:*

Very high peak-to-average power ratio of an OFDM signal is because of the adding up of a large number of sub-carriers [9]. When there is high no. of sub-carriers, the value of PAPR approaches to exceed and thereby give rise to different types of complexities.

*Frequency and Phase Offset Sensitivity:*

OFDM signal is very susceptible to errors in frequency values because of the sub-carriers are very closely spaced which results in phase offset errors and frequency offset errors. To look after the phase and frequency offsets very fine tuning is required.

*Inter-carrier Interference:*

In the real world during transmission the property of orthogonality is sometimes violated by the sub-carriers and due to this violation of orthogonality, inter-carrier interference arise. This will lead to alteration in the signal and there will be loss in information.

### 2.4 Various techniques for PAPR reduction

Many PAPR reduction techniques have been proposed during the advancement of OFDM technology. The Primary aim is to lessen the PAPR of the OFDM signal to a significant value which is acceptable prior to the OFDM signal is sent to the transmitter. Some of the techniques are given below [1][2][6].

*Amplitude clipping and filtering:*

It is the fundamental and the simplest technique used for PAPR reduction. In this the amplitude of the signal is clip to a predetermined value. The pseudo maximum amplitude in this case is considered as clipping level μ. It helps to better the SQNR in Analog to Digital converter. If a clipping level is set low, the signal will experience from a clipping distortion while PAPR and quantization noise get decreased. Clipping distortion decreases while it suffers from PAPR and quantization noise if clipping level is high.

Clipping result in in-band signal distortion which have consequence in Bit Error Rate performance degradation. It also gives rise to out-of-band radiation, which results in out-of-band interference signals to channels which are adjacent. The out-of-band radiation can be overcome by filtering.

This filtering of the clipped signal results in the peak re growth. That means the signal after filtering operation may surpass the clipping level specified for the clipping operation. Consequently, we came to know that this clipping and filtering [4] technique has some kind of distortion during the transmission of data but a practical solution to the problem.

*Coding:*

Code words that minimize or reduce the PAPR are selected in this coding technique It results in no distortion and creates no out-of-band radiation, but it has problem of bandwidth efficiency as the code rate get reduced in this method. It has to find the best code and to find the best codes is complex and to store large lookup tables for encoding and decoding particularly for a large number of sub carriers is complex.

*Partial Transmit Sequence:*

An input data block of L symbols is partitioned into disjoint sub blocks in the Partial Transmit Sequence (PTS) technique. The sub-carriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected in a way that the PAPR of the combined signal is minimized. Although, technique there will be data rate loss by using this technique.

*Tone Reservation:*

The transmitter does not transmit data on a small subset of subcarriers that are optimized for PAPR reduction according to this technique. In this method, the purpose is to find the time domain signal to be added to the original time domain signal such that the PAPR is abridged. In this technique the data rate loss will also be offered and also probability of power increase is increased.

*Tone Injection Technique:*

The critical idea used in this technique is to increase the constellation size so that each symbol in the data block can be mapped into one of the several corresponding constellation points, these extra degrees of freedom can be subjugated for PAPR reduction. Here the power that is to be transmitted increased.

*Active Constellation Extension (ACE) Technique:*

This technique for PAPR reduction is comparable to Tone Injection technique. By this technique, some of the outer signal constellation points in the data block are dynamically increased towards the outside of the original constellation such that PAPR of the data block gets reduced. In this case there transmitted power will be increased.

*Selected Mapping (SLM) Technique:*

The fundamental idea of this technique is first create a number of alternative OFDM signals from the original data block and then transmit the OFDM signal having minimum PAPR. But the two basic disadvantages for this technique data rate loss and complexity at the transmitter side. The table shows the Comparison of different reduction technique.

| Technique name | Power increase | Distortion-less | Loss in data rate | Computational Complexity |
|---|---|---|---|---|
| Amplitude clipping & filtering | No | No | No | Low |
| Coding | No | Yes | Yes | Medium |
| Partial Transmit Sequence | No | Yes | Yes | Very High |
| Selected Mapping | No | Yes | Yes | High |
| Interleaving | No | Yes | Yes | Medium |
| Tone Reservation | Yes | Yes | Yes | Medium |
| Tone Injection | Yes | Yes | No | Medium |
| Active constellation extension | Yes | Yes | No | Medium |

Table 2.1: Comparison of different reduction technique

## 2.5 Review of the Research Papers :

### (a) Bahubali K.Shiragpur, IEEE-2013 [1]

In this paper different PAPR reduction techniques has been given. In signal Distortion technique, clipping and Filtering is easiest approach which can reduce PAPR. The research on signal scrambling technique is done. The algorithm for SLM technique is given. The modification on SLM technique shows better PAPR.

### (b) Signals by Tao Jiang, IEEE-2008 [2]

OFDM has been recently used as multi-carrier modulation technique to provide a significant high spectral efficiency, tolerance to multipath delay spread, resistant to the frequency selective fading channels and give power efficiency. As a consequence OFDM has been preferred for high data rate communications and has been extensively set-up in wireless communication standards for instance Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile WiMAX) based on OFDM access technology .Some demanding issues remain vague in the design of the OFDM systems. One of the chief problems that exist is high Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals. As a result, in the detection of OFDM receiver, efficiency gets reduced. For instance, most of the radio systems utilize the HPA in the transmitter to attain sufficient transmit power and the operation of HPA is usually at or near the saturation region to attain the maximum power efficiency at output and thus there will be introduction of memory-less nonlinear distortion owing to high PAPR of the input signals into the communication channels. It is not possible to keep the out-of-band below the specified limits if the HPA is not operated in linear region with huge power back-off,. A very inefficient amplification will be present and expensive transmitters are required due to this situation. Thus, its compulsory to research on the properties of the PAPR as well as its distribution and decline in OFDM systems so as to utilize the technical features of the OFDM. The distribution of PAPR commonly can be expressed in terms of Complementary Cumulative Distribution Function (CCDF). Recently, some researchers have given report on purpose of the PAPR distribution based on different theories and hypotheses. Furthermore various techniques also have been projected to reduce the PAPR together with clipping , Selective Mapping (SLM) , coding schemes, nonlinear companding transforms, phase optimization, Partial Transmission Sequence (PTS) and Tone Injection (TI) , constellation shaping, Tone Reservation (TR) and other techniques such as pre-scrambles has been proposed. These schemes can generally be considered into signals scrambling method, such as PTS and block codes etc., and signal distortion techniques as clipping.

An efficient PAPR reduction technique should be able to give the best trade off between the capacity of PAPR reduction and transmission power, , implementation complexity, data rate loss and Bit-Error-Ratio (BER) performance etc. In the paper, firstly there is investigation of the distribution of PAPR depending on the characteristics of the OFDM signals. Then there is analyzation of five typical techniques of PAPR reduction

**(c) Tao Jiang, Cai Li, and Chunxing Ni , IEEE-2013 [3]**

In the paper, there is analyzation of the relations between peak-to-average power ratio (PAPR) reduction, and energy efficiency (EE), spectrum efficiency (SE), in orthogonal frequency division multiplexing (OFDM) systems, respectively.

The reduction in PAPR substantially improved the efficiency of high power amplifier (HPA) and the nonlinear distortion noise can also be considerably reduced. As a effect, the SE and EE are improved with a total transmit power constraint over additive white Gaussian noise (AWGN) channel. Furthermore there are the quantitative relations between PAPR reduction, EE and SE .

The result of Simulation showed that the OFDM system with PAPR reduction could achieve higher SE and EE than the system without PAPR reduction. The improvement in the efficiency of HPA will give significant power saving, and thus the EE performance improves for OFDM systems.

**(d) Li X, Cimini LJ Jr, IEEE-1998 [4]**

An OFDM signal has one of the major drawback of large peak-to-mean envelope power ratio, which can cause in significant distortion when signals are passed through a nonlinear devices as a transmitter power amplifier. Through simulation it is investigated that the effects of clipping and filtering on the performance of OFDM, with the power spectral density, and the bit-error rate and the crest factor. The results show that clipping and filtering is a procedure which promises for the transmission of OFDM signals using practical linear amplifiers. Clipping could be a successful method for PAPR reduction. However, the process of clipping is a nonlinear process and can cause significant in-band distortion, which degrades the BER performance, and out-of-band noise, which decreases the spectral efficiency. Filtering after clipping can reduce the spectral splatter but there is some peak re growth after filtering. Here, to analyse the effects of clipping and filtering, simulation is made on the performance of an OFDM wireless communication system. So as a substitute of using an fixed CF, to better characterize the "peakiness" of an OFDM signal, it uses the CF's at various percentiles.

**(e) W. Aziz, E. Ahmed, World Applied Science Journal -2012 [5]**

Peak to Average Power Ratio (PAPR) is the factor which limits the OFDM system as it is having degrading factor on the system performance by reducing SQNR of ADC/DAC and it also affects transmitter amplifier. There are various techniques to prevail over the problem of PAPR like Clipping and Filtering, Scrambling Technique, Coding Technique and many more. In this paper we discussed clipping and filtering technique which is easy to implement and produce significant reduction in the amount of PAPR by clipping the peak of the maximum signal's power. Moreover, analysis of PAPR is given by changing different parameters.

**(f) Wang L, Tellambura, IEEE-2005 [6]**

Simplified Clipping and Filtering is the Method that uses single iteration, in which this method obtains the PAPR reduction equal to that of ICF which uses several iterations. The analyzation of

Clipping and Filtering is done by approximating each clipping pulse with a parabolic function. An analysis result that the clipping noise after several CF iterations is approximately same to that was generated in the first iteration. As a result, it can be scaled that the clipping noise produced in the first iteration to approximate with that we get after several iterations.

The approximately same PAPR reduction can then be obtained with single iteration with only three FFT/IFFT operations, which significantly reduces the computational complexity of system by using Simplified Clipping and Filtering Method. The iterative clipping and filtering technique need several iterations to mitigate the peak regrowth that arise due to the filtering after Clipping. In this, there is analyzation of the conventional clipping and filtering using a parabolic approximation of the clipping pulse. It show that the clipping noise obtained after several clipping and filtering iterations is almost proportional to that produced in the first iteration.

**(g) Byung Moo Lee,IEEE-2013 [7]**

The iterative clipping and filtering (ICAF) technique proposed is considered to be the most realistic solution to reduce PAPR and is widely used because it provide signal non-expansion of bandwidth, simplicity in implementation without receiver-side cooperation and low computational complexity and The Figure 2.7 shows iterative clipping and filtering.

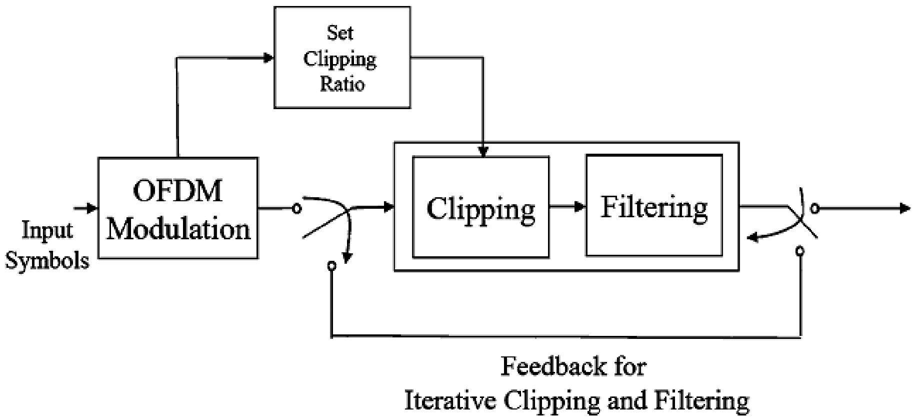


Figure 2.7 Block Diagram for iterative clipping and filtering

The clipping ratio (CR) is fixed and preset and feedback is used for the iterative feature. In this scheme, the modulated signal is iteratively clipped and then filtered to get reduction of the PAPR of OFDM signals. The PAPR performance of ICAF can be improved as the number of iterations gets increased, but the performance improvement is restricted. It is noticed that the most of the PAPR reduction occurs in the first iteration and then PAPR reduction remarkably decreases as the number of iterations increased.

There is analyzation of the performance of conventional ICAF technique in this paper and then it propose an adaptive ICAF scheme which clips the signal with an adaptively modified CT in every clipping operation to achieve better PAPR reduction of OFDM signals. The simulation results show that the proposed scheme significantly performs the conventional scheme, in PAPR reduction of OFDM signals at the equivalent number of iterations.

**(h). Wang Y-C, Luo Z-Q, IEEE-2011 [8]**

Wang and Luo determined their attention on the clipped signals and an algorithm called optimized ICF (OICF) is developed. In this algorithm, frequency-domain filtering is formulated as an optimization problem and the optimization parameters used are the filter coefficients. To weigh the clipped signals by using these optimal coefficients, one can minimize the signal distortion under the constraints of PAPR reduction and out-of-band radiation. So OICF is an optimal algorithm is used and another attractive advantage of this algorithm is that it only desires that about three iterations to converge to the needed signal. But the optimal filter design desires to solve a convex optimization problem by using some special software, which has O N3 complexity for OFDM systems with N subcarriers. The OICF algorithm is a high-performance clipping and filtering technique [6,8]. However, it needs to solve a convex optimization problem related with filter, which tends to high complexity. The simulation results show that the original and simplified algorithms have almost the same performance of PAPR reduction, BER and out-of-band radiation

**(i) Armstrong J,IEEE (2002) [9]**

It is shown that repeated clipping and frequency domain filtering of an orthogonal frequency division multiplexing (OFDM) signal can decrease the peak-to-average power ratio (PAPR) of the transmitted signal significantly. This technique causes no increase in out-of-band power. Significant PAPR reduction can be achieved by using with only moderate levels of clipping noise.

**(j). Hamid Saeedi, IEEE-2002 [10]**

Another very much composed PAPR diminishment plan for OFDM signs is proposed which uses the allegorical crest retraction (PPC) utilizing the truncated bit sign got from the backwards quick Fourier change (IFFT) of the molded top decrease tones (PRTs). The proposed plan just rehashes top dropping in the time space without iteratively performing IFFT and FFT. Additionally the quantity of emphasess of IFFT and FFT can lessen by utilizing the utilization of the proposed PPC plan to dynamic heavenly body expansion (ACE) Moreover, to soothe the debasement of bit lapse rate (BER) a transmit power designation plan is likewise recommended by the proposed PAPR lessening plan. Numerical examination demonstrates that if the molding parameters of PRTs are chosen appropriately, the PAPR lessening execution is kept up and out-of-band (OOB) radiation and BER can be made strides.

# CHAPTER 3

# CF AND SLM

### 3.1 Introduction

The Clipping and Filtering technique is the basic technique which can provide better PAPR reduction and have no complexity and provide spectrum efficiency. Another technique which can meet our requirement is the SLM technique which is also have low complexity and reduce PAPR.

### 3.2 Clipping and Filtering

Clipping and filtering is operated digitally on an oversampled signal In genuine framework, the Oversampling is needed subsequent to the PAPR of computerized sign is not the like the PAPR of the simple sign. On the off chance that we cut the oversampled sign, mutilation clamor additionally falls in the out of the given band, called unearthly spillage [12]. The ghastly spillage debases the execution of nearby channels, yet it can be lessened by separating in the wake of section [3, 4]. Because of the out-of-band radiation, on account of the oversampling, in-band twisting is not as much as on account of Nyquist rate.

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_n e^{j2n\Delta f t} \qquad (3.1)$$

With $N$ sub-carriers, an oversampling rate of $L$ can be achieved by inserting $(L$-1)*$N$ zeros in the middle of the modulated symbol vector to form a 1×$LN$ data vector **X** in OFDM system.

X=[X[0], X[1], …….., X[$N/2-1$], 0, ….,0, X[N/2], … , X[N-1]]

The PAPR computed from the $L$-times oversampled time-domain signal samples is given by

$$PAPR = \frac{\max_{0 \le k \le LN-1} |x_k|^2}{E\left[|x_k|^2\right]} \qquad (3.2)$$

If the digital OFDM signals are directly clipped, the resulting clipping noise will all fall in-band and cannot be reduced by filtering. To get rid of this aliasing problem, in this simulation, we oversample the OFDM signal. This oversamples have advantage of reducing in band distortion and peak re growth to some extent.

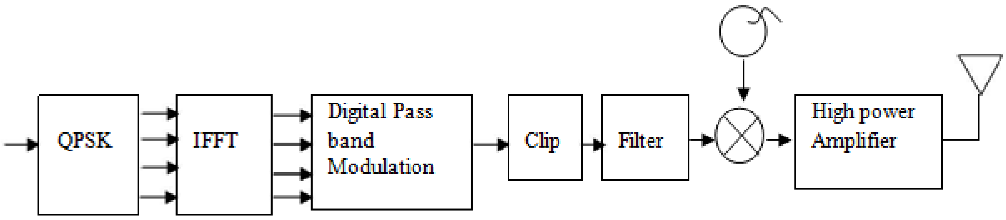


Figure 3.1 OFDM Transmitter Block Diagram for Clipping and Filtering

The clipping operation on the real band pass signal is given by

$$z_n = \begin{cases} -A & if\ y_n < -A \\ y_n & if\ -A \le y_n \le A \\ A & if\ y_n > A \end{cases} \quad (3.3)$$

where $z_n$ is the clipped signal and $A$ is the clipping level. A normalized clipping level, called the clipping ratio (CR), is calculated as

**Advantages of Clipping and Filtering**

- It is fundamental and simplest reach for reduction of PAPR in OFDM system.
- It is trouble-free to implement.
- It offer spectral efficiency that also within limit of cost.

**Disadvantages of Clipping and Filtering**

- It also cause out of radiation which imposes out of band interference signals to adjacent carriers and thus causes spectral inefficiency.
- Clipping is process which is nonlinear and it might cause in band distortion and marks in BER performance degradation.
- Aliasing problem is occur in clipping after filtering

  **Solution**: It can be reduced by adding zeros in original input called zero padding.

**Clipping and Filtering with noise Cancellation**

Filtering cause re growth and to suppress that iterative clipping filtering (ICF) techniques can be used [12]. The convergence rate of reduction decreases after the first few iterations [9]. Every iteration need only two fast Fourier transform/inverse fast Fourier transform (FFT/IFFT), and after the last iteration, one additional IFFT is needed to change the clipped OFDM symbol to time domain. As a k-iteration process requires (2k+1) FFT/IFFT operation and this increased number of iterations means increased computational complexity, particularly when the number of subcarriers is in a large number [3]. This method need three Fast Fourier Transform(FFT)/Inverse Fast Fourier transform IFFT operations while the conventional CF method requires (2k+1) FFT/IFFT operations, where k is the number of iterations. The simulation result shows that the QPSK modulated OFDM signal with 1,024 sub-carriers achieves a PAPR reduction up to 6 dB. Clipping to reduce PAPR initiate distortion and the signal distortion given by clipping operation can be reduced by applying a low pass filtering operation on the clipped signal. But repeated clipping and filtering operation with k iterations requires (2k+1) FFT/IFFT operations [12].

Based on central limit theorem, when there is large number of subcarriers, the amplitude of OFDM signal is Gaussian distributed, hence the clipping operation can be viewed as Gaussian input memory less non-linear systems .

According to Price's theorem, the clipping operation can be modelled as a linear process

$$xn^\wedge = xn + \alpha * d \qquad (3.4)$$

where α is attenuation factor, d is added noise

The total clipping noise after k iterations is calculate based on the clipping noise generated after first iteration which is expressed by the parameter β as:

$$\beta = \frac{1-(1-\alpha)^{3k/2})}{1-(1-\alpha)^{3/2}} \qquad (3.5)$$

Block diagram of Clipping and Filtering with noise cancellation:-

The Figure 3.2 shows the block diagram of proposed clipping and filtering algorithm with cancellation of clipping noise. With subcarriers of 1024 and oversample factor, L=4 and FFT size 4096 and using clipping and filtering algorithm based on cancellation of noise, we get PAPR reduction to 6dB.

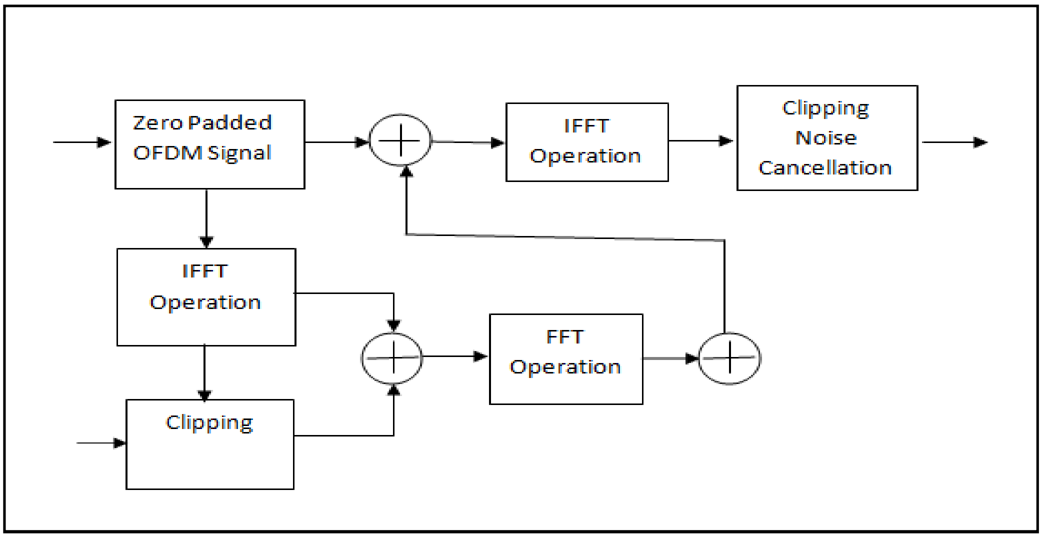


Figure 3.2: Block Diagram of  Clipping and Filtering Algorithm with noise cancellation

**Algorithm of clipping and Filtering with Noise Cancellation:**

The algorithm of Clipping and Filtering with Noise Cancellation can be stated as follow:

1. The frequency domain OFDM signal is padded with (L-1)N zeros, L is the oversampled value.
2. Compute time domain signal by applying IDFT on step 1
3. Perform clipping operation to a threshold value
4. Determine clipping noise which is the difference of original and clipped signal.
5. Transform the noise in frequency domain
6. Compute the clipped OFDM signal which is subtraction of frequency domain OFDM signal and β noise in frequency domain.
7. Compute IDFT on step6 to obtain time domain clipped OFDM signal.
8. Filtration is applied to remove out of band radiation.
9. Cancel the clipped noise by subtracting the above from expected value of noise in time domain

.

### 3.3 SLM (Selective Level Mapping)

This is a twisting less and productive strategy utilized for the PAPR lessening as a part of OFDM. The name of this procedure infers that one succession must be chosen out of L arrangements. As indicated by the idea of discrete time OFDM transmission we ought to make an information square considering L number of images from the heavenly body plot. Where L is the quantity of subcarriers utilized. At that point, U number of free applicant vectors are to be created by utilizing that information hinder with the augmentation of autonomous stage vectors. Let us consider X is the data block with X (k) as the mapped sub symbol(i.e. the symbol from the constellation).Where k = {0, 1, 2, ..........L − 1}. Let $u^{th}$ the phase vector is denoted such by $B^{(u)}$.

,where u = {1, 2, ..........U}. The $u^{th}$ be candidate vector that is generated by the multiplication of data block with the phase vector is denoted with $X^{(u)}$.

So we can write the equation as to get the $k^{th}$element of $u^{th}$ uth candidate vector as

$$X^{(u)}(k) = B^{(u)}(k)\, X(k) \qquad (3.6)$$

Then by proceeding with IFFT operation to each candidate vector we will obtain U number of alternative OFDM signals, so the $l^{th}$ symbol of $u^{th}$ alternative OFDM signal can be written mathematically as

$$X^{(u)}(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{L-1} X^{(u)}(k) e^{j(2\pi nk/L)} \qquad (3.7)$$

Then out of the U number of alternative OFDM signals the signal which is having minimum PAPR is to be selected for transmission.

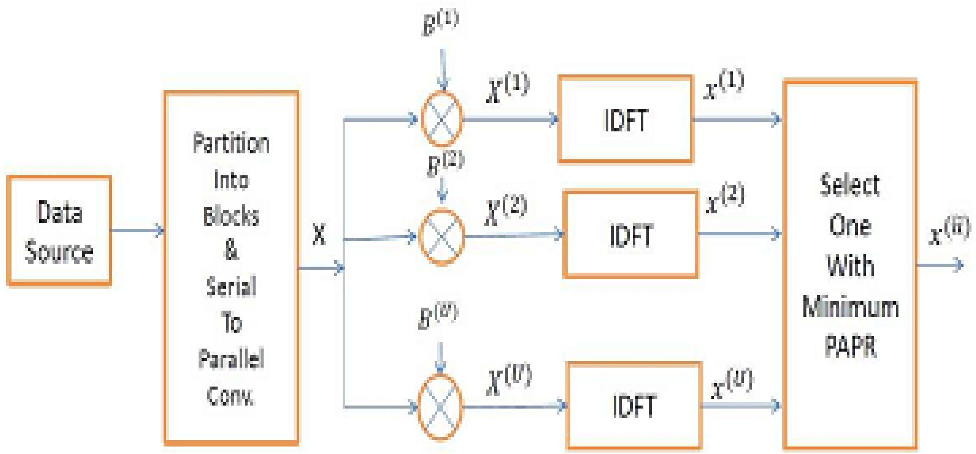


Figure 3.3 Block Diagram of SLM

# CHAPTER 4
# PROBLEM STATEMENT

## 4.1 Introduction

The drawback of PAPR in OFDM is to be reduced by an efficient technique. The Clipping and Filtering is combined with the SLM technique to get the reduction in PAPR which in turn improve the performance of OFDM. The method of reducing PAPR in this thesis is named as a hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR in OFDM.

## 4.2 A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR in OFDM

The Clipping and Filtering method gives quite a better PAPR reduction but the demand to reduce PAPR is still increasing so it is combined with the SLM technique to give better results.

An OFDM has been implemented with the hybrid scheme of clipping and SLM technique to reduce PAPR in OFDM. The clipping noise is also cancelled in this method. The elimination of clipping noise cause reduction in band distortion and hence gives reduction in BER.

The Block diagram shows that the SLM technique is applied to clipped signal and the low pass filter is applied. This gives the reduction in PAPR to 2.5 dB.

*Block Diagram:*

The Figure 4.1 shows the block diagram of proposed clipping and filtering algorithm with cancellation of clipping noise. With subcarriers of 1024 and oversample factor, L=4 and FFT size 4096 and using clipping and filtering algorithm based on noise cancellation, we get PAPR reduction to 2.5dB.

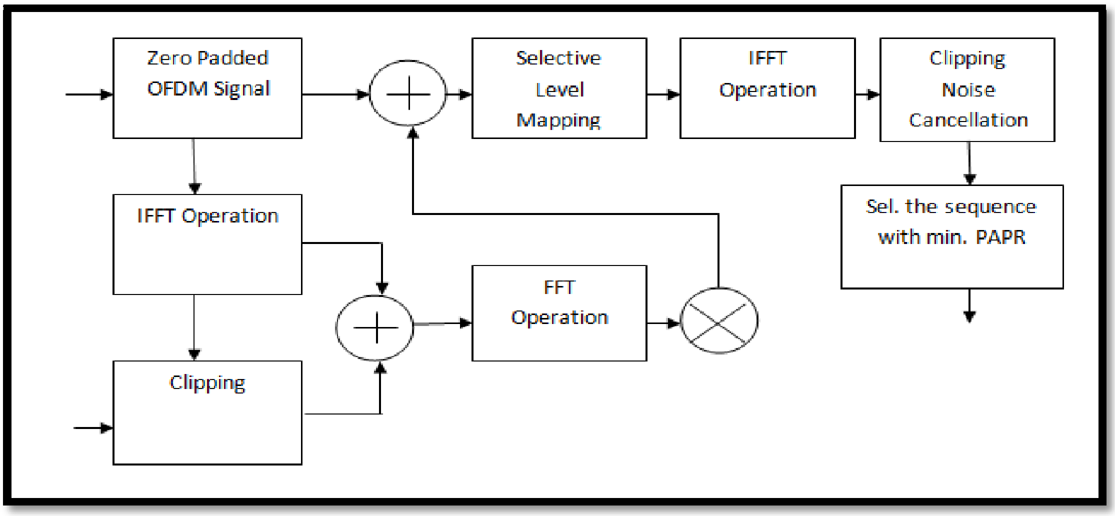


Figure 4.1 Block Diagram of A Hybrid approach using CF and SLM technique with cancellation of noise

**Algorithm of a Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR in OFDM**

The various steps for algorithm of the method can be given as follow:

1. The frequency domain OFDM signal is padded with (L-1) N zeros, L is the oversampled value.
2. Compute time domain signal by applying IDFT on step 1
3. Perform clipping operation to a threshold value.
4. Determine clipping noise which is the difference of original and clipped signal.
5. Transform the noise in frequency domain.
6. Compute the clipped OFDM signal which is subtraction of frequency domain OFDM signal and β *noise in frequency domain.
7. Apply SLM technique on the clipped OFDM signal.
8. Compute IFFT on the signal obtained from step 6.
9. Filtration is applied to remove out of band radiation.
10. Cancel the clipped noise by subtracting the above from expected value of noise in time domain.

# CHAPTER 5
# RESEARCH METHODOLOGY

## 5.1 Introduction

High data rate is the demand of today since the users of wireless communication are increasing day by day and the services requirement is very reliable data transmission over very harsh environment. In modern years, to achieve better performance using multi carrier modulation we should make the subcarriers to be orthogonal to each other which is known as the Orthogonal Frequency Division Multiplexing (OFDM) technique. But the immense disadvantage of the OFDM technique is its high Peak to Average Power Ratio (PAPR). So there are some improvement can we do. The research has been done to get overcome with this problem by using some efficient technique.

## 5.2 Research Methodology

After Consulting with the mentor they told us what we want to do in the thesis. We search from the web about the topic of thesis. In wireless communication, high data rate is required which can be met by multicarrier modulation technique such as orthogonal frequency division multiplexing but I found it has a drawback of Peak to Average Power Ratio. I read different modulation techniques. Finally I choose my objective to reduce PAPR. So I search from the internet and it's all part including the OFDM, PAPR, Clipping and Filtering etc. I studied its whole related topic. I study about the OFDM and its PAPR. While studying these I found improvement can be done by combining this with some other techniques. I started with clipping and Filtering which I found the basic technique and the technique having low complexity. I started reading about this particular technique to reduce PAPR in OFDM. I studied my base paper which is A Novel Clipping and Filtering Algorithm Based on Noise Cancellation for PAPR Reduction in OFDM Systems. Here I read references of the base paper. I simulated my base paper using MATLAB. I get the graph which is same as that of my base paper. Then to further reduce PAPR I used SLM combination with the existing method. I simulated by using matlab software and found that SLM technique after Clipping can reduce PAPR to a great extent. Moreover BER gets improved using this technique.

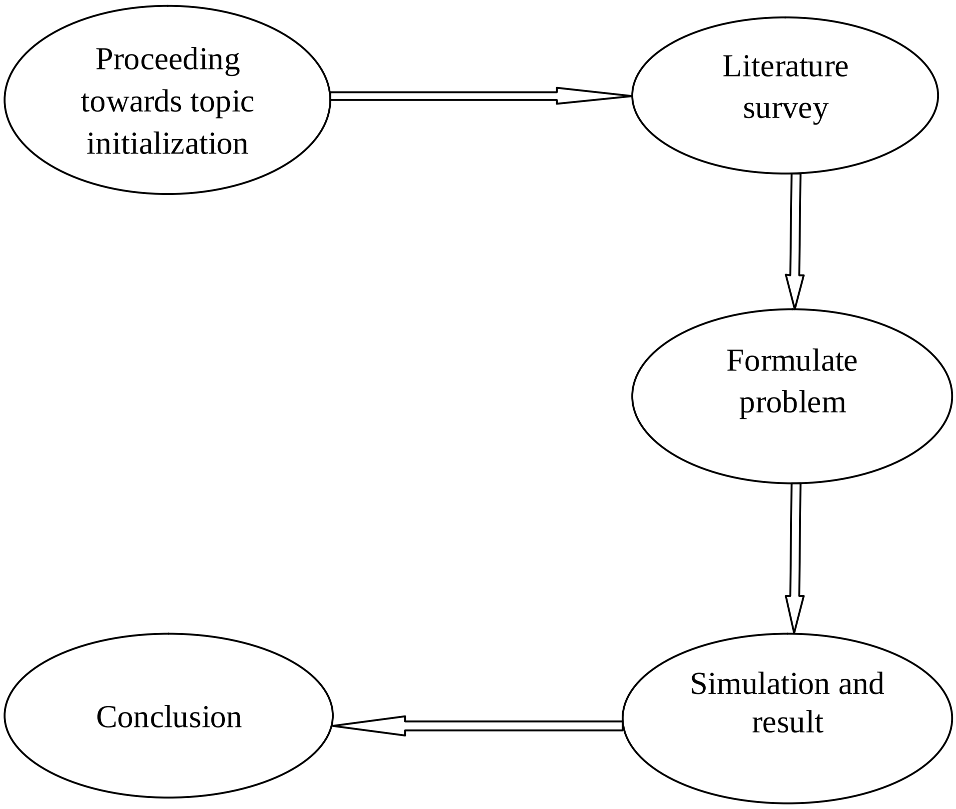


Figure 5.1 various steps for research methodology

In order to precede research, topic selection is more important, because which topic is critical with the rapid growth of technology. After that literature survey is must be done related the topic. Literature survey is to exploit the research and gather information about methods to approach. After doing literature survey next step is to formulate the hypothesis which can lead to better results and then formulate the problem based on the analysis and the maximum improvement over the existing method is done.

# CHAPTER 6

# SIMULATION RESULTS AND DISCUSSION

## 5.1 Introduction

The simulation has been done by using matlab software to reduce PAPR. The simulation shows the reduction in PAPR which is due to large number of subcarriers in OFDM. Firstly, the simulation has been done for clipping and Filtering and then by using cancellation of clipped noise. The simulation of hybrid method is done for significant reduction in OFDM and decrease the BER**.**

## 5.2 Simulation 1: CCDF of the PAPR for Clipping and Filtering with noise cancellation

With subcarriers of 1024 and oversample factor, L=4 and FFT size 4096 and using clipping and filtering algorithm with  noise cancellation of clipping noise, we get PAPR reduction up to 6dB

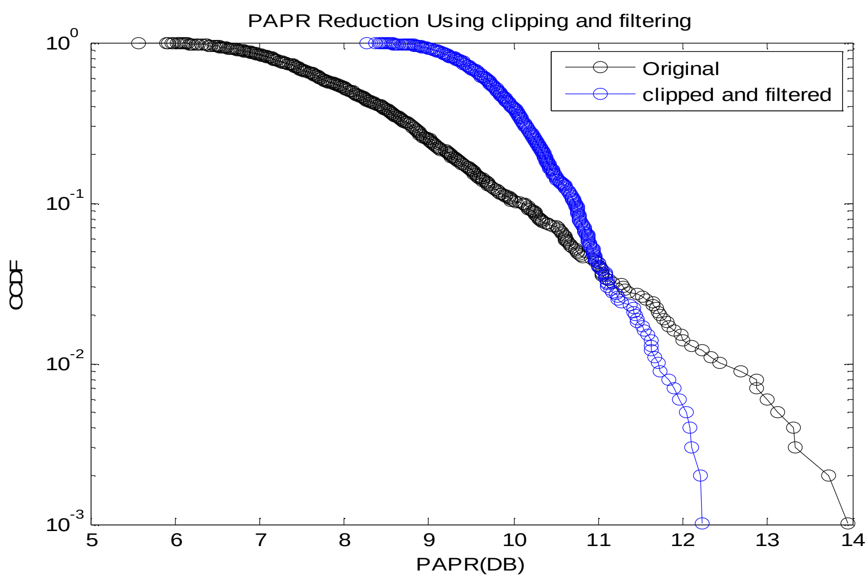


Figure 5.1 CCDF of the PAPR for Clipping and Filtering

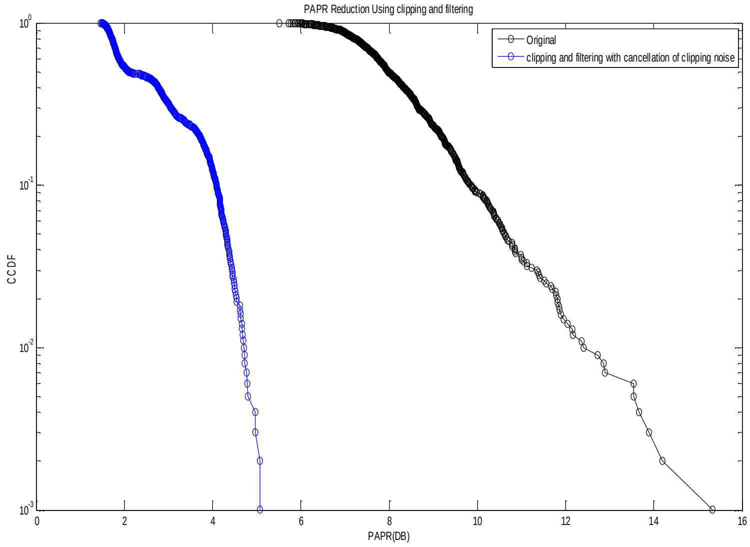


Figure 5.2 CCDF of the PAPR for Clipping and Filtering with noise cancellation

## 5.3 Simulation 2: CCDF of the PAPR for A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR

With subcarriers of 1024 and oversample factor, L=4 and FFT size 4096 and using clipping and filtering with SLM technique after clipping algorithm with noise cancellation of clipping noise, we get PAPR reduction up to 2.5dB.

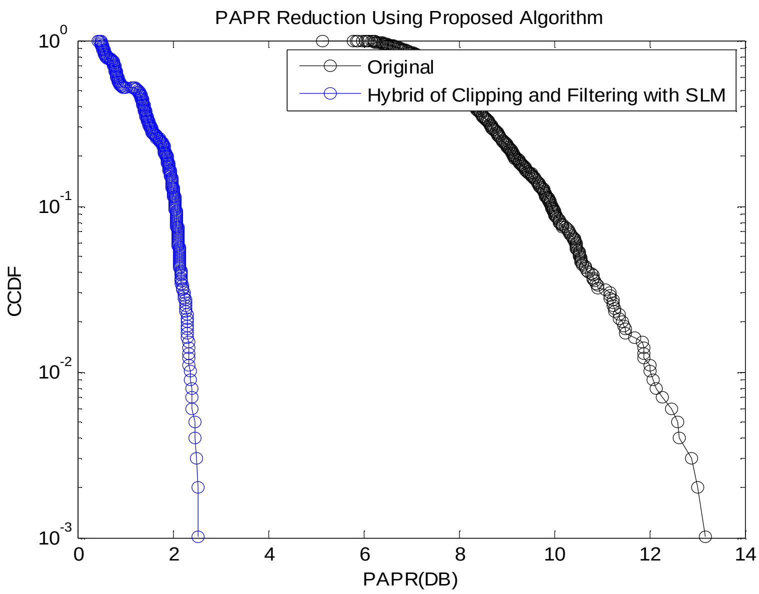


Figure.5.3 CCDF of the PAPR for A Hybrid approach using CF and SLM technique with cancellation of noise to reduce PAPR

### 5.4 Simulation 3 :Comparison of BER

The simulation result for comparison of BER is shown in Figure5.4.

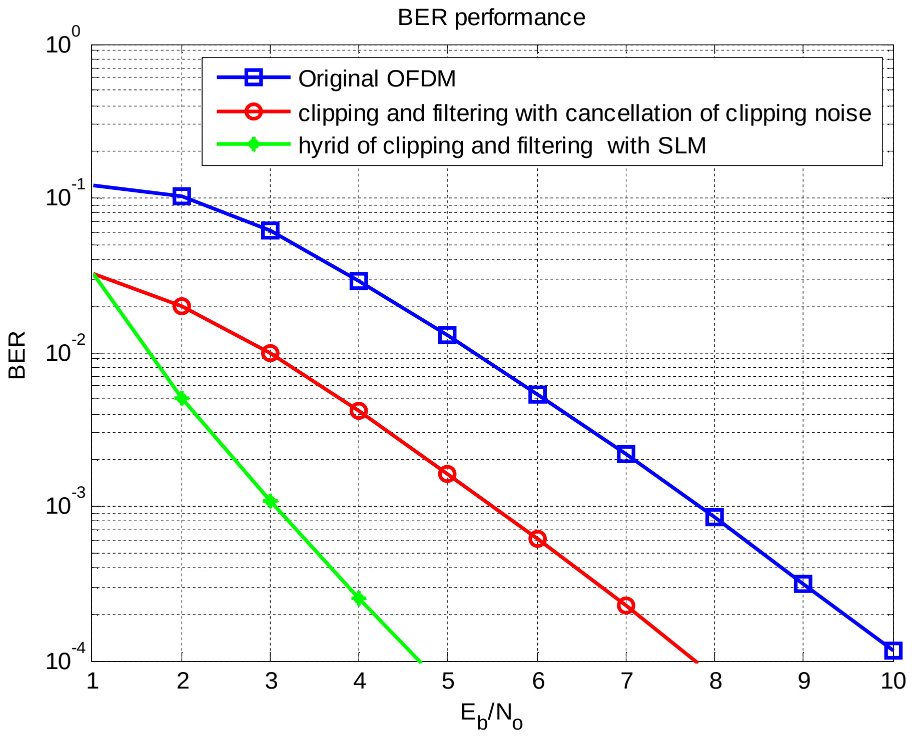


Figure 5.4 Comparison of BER Performance

### 5.5 Results and Discussion

The MATLAB simulations have been performed with subcarriers=1024 using QPSK modulation with oversampling factor, L=4 and corresponding constellations having M=4 points. For the clipping block was considered a clipping rate CR set to 1.4 and clipping threshold to 6dB. The low pass Butterworth filter is used having order of 2 and cut off frequency Wn=0.5 The Figure 5.1shows the simulation result for the basic clipping and filtering method to reduce PAPR which shows the reduction up to 12 dB only.

The clipping noise is then cancelled from clipped and filtered OFDM signal which shows significant reduction of PAPR. The Figure 5.2 shows comparison of CCDF of original OFDM signal with the CCDF by applying clipping and filtering algorithm with noise cancellation. The result shows that PAPR is reduced to 6 dB using the clipping and filtering with elimination of noise. The PAPR reduction is significantly shows the better result with the cancellation of clipping noise after clipping and filtering as shown in Figure 5.2.

Thus elimination of clipping noise at the transmitter reduces the in-band distortion and demands no additional complexity at the receiver. This is the reduction in the problem of PAPR to 51%.This can be further reduce by joining another technique with this. The exclusion of clipping noise makes a significant reduction of in band distortion which is the major problem of clipping .The elimination of clipping noise at the transmitter reduces the in-band distortion and demands no additional complexity at the receiver.

Selective Level Mapping is applied to this clipped signal to get the maximum reduction in PAPR whose algorithm is discussed above with the subcarriers=1024 using QPSK modulation with oversampling factor, L=4 and corresponding constellations having M=4 points. The combination of SLM with clipped signal shows the better result if compared to the individual technique by considering the same parameters. The signal with minimum PAPR is transmitted. Figure 5.3 shows the reduction to 2.5dB.

Eb/N0 denotes the Carrier to noise ratio. BER is degraded at the receiver due to the in-band distortion contributed by the clipping process [3]. The elimination of clipping noise results in significant reduction of in-band distortion and there is improvement in BER performance .

Moreover the BER performance of clipping and filtering with noise cancellation and its hybridization with SLM is compared with original OFDM signal which shows that the method shows the reduction in BER.

# CHAPTER 6

# CONCLUSION AND FUTURE WORK

## 6.1 Introduction

The major problem in OFDM is reduced by applying a hybrid approach using clipping and filtering and SLM. This causes the reduction in OFDM to 2.5 dB. If this technique is compared with the simple clipping and Filtering techniques alone, it gives better PAPR

## 6.2 Conclusion

In this, a non-iterative clipping and filtering algorithm employing a clipping noise cancellation technique is proposed and its performance in terms of PAPR reduction is shown. This algorithm attains a 6 dB reduction in PAPR. The computational complexity of this algorithm is less compared to other Clipping and Filtering techniques. Elimination of clipping noise at the transmitter reduces the in-band distortion and demands no additional complexity at the receiver. The CF algorithm acquires PAPR reduction by 51.09 % when compared to the original OFDM signal. The algorithm can be used to optimize OFDM systems by employing SLM technique after clipping and the filter followed with noise cancellation such that PAPR is further reduced and is more appropriate for real time applications. The combining of SLM technique with the existing reduce the PAPR to 2.5 dB. The BER graph shows that this method shows the reduction in the BER.

## 6.3 Future work

The reduction in OFDM increases the performance of OFDM. To further improvement the system the OFDM signal can be transmitted through different channel. The algorithm can be used to optimize OFDM systems by employing pre distortion with noise cancellation such that PAPR is reduced and is more suitable for real time applications. This method can be further added to assess its performance over Stanford University Interim channel models and fading.

# REFERENCES


[1] Bahubali K.Shiragpur,Udhay Wali, Sandeep Bidwai(2013),Novel techniques to reduce PAPR in OFDM Systems Using SLM,3rd IEEE international Advance Computing Conference,Dec.2013,pp.515-519.

[2] Tao Jiang(2008) ,An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM, IEEE transaction on broadcasting, vol. 54, NO. 2, JUNE 2008,pp.257-267.

[3] Tao Jiang, Senior Member, IEEE, Cai Li, and Chunxing Ni(2013) , Effect of PAPR Reduction on Spectrum andEnergy Efficiencies in OFDM Systems With Class-A HPA Over AWGN Channel, IEEEtransaction on broadcasting, vol. 59, NO. 3, sep. 2013.

[4] Li X, Cimini LJ Jr (1998) Effects of clipping and filtering on the performance of OFDM. IEEE Commun Lett 2(5):131–133.

[5] W.Aziz, E. Ahmed, G. Abbas, S. Saleem and Q. Islam(2012), PAPR Reduction in OFDM using Clipping and Filtering, World Applied Sciences Journal 18 (11): 1495-1500, 2012.

[6] Wang L, Tellambura C (2005) A simplified clipping and filtering technique for PAR reduction in OFDM systems. IEEE Transaction on Signal Process 12(6):453–456

[7] Byung Moo Lee, Youngok Kim(2013),An Adaptive Clipping and Filtering Technique for PAPR Reduction of OFDM Signals,Circuits Syst Signal Process (2013) 32:1335–1349.

[8] Wang Y-C, Luo Z-Q (2011) Optimized iterative clipping and filtering for PAPR reduction of OFDM signals. IEEE TransCommun 59(1):33–38.

[9] Armstrong J (2002) Peak-to-average power ratio for OFDM by repeated clipping and frequency domain filtering. Electron Lett38(8):246–247.

[10] Hamid Saeedi, Masoud Sharif, Farokh Marvasti(2002), Clipping Noise Cancellation in OFDM SystemsUsing Oversampled Signal Reconstruction, IEEE ,communication letter, VOL. 6, NO. 2, Feb. 2002

[11] Byung Moo Lee , Youngok Kim ,Rui J. P& de Figueiredo(2012) Performance Analysis of the Clipping Scheme with SLM Technique, Wireless Pers Commun 63:331–344

[12] G.T. Zhou and Liang Peng(2007) Optimality condition for selected mapping in ofdm. IEEE Transactions on Signal Processing, 54(8):3159 – 65, 2006/08/.

[13] Jayalath, A.D.S., & Tellambura, C. (2000), Reducing the peak-to-average power ratio of orthogonal frequency division multiplexing singal through bit or symbol interleaving. ElectronicsLetters, 36(13), 1161–1163.

[14] Tellado, J. (1999),Peak to average power reduction for multicarrier modulation. Ph.D dissertation,Stanford university, Sept.

[15] Yoo, S., Yoon, S., Kim, S.Y., & Song, I. (2006),A novel PAPR reduction scheme for OFDM systems:Selectivemapping of partial tones (SMOPT),IEEE Transactions on Consumer Electronics, 52(1), 40–43.

[16] Krongold, B.S., & Jones, D.L. (2003), PAR reduction in OFDM via active constellation extension.IEEE Transations on Broadcasting, 49(3), 258–268.

[17] Huang, X., Lu, J., Zheng, J., Letaief, K.B., & Gu, J. (2004),Companding transform for reduction in peak-to-average power ratio of OFDM signals. IEEE Transations on Wireless Communication