Analysis of Effective PAPR Simulation for LTE-A Carrier Aggregation under Robust Environment

DISSERTATION

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By
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Om Prakash Tripathi
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CERTIFICATE

This is to certify that **Om Prakash tripathi** bearing Registration no. 11008392 has completed objective formulation of thesis titled, **“**Effective PAPR Simulation For LTE-A. Carrier Aggregation Under Robust Environment **”** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfilment of the conditions for the award of Masters of Technology in Electronics and Communication Engineering.

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DECLARATION

I, **Om Prakash Tripathi**, student of **B.Tech/M.Tech (Integrated)** under Department of **ECE** of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

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

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ABSTRACT

Wireless Communication Technology has developed many folds over the past few years. Orthogonal Frequency Division Multiplexing is a technique to transmit data on multiple subcarriers. Therefore it achieves high data rate, less multipath fading effects and much more improvement in bandwidth efficiency. Carrier Aggregation technique is deployed in LTE-A(Long Term Evolution –Advanced) system that can extends system bandwidth up to 100 MHz . It will also increase the downlink spectral efficiency. In order to achieve higher data rates as specified in LTE-Advanced, support of wider Bandwidths are required than the existing 20 MHz system bands. N-x-OFDMA will be used as the downlink transmission scheme in LTE-A as higher data rates are required for transmission. The major problem which arises in carrier aggregation is the significant increase in PAPR of the time domain signal, and in order to accommodate large peaks PA has to operate with sufficient power back-off which results in lower operating efficiency. So we have to maintain both a ratio between power back-off and operating efficiency. As a result, power amplifiers have to operate with back-off and result in relatively low efficiency. Multicarrier modulation, often also denoted as orthogonal frequency-division multiplexing (OFDM), has been proposed for many applications.

Various schemes have been proposed to reduce the PAPR of OFDM signals including clipping method, probabilistic techniques, and coding techniques etc. Among these techniques, clipping of the OFDM signal before amplification is a one type of simple and efficient way of controlling the PAPR. The pulse cancellation method (PCM) is one of the clipping techniques which find its way into practical implementation due to its higher efficiency and better spectral characteristics. In this dissertation, steps have been taken to improve the performance of OFDM system. The accuracy in result is obtained with increase in signal to noise ratio and decrease in peak to average power ratio. To fulfil this objective efficient algorithm is to be used which can reduce PAPR and give better SNR. This can be obtained by applying various algorithm and one of them is repetition of Noise Shaping process two times for reducing the PAPR of the carrier aggregated composite signal. This has been observed that Noise Shaping process shows the performance improvement in PAPR.

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LIST OF ABBREBATIONS

OFDM	Orthogonal Frequency Division Multiplexing
DF	Degradation Factor
FDM	Frequency division multiplexing
ISI	Inter symbol interference
ICI	Inter carrier interference (ICI) .
RF	Radio frequency power amplifier
SLM	Selected mapping
,BER	Bit error rate
LTE	Long term evolution
UMTS	Universal Mobile Telephone System
SC-FDMA	Single Carrier - Frequency Division Multiple Access
FDD	Frequency Division Duplexing
TDD	Time Division Duplexing
PAPR	Peak-to-average power ratio
CA	Carrier Aggregation
CC	Component Carrier
CFR	Crest factor

CHAPTER 1

INTRODUCTION

In wireless communication, concept of parallel transmission of symbols is applied to achieve high throughput and better transmission quality. Orthogonal Frequency Di- vision Multiplexing (OFDM) is one of the techniques for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal subcarriers in order to transmit the symbols using these subcarriers in parallel [1]. Schemes used in OFDM system can be selected on the basis of the requirement of power or spectrum efficiency and BER analysis. DF (degradation factor) that is the ratio of SNR without phase noise (Without (S/N)) to SNR with phase noise (With (S/N)) is used for the performance measure. Multi-carrier modulation, Orthogonal Frequency Division Multiplexing (OFDM) particularly, has been successfully applied to a wide variety of digital communications applications over the past several years. OFDM has been chosen as the physical layer standard for a variety of important systems and its implementation techniques continue to evolve rapidly.

Since the very genesis of man, communication has been one of the main aspects in human life. Previously various methods like sign languages were implemented for this purpose. As various civilizations started coming into existence, many innovative ideas came to the minds of the people – special birds and human messengers were employed to meet these challenges. As ages rolled by, post system developed and transportation vehicles like trains and ships were used to maintain link between people miles apart. But by the turn of the nineteenth century, a great leap in communication system was observed when wireless communication was introduced. After the advent of wireless communication huge change has been observed in the lifestyle of people. Wireless communication which was initially implemented analogy domain for transfer has is now-a-days mostly done in digital domain. Instead of a single carrier in the system multiple sub-carriers are implemented to make the process easier. [1]

1.1 Electronic Communication System

Electronics communication system has revolutionized the face of the world. Communication with someone a mere century back was only possible by physical mode. But now that can be done just by clicking a switch on the telephone pad or by just a click of the mouse. Even live television report, live games telecast could not be possible without wireless communication.

A simple communication system consists of a transmitter end which send the data and a receiver end at which the data is received. Usually there received data is not the same as the data sent. Because of the noise present in the medium the signal gets affected and distortion is observed in the signal. Various modulation techniques are under taken in order to ensure that the signal sent is safely available at the receiver end.

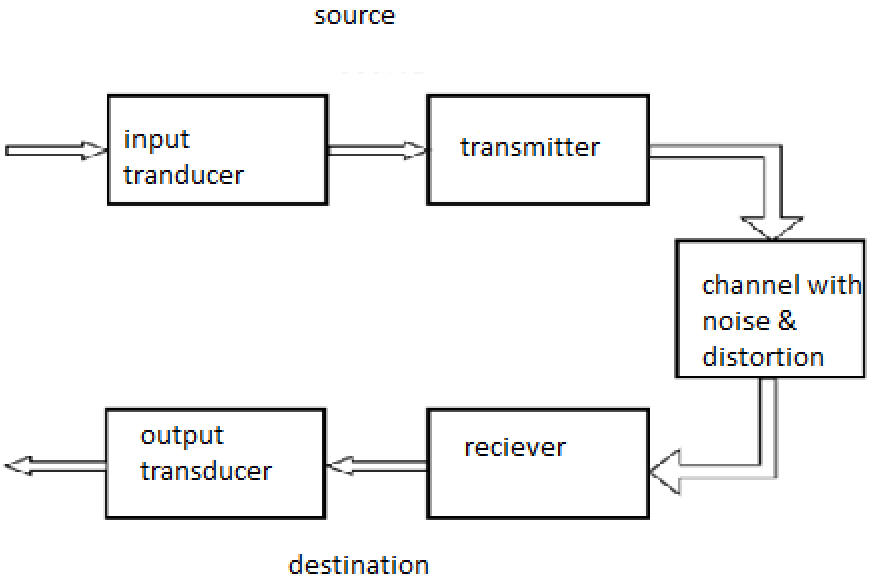


Figure1.1: A Diagram Representation of Electronic Communication System Block[3]

1.1.1 Convolution

Convolution is the process by which the output of a system can be determined. One of the signals is time reversed, shifted, multiplied with another signal and finally integrated to generate the output signal in this process. Mathematically, it is represented as

$$V(t) = w(t) * h(t) = \int_{-\infty}^{+\infty} w(\tau)h(t-\tau)d\tau \qquad (1.1)$$

Linear time invariant systems obey the above rules. [1]

1.1.2 Discrete Fourier Transform

In many occasions signals are available in a set of N sample values, taken at regularly spaced intervals, over a time period. So it is desirable to have some approximate idea about the signal spectral content by interpreting its interval space and time period. For this, it is assumed that the signal is periodic (time period) and the Nyquist criterion is satisfied for sampling period. For simplicity, even number of samples are assumed and symmetrical.

If the waveform to be sampled is m (t), we obtain m (t) S (t) after sampling, where S (t) is the sampling function. Similarly, the value of can be computed for all N samples. The period of the highest frequency component should be 2. [1]

1.1.3 Multipath Channel

The transmitted signal faces various obstacles and surfaces of reflection, as a result of which the received signals from the same source reach at different times. This gives rise to the formation of „echoes" which affect the other incoming signals. Dielectric constants, permeability, conductivity and thickness are the main factors affecting the system. Multipath channel propagation is devised in such a manner that there will be a minimized effect of the echoes in the system in an indoor environment. Measures are needed to be taken in order to minimize echo in order to avoid ISI. [3]

Figure1.2: Multipath Channel Propagation [3]

1.2 Orthogonal Frequency Division Multiplexing

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. Various multicarrier modulation techniques have evolved in order to meet these demands, few notable among them being Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Orthogonal Frequency Division Multiplexing is a frequency – division multiplexing (FDM) scheme utilized as a digital multi – carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data. The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining total data rates similar to the conventional single carrier modulation schemes in the same bandwidth.

1.2.1 Development of OFDM System

The development of OFDM systems can be divided into three parts. This comprises of Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing.

1.2.2 Frequency Division Multiplexing

Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non – overlapping frequency ranges or channels to different signals or to each „user‟ of a medium. A gap or guard band is left between each of these channels to ensure that the signal of one channel does not overlap with the signal from an adjacent one. Due to lack of digital filters it was difficult to filter closely packed adjacent channels. [2]

1.2.3 Multicarrier Communication

As it is ineffective to transfer a high rate data stream through a channel, the signal is split to give a number of signals over that frequency range. Each of these signals are individually modulated and transmitted over the channel. At the receiver end, these signals are fed to a de – multiplexer where it is demodulated and re – combined to obtain the original signal. [2]

1.2.4 OFDM Theory

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.

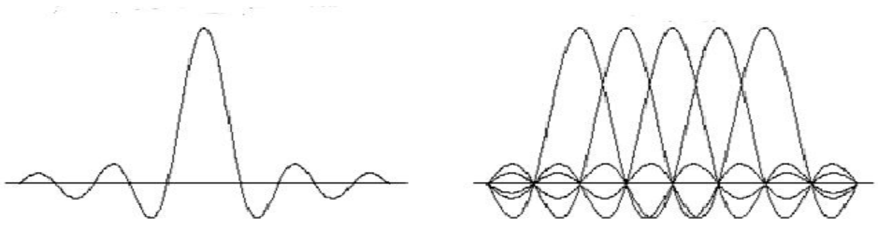


Figure1.3: OFDM Spectrum [3]

1.2.5 Inter – Symbol Interference

Inter – symbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non – linear frequency response of a channel causing successive symbols to „blur“ together. The presence of ISI in the system introduces error in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI and thereby deliver the digital data to its destination with the smallest error rate possible. [2]

1.2.6 Inter – Carrier Interference

Presence of Doppler shifts and frequency and phase offsets in an OFDM system causes loss in orthogonality of the sub – carriers. As a result, interference is observed between sub – carriers. This phenomenon is known as inter – carrier interference (ICI).

1.2.7 Cyclic Prefix

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation .The cyclic prefix has to two important benefits

1. The cyclic prefix acts as a guard interval. It eliminates the inter–symbol interference from the previous symbol.
2. It acts as a repetition of the end of the symbol thus allowing the linear convolution of a frequency – selective multipath channel to be modelled as circular convolution which in turn maybe transformed to the frequency domain using a discrete Fourier transform. This approach allows for simple frequency – domain processing such as channel estimation and equalization

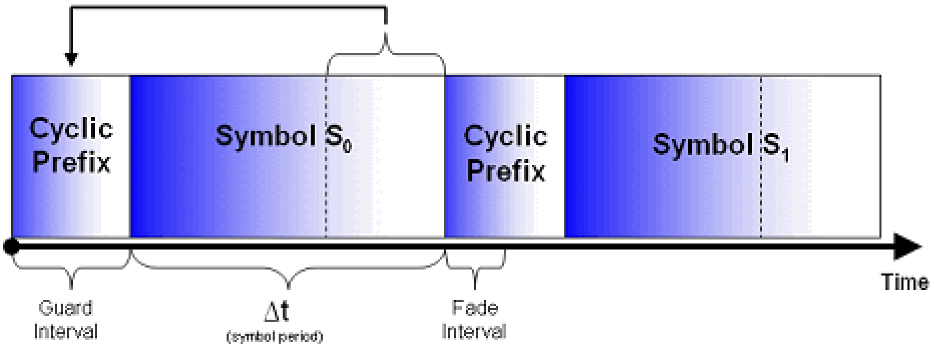


Figure 1.4: Cyclic Prefix [4]

1.3 Modulation & Demodulation in OFDM Systems

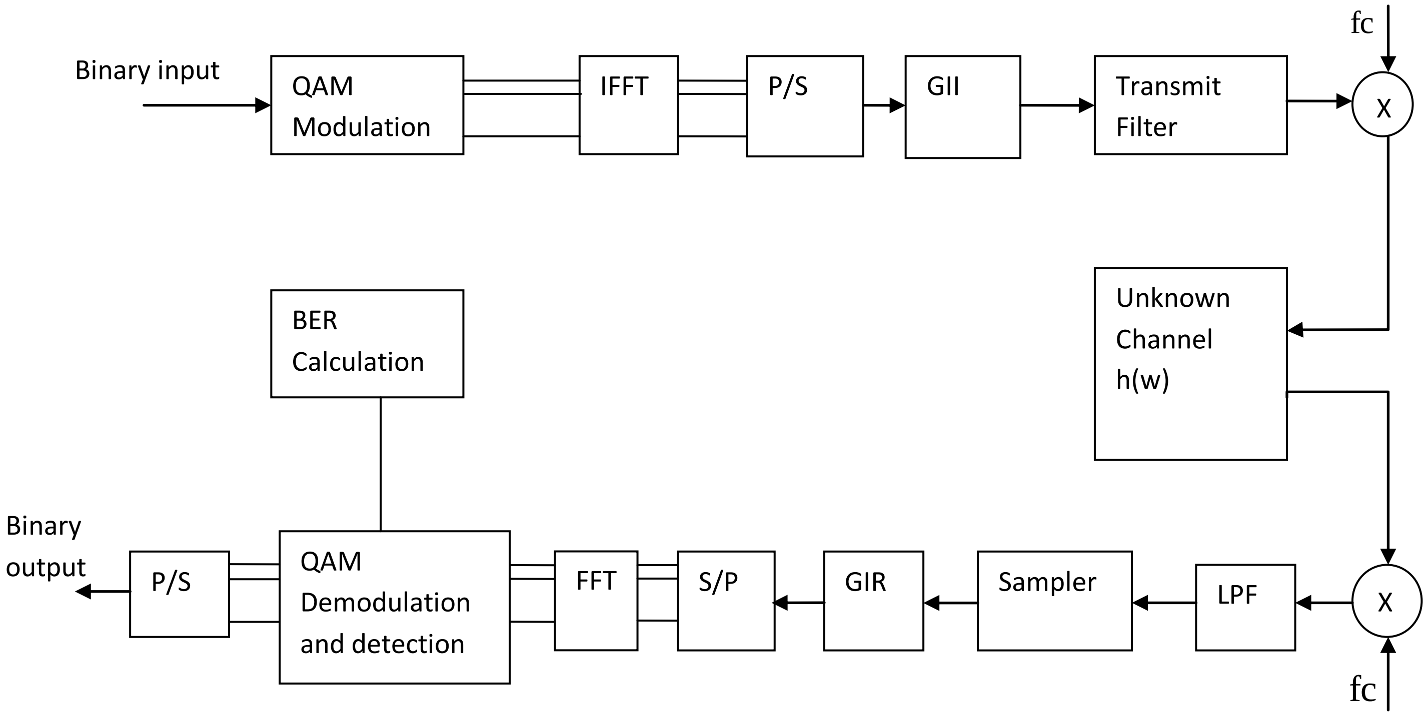


Figure1.5: Modulation & Demodulation in OFDM Systems

1.3.1 Modulation

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique (QPSK). After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel – to – serial converter. In order to avoid ISI we provide a cyclic prefix to the signal. [2]

1.3.2 Communication Channel

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

1.3.3 Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial – to – parallel converter. A demodulator is used, to get back the original signal.

The bit error rate and the signal – to – noise ratio is calculated by taking into consideration the un – modulated signal data and the data at the receiving end. [3]

1.3.4 Peak- to – Average Power Ratio

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value.

There are a number of techniques to deal with the problem of PAPR. Some of them are „amplitude clipping‟, „clipping and filtering‟, „coding‟, „partial transmit sequence (PTS) ‟, „selected mapping (SLM) ‟ and „interleaving‟. These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on .

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal. [4]

1.3.5 The Major Disadvantages of a High PAPR are-

1. Increased complexity in the analog to digital and digital to analog converter.
2. Reduction is efficiency of RF amplifiers.

1.4 PAPR Reduction Techniques

PAPR reduction techniques vary according to the needs of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system. The PAPR reduction techniques on which we would work upon and compare in our later stages are as follows:

1.4.1 Amplitude Clipping and Filtering

A threshold value of the amplitude is set in this process and any sub-carrier having amplitude more than that value is clipped or that sub-carrier is filtered to bring out a lower PAPR value.

1.4.2 Selected Mapping

In this a set of sufficiently different data blocks representing the information same as the original data blocks are selected. Selection of data blocks with low PAPR value makes it suitable for transmission. [4]

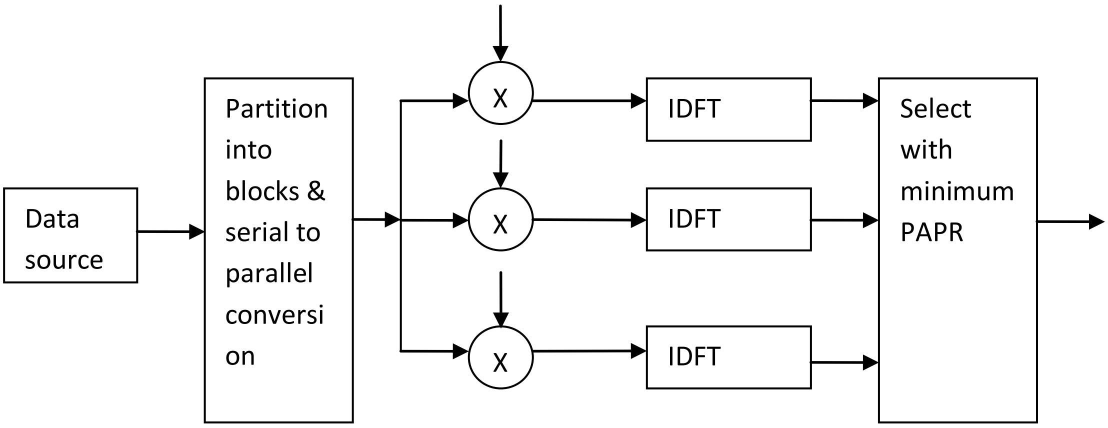


Figure1.6: Selected Mapping

1.4.3 Partial Transmit Sequence

Transmitting only part of data of varying sub-carrier which covers all the information to be sent in the signal as a whole is called Partial Transmit Sequence Technique.

1.4.4 Amplitude Clipping and Filtering

Amplitude clipping is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed.

The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise. This distortion falls in both in – band and out – of – band. Filtering cannot be implemented to reduce the in – band distortion and an error performance degradation is observed here. On the other hand spectral efficiency is hampered by out – of – band radiation. Out – of – band radiation can be reduced by filtering after clipping but this may result in some peak re – growth. A repeated filtering and clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several tone injection technique.

The basic 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 equivalent constellation points, these extra degrees of freedom can be exploited for PAPR reduction. Here the transmitted power increases.

1.4.5 Active Constellation Extension (ACE) Technique

This technique for PAPR reduction is similar to Tone Injection technique. According to this technique, some of the outer signal constellation points in the data block are dynamically extended towards the outside of the original constellation such that PAPR of the data block is reduced. In this case also there will be increase of transmitted power take place iteration of this process. [4]

1.4.6 Techniques Based on Phase Shifting

Tarokh and Jafarkhani have proposed a method where, instead of transmitting S, they transmit $S\Phi T$ where $\Phi$is a vector of optimally chosen phase shift angles $\{\phi 0, \phi 1, ... \phi M-1\}$. Tarokh and Jafarkhani have reported results for 48 sub-carriers, which in practice is a fairly good block size for OFDM type systems. The authors demonstrate a PAPR reduction of 4.22dB for 8PSK modulation. There is no direct method for computing the optimal phase shift vector Φ, however, there are iterative algorithms to compute them for different modulation techniques. There is no direct method for computing the optimal phase shift vector Φ, however, there are iterative algorithms to compute them for different modulation techniques.

This technique also goes by the name partial transmit sequences. In this technique, S is broken into a set of blocks, $\{S0, S1, ... Sc-1\}$ of size $k=S/C$, and then the entire block is weighted using an optimal weight vector $B=\{b0, b1, ... bc-1\}$. Block partitioning can be interleaved, adjacent, or pseudo-random. The obvious bottleneck is again the search time taken to find an optimal weight vector. To reduce the possible number of combinations, the phase shift values are taken from $P=ej2\pi l/c, l=0, 1, ... c-1$. Phase shifting can also be done in blocks, instead of individual sub-carriers. This also means that the side-information to be transmitted about the phase shifts used is limited to clog (l). For l=0, there is no shift. One technique, called iterative flipping, works as follows

- Start with an initial vector {1,1,1,1,1,1,1}
- Fix the first value b0 to 1, and then search for optimal setting for the second value b1, which yields the lowest PAPR.
- After finding the optimal value of b1, fix it and go on to b2. For c=2, the second term is obtained by flipping the sign of the first term, hence the term iterative flipping. This method is a heuristic search and obviously does not give the global optimum. Han and Lee have suggested an improvement where instead of changing just one index at one time, they search for the optimum out of all possible vectors with up to r changes from the current one i.e. a Hamming Distance of r.

An alternative method to this method, known as Selective Mapping is to construct K different phase shift vectors $\Psi m=\{\psi 0m, \psi 1m, ... \psi mM-1\}$. For each input block of N symbols, we generate K candidate blocks by multiplying the input block with the k possible sets of phase shifts ϕk. The output block $S\phi k_* T$ with the least PAPR is transmitted. Here k_* is the index of the optimal phase shift vector for this particular input block.

In all the above techniques, it is necessary to transmit side information to the receiver about the transformation affected on the original block. This side information is an overhead, since it consumes bandwidth and energy to transmit it. [5]

1.4.7 Block Coding Techniques

Block coding technique simply proposed use of codes in a given coding technique which have a low PAPR. For example, consider we have an R (3, 4) coding technique and input code words of 6 bits in length. There are 256 possible output code words out of which, say, 150 code words have low PAPR. We then start handling smaller input words, which can be mapped into one of those 6 bit inputs which generate the low PAPR code words.

Even more problematic is that a general search of a large code-word space to compute the PAPR of each output code word is very expensive computationally; for large block codes it is simply out of the question The obvious side-effect of this technique is to reduce coding efficiency. However, this technique is severely limited in that it can only handle a small number of sub-carriers and is thus not frequently used. [6]

CHAPTER 2

LITERATURE SURVEY

2.1 Review of Literature

G.Srivastava et al. [1] described that higher data rate required wider bandwidth. For achieving higher data rate as specified in LTE-Advanced support of wider Bandwidths are required than the existing 20 MHz system bands. Carrier Aggregation is the technique deployed in LTE-A system. It can extends system bandwidth up to 100 MHz which also increases the downlink spectral efficiency. N-x-OFDMA will be used.

Here as the downlink transmission scheme in LTE-A. The primary concern in carrier aggregation is the significant increase in PAPR of the time domain signal, to accommodate large peaks PA has to operate with sufficient power back-off which results in lower operating efficiency. They proposed two stages of Noise Shaping process for reducing the PAPR of the carrier aggregated composite signal which is a transmitter- side processing technique and does not require any information at the receiver. This paper analyzes different PAPR scenarios using contiguous & non-contiguous frequency bands for carrier aggregation and the simulation result shows the performance improvement in PAPR of about 3 & 4dB respectively.

Y.-C. Wang, et al. [2] proposed iterative clipping and filtering (ICF) technique to reduce the peak-to-average power ratio (PAPR) of orthogonal frequency division multiplexing (OFDM) signals. However, this ICF technique, when implemented with a fixed rectangular window in the frequency-domain, it requires many iterations to approach specified PAPR threshold in the complementary cumulative distribution function (CCDF). Here, in this research paper, we develop an optimized ICF method which determines an optimal frequency response filter for each ICF iteration using convex optimization techniques. The optimal filter is designed in a manner to minimize signal distortion such that the OFDM symbol’s PAPR is below a specified value. Simulation results here show that our proposed method can achieve a sharp drop of CCDF curve and reduce PAPR to an acceptable level after only 1 or 2 iterations, whereas the classical ICF method would require 8 to 16 iterations to achieve a similar PAPR reduction. Moreover, the clipped OFDM symbols we obtained by our optimized ICF method have less distortions and thus lower out-of-band radiation than the existing method.

Carole A. Devlin, et al. [3] studied One of the major drawbacks of OFDM is high Peak to-Average Power Ratio (PAPR) that can result in poor power efficiency and serious distortion in the transmitter amplifier. Tone Reservation (TR) technique is designed to combat this type of problem by reserving a number of carriers (tones) in the frequency domain to generate a cancellation signal in the time domain to remove high peaks. However, TR can have a high associated computational cost due to the problems in finding an effective cancellation signal in the time domain by using only a few tones in the frequency domain. Here, they have proposed a novel approach to overcoming this problem by creating a Gaussian pulse as the cancellation signal from only a small number of reserved tones. This paper facilitates a simple and effective algorithm that help in reducing peak values while minimizing the occurrence of secondary peaks, the latter being a key factor in contributing to the high computational complexity of tone reservation algorithms.

Wong Sai Ho, et al. [**13**] studied the major problem in multicarrier system is high peak to average power ratio. It creates nonlinearity in the transmitter, degrading the performance of the system significantly. . Though PAPR reduction by PTS is more effective with more subblocks, there is a corresponding exponential increase in complexity. Partial transmit sequences (PTS) is one of the best methods in reducing PAPR, in which the information-bearing subcarriers are divided into disjoint subblocks, each controlled by a phase rotation factor which brings PAPR down. Here, in this research paper, a novel implementation of PTS is presented, in which a dual-layered approach is employed to reduce the complexity.

Slimane Ben Slimane, et al. [9] proposed an efficient technique for reducing the PAPR of OFDM signals. Orthogonal Frequency Division Multiplexing (OFDM) techniques is used for transmission of high data rates over broadband radio channels subject to multipath fading without the need for powerful channel equalization. However, they are very sensitive to nonlinear effects due to the high Peak-to-Average Power Ratio (PAPR) owned by the transmitted signal. The proposed technique is very effective and flexible. The method avoids the use of extra Inverse Fast Fourier Transformations (IFFTs) as was done in some previously published techniques but instead is based on a proper selection of the time waveforms of the different subcarriers of the OFDM modulation scheme. Thus, its implementation complexity is much low in comparison to the previous published methods. A closed form relation between the maximum PAPR and the used pulse shaping waveform is derived. The obtained results show that with broadband pulse shaping, the PAPR of OFDM modulated signals can be made very close to that of single carrier signals. The improved statistics of the PAPR in the transmitted signal is demonstrated through numerical results for some sets of time waveforms. The major improvement that is reduction in PAPR given by the present technique permits to reduce the complexity and cost of the transmitter significantly. In that, pulse shaping can be used not only to shape the spectrum of the transmitted signal but also to reduce its PAPR.

R.W. Bguml, et al. [7] proposed a method called selected mapping. Average transmit power ratio of multicarrier modulation systems, called selected mapping and presented by which appropriate for a wide range of applications. Significant gains can bc achieved by selected mapping whereas complexity remains quite moderate. Multicarrier modulation, often also denoted as orthogonal frequency-division multiplexing (OFDM), has been proposed for many applications. In OFDM transmission schemes, a block of D distinct complex-valued carriers is transformed into the time-domain using the inverse discrete Fourier transform (IDFT).

Zhibin Zeng, et al. [10] studied digital predistortion, which is used to compensate forthe nonlinearity introduced by power amplifiers, plays an important role in the linearization techniques. Saturation distortions caused by high peak-to-average ratio of input signal, however, cannot be compensated through digital predistortion. As a result, power amplifiers have to operate with back-off and result in relatively low efficiency. A new pulse cancellation method of crest factor reduction technique is proposed which can considerably increase power efficiency without power back-off by reducing the high peak-to-average ratio.

Luqing Wang, et al. [11] studied that the existing iterative clipping and filtering techniques require several iterations to mitigate the peak regrowth. In this letter, we analyze the conventional clipping and filtering using a parabolic approximation of the clipping pulse. We show that the clipping noise obtained after several clipping and filtering iterations is approximately proportional to that generated in the first iteration. Therefore, we scale the clipping noise generated in the first iteration to get a new clipping and filtering technique that, with three fast Fourier transform/inverse fast Fourier transform (FFT/IFFT) operations, obtains the same PAR reduction as that of the existing iterative techniques with 2 + 1 FFT/IFFT operations, where represents the number of iterations.

D.J.Goodman, et al. [6] studied that the single carrier frequency division multiple access (SCFDMA), which utilizes single carrier modulation and frequency domain equalization is a technique that has similar performance and essentially the same overall complexity as those of OFDM, in which high peak-to-average power ratio (PAPR) is a major drawback. An outstanding advantage of SC-FDMA is its lower PAPR due to its single carrier structure. In this paper, we analyze the PAPR of SC-FDMA signals with pulse shaping. They analytically derive the time domain SC-FDMA signals and numerically compare PAPR characteristics using the complementary cumulative distribution function (CCDF) of PAPR. PAPR compared to IFDMA, but compared to OFDMA, it is lower, though not significantly. Another noticeable fact is that pulse shaping increases PAPR and that rolloff factor in the case of raised-cosine pulse shaping has a significant impact on PAPR of IFDMA. A pulse shaping filter should be designed carefully in order to reduce the PAPR without degrading the system performance. They proposed to fully exploit the low PAPR advantage of SC-FDMA, IFDMA is more desirable than LFDMA when choosing subcarrier mapping method.

Pochun yen, et al. [14] studied that the next generation wireless systems require much higher data rate supports and hence larger bandwidths than the existing systems. Due to the compatibility requirement with the existing legacy systems and the constraints on the availability of contiguous spectrum, bandwidth (or carrier) aggregation has recently emerged as a practical means for supporting high data rate requirement of next-generation systems. A practical issue associated with the bandwidth or carrier aggregation is the significant increase of the peak-to-average power ratio (PAPR) of the time-domain signal. The proposed approach adopts the existing selective mapping concept, but with some modifications for substantially reducing complexity and signaling overhead, while adapting to carrier-aggregated systems. Performance evaluation under 3GPP LTE-Advanced environment shows PAPR reduction advantage of the proposed method while not requiring any signaling overhead.

CHAPTER 3

LONG TERM EVOLUTION

3.1 Introduction

The 3rd Generation Partner Ship Project (3GPP) produced the first version of WCDMA standard in the end of 1999, which is the basis of the Universal Mobile Telephone System (UMTS) deployed in the field today. This release, called release 99, contained all the basic elements to meet the requirements for IMT-2000 technologies. Release 5 introduced the High Speed Downlink Packet Access (HSDPA) in 2002, enabling now more realistic 2 Mbps and even beyond with data rates up to 14 Mbps. Further Re- lease 6 followed with High Speed Uplink Packet Access (HSUPA) in end of 2004, with market introduction expected in 2007. Long Term Evolution (LTE) is the next step forward in cellular 3G services. Expected in the 2008 time frame, LTE is a 3GPP standard that provides for an uplink speed of up to 50 megabits per second (Mbps) and a downlink speed of up to 100 Mbps. LTE will bring many technical benefits to cellular networks. Bandwidth will be scalable from 1.25 MHz to 20 MHz. This will suit the needs of different network operators that have different bandwidth allocations, and also allow operators to provide different services based on spectrum. LTE is also expected to improve spectral efficiency in 3G networks, allowing carriers to provide more data and voice services over a given bandwidth. The 3GPP Long Term Evolution (LTE) represents a major advance in cellular technology. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade. The LTE PHY employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier - Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of sym- boll periods. Due to the novelty of these technologies in cellular applications, they are described separately before delving into a description of the LTE PHY. Although the LTE specs describe both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) to separate UL and DL traffic, market preferences dictate that the majority of deployed systems will be FDD. This paper therefore describes LTE FDD systems only. Alongside with on-going further WCDMA development, work on Evolved Universal Terrestrial Radio Access (UTRA) has been initiated in 3GPP. The objective of Evolved UTRA is to develop a framework for the evolution of the 3GPP radio-access technology towards wider bandwidth, lower latency and packet-optimized radio-access technology with peak data rate capability up to 100 Mbps. [5]

3.1.1 Requirements of LTE

1. Peak data rate - 100 Mbps DL/ 50 Mbps UL within 20 MHz bandwidth.
2. Up to 200 active users in a cell (5 MHz)
3. Less than 5 Ms user-plane latency
4. Mobility - Optimized for 0 -15 km/h.
5. Enhanced multimedia broadcast multicast service (E-MBMS)
6. Spectrum flexibility: 1.25 20 MHz
7. Enhanced support for end-to-end QoS.

3.2 SCFDMA in Uplink

While PAPR is a major concern in portable terminals, Information throughput is an even more important indicator of system performance. As in OFDMA, throughput in SC-FDMA depends on the way in which information symbols are applied to sub- carriers. There are two approaches to apportioning subcarriers among terminals. In localized SC-FDMA (LFDMA), each terminal uses a set of adjacent subcarriers to transmit its symbols. Thus the bandwidth of an LFDMA transmission is confined to

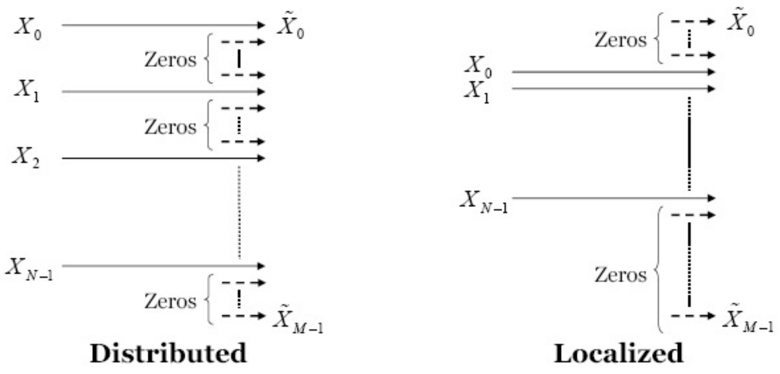
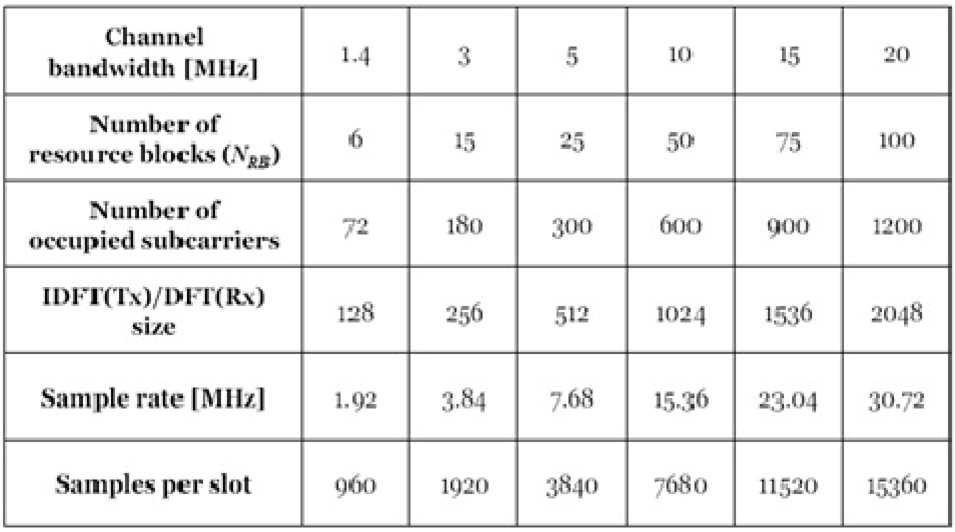


Figure 3.1: Distributed and Localized Sub-Carriers [7]

The alternative to IFDMA is distributed SC- FDMA in which the subcarriers used by a terminal are spread over the entire signal band. One realization of distributed SC-FDMA is interleaved IDMA (IFDMA) where occupied subcarriers are equidistant from each other.

Figure 1 shows the two arrange- mints in the frequency domain. There are three terminals, each transmitting symbols on four subcarriers in a system with a total of 12 subcarriers. In the distributed are- arrangement, terminal 1 uses subcarriers 0, 3, 6, and 9; with LFDMA it uses subcarriers. [6]

3.2.1 LTE Specifications:



Channel bandwidth [MHz]	1.4	3	5	10	15	20
Number of resource blocks (N_{RB})	6	15	25	50	75	100
Number of occupied subcarriers	72	180	300	600	900	1200
IDFT(Tx)/DFT(Rx) size	128	256	512	1024	1536	2048
Sample rate [MHz]	1.92	3.84	7.68	15.36	23.04	30.72
Samples per slot	960	1920	3840	7680	11520	15360

Figure3.2: LTE Specifications [7]

3.2.2 Effect of Varying Sub Carrier Spacing on Receiver Performance

Complex envelope of the transmitted OFDM signal for a given OFDM Symbol, sampled with sampling frequency fs=B;

$$X(n) = \sum_{k=0}^{N-1} s_{k.}\, e^{-j*2*pi*k*n/N} \qquad (3.1)$$

This symbol is actually extended with a Time Guard in order to cope with multipath delay spread. For the sake of simplicity, we will not consider this prefix since it is eliminated in the receiver .Assuming that the channel is flat, the signal is only affected by phase noise at the receiver the received signal is Orthogonal Frequency Division Demultiplexed (OFDD) by means of a Discrete Fourier Transform.

$$\text{r (n)}= X_n * e^{-j*\varphi*n} \tag{3.2}$$

In order to separate the signal and noise terms, let us suppose that is small, so that

In this case, the demultiplexed signal is

$$e^{j*\varphi(n)} \approx 1 + j * \varphi(n) \tag{3.3}$$

Thus we have an error term for each sub-carrier which results from some combination of all of them and is added to the useful signal. Let us analyze more deeply this noise contribution:

$$\text{y(k)} \approx s_{k.} + e_k \tag{3.4}$$

3.2.3 Common Phase Error: for (r=k)

We have a common error added to every sub-carrier that is proportional to its value multiplied by a complex number that is a rotation of the constellation. This angle results from an

$$\varphi = 1/N{*}\textstyle\sum_{n=0}^{N-1} \varphi(n) \tag{3.5}$$

Average of phase noise. This average implies low frequencies of phase noise spectrum up t

o, that is the inter-carrier spacing. Since it is constant for all sub-carriers, it can be corrected by some kind of phase rotation.

3.2.4 Inter Carrier Interference: for (r not equal to k)

$$\emptyset = \mathbf{j/N} * \sum_{r-0}^{N-1} S_{r*} \sum_{r-0}^{N-1} e^{j*2*pi*(r-k)*n/N} \qquad (3.6)$$

This term corresponds to the summation of the information of the other sub-carriers each multiplied by some complex number which comes from an average of phase noise with a spectral shift. The result is also a complex number that is added to each sub- carrier's useful signal and has the appearance of Gaussian noise. It is normally known as inter-carrier interference.

1. When the ratio between the phase noise bandwidth and he OFDM inter-carrier spacing is small, it comes out from that the common phase error dominates over the inter-carrier interference (ICI). Since this error can be corrected together with the channel effects the symbol error rate after correction is much lower.
2. On the other hand, as this ratio approaches unity, that is, the phase noise bandwidth becomes closer to the inter-carrier spacing value, the inter-carrier interference increases and the correction capabilities decrease.
3. If it is greater than 1, then symbol error rate after correction can be equal to that obtained before correction or even worse if the chosen phase correcting. Scheme fails due to the presence of noise. [7]

3.3The Peak Power Problem

An OFDM signal consists of a number of independently modulated SCs, which can give a large peak-to-average power (PAP) ratio when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. This effect is illustrated in Figure below. For this example, the peak power is 16 times the average value. The peak power is defined as the power of a sine wave with an amplitude equal to the maximum envelope value. Hence, an unmodulated carrier has a PAP ratio of 0 db. An alternative measure of the envelope variation of a signal is the Crest factor, which is defined as the maximum signal value divided by the RMS signal value. For an unmodulated carrier, the Crest factor is 3 dB. This 3-dB difference between the PAP ratio and Crest factor also holds for other signals, provided that the center frequency is large in comparison with the signal bandwidth. A large PAP ratio brings disadvantages like an increased complexity of the analog-to- digital (A/D) and digital-to-analog (D/A) converters and a reduced efficiency of the RF power amplifier. To reduce the PAP ratio, several techniques have been proposed, which basically can be divided in three categories. First, there are signal distortion techniques, which reduce the peak amplitudes simply by nonlinearly distorting the OFDM signal at or around the peaks. Examples of distortion techniques are clipping, peak windowing, and peak cancellation. Second, there are coding techniques that use a special FEC code set that exclude OFDM symbols with a large PAPR. The third technique scrambles each OFDM symbol with different scrambling sequences and selecting the sequence that gives the smallest PAP ratio. [8]

3.3.1 Distribution of the PAPR

For one OFDM symbol with NSCs, the complex baseband signal can be written as

$$X\,(n) = 1/\sqrt{N} * \sum a_n * e^{j*\omega*t} \qquad (3.7)$$

Here, a_n are the modulating symbols. For QPSK, for instance,

$$a_{n=}\varepsilon - 1, 1, -j, j \qquad (3.8)$$

From the central limit theorem it follows that for large values of N, the real and imaginary values of x (t) become Gaussian distributed, each with a mean of zero and a variance of 1/2. The amplitude of the OFDM signal therefore has a Rayleigh distribution, while the power distribution becomes a central chi-square distribution with two degrees of freedom and zero mean with a cumulative distribution given by

$$F\,(z) = 1 - e^{z} \qquad (3.9)$$

The simplest way to reduce the PAP ratio is to clip the signal, such that the peak amplitude becomes limited to some desired maximum level. Although clipping is definitely the simplest solution, there are a few problems associated with it. First, by

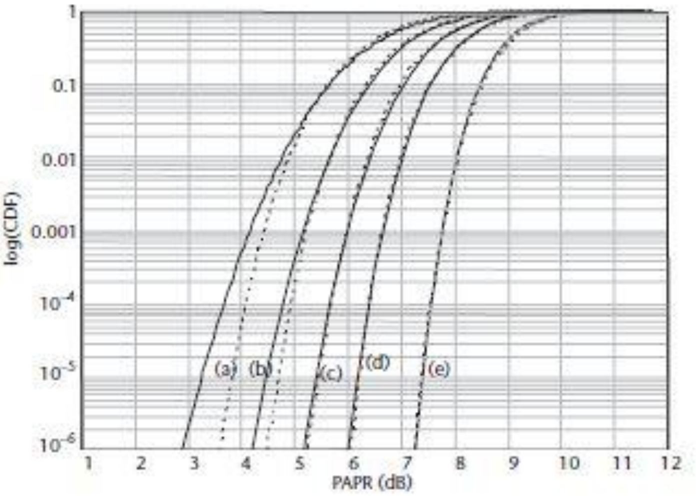


Figure 3.3: CDF of The PAP Ratio (PAPR) for a Number of SCs of (a) 32, (b) 64, (c) 128, (d) 256, and (e) 1,024[1]

Distorting the OFDM signal amplitude, a kind of self-interference is introduced that degrades the BER. Second, the nonlinear distortion of the OFDM signal significantly increases the level of the out-of-band radiation. The latter effect can be understood easily by viewing the clipping operation as a multiplication of the OFDM signal by a rectangular window function that equals one if the OFDM amplitude is below a threshold and less than one if the amplitude needs to be clipped. The spectrum of the clipped OFDM signal is found as the input OFDM spectrum convolved with the spectrum of the window function. The out-of-band spectral properties are mainly determined by the wider spectrum of the two, which is the spectrum of the rectangular window function. This spectrum has a very slow roll off that is inversely proportional to the frequency. To remedy the out-of-band problem of clipping, a different approach is to multiply large signal peaks with a certain non rectangular window. In, a Gaussian shaped window is proposed for this, but in fact any window can be used, provided it has good spectral properties. To minimize the out-of-band interference, ideally the window should be as narrow band as possible. On the other hand, the window should not be too long in the TD because that implies that many signal samples are affected, which increases the BER. Examples of suitable window functions are the cosine, Kaiser, and hamming windows. Figure gives an example of reducing the large peaks in OFDM with the use of windowing.

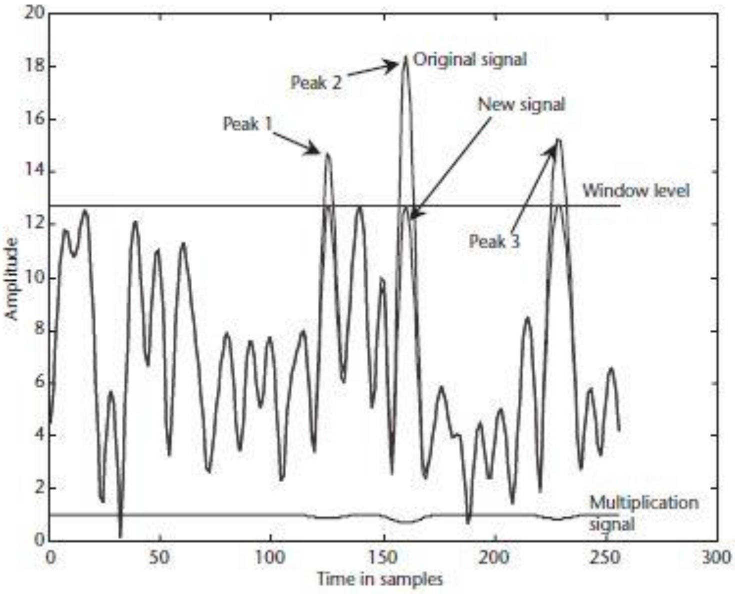


Figure3.4: Windowing [2]

3.3.2 Coding, Scrambling and Peak Cancelation

A disadvantage of distortion techniques is that symbols with a large PAP ratio suffer more degradation, so they are more vulnerable to errors. To reduce this effect, FEC coding can be applied across several OFDM symbols. By doing so, errors caused by symbols with a large degradation can be corrected by the surrounding symbols. In a COFDM system, the error probability is no longer dependent on the power of individual symbols, but rather on the power of a number of consecutive symbols.

The key element of all distortion technique is to reduce the amplitude of samples whose power exceeds a certain threshold. In the case of clipping and peak windowing, this was done by a nonlinear distortion of the OFDM signal, which resulted in a certain amount of out-of-band radiation. This undesirable effect can be avoided by performing a linear peak-cancellation technique, whereby a time-shifted and scaled-reference function is subtracted from the signal, such that each subtracted reference function reduces the peak power of at least one signal sample. By selecting an appropriate reference function with approximately the same bandwidth as the transmitted signal, it can be assured that the peak power reduction will not cause any out-of-band interference. One example of a suitable reference signal is a sinc function. A disadvantage of a sinc function is that it has infinite support. Hence, for practical use, it has to be time limited in some way. One way to do this without creating unnecessary out-of-band interference is to multiply it by a windowing function, for instance, a raised cosine window. Peak cancellation can be performed digitally after generation of the digital OFDM symbols. It involves a peak power (or peak amplitude) detector, a comparator to see if the peak power exceeds some threshold, and a scaling of the peak and surf- rounding samples. Incoming data is first coded and converted from a serial bit stream to blocks of N complex signal samples. On each of these blocks, an IFFT is performed. Then, a cyclic prefix is added, extending the symbol size to N + NG samples. After parallel-to-serial (P/S) conversion, the peak cancellation procedure is applied to reduce the PAP ratio. It is also possible to do peak cancellation immediately after the IFFT and before the cyclic prefix and windowing. Except for the peak cancellation block, there is further no difference from a standard OFDM transmitter. For the receiver, there is no difference at all, so any standard OFDM can be used. [9]

CHAPTER4

RESEARCH METHODOLOGY

4.1 Modulation and Demodulation in OFDM Systems

The demand of high data rate services has been increasing very rapidly and there is no slowdown in sight. We know that the data transmission includes both wired and wireless medium. Usually, these type of services require very reliable data transmission over very harsh environment. Most of these type of transmission systems experience much degradation such as large attenuation, noise, multipath, interference, time variance, nonlinearities and must meet the finite constraints like power limitation and cost factor. One physical layer technique that has gained a lot of popularities for its robustness in dealing with these impairments is multi-carrier modulation technique. In multi-carrier modulation techniques, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication. Unfortunately, the major drawback of OFDM transmission that has been noticed is its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since we know power amplifier is used at the transmitter, so as to operate in a perfectly linear region the operating power must lies below the available power. For reduction of this drawback PAPR lot of algorithms have been developed. All the techniques which we know have some sort of advantages and disadvantages. Clipping and Filtering is one of the basic techniques where some part of transmitted signal undergoes into distortion. Also the Coding schemes reduce the data rate which is undesirable. When we are considerin .

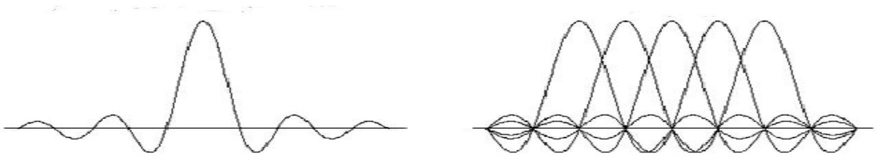


Figure4.1: Orthogonality Spectrum

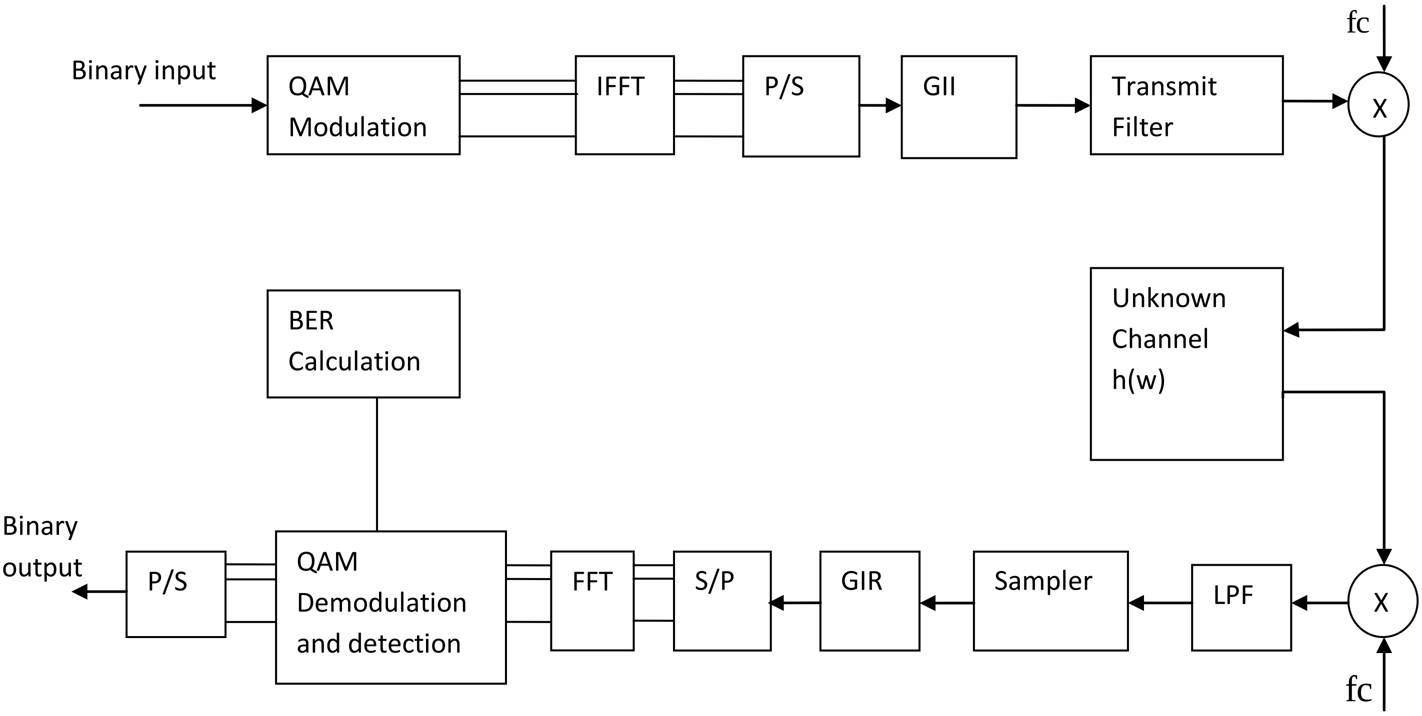


Figure4.2: Modulation & Demodulation in OFDM Systems

4.2 Limitation of LTE

3GPP requirements for LTE(Long Term Evolution)-Advanced demands data throughput in the downlink at 1 Gaps (for low mobility) and 100 Mbps (for high mobility). Even with the high spectral efficient transmission techniques it is not possible to provide the required data throughput rates within the maximum within 20 MHz channel. One of the possible solutions here is to increase the overall bandwidth in order to obtain the higher data rates. Upper limit set by ITU Requirements for IMT- Advanced is 100 MHz but in current scenario with available spectrum it is quite difficult to get contiguous 100MHz bandwidth spectrum. This leads to the idea of increasing the overall bandwidth by utilizing the spectrum available in different size of chunks

The three possible LTE-A CA scenarios are Intraband contiguous CA in which contiguous bandwidth wider than 20 MHz in the same band is used for CA but in current spectrum allocation scenarios this situation is least likely. Intra band Non-Contiguous CA where multiple CCs belonging to the same band are used in a non-contiguous manner, this could be a practical scenario where allocated spectrum could not be contiguous and where active sharing of networks is allowed. Inter band Non-Contiguous CA where multiple CCs belonging to different bands with this type of aggregation, mobility robustness can potentially be improved by exploiting different radio propagation characteristics of different bands. But to cover the different bands in the same UE makes the RF front end design challenging. Carrier Aggregation (CA) is used in LTE-Advanced to increase the overall bandwidth.[10]

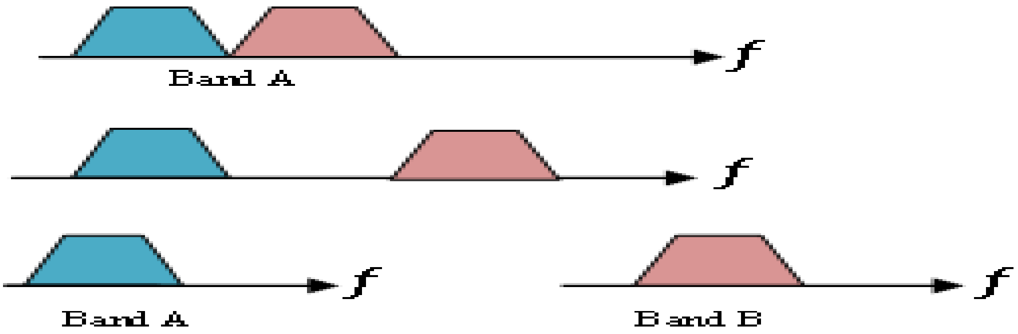


Figure4.3: Carrier Aggregation Types: a) Intraband Contiguous; b) Intraband Non-Contiguous; c) Interband Non-Contiguous. [1]

4.3 Objective: Algorithm to Reduce PAPR

The main objective of this thesis is to achieve higher data rate as specified in LTE-Advanced, support of wider Bandwidths are required than the existing 20 MHz system bands. The primary concern in carrier aggregation is the significant increase in PAPR of the time domain signal, to accommodate large peaks PA has to operate with sufficient power back-off which results in lower operating efficiency. We propose two stages of Noise Shaping process for reducing the PAPR of the carrier aggregated composite signal which is a transmitter- side processing technique and does not require any information at the receiver. This paper analyzes different PAPR scenarios using contiguous & non-contiguous frequency bands for carrier aggregation and the simulation result shows the performance improvement in PAPR

Noise shaping process where in the first stage the baseband OFDM Signal will be clipped to some optimal threshold (*T1*) and spectrally confined to the input high PAPR signal. The next stage Noise shaping process will further reduce the overall carrier aggregated Pass band composite signal to desired threshold (*T2*) PAPR level. Two stage approach results in better ACPR performance and minimal in band distortion compared to single stage where the High PAPR input signal will be clipped with higher threshold (C) to achieve desired level which results in poor out of band spectral constraints and even degrades the BER performance. CA technique deployed in LTE-A system will extend system bandwidth up to 100 MHz which also increases the downlink spectral efficiency. N-x-OFDMA shall be used as the downlink transmission scheme in LTE-A.

$$C > T2 > T1 \tag{4.1}$$

Our simulation result shows that the two stage noise shaping approach drastically reduces the PAPR in non-contiguous CA bands compared to single stage Noise Shaping approach.

The aim of the technique is to apply a (Noise filtered) pulse of magnitude equal to the difference between the desired magnitude and the actual incoming signal magnitude rotated by 180 degrees in phase. The Noise Shaping Process is a type of clipping techniques that find its way into practical implementation due to their higher efficiency and better spectral characteristics. Peaks in the input signals are cancelled with Noise shaped pulses to produce a reduced PAPR signal which involves the following steps:

1. The first step in the algorithm is to clip the magnitude of the incoming OFDM signal. The clipped signal is subtracted from the original signal to create the clipping noise.

2. The spectrum of the clipping noise is then confined in the same frequency band of the incoming signal by the noise shaping filter.

3. Finally, the spectrally shaped clipping noise is subtracted from a delayed version of the original signal to create a signal with reduced PAPR and constrained adjacent channel leakage ratio (ACLR).

4. The above steps can be repeated to further reduce any increase in PAPR introduced by Noise shaping process. [1]

4.4 Transmission Process

Let $X_k = 0,1.....N-1$ be the input block of frequency domain modulated symbols where N is the no of Symbols in each Component Carrier (CC). Hence, it is desirable to show the CFR performance on the over-sampled discrete time signals, typically an oversampling rate factor of $L \geq 4$ will be used so that the PAR before D/A conversion accurately describes the one after D/A. When the clipping is performed with the Nyquist sampling rate in the discrete time domain it may affect the high frequency components in the in-band and the clipping noise directly sits in the desired in-band which may degrade the BER performance. Oversampling is also necessary to examine the out-band distortions introduced by the noise shaping algorithm.

The oversampled discrete-time domain OFDM symbols can be calculated as follows $x_n^{(L)}$

$$x_n^{(L)} = \frac{1}{\sqrt{LN}} \sum_{k=0}^{LN-1} X_k^{(L)} e^{j\frac{2\pi kn}{LN}} \quad , 0 \leq \text{n} \leq \text{LN-1}. \tag{4.2}$$

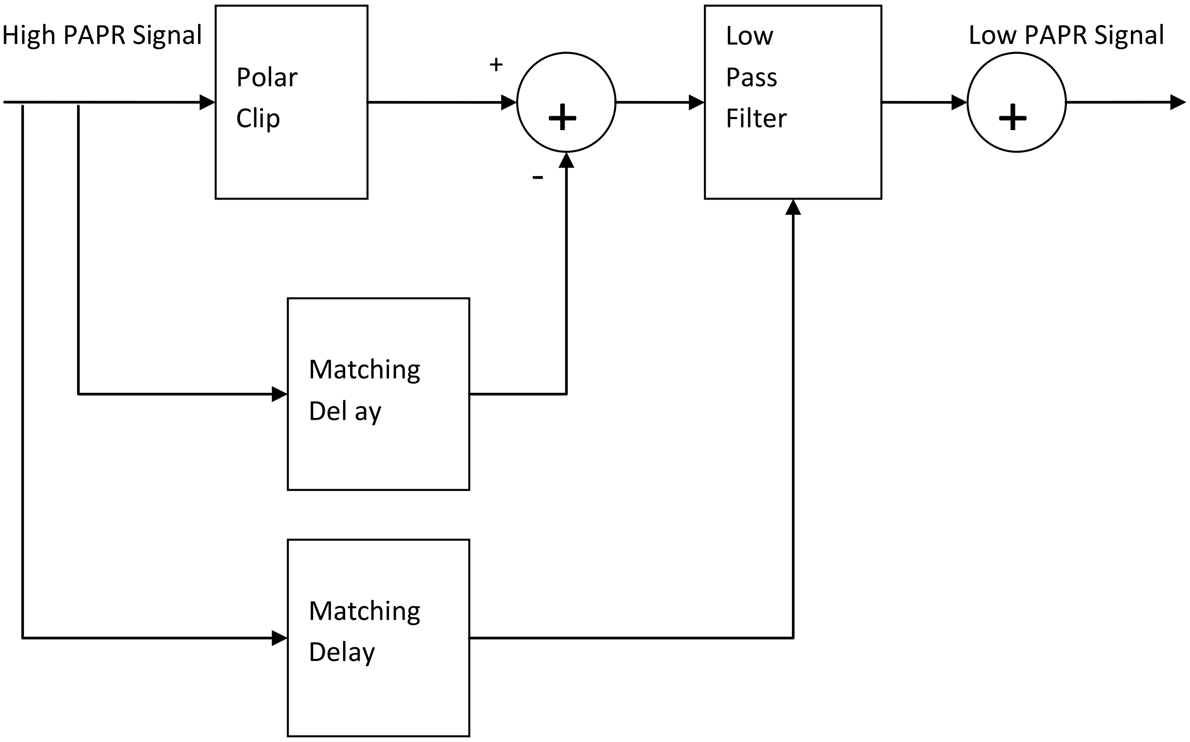


Figure4.4: First Stage Noise Shaping Process

The Block diagram of the First stage Noise shaping process is shown in figure 4.4. To clip the peak we can use either Cartesian or polar clipping can be used, with Cartesian clipping the In-phase and quadrature components are clipped independently and with polar clipping, the magnitude of the signal is clipped while preserving the phase. While either method can be used to limit the PAPR of the signal, it has been shown that the polar clipping provides better results in terms of overall signal distortion (i.e. lower EVM and ACLR performance).

By selecting an appropriate threshold Amax, the PAPR of the signal can be maintained at a desired level. Polar clipping of the time domain discrete data $x_n^{(L)}$ with clipping threshold Amax results in the following equation

$$\bar{x}_n^{(L)} = \begin{cases} x_n^{(L)} & \left|x_n^{(L)}\right| \le A_{\max} \\ A_{\max} e^{j\angle x_n^{(L)}} & \left|x_n^{(L)}\right| > A_{\max} \end{cases} \tag{4.3}$$

Now the polar clipped signal is subtracted from the delayed version of the incoming OFDM symbols to generate the clipping noise.

$$E_n = \bar{x}_n^{(L)} - x_n^{(L)}, 0 \le n \le LN - 1. \tag{4.4}$$

Spectrum shaping Low pass filter structure is adopted by Raised-cosine function with roll-factor β = 0.22. The spectrum of the clipping noise is then constrained by the Noise shaping filter to lie within the same frequency band as the input signal, in other words the noise shaping low pass filter has the characteristics similar to that of a single carrier before it has been unconverted.

Finally the spectrally shaped clipping noise is subtracted from the delayed version of the incoming OFDM signal to create a signal with lower PAPR.

$$y_n = x_n - h \otimes (E_n), 0 \le n \le \mathrm{LN} - 1. \tag{4.5}$$

Now the individual component carriers are frequency shifted to the band of interest in the given spectrum. The time domain data of each Component Carrier can be described as y (i, j), where i is the i th Component carrier and j is the sub-frame. Since, the technique doesn't involves any hard clipping on the OFDM signal there will be minimal impact on the in-band and out-band performance.

The PAPR of the aggregated carriers may increase even after clipping individual component carriers using Noise Shaping Technique since few subcarriers of component carriers' s may add up constructively in time domain after Carrier aggregation. The effect could be alarming if the component carriers are Contiguous. Hence further iterations of Noise shaping technique are required to achieve the desired PAPR. In the second iteration clipping is performed on sufficiently oversampled (R ≥ 4) pass band carrier aggregated OFDM signals. Oversampling results in lower in-band distortion upon clipping the pass band signal because the clipping noise will transit into out-band which could be further filtered out.

Clipping noise is further spectrally shaped using noise shaping filter. To support multiple CC's, filtering has to be done for multiple frequency components in the spectrum. Clipping noise is generated exactly in the same way as in the first Noise shaping process by subtracting the polar clipped signal from the delayed version of the Composite pass band signal. Clipping noise is further spectrally shaped using noise shaping filter. Furthermore, the number of taps required to implement such filter is often quite high. Hence As illustrated in the Fig. 4. firstly the pass band clipping noise will be down converted to baseband ,perform low pass filtering and then up convert the filtered noise back to its carrier frequency. This approach provides more flexible multi-band filtering capability that supports dynamically changing carrier configurations. To support multiple CC's, filtering has to be done for multiple frequency components in the spectrum. In general, the spectrum of the complex composite signal might be asymmetrical and using a single multiband filter would require complex coefficients.
After frequency translation the individual k component carriers are summed to form composite pass band clipping noise. [12]

$$z(n) = \sum_{k=0}^{4} z_k(n) \qquad (4.6)$$

After noise shaping algorithm, again the spectrally confined clipping noise is subtracted from an appropriately delayed version of the CFR input signal which results in desired PAPR.
This paper does the simulations of different scenarios using contiguous & non-contiguous frequency bands for carrier aggregation. PAPR performance with and without Noise shaping technique is evaluated using the following equation.

$$papr = \frac{Max\left\{|x(t)|^2\right\}}{E\left\{|x(t)|^2\right\}} \qquad (4.7)$$

In contiguous bands scenario the first shaping process reduces the PAPR of the individual component carriers to some optimized threshold but the effect will be minimal since after carrier aggregation some of the subcarriers of different CC's may add up constructively resulting in little improvement in PAPR. [13]

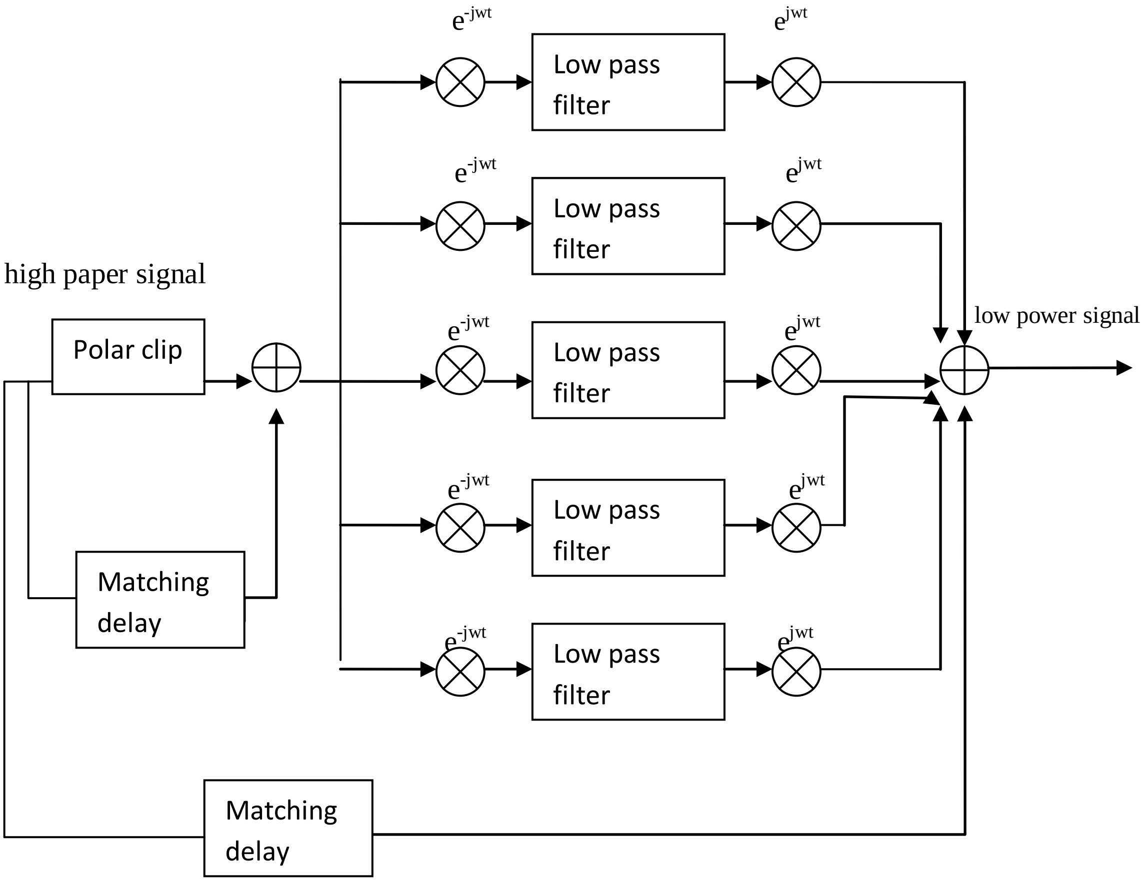


Figure4.5: Second Noise Shaping Stage

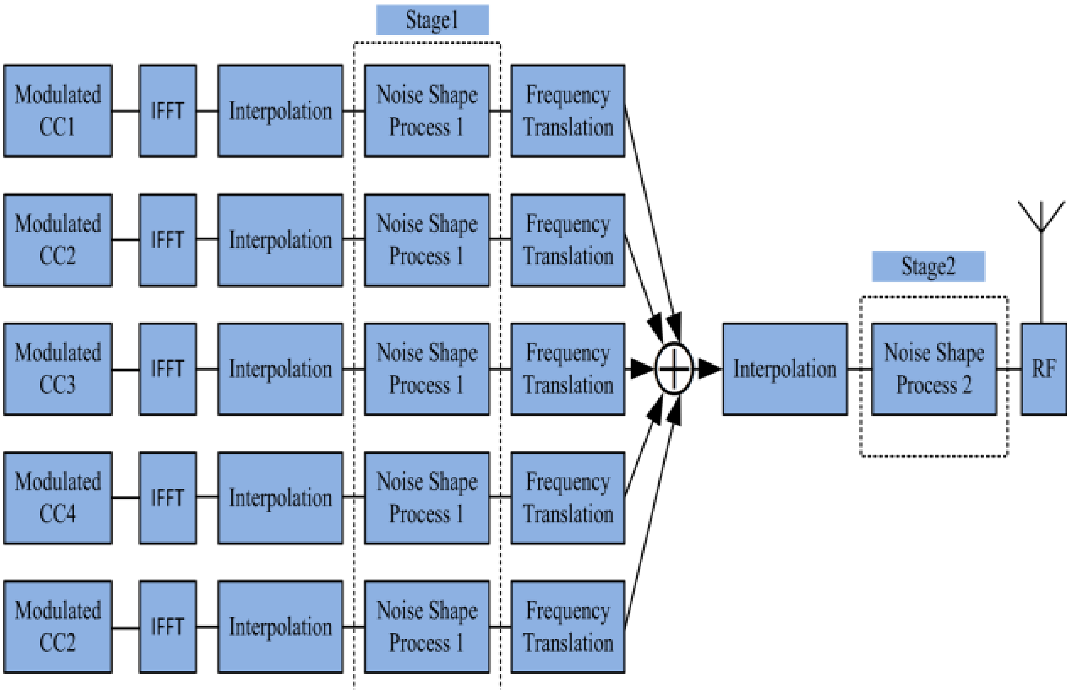
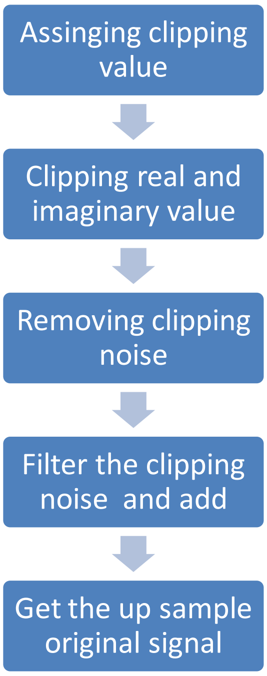


Figure4.6: Noise Shaping Process

4.5 Flow chart

First stage

Second stage



CHAPTER5

RESULTS and DISCUSSION

5.1 Simulation Results

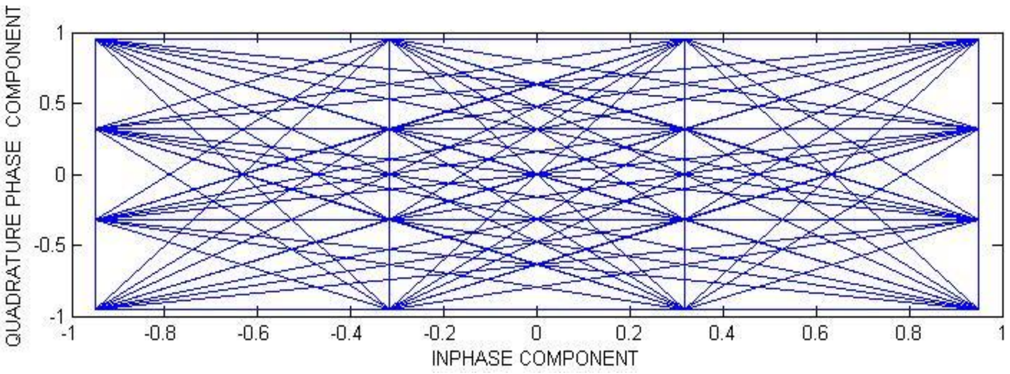


Figure5.1 : Input Data using QAM

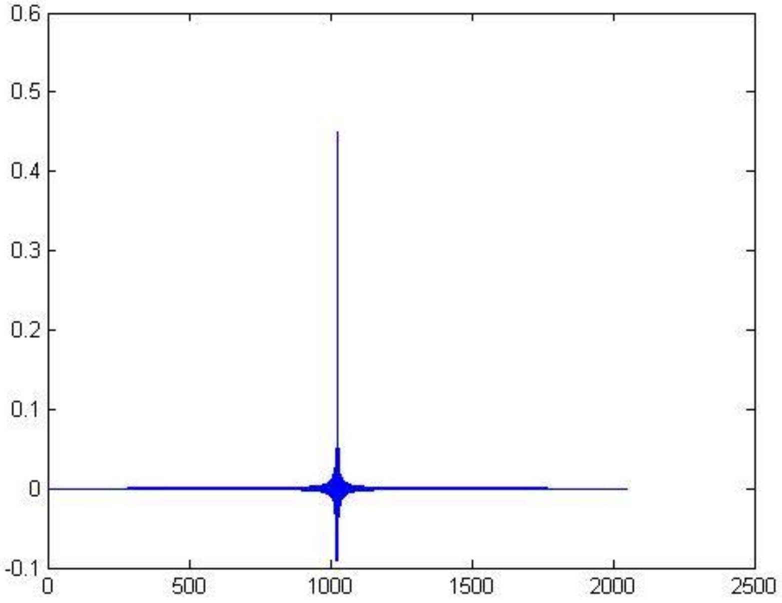


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Figure5.2 : Lowpass Filter Coefficients

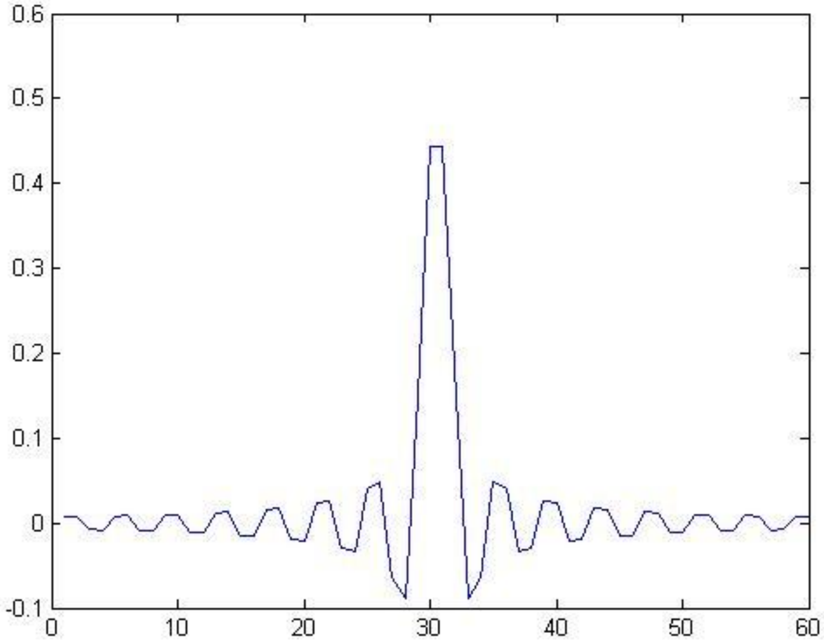

Figure5.3: LPF Window

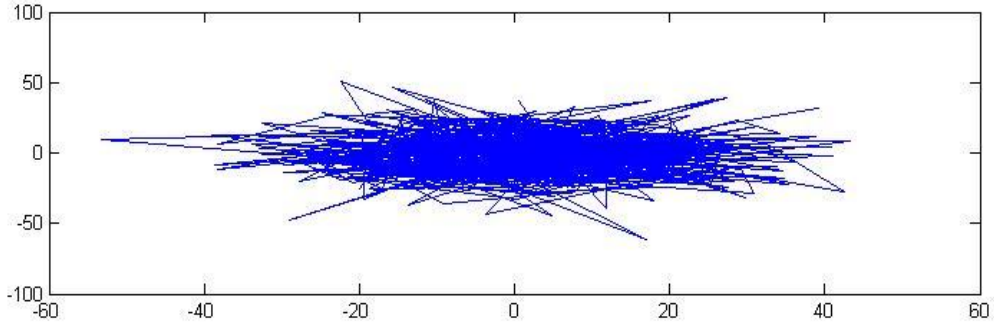

Figure5.4: IFFT Output After Modulation

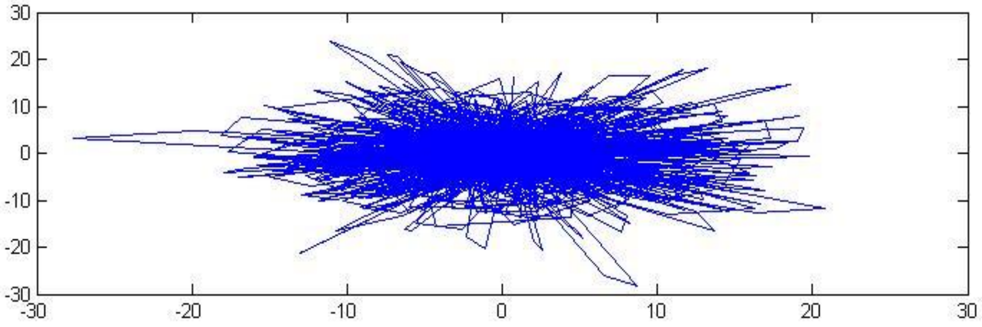

Figure5.5: Interpolation Output

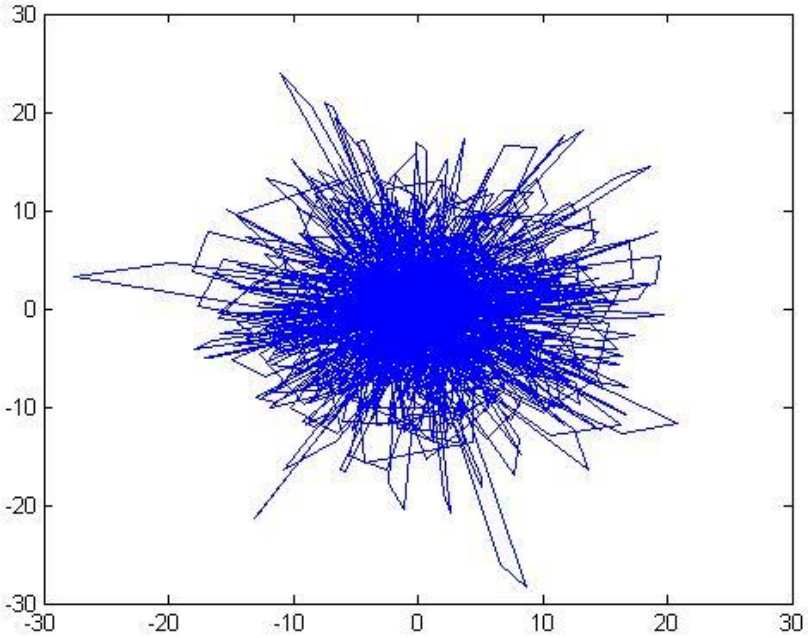

Figure5.6: Interpolation After Iterations and Compared

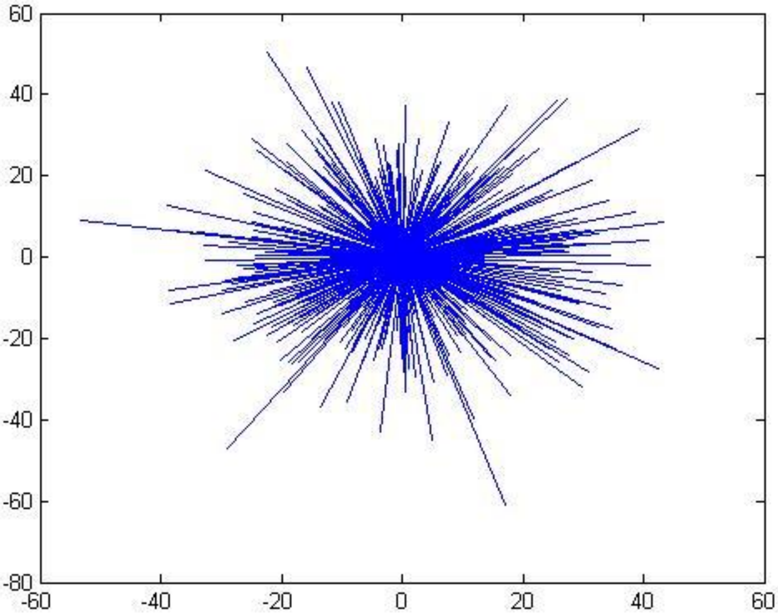

Figure5.7: Upsampling Factor Inband Outband Correction

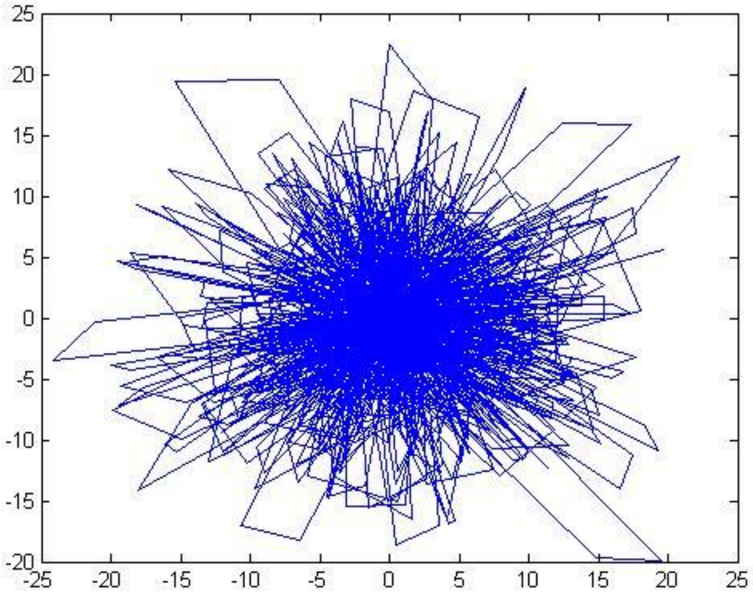

Figure5.8.1: Interpolation

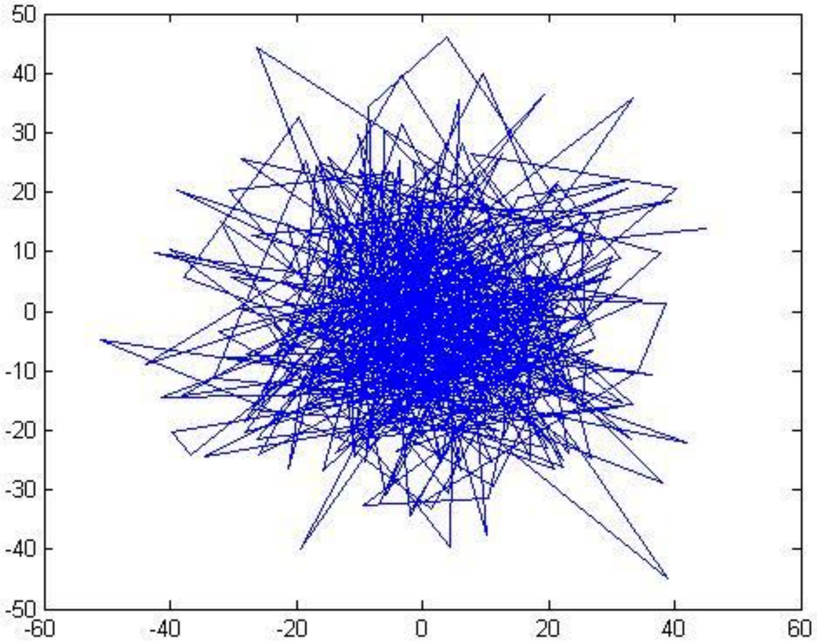

Figure5.8.2: IFFT output after modulation

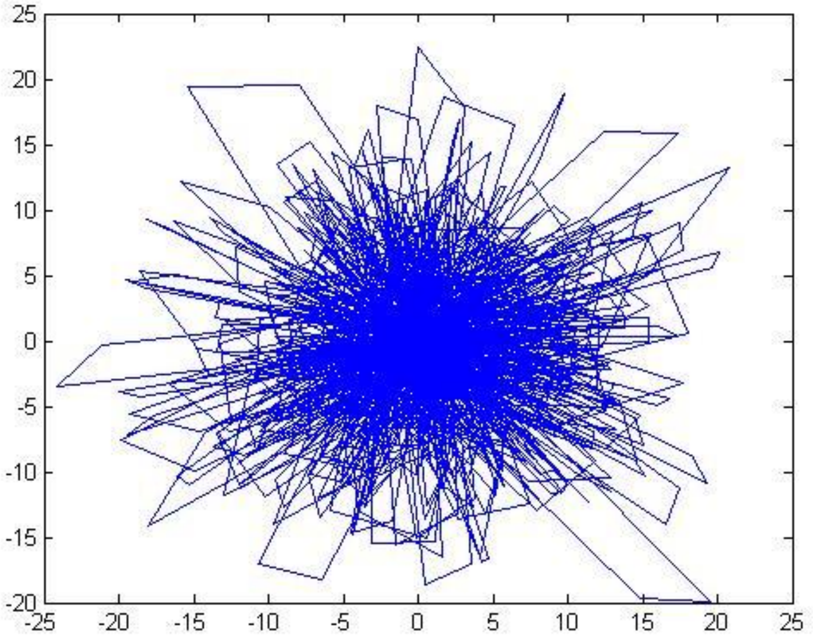

Figure5.9: Interpolation After Iterations and Compared

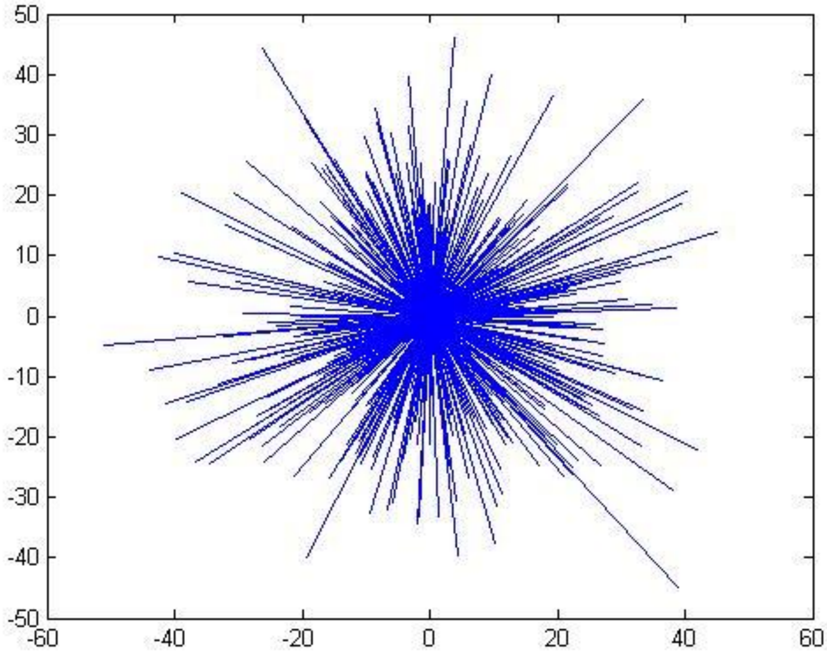

Figure5.10 : Upsampling Factor Inband Outband Correction

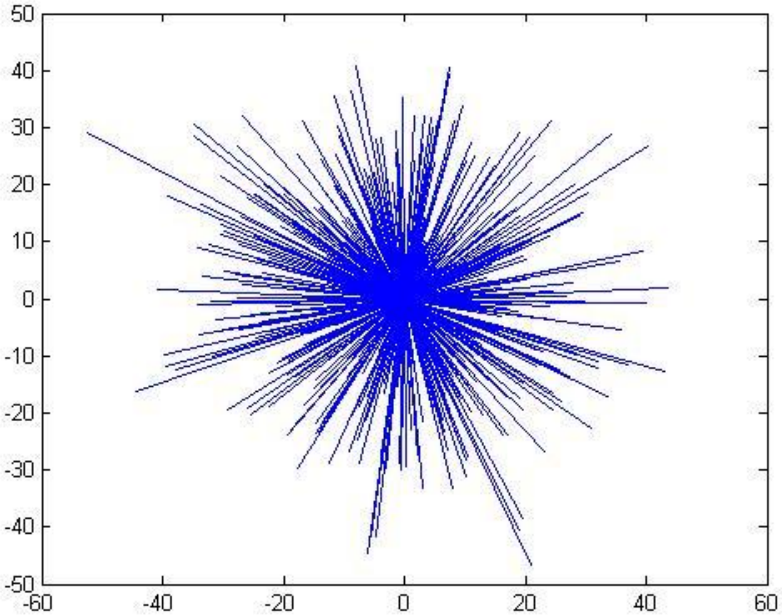

Figure5.11: Upsampling Factor Inband Outband

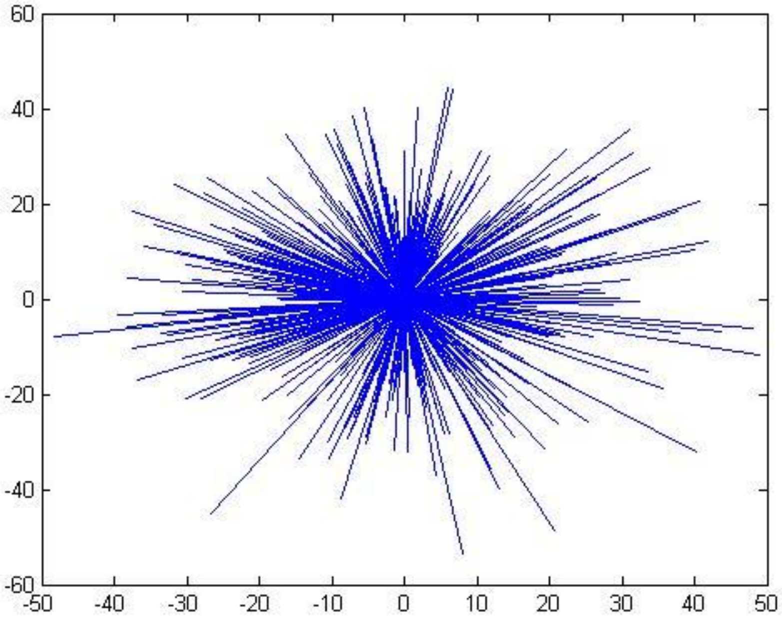

Figure5.12: Upsampling Factor Inband Outband

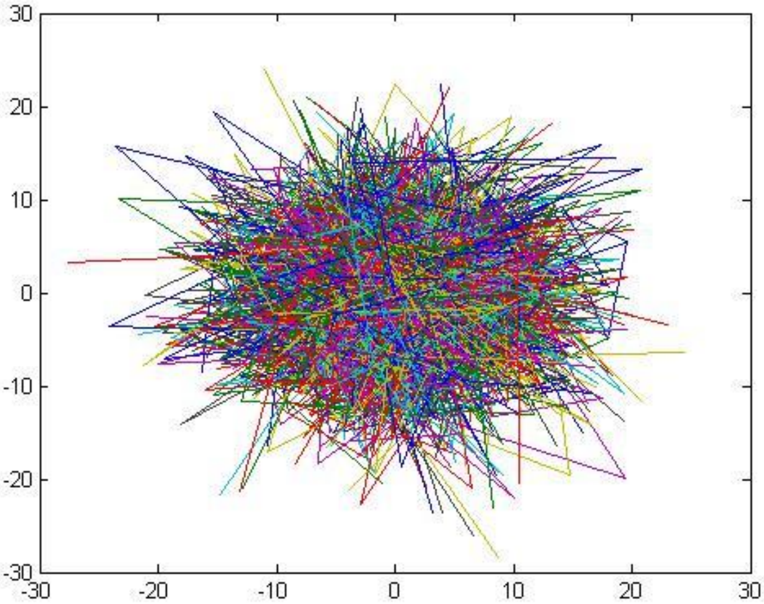

Figure5.13: Cascade Output Interpolation Signal

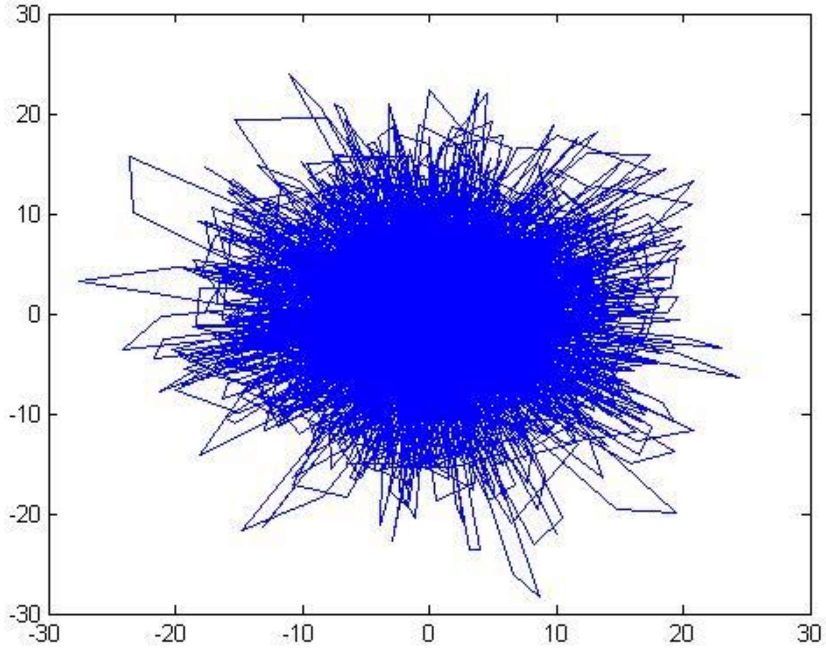

Figure5.14: Resultant signal for noise shaping

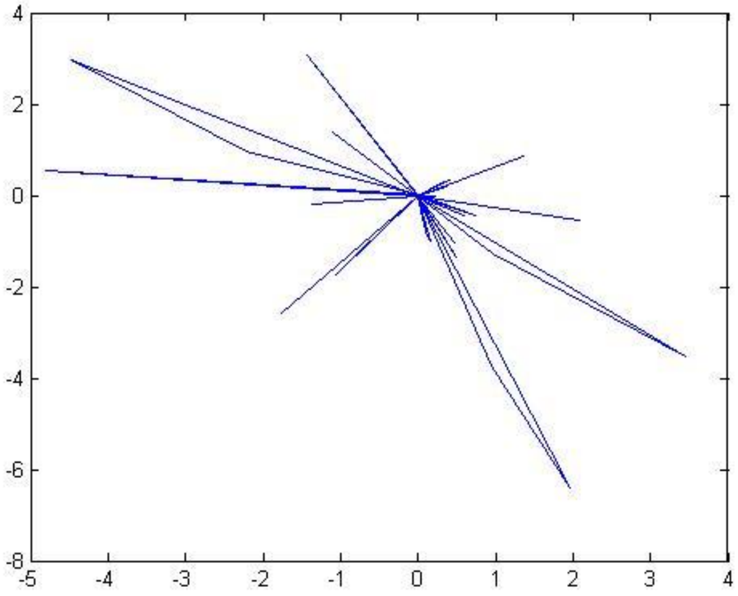

Figure5.15: Clipping Noise for Resultant Signal

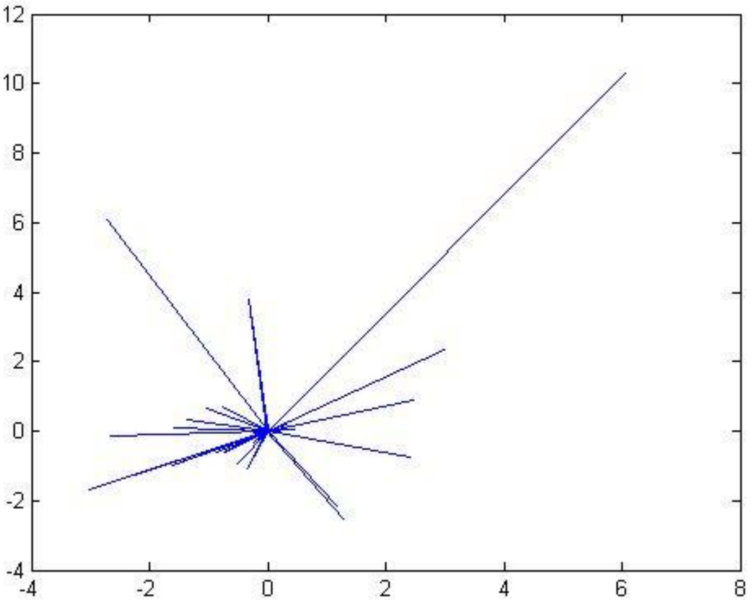

Figure5.16: Clipping Noise from OFDM Signal

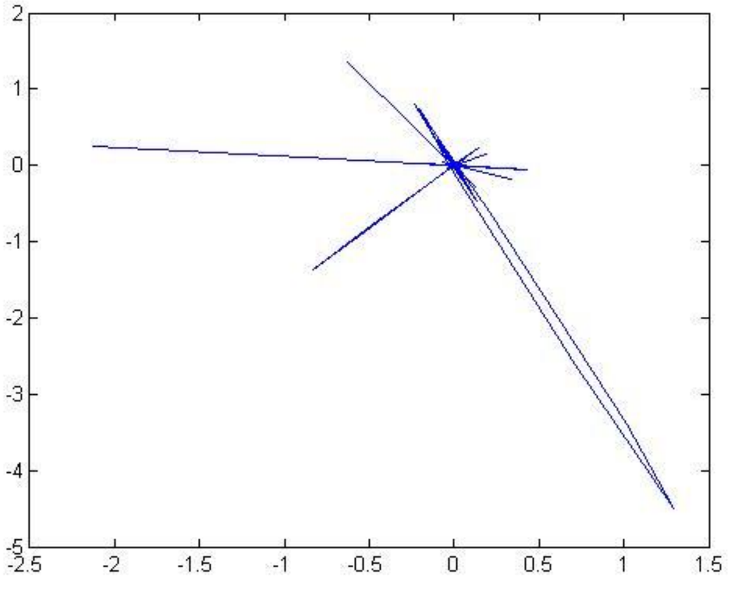

Figure5.17: Noise Filter Output of First Stage

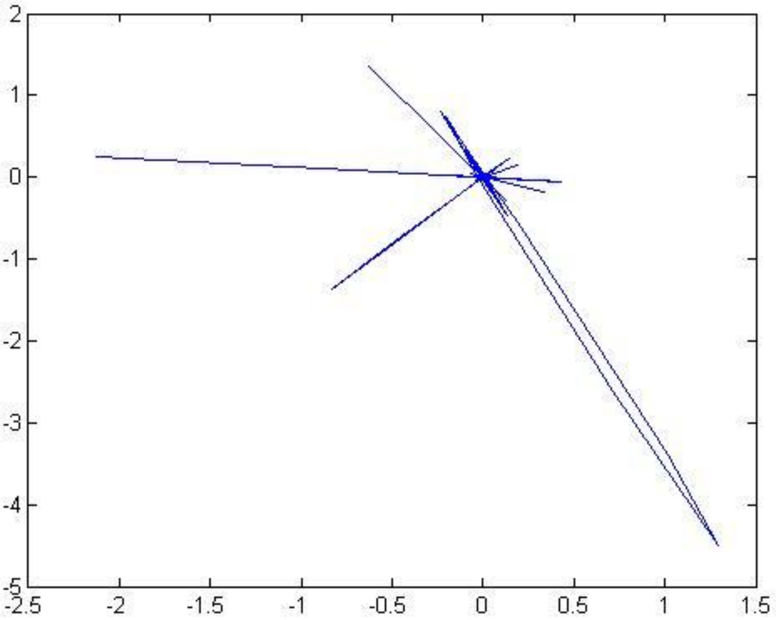

Figure5.18: Individual Noise Filter

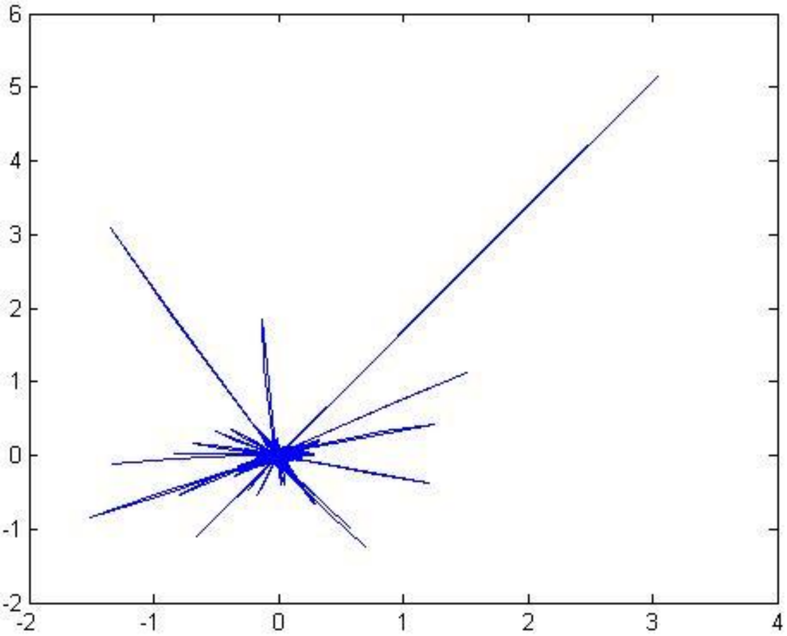

Figure5.19: 2 Individual Noise Filter

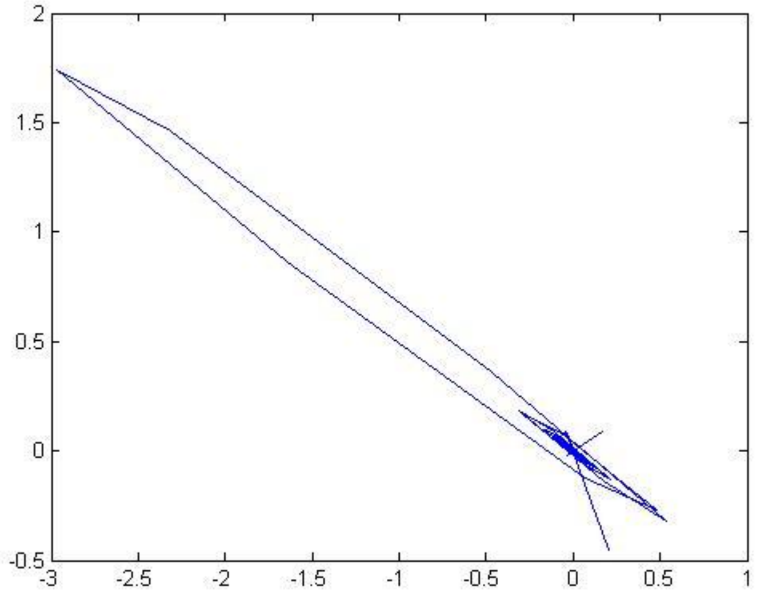

Figure5.20: Individual Noise Filter

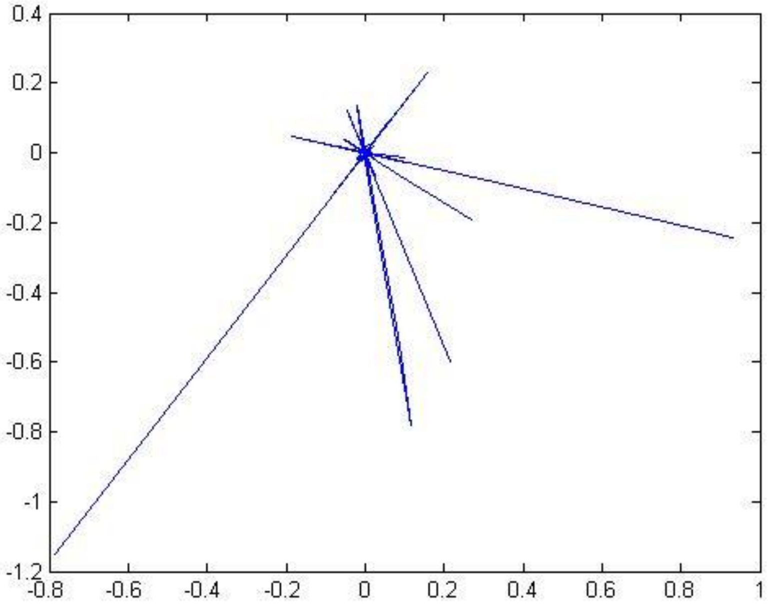

Figure5.21: Individual Noise Filter

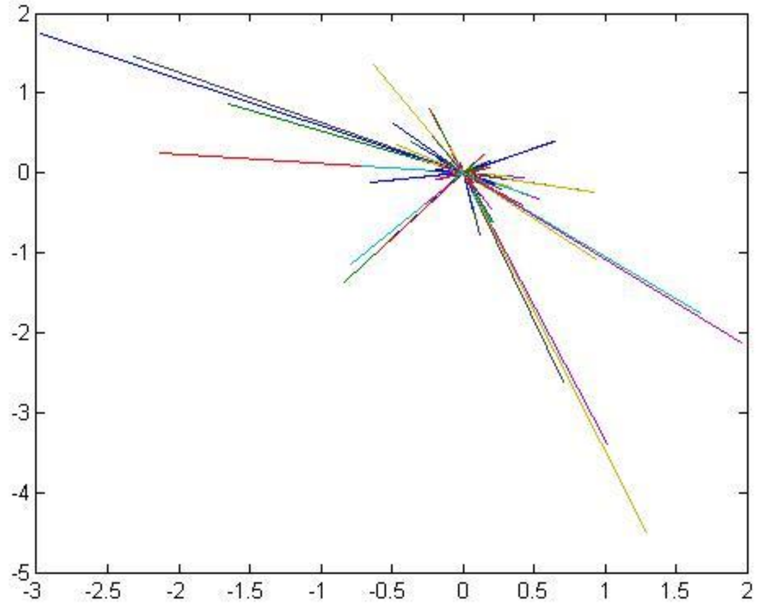

Figure5.22: Output of Noise Filter

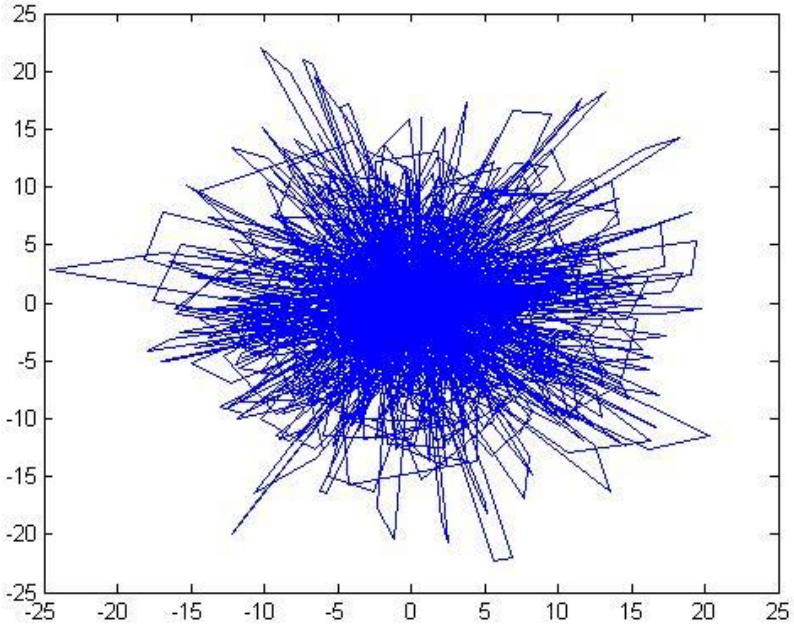

Figure5.23: Second Stage Noise Shaping for R=1

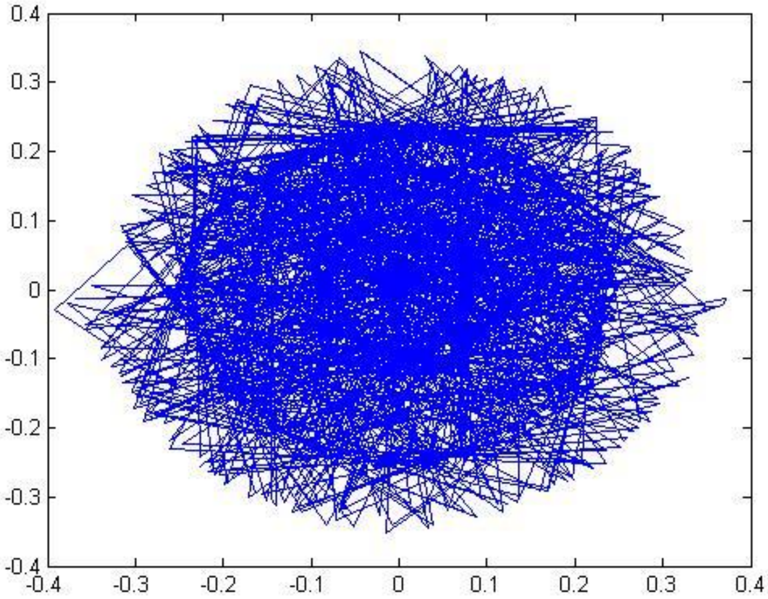

Figure5.24: Final Clipped Output for R=1 for Second Stage Noise Shaping

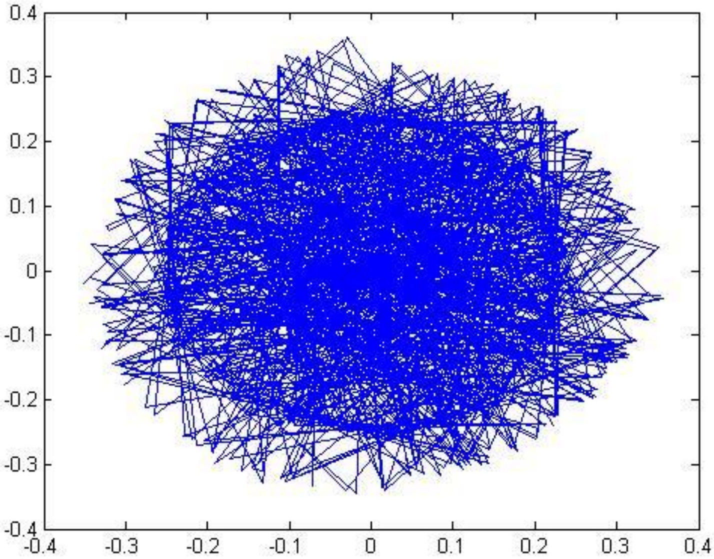

Figure5.25: Final Clipped Output for R=2 for Second Stage Noise Shaping

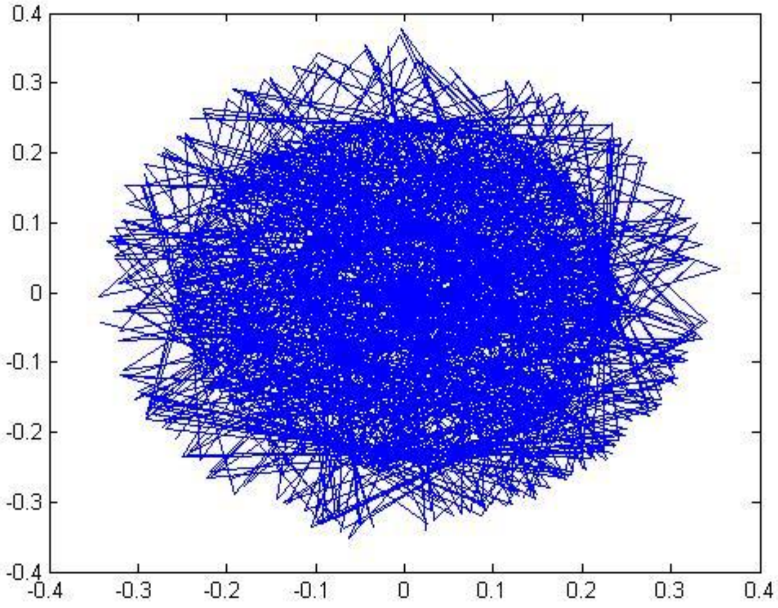

Figure5.26: Final Clipped Output for R=3 for Second Stage Noise Shaping

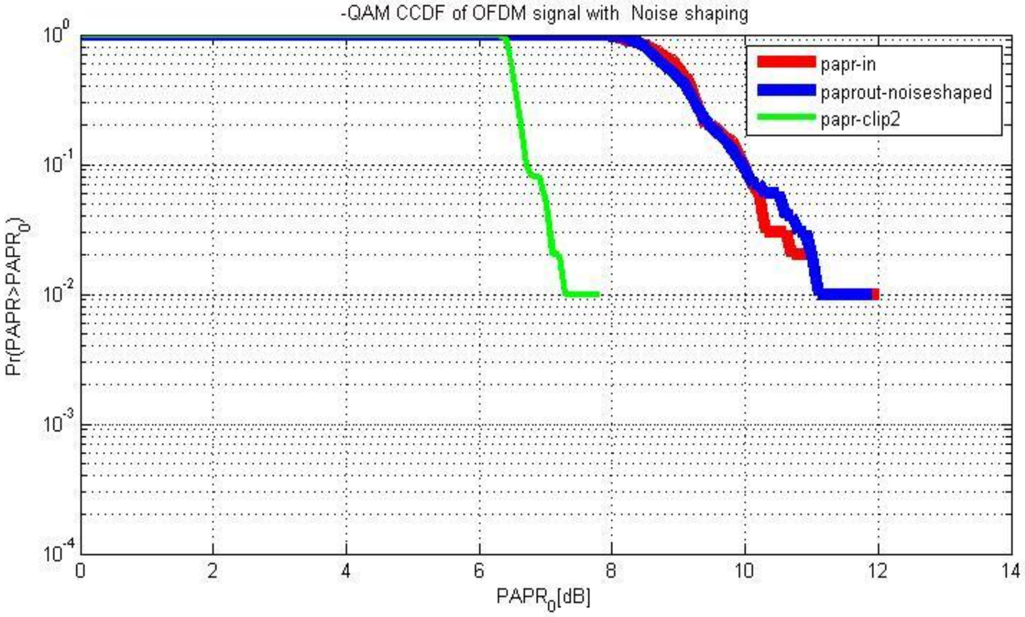

Figure5.27: Final Output of PAPR

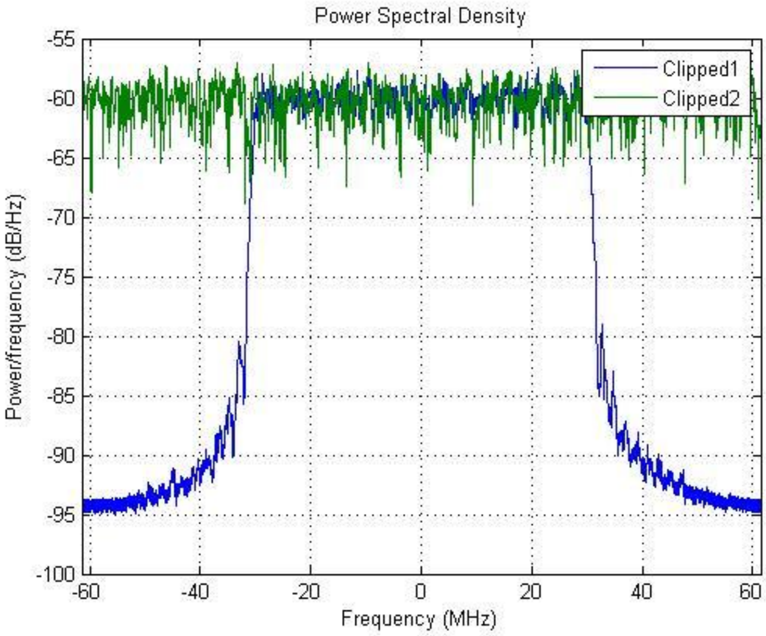

Figure5.28: PSD

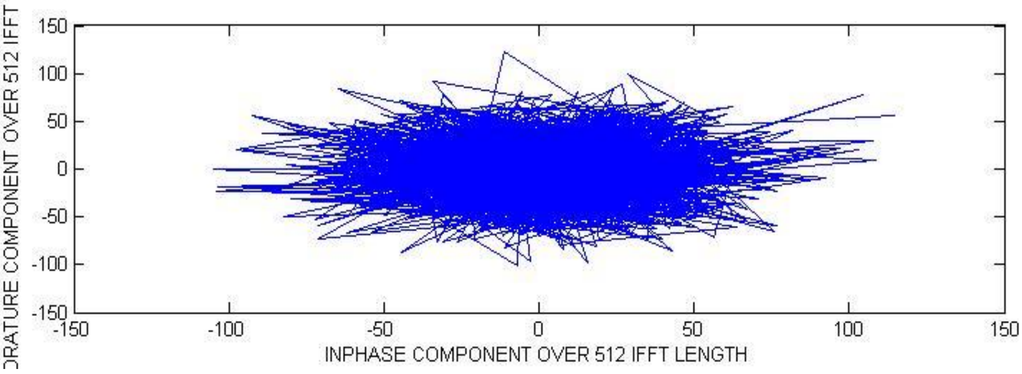

Figure5.29: IFFT Output to QAM Signal

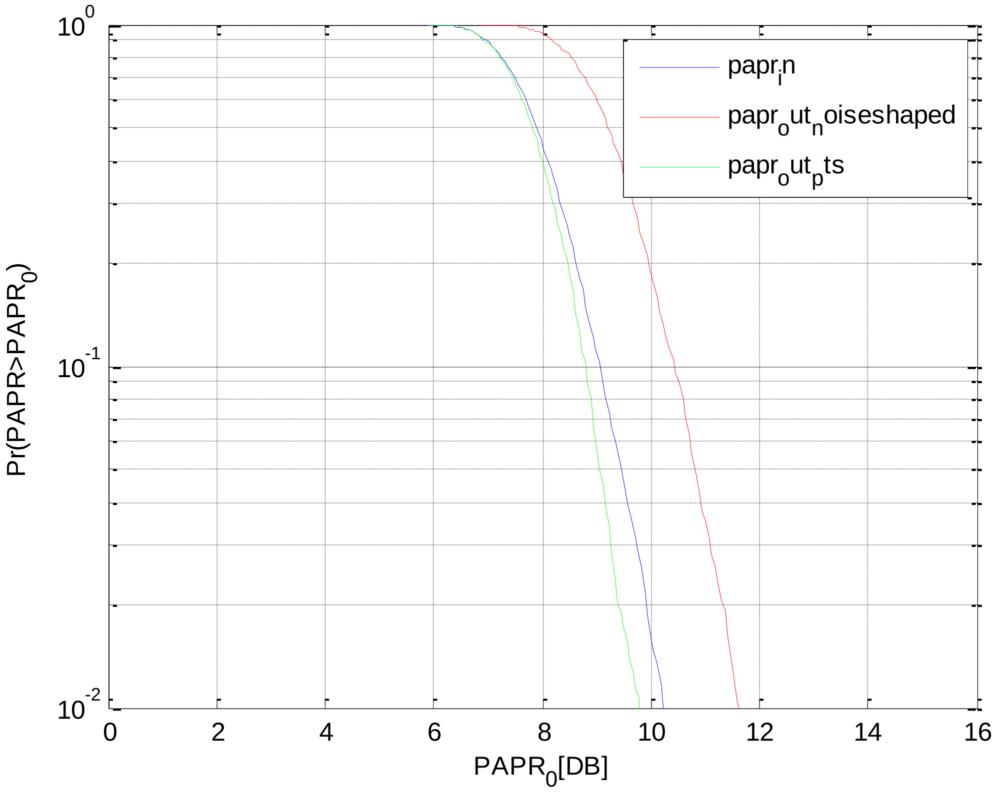

Figure5.30: Final Output of PAPR

5.2 Discussion

The simulation results here show the analysis performance of PAPR with the help of noise shaping technique. Simulations have been done in order to reduce the PAPR of OFDM system. The above simulation result shows the improvement in PAPR of the system with the use two stage noise shaping technique. Above figure shows the relation between noise, input and output of the system. Desired output is obtained with noise shaping algorithm.

CHAPTER 6

FUTURE SCOPE AND CONCLUSION

6.1 Conclusion

Analysis and reduction of PAPR is a challenging task. Simulation result shows the reduction in PAPR value and thus we get the desired output. In this thesis, we have proposed a two stage Noise shaping process ,a crest factor reduction method has been designed to reduce the PAPR while satisfying EVM and ACLR /spectral mask constraints. In contiguous bands scenario the first Noise shaping process reduces the PAPR of the individual component carriers to some optimized threshold but the effect will be minimal since after carrier aggregation some of the subcarriers of different CC's may add up constructively resulting in little improvement in PAPR .Hence the second Noise shaping process is utilized to further reduce the PAPR to desired level. In case of non-contiguous bands scenario, since the Component carriers are far apart, the first noise shaping process itself results in higher PAPR improvement even after carrier aggregation since the impact of component carriers adding up constructively in time domain will be minimal. The improvement in PAPR with the use of two stages of Noise shaping process will be better in case of Non-contiguous scenario compared to the contiguous.

6.2 Future Scope

Reduction in PAPR value has gained much attention as a field of research in the field of wireless communication. This is due to the reason that the significant increase in PAPR of the time domain signal due to CA, to accommodate large peaks PA has to operate with sufficient power back-off which results in lower operating efficiency. Therefore, efficient and optimized techniques are required for reduction of PAPR. In this dissertation improved technique for reduction of noise has been investigated which is efficient in terms of improving the PAPR performance of the system. But there is always demand to increase system performance so reduction of noise in wireless systems. For future research work, other algorithm can be investigated There are also other improved versions of these algorithms so they can also be used in conjunction.

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