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A comparison of Different Peak to Average Power Ratio Reduction Techniques in Long Term Evaluation Downlink

مقارنة بين التقنيات المختلفة لتقليل نسبة القمة لمتوسط القدرة في نظام
التطوير طويل الأمد للوصلة الهابطة

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Electronic Engineering (Communication)**

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الآية

قال تعالى :

(أَمَّنْ هُوَ قَانِتٌ آنَاءَ اللَّيْلِ سَاجِدًا وَقَائِمًا يَحْذَرُ الْآخِرَةَ وَيَرْجُو رَحْمَةً رَبِّهِ ۚ قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ ۚ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَابِ)

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Abstract

The main drawback of Orthogonal Frequency Division Multiplexing (OFDM) systems is the high peak-to-average power ratio (PAPR), which leads to a significant reduction in power efficiency. In this research discusses different PAPR Reduction techniques in OFDM. Techniques like clipping, Selective Mapping (SLM), Partial Transmit Sequence (PTS) based different modulation and different channel. Clipping technique is simple, SLM reduction technique; generation of phase sequence is very random and has to be sent to receiver before the actual communication. Selection of proper phase sequence to achieve good PAPR reduction is very important; the PTS technique is that an input symbol is partitioned into number of disjoint symbol. Through the Analysis, it is shown that Clipping on AWGN channel and QPSK modulation is better than other techniques.

المستخلص :

العيب الرئيسي لـأنظمة التردد المتعامد بالتقسيم هو ارتفاع نسبة القدرة العالية للمتوسطة مما يؤدي لانخفاض كبير في كفاءة النظام. في هذا البحث نناقش مختلف تقنيات تقليل نسبة القدرة العالية للمتوسطة في نظام التردد المتعامد بالتقسيم مثل القصاصات, رسم خرائط انتقائية والارسال التسلسلي الجزئي بناء لتضمين مختلف وقنوات مختلفة . تقنية القصاصات بسيطة , تقنية رسم الخرائط الانتقائية تولد اطوار متتابعة بصوري عشوائية وترسل للمستقبل قبل الاتصالات الفعلية . الاختيار المناسب للطور المتتابع مهم جدا ليحقق تقليل جيد لنسبة القدرة العالية للمتوسطة , تقنية الارسال التسلسلي الجزئي يقسم الرمز المدخل لعدد منفصل من الرموز . خلال التحليل موضح ان القصاصات حسب قناة مضاف اليها تداخل موجات قاوس البيضاء و تضمين اراحة القفل للطور التربيعي افضل من غيرها من التقنيات .

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Abbreviations

3GPP	Third Generation Partnership Project
LTE	Long Term Evolution
4G	Fourth generation
OFDMA	Orthogonal Frequency Division Multiple Access
SC-FDMA	Single Carrier Frequency Division Multiple Access
PAPR	peak to- average power ratio
BS	base station
MS	Mobile station
BER	Bit Error Rate
OFDM	Orthogonal Frequency Division Multiplexing
SLM	Selective Mapping
TR	Tone Reservation
TI	Tone Injection
PTS	Partial Transmit Sequence
HPA	High Power Amplifier
DAC	Digital-to-Analog converter
CCDF	Complementary cumulative distribution function
DL	Downlink
UL	Uplink
TTI	transmission time interval
FDD	Frequency division duplex

TDD	Time division duplex
QOS	quality of service
CP	cyclic prefix
ISI	inter symbol interference
MIMO	Multiple Input Multiple Output
FDM	Frequency Division Multiplexing
DFT	Discrete Fourier Transform
SOBC	Simple Odd Parity Code
CC	Cyclic Coding
SBC	Simple Block Code
CBC	Complement Block Coding
MCBC	Modified Complement Block Coding
SI	Side information
IBI	inter-block interference
ACE	Active Constellation Extension
AWGN	Additive white Gaussian noise

Chapter One

1.1 Introduction

The Third Generation Partnership Project (3GPP) group developed the Long Term Evolution (LTE) standards for the fourth generation (4G) wireless communication systems. Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Access (SC-FDMA) are the two multiple access techniques which are generally used in LTE. The objective of this study is to make the multiple access techniques adaptive according to the parameter peak to-average power ratio (PAPR) in LTE to save power at base station (BS) as well as at mobile station (MS). PAPR is uses some parameter to change the modulation order used for symbol mapping in LTE systems. Algorithms to determine modulation order on the basis of PAPR. A comparison between proposed method and Clipping and Filtering method for reduction of PAPR is also presented. Simulations result shows that the proposed algorithms can reduce the PAPR values without affecting Bit Error Rate (BER) for multicarrier as well as single-carrier modulation systems [1].

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising techniques for today's wireless broadband communication systems. 3GPP's LTE was the first to adopt OFDM as its downlink technique. One of the major disadvantages is its high peak-to-average power ratio (PAPR). Various PAPR Reduction Techniques are discussed along with their advantages, disadvantages and improvements done so far. Techniques like clipping, Companding, Selective Mapping (SLM), Interleaving, Tone Reservation (TR), Tone Injection (TI), Partial Transmit Sequence (PTS), etc [1].

Due to various advantages like robustness to multipath fading, high spectral efficiency, immunity to impulse interferences, flexibility and easy equalization over single carriers communication systems, OFDM is currently being deployed in many high speed data communication systems described in [1] after LTE [2].

1.1.1 PAPR Reduction Techniques

1.1.1.1 Clipping and windowing

The clipping method is the simplest way to reduce PAPR. However, it distorts signals nonlinearly and significantly increases the out-of-band radiation. A different approach is to multiply large signal peaks with a certain window function. In order to maintain the out-of-band radiation within a certain level, it is benefit to increase the window length. On the other hand, the window should not be too long, because a long widow length implies that many signal samples are affected, which degrades the BER performance [3].

1.1.1.2 Selective Mapping

Selective Mapping (SLM) is a distortion less technique that can reduce PAPR efficiently without increase in power requirement and incurring data rate loss. The simulation result shows that proposed SLM technique has better PAPR reduction performance [3].

1.1.1.3 Partial transmit

In the PTS technique, an input data block of N symbols is partitioned into disjoint sub blocks and then the signal is transmitted. Another factor that may affect the PAPR reduction performance in PTS is the sub block partitioning, which is the method of division of the subcarriers into multiple disjoint sub blocks .There are three kinds of Sub block partitioning schemes :adjacent, Interleaved and pseudo-random partitioning. The PTS

technique works with an arbitrary number of subcarriers and any modulation scheme. Advantage is that works with an arbitrary number of subcarriers any modulation scheme. But, this scheme includes complexity and side information like SLM [4] [5].

1.2 Problem definition

High Peak-to-Average Power Ratio (PAPR) causes distortion in the signal when it passes through High Power Amplifier (HPA) and Digital-to-Analog converter (DAC) which results in lower mean power level and as known PAPR cannot be increased just by increasing the signal power as many regulatory norms restrict the transmit powers.

1.3 Scope of the study

The scopes of the study in this project are:

- Conceptual Study

Understand the concept of LTE, OFDM, CCDF and PAPR.

- Development and Analysis

Develop PAPR techniques. Performance analysis of this project will consider Performance evaluation such as (CCDF).

- Simulation

The simulation tool used is Mat lab.

1.4 Objectives

The objective of this research to solve the problem of PAPR using one of the techniques includes Clipping, Selective Mapping, Partial Transmit Sequence and Active Constellation Extension. Many PAPR reduction techniques result in performance degradation in terms of CCDF as compared to original OFDM signal.

In this project a discussion of all the prominent PAPR reduction techniques will be described and a matlab simulation will be constructed to simulate the performance of three techniques that listed above.

1.5 Expected result

Reduce power consumption and improve system performance.

1.6 Methodology

A study and analysis of the LTE network structure then examine the mathematical model of the techniques then perform simulations using MATLAB to construct the system with the techniques; many parameters will be used to examine the performance of the system.

Three techniques were selected Clipping and windowing, Selective mapping and partial transmit the selected techniques will be evaluated in form of Signal to Noise Ratio and Bit Error Rate in a mobile network structure which is simulated by using Matlab.

The three techniques were selected because of the international high rating of each.

1.7 Thesis Outline

The thesis is consist five chapters, in chapter one an introduction along with problems and objectives are included, while in chapter two the methodology is included along with the literature review and the study of the PAPR Power Reduction Techniques, in chapter three the methodology represents the computer model and the mathematical model, in chapter four, the results and discussion included, in the last chapter the conclusion and recommendations along with the reference are included.

Chapter Two

Literature Review

This chapter represents a general description of the most important topics related to this work. Overview of LTE the first described including architecture, feature and technology. Is second described including Information of Radio Resource Management. Is third described including Related Work.

2.1 LTE Overview

LTE is the new standard recently specified by the 3GPP on the way towards fourth-generation mobile. The first Release LTE standard (Release 8) was deployed by the 3GPP, and it has already been finalized with release9 as its final version.

2.1.1 Feature of LTE

LTE use scalable bandwidth 1.25 MHz to currently 20 MHz , provide data rate up to 100Mbps in DL and 50 Mbps in UL, Spectral efficiency associated to data rate shown above : 5bit/sec/Hz in DL and 2.5 bit/sec/Hz in UL, Latency smaller than 5msec and Source e NB can use the x2 interface to forward DL Packet [6].

2.1.2 Technology of LTE

LTE based on SC-FDMA in uplink and OFDMA in downlink to support Internet service in high mobility and wide range of multimedia. OFDM which provide higher spectral efficiency and more robustness against multipath and fading OFDM divides the data over a number of subcarrier the spacing between two subcarrier is fixed at 15KHZ .in Figure 2.1 A resource blocks (small unit in time and frequency) is consisting of 12

subcarrier in frequency and 14 continuous symbols in Time. To make one resource blocks to span 180 kHz.

Each sub-frame consist of 6 or 7 OFDM symbol, this sub-frame is also minimum transmission time interval (TTI), this choice of short TTI helps to achieve the requirement of Low latency [7].

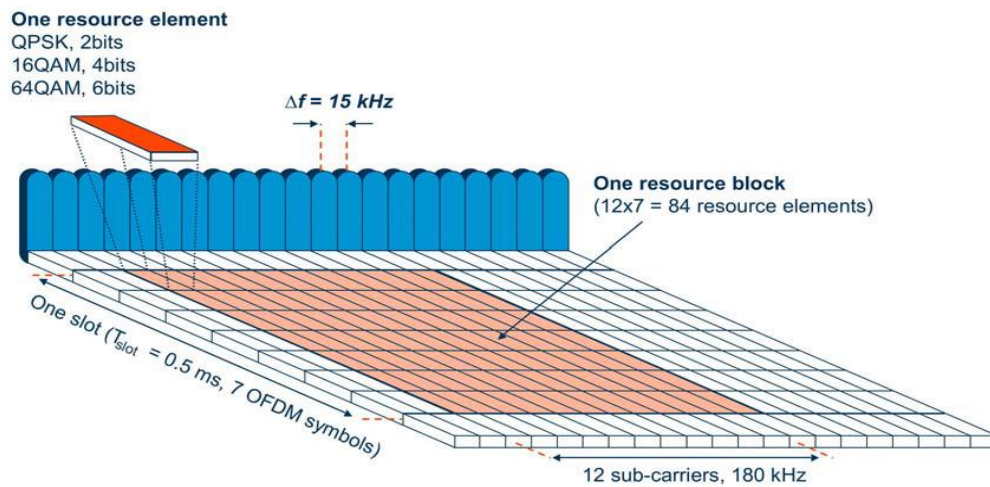


Figure 2.1 OFDM framing

- LTE system support in both FDD&TDD duplex methods.
- Adaptive modulation and coding using QPSK/16 QAM/64 QAM and HARQ in both UP&DL.
- 2 or 4 transmit antenna in DL.
- LTE to support QOS for real time packet data services like VoIP and video streaming [8].

2.2 Technologies involved

LTE employs different technologies such as OFDM, OFDMA, MIMO and SCFDMA. These methods are briefly described in the following subsections.

2.2.1 OFDM (Orthogonal Frequency Division Multiplexing)

OFDM is a digital multi-carrier modulation scheme that distributes the data over a large number of carriers closely spaced. The two main characteristics are that each subcarrier is modulated using varying levels of QAM modulation and each OFDM symbol is preceded by a cyclic prefix (CP) used to effectively eliminate inter symbol interference (ISI). OFDM has several advantages such as can easily adapt to severe channel conditions, is robust against ISI and fading caused by multipath and provide high spectral efficiency. But it also has disadvantages as it is sensitive to Doppler shift, defined as the change in frequency of a wave for an observer moving relative to the source of the waves. It is also sensitive to frequency synchronization problems and having high peak-to-average-power ratio (PAPR).

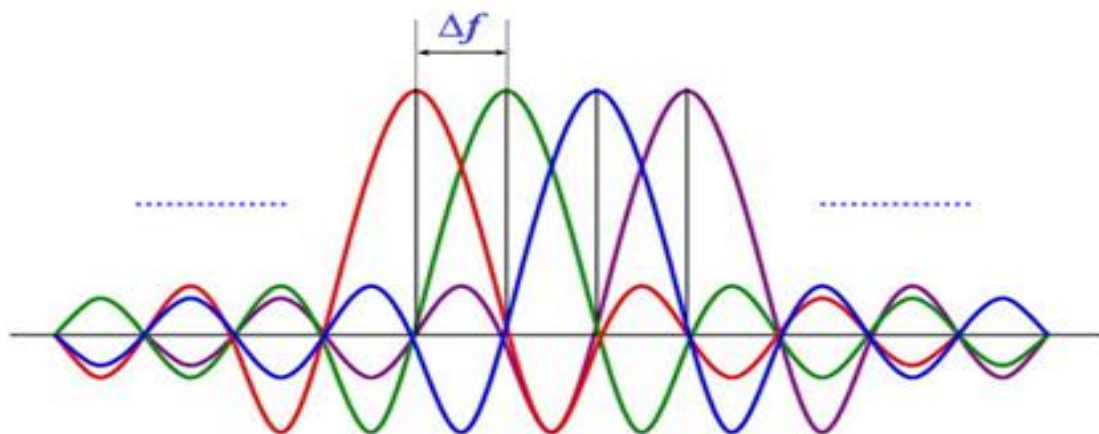


Figure 2.2: Subcarrier spacing in OFDM

2.2.2 OFDMA (Orthogonal Frequency Division Multiple Access)

Orthogonal Frequency Division Multiple Access (OFDMA) is a multi-user version of OFDM. Multiple accesses is achieved by assigning different OFDM sub-channels to different users.

Among the advantages of OFDMA, one important property is having its robustness to fading and interference. It also averages the interferences within the cells using allocation with cyclic permutation and offers frequency diversity by spreading the carriers all over the used spectrum. On the other hand, OFDMA is higher sensible to frequency offsets and phase noise .Moreover, the resistance to the frequency-selective fading may partly be lost if very few sub-carriers are assigned to each user and if the same carrier is used in every OFDM symbol. OFDMA is used as the multiplexing scheme in the LTE down link[9].

2.2.3MIMO (Multiple Input Multiple Output)

MIMO technology offers significant increases in data throughput and link range without additional bandwidth or transmitted power. There are multiple transceivers at both the base station and UE in order to enhance link robustness and increase data rates for the LTE downlink.

2.2.4 SC-FDMA (Single Carrier Frequency Division Multiple Access)

LTE requirements in uplink differ in several aspects from downlink. The main fact is the transmission scheme used. Power consumption is a key consideration for UE terminals and for this; the high PAPR and related loss of efficiency associated to OFDM signaling are major concerns. As a result, an alternative to OFDM was sought for use in the LTE uplink.

The solution is Single Carrier - Frequency Domain Multiple Access (SC-FDMA) that suits very well with the LTE uplink requirements. The basic transmitter and receiver architecture is very similar (nearly identical) to OFDMA [10].

2.3 Brief History of OFDM

The idea of Orthogonal Frequency Division Multiplexing (OFDM) was proposed in mid 1960's which used parallel data transmission and Frequency Division Multiplexing. In the 1960's the OFDM was used in several high frequency military systems. In 1971 Weinstein and Ebert applied the Discrete Fourier Transform to parallel data transmission systems as a part of modulation and Demodulation process. In 1980's OFDM was studied for high speed modem digital mobile communication and high density recording in which pilot tone was used to stabilize carrier and Frequency control and Trellis code was implemented which gave rise to Coded-OFDM. In 1980, Hirosaki suggested an equalization algorithm in order to suppress both inter symbol and inter carrier interference caused by the channel impulse response or timing and frequency errors. In 1980, Hirosaki introduced the DFT -based implementation of Saltzburg's O-QAM OFDM system. In 1990s, OFDM has been used extensively for wideband data communication over mobile radio FM channels, high-bit-rate digital subscriber lines (HDSL, 1.6 Mb/s), asymmetric digital subscriber lines (ADSL, 1536 Mb/s), very high-speed digital subscriber lines (VHDSL, 100 Mb/s), digital audio broadcasting (DAB) and HDTV terrestrial broadcasting. OFDM is used in wireless digital radio, TV transmissions, particularly in Europe, also used in wireless Local Area Networks (LANs) as specified by the IEEE 802.11, IEEE 802.16, IEEE802.20 and the European

Telecommunications Standards Institute (ETSI) Hiper LAN/2 standards [11].

2.3.1 Multipath Channels

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.

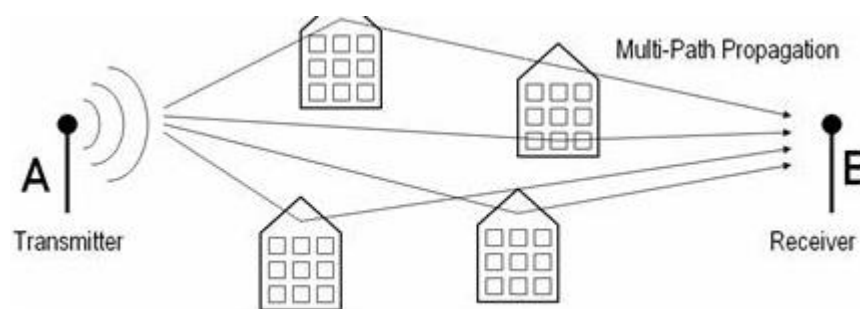


Figure 2.3 Multipath propagation

2.4 Basic Concepts

2.4.1 Frequency Division Multiplexing (FDM)

Frequency Division Multiplexing is being used for a long time to carry the data more than one carrier signal. It divides the total channel bandwidth into sub channels so that each sub channel carries the modulated data into a separate carrier frequency. There will be some guard bands between the adjacent channels so that there is no inter channel interference .FDM technique are quite popular technique used in telephones line.

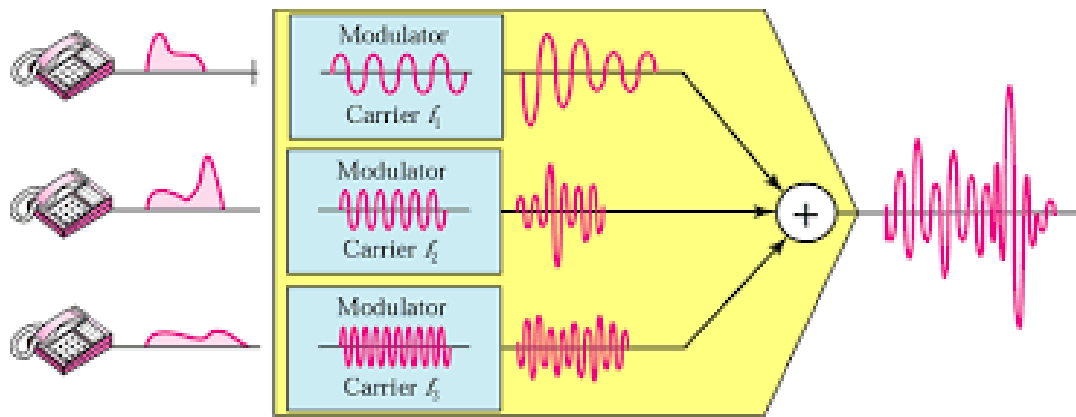


Figure 2.4 Frequency Division Multiplexing

2.4.2 Time Division Multiplexing (TDM)

Time Division Multiplexing is another efficient technique which improves the capacity by splitting the frequencies in different time slots. It allows the user to access the entire frequency band at a particular instant of time. Other users share the same frequency channel at different time slot. TDMA system divide the radio spectrum into time slots, and in each slot only one user is allowed to transmit and receive

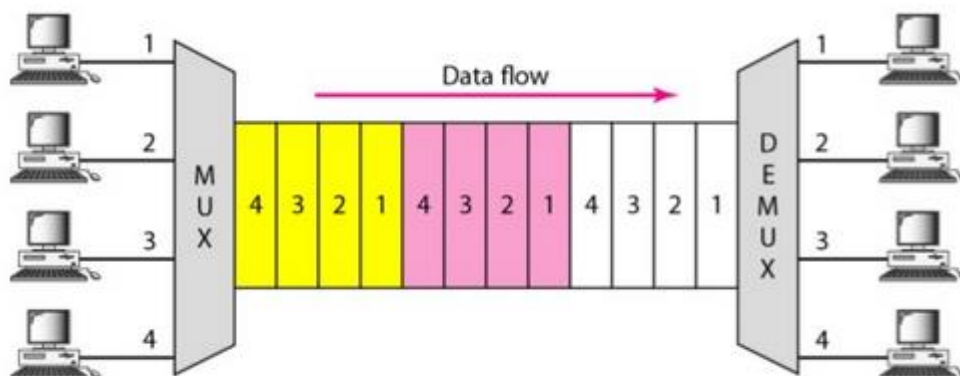


Figure 2.5 Time Division Multiplexing

2.4.3 Orthogonal Frequency Division Multiplexing (OFDM)

In order to solve the bandwidth efficiency problem, Orthogonal Frequency Division Multiplexing (OFDM) technique is used. OFDM is a multicarrier transmission technique, which divides the total available bandwidth into many subcarriers; each subcarrier is modulated by a low rate data stream. In term of multiple access technique OFDM is similar to FDMA such that the multiple users access is achieved by subdividing the available bandwidth into multiple channels. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing to be spaced as close as theoretically possible. This overcomes the problem of overhead carrier spacing required in FDMA.

2.4.3.1 Advantages of OFDM

The Orthogonal Frequency Division Multiplexing (OFDM) transmission scheme has the following key advantages³⁴

- OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions.
- By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems. By using adequate channel coding and interleaving, the symbols lost can be recovered, due to the frequency selectivity of the channel.

- OFDM is a bandwidth efficient modulation scheme and has the advantage of mitigating ISI in frequency selective fading channels.
- Channel equalization becomes simpler as compared to adaptive equalization techniques with single carrier systems.
- In conjunction with differential modulation, there is no need to implement a channel estimator.
- OFDM provides good protection against co-channel interference and impulsive parasitic noise.
- OFDM can easily adapt to severe channel conditions without complex time- domain equalization.
- OFDM eliminates Inter Symbol Interference (ISI) through the use of a cyclic prefix.
- OFDM is less sensitive to sample timing offsets than the single carrier systems.
- OFDM provides greater immunity to multipath fading and impulse noise.
- OFDM makes efficient use of the spectrum by allowing overlapping.

2.4.3.2 Disadvantages of OFDM

The Orthogonal Frequency Division Multiplexing (OFDM) transmission scheme is an attractive technology but has the following disadvantages:

- OFDM is more sensitive to carrier frequency offset and drift than single carrier systems, due to leakage of the Discrete Fourier Transform (DFT).
- OFDM is sensitive to frequency synchronization problems.
- OFDM is sensitive to Doppler Shift.

- The OFDM signal has amplitude with a very large dynamic range; therefore it requires RF power amplifiers with a high Peak-to-Average Power Ratio (PAPR).
- The high PAPR increases the complexity of the Analog-to-Digital (A/D) and Digital to-Analog (D/A) converters.
- The high PAPR also lowers the efficiency of power amplifiers.³

2.5 Peak to Average Power Ratio

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. The coherent addition of N signals of same phase produces a peak which is N times the average signal. The major disadvantages of a high PAPR is increased complexity in the analog to digital and digital to analog converter.

2.6 PAPR Reduction Techniques

The high Peak-to-Average Power Ratio (PAPR) or Peak-to-Average Ratio (PAR) or Crest Factor of the Orthogonal Frequency Division Multiplexing (OFDM) systems can be reduced by using various PAPR reduction techniques.

2.6.1 Clipping

Clipping is by far simplest technique for PAPR Reduction in which signal above a predetermined threshold level is clipping which introduces both in-band and out-of-band distortion which can destroy orthogonality of the subcarriers .For the later windowing of the clipped signal can be done which should be ideally as narrow as possible[12][13].

2.6.2 Interleaving

This method is also termed as Adaptive Symbol Selection Method. Multiple OFDM symbols are created by bit interleaving of input sequences. The basic Idea is to use W interleaving ways and selecting one with the lowest PAPR.

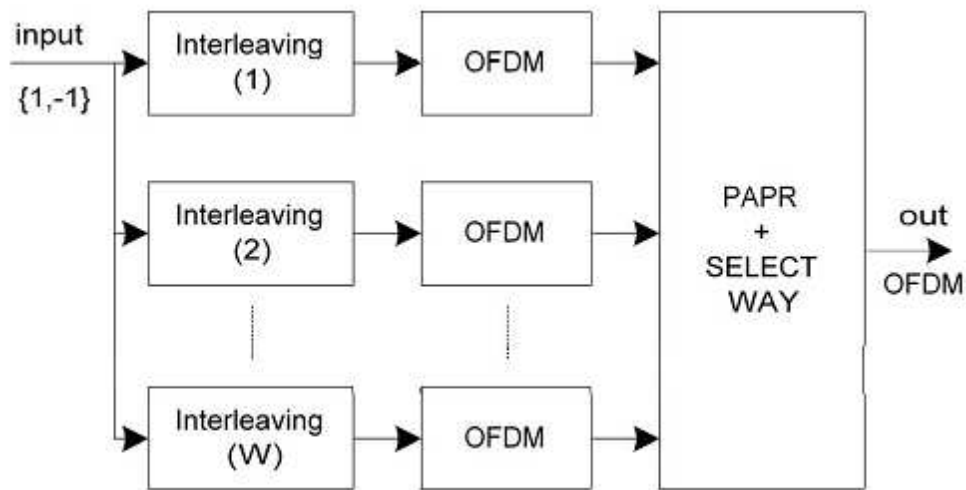


Figure 2.6: Interleaving

Figure 3 shows an interleave, PAPR Reduction capability depends on the number of interleave used. To recover the signals the receiver need to know the information about which interleave is used [14][12].

2.6.3 Coding

When FEC codes are used to mitigate the effect of the distortion techniques, the OFDM is termed as COFDM so that the signal degradation can be made less. The basic concept is that when N signals are added in phase they add up to the signal power, such arrangements can be made with different coding schemes like Simple Odd Parity Code (SOBC), Cyclic Coding (CC), Simple Block Code (SBC) Complement Block Coding (CBC) and Modified Complement Block Coding (MCBC),

Reed-Solomon, Simplex codes[15], Reed-Muller codes and Golay complementary codes described in [16][17] can significantly reduce PAPR.

2.6.4 Companding

The idea of companding came from the companding of speech signal and that the OFDM signal is similar to it from the fact that large signals occur very infrequently. Companding are of two types- linear and non-linear. Linear companding focuses on expanding small signals only while non linear companding enlarges small signals as well as compresses the large ones thereby obtaining uniform distribution of signals [18]. Therefore, the average power is increased and thus the Peak-to-Average Power Ratio (PAPR) of the Orthogonal Frequency Division Multiplexing (OFDM) systems can be reduced, which in turn helps in increasing the efficiency of the power amplifiers. In terms of BER Linear companding performs well [18]. Uniform distribution can be achieved by using transforms like trapezium distribution [19], Hadamard transform [20], Discrete Cosine Transform [21], airy function [22], exponential companding [23] [24]. Companding gives better PAPR performance and also BER degradation is less.

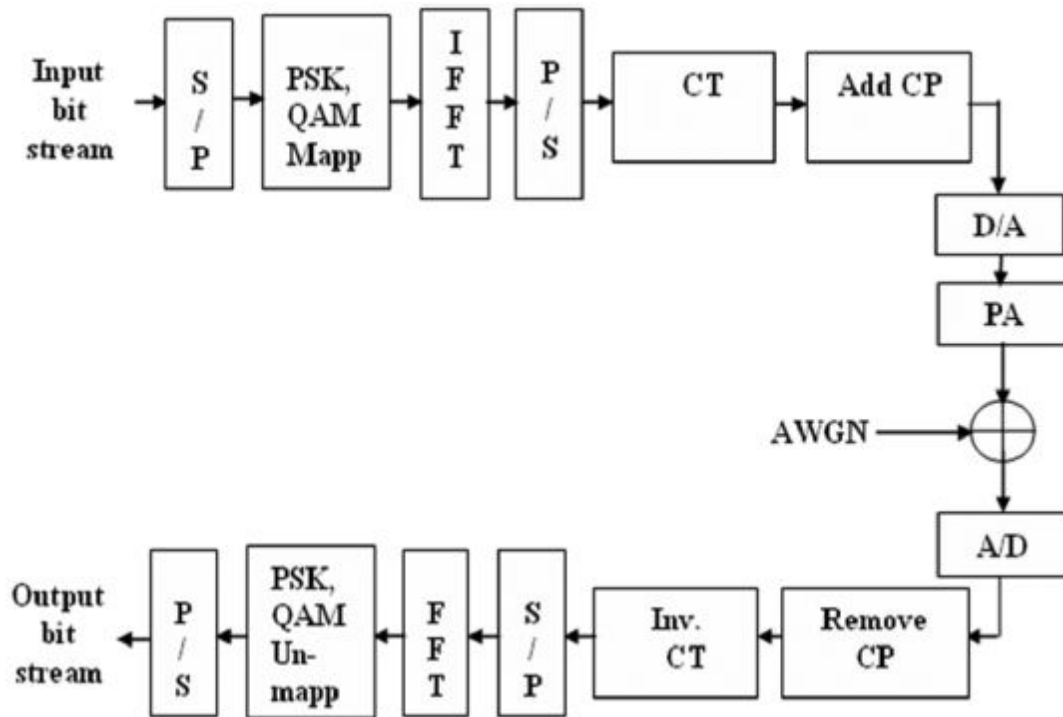


Figure 2.7: Companding in OFDM system

2.6.5 Selective Mapping

The paper that coined the term “selected mapping” was written by Bauml, Fischer and Huber in 1996[25]. Among all the techniques SLM is most promising because it introduces no distortion yet can achieve significant PAPR reduction

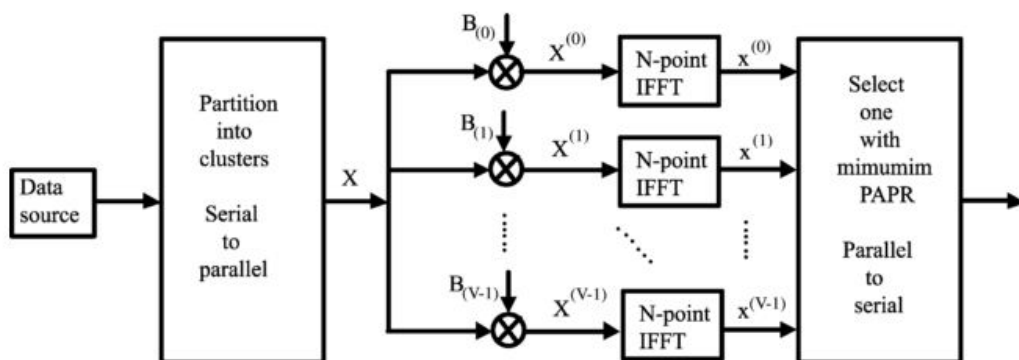


Figure 2.8 : Selective Mapping

Data blocks are converted into several independent blocks and the one with lower PAPR is sent in which converting process involves multiplying data sequences to random phase sequences generated. The selected index is called side-information index (SI Index), must also be transmitted to allow recovery of the data block at the receiver side. SLM leads to the reduction in data rate. Probability of erroneous SI detection has a significant influence on error performance of the system [12][16][26]. In this technique complexity involves in recovering the side information. Moreover, this reduces the data rate of the system because the side information is sent with the data blocks carrying information. Many methods have been proposed to reduce this side information such as Semi-Blind SLM described in [27], known phase sequences like chaotic, Hadamard, Riemann and lots of other techniques described in [28] –[29].

2.6.6 Active Constellation Extension (ACE)

This technique deals with extending the constellation points outside the signal constellation which is then used to cancel the time domain peaks [12][16][30]. Figure 5 shows the points where these constellation points can be extended. This technique has several advantages like no loss of data, no degradation in system performance, lower BER as compared to other techniques and bears no side information like SLM. Some variations of this method like clipping-based ACE and Adaptive ACE in which repeated CAF and in later an adaptive control has been used to optimize the performance [31][32].

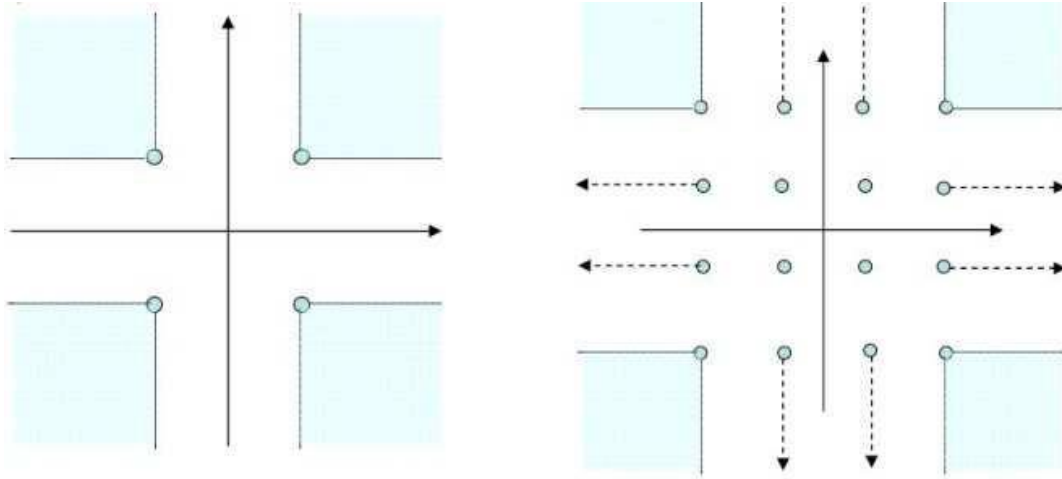


Figure 2.9: Active Constellation Extension (a) for QPSK (b) for 16 QAM

2.6.7 Partial Transmit Sequence (PTS)

Block diagram of PTS is shown in Figure 6. In the PTS technique, an input data block of N symbols is partitioned into disjoint sub blocks and then the signal is transmitted. Another factor that may affect the PAPR reduction performance in PTS is the sub block partitioning, which is the method of division of the subcarriers into multiple disjoint sub blocks. There are three kinds of Sub block partitioning schemes :adjacent, Interleaved and pseudo-random partitioning. The PTS technique works with an arbitrary number of subcarriers and any modulation scheme. Advantage is that works with an arbitrary number of subcarriers any modulation scheme. But, this scheme includes complexity and side information like SLM [12][16][33]-[34].

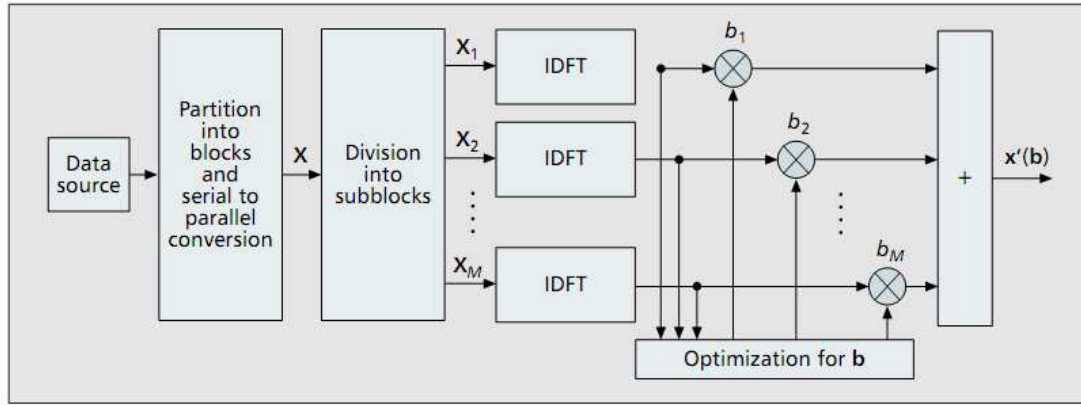


Figure 2.10: Partial Transmit Sequence

2.6.8 Tone Reservation (TR) and Tone Injection (TI)

In this Technique some set of tones are reserved called as peak reduction carriers and these are added to the data signal to isolate energy to cancel large peaks. These tones does not bear any information and are orthogonal to each other[30][35] while Tone Injection technique reduces the PAPR without reducing the data rate similar to ACE some constellation points are extended outside the signal constellation but in a different way than in ACE . Extra flexibility is provided by mapping points of original constellation into extended constellation and then by combining the data signal and Peak reduction carrier so generated [36][37] By maximizing signal-to-distortion ratio error probability can be increased for the same transmit power and same order of computational cost in the tone Reservation method [35].

Literature Review

Himanshu Bhushan Mishra et al. in 2012 proposed a new Selective-Mapping (SLM) technique in WiMAX without side information which is the major issue in the classical SLM Technique. In this project the PAPR performance is measured using complementary cumulative distribution function (CCDF) plot and the probability of SI detection error performance have been evaluated as the criteria for WiMAX standard IEEE 802.16e. WiMAX with its standard IEEE 802.16d/e is the advanced technology used for long range communication with high data rate. It is well known that the Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for getting high data rates in a multipath fading environment. Hence, the physical layer of WiMAX uses OFDM. But the main disadvantage of OFDM is the high peak to average power ratio (PAPR). In this paper PAPR reduction is achieved using selected mapping (SLM) technique and simultaneously without sending the side information (SI) along with the OFDM symbol [38].

E. Al-Dalakta et al. in 2012 proposed an efficient technique for reducing the bit error rate (BER) of Orthogonal Frequency Division Multiplexing (OFDM) signals transmitted over nonlinear solid-state power amplifiers (SSPAs). The proposed technique is based on predicting the distortion power that an SSPA would generate due to the nonlinear characteristics of such devices. Similar to the Selective-Mapping (SLM) or Partial-Transmit-Sequence (PTS) schemes, the predicted distortion is used to select a set of phases that minimize the actual SSPA distortion. Simulation results confirmed that the signal-to-noise ratio that is required to [Abbildung in dieser Leseprobe nicht enthalten] using the proposed technique is less by about 8 dB when it is obtain a BER of [Abbildung in dieser Leseprobe nicht enthalten] compared to the standard PTS utilizing 16 partitions. Moreover, complexity analysis demonstrated that the proposed system offers a

significant complexity reduction of about 60% compared to state-of-the-art methods. This work demonstrated that less direct PAPR indicators can provide better performance when combined with distortion less techniques such as PTS and SLM. Therefore, the proposed techniques are optimized to combat the consequences of high PAPR rather than reducing the PAPR itself. The proposed techniques are based on using the distortion level to select the optimal PTS and SLM system parameters [39].

Shiann-Shiun Jeng et al. in 2011 proposes a new method based on companding Peak-to-Average Power Ratio (PAPR) Reduction of Orthogonal Frequency Division Multiplexing (OFDM) signals. This paper suggests that uniformly distributed companding scheme and piecewise companding scheme cannot deliver the performance that satisfies various requirements of the system. So, the distribution of the OFDM signal is transformed into the trapezium distribution and the general formulas for the proposed scheme are derived that enable the desired performance to be achieved by controlling the parameter. The simulation results reveal that the proposed scheme may offer the more efficient PAPR reduction or the lower BER than the uniformly-distributed and piecewise schemes under the condition of efficient PAPR reduction or efficient BER performance [40].

Suma M N et al. gives a survey on developments in OFDM so far. He suggested that apart from high Peak-to-Average Power Ratio (PAPR) there are many more techniques that are needed to increase the performance of OFDM systems like interference cancellation, phase noise mitigation, Synchronization among carriers and post equalization. In today's communication scenario, high data rate single-carrier transmission may not be feasible due to too much complexity of the equalizer in the receiver. To overcome the frequency selectivity of the wide band channel experienced

by single-carrier transmission, multiple carriers can be used for high rate data transmission. Orthogonal Frequency Division Multiplexing (OFDM), is multicarrier system which has become a modulation in physical layer of next generation WiMAX, LTE system. In this work effort is made to present challenges in OFDM and work done so far in channel equalization and different transforms used in OFDM system like Discrete Fourier Transform (DFT) Based OFDM, Discrete Cosine Transform (DCT) Based OFDM, Wavelet based and Wavelet packet based OFDM, Discrete Hartley Transform (DHT) Based OFDM, and Coded OFDM which includes Turbo codes and Alamouti codes[41].

Jun Hou et al. proposed a nonlinear companding scheme to reduce the Peak-to- Average Power Ratio (PAPR) and improve Bit Error Rate (BER) for OFDM systems. This proposed scheme mainly focuses on compressing the large signals, while maintaining the average power constant by properly choosing transform parameters. Moreover, analysis shows that the proposed scheme without de companding at the receiver can also offer a good BER performance. Finally , simulation results show that the proposed scheme out performs other companding scheme in terms of spectrum side-lobes, PAPR reduction and BER performance[42].

Yuan Jiang in 2010 suggest a new companding algorithm that offers improved performance in terms of BER and OBI while reducing PAPR effectively. Orthogonal Frequency Division Multiplexing (OFDM) mitigates the effect of inter symbol interference (ISI) but it suffers from inter-block interference (IBI).A good remedy for the OBI is companding. This paper proposes and evaluates a new companding algorithm. This work uses the special airy function and is able to offer an improved bit error rate (BER) and minimized OBI while reducing PAPR effectively [43] Kitaek Bae et al. in 2010 proposed a new method for Peak-to-Average Power

Ratio (PAPR) Reduction in Orthogonal Frequency Division Multiplexing (OFDM), a novel Active Constellation Extension (ACE) algorithm with adaptive clipping control namely Adaptive ACE which is an improvement in the technique based on the combination of two techniques namely clipping and Active Constellation Extension (ACE) known as Clipping-Based Active Constellation Extension (CB-ACE) technique. This work suggests that CB-ACE cannot achieve the minimum PAR when the target clipping level is set below an initially unknown optimum value. To overcome this low clipping ratio problem, Adaptive ACE is proposed. Simulation results demonstrate that proposed algorithm can reach the minimum PAR for severely low clipping ratios. In addition, the tradeoff between PAR and the loss in [Abbildung in dieser Leseprobe nicht enthalten]over an AWGN channel in terms of the clipping ratio has also been described[44].

Ms. V. B. Malode et al. in 2010 proposed a new method to reduce Peak-to-Average Power Ratio (PAPR) Peak-to-Average Power Ratio (PAPR) by probabilistic method, modified selective mapping technique using the standard arrays of linear block codes. In this work lowest PAPR in each coset of a linear block codes is chosen as its coset leader from several transmitted signal , which further results in high performance of wireless communication[45].

Stephane Y. Le Goff et al. in 2009 suggest an improvement in classical Selective Mapping (SLM) technique and proposed a new method in which SLM can be implemented without sending the side information which is a major issue in classical Selective Mapping (SLM) technique .SLM requires the transmission of several side information bits for each data block, which results in some data rate loss. These bits must generally be channel-encoded because they are particularly critical to the error performance of

the system. This increases the system complexity and transmission delay, and decreases the data rate even further. In this paper, we propose a novel SLM method for which no side information needs to be sent. This technique is particularly attractive for systems using a large number of subcarriers and the probability of SI detection error can be made very small by increasing the extension factor and/or the number of subcarriers[46].

Sulaiman A. Aburakhia et al. in 2009 proposed a new linear companding transform (LCT) with more design flexibility than linear non symmetrical companding transform (LNST). Simulation results have been shown comparing both the above technique assuming AWGN channel. The results show that the proposed method has a higher PAPR reduction capability and better BER performance than LNST, with less spectral broadening. This work suggests that the proposed can be designed to meet system requirements, power amplifier characteristics, and achieve an excellent tradeoff between PAPR reduction and BER performance. Furthermore, the proposed transform is simple to implement and has no limitations on the system parameters such as number of subcarriers modulation order, or constellation type [47].

F.S. Al-kamaliet al. suggested the design of a new transceiver scheme for the SCFDMA scheme using the wavelet transform. No redundancy is added to the new system because of the discrete wavelet transform. Thus, its complexity is slightly increased as compared to the conventional SC-FDMA scheme. This work describes that the proposed scheme has better PAPR performance and BER performance than the conventional SC-FDMA scheme. The proposed HW-SC-FDMA scheme provides about 3 dB gain when compared to the conventional SC-FDMA scheme over the vehicular achannel [48].

Chapter Three

System design

3.1 LTE OFDMA System Model

A simplified block diagram of the 3GPP LTE OFDMA transceiver is shown in figure1 a baseband modulator transmits the binary input to a multilevel sequences of complex number $x(k)$ in one of several possible modulation formats including, Binary phase shift keying (QPSK), and 16 level-QAM at the transmitter side. BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180° . This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications when bandwidth is limited.

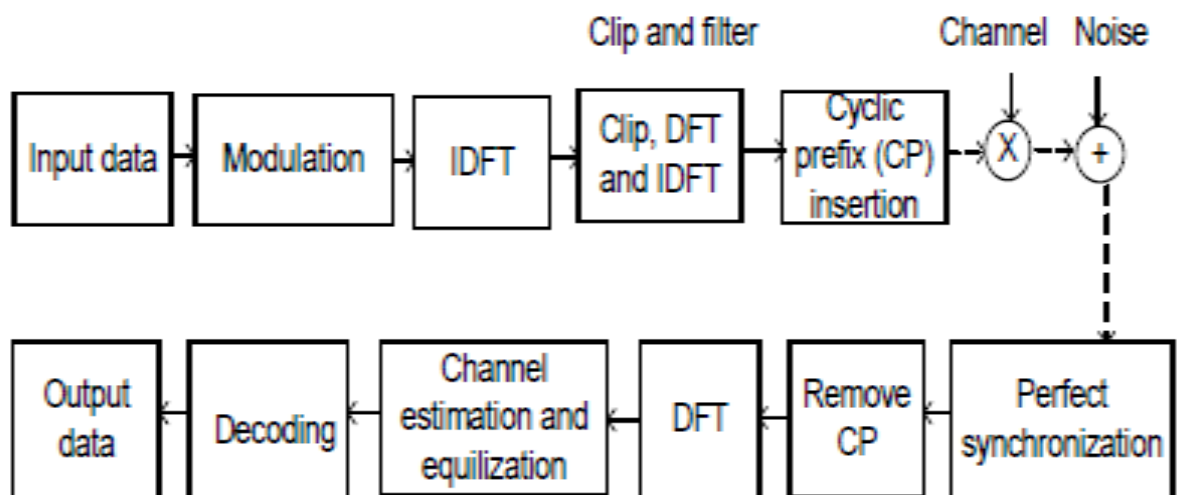


Figure 3.1: 3GPP LTE OFDMA system

These modulated symbols, are perform an N-point discrete Fourier transform (DFT) to produce a frequency domain representation [2]:

$$s_1(n) = \frac{1}{\sqrt{N}} \sum_{K=1}^{N-1} X(K) e^{\frac{(-j2\pi kn)}{N}} \quad (3.1)$$

And inverse discrete Fourier transform for time domain expression:

$$X(k) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} s_1(n) e^{\frac{(-j2\pi kn)}{N}} \quad (3.2)$$

Where k is the sample index, j is the imaginary unit, x is the discrete symbol and $x(k)$ is the data symbol. From IDFT, the time domain signal is passed for clipping and filtering. The clipping is followed by filtering to reduce out of band power. The DFT transform the clipped signal into frequency domain signal. The in-band frequency domain signals are passed to the second IDFT while out-of band signal components are null. Therefore it doesn't cause interference to the in-band OFDMA signal. Then cyclic prefix is inserted and transmitted through the channel. In the same way at the receiver side the signal is received and the cyclic prefix is removed. Then this incoming signal is DFT and we get the base band signal after decoding. Peak to average power ratio (PAPR) is a comparison of the peak power detected over a period of sample occurs over the same time period and defined as :

$$PAPR = \frac{\max_{0 \leq m < T} |S(m)|^2}{\frac{1}{TN} \int_0^{TN} |S(m)|^2 dm} \quad (3.3)$$

Expression in decibels: $PAPR_{dB} = 10 \log_{10}(PAPR)$

Where (m) is the transmitted signal, T is the symbol period of the transmitted signal. One of the most frequently used performance measures for PAPR reduction techniques is cumulative distribution function (CDF). But in this research we use, the complementary CDF (CCDF) is commonly used instead of the CDF. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold. There is another performance parameter bit error rate analysis. Although QPSK can be viewed as a quaternary modulation, it is easier to see it as two independent

modulated quadrature carriers. With this interpretation, the even bits are used to modulate the in-phase component of the carrier, while the odd (or even) bits are used to modulate the quadrature-phase component of the carrier. BPSK is used on both carriers and they can be independently demodulated. Generally bit error rate of QPSK is lower than the 16 QAM.

3.2CLIPPING

The Clipping based techniques clips the time domain signal to predefined level . The method of Clipping and Filtering can be described with tow modulation techniques, Quadrature Phase Shift Keying (QPSK) Quadrature Amplitude Modulation (16QAM).

The OFDM signal contains high peaks so it is transferred from the clipping block shown in Fig (3b). In this when amplitude crosses the threshold or cut off level, the amplitude is clipped off shown in Fig (2), while saving the phase. The clipped sample is given by

$$X(n) = \begin{cases} |x(n)| & \text{if } |x(n)| \leq C(\text{threshold}) \\ C & \text{if } |x(n)| > C(\text{threshold}) \end{cases} \quad (3.4)$$

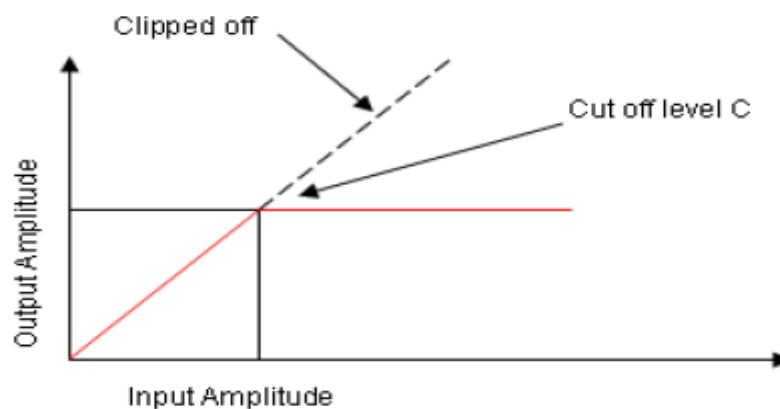


Figure3.2: Clipping method

The out-of-band radiations occurred without filtering due to non linearity. To reduce the interference to neighboring channels, out-of-band components must be reduced with a band limiting filter. The peak growth becomes small after filtering the oversampled signal. The repeated clipping

and filtering can reduce the peak re growth and increases the system cost. So there has been a tradeoff between PAPR and system cost. The Modulated data can be of any type 16-QAM, QPSK during classical clipping. The different PAPR reduction techniques using QPSK modulation is used. The Smooth Clipping method is compared with classical clipping in.

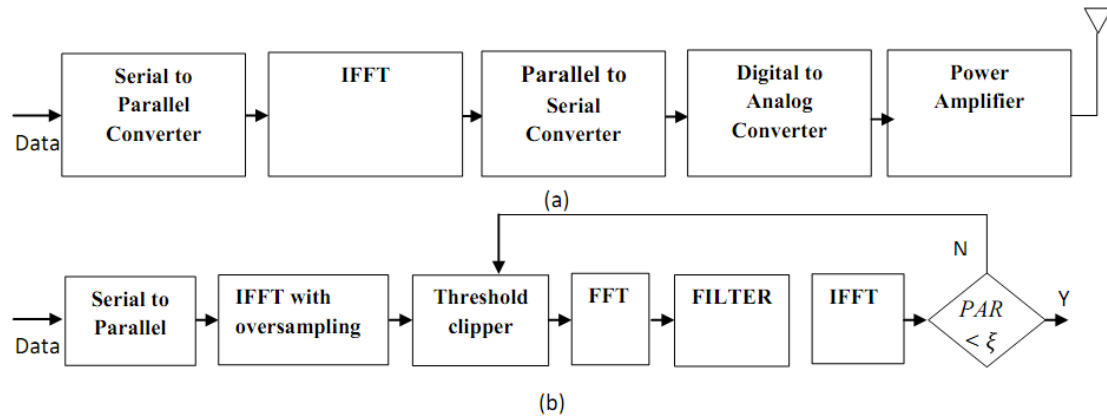


Figure3.4: Block Diagram of (a) Original OFDM system (b) Clipped using threshold.

3.3 Selective Mapping

The input data sequences are multiplied by each of the phase sequences to generate alternative input symbols sequences. Each of these alternative input data sequence is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission. In Fig (4) each data block is multiplied by V different phase factors, each of length N ,

$B_v = [b_{v,0}, b_{v,1}, \dots, b_{v,N-1}]^T$ ($v=0,1,\dots,V-1$), Resulting in V different data blocks. Thus, the V th phase sequence after multiplied is

$$X^v = [X_0, b_{v,0}, b_{v,1}, \dots, X_{N-1}, b_{v,N-1}]^T \quad (v=0,1,\dots,V-1), \quad (3.5)$$

Therefore, OFDM signals can be taken as

$$X^v(T) = \frac{1}{\sqrt{N}} \sum_{N=0}^{N-1} X_N B_{V,N} E^{j2\pi FNT} \quad (3.6)$$

Where $0 \leq t \leq NT$, $v=1,2,\dots,v-1$, Among the data blocks $X^v(v = 0,1, \dots, v-1)$ Among the data blocks Only one with the minimum PAPR is selected for transmission and the matching selected phase factors $b_{v,n}$ also should be transmitted to receiver as side information. SLM requires V IFFT operation and the number of required bits as side information is $\lceil \log_2 V \rceil$ for each data block.

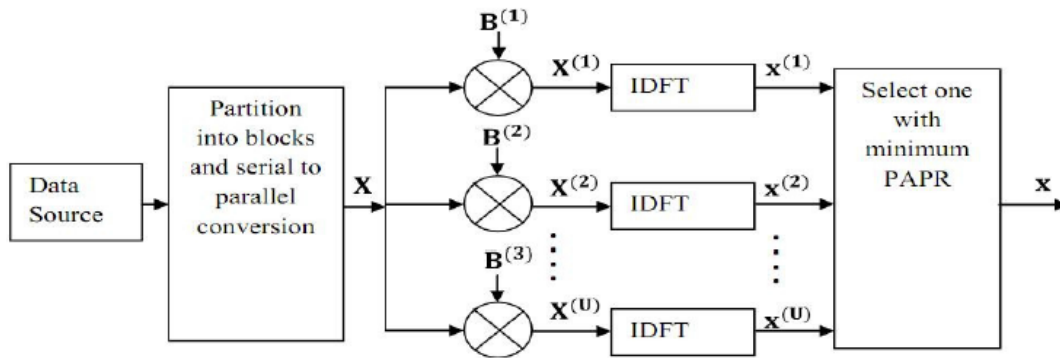


Figure 3.5. Selective Mapping Technique

3.4. Partial transmit sequence

In PTS technique, the input data block in X is partitioned into M disjoint sub blocks, which are represented by vector $\{x^m, m = 0,1, \dots, M-1\}$ as shown in Fig (6). Therefore, we can get

$$X = \sum_{m=0}^{M-1} X_K^m \quad (3.7)$$

Where $x^m = [x_0^m x_1^m \dots x_{N-1}^m]$ with $X_K^m = X_K$ or 0 ($0 \leq m \leq M-1$)

Technique, the known sub block partitioning methods can be classified into three types:

Adjacent partition, interleaved partition and pseudorandom partition. Then, the sub blocks x^m are transformed into M time-domain partial transmit sequences

$$x^m = [x_0^m x_1^m \dots x_{LN-1}^m] = \text{IFFT}_{LN \times N}[X^m] \quad (3.8)$$

These partial sequences are rotated independently by phase factors

$$\mathbf{b} = \{b_m = e^{j\theta_m}, m=0,1,\dots,M-1\} \quad (3.9)$$

The approach is to optimally combine the M sub blocks to obtain the time domain OFDM signals with the minimum PAPR

$$X = \sum_{m=0}^{M-1} b_m x^m \quad (3.10)$$

So, there are two important issues should be taken into consideration in PTS: high computational complexity for finding the optimal phase factors and the overhead of the optimal phase factors as side information required to transmitted to receiver for the correct decoding of the transmitted bit sequence. Normally, PTS needs M IFFT operations for each block, and number of required side information bits is $\lceil M \log_2 w \rceil$

Where $\lfloor x \rfloor$ denotes the smallest integer that does not exceed x.

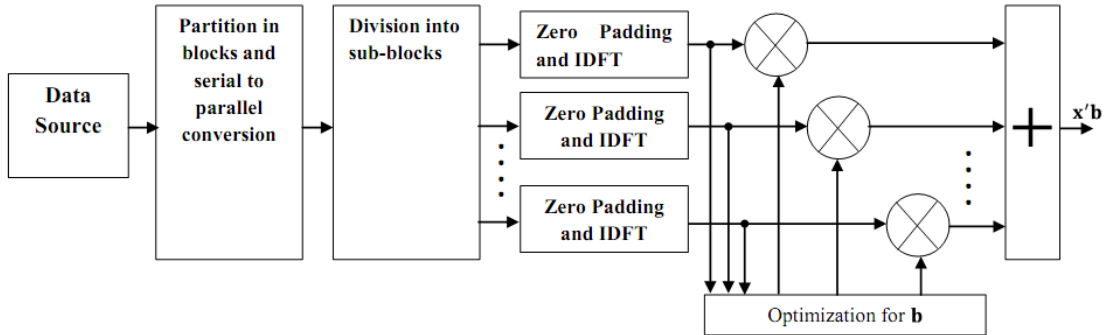


Figure3.6: Partial Transmit Sequence

Chapter Four

Results and Discussion

4.1Results

Use the computer simulations to evaluate the performance of the proposed PAPR reduction technique over different types of modulated data. As a performance measure for proposed technique, we use the CCDF of the PAPR. Performances of the proposed system are first compared original signal without any technique, with clipping, with partial transmit and selective mapping to OFDM system with QPSK symbol modulated and AWGN channel. Fig (4.1) shows the clipping technique is better than selective mapping and partial transmit. The second compared original signal without any technique, with clipping, with partial transmits and selective mapping to OFDM system with QPSK symbol modulated and fading channel. Fig (4.2) shows the clipping technique is better than partial transmit and selective mapping. Third compared original signal without any technique, with clipping, with partial transmit and selective mapping to OFDM system with 16QAM symbol modulated and AWGN channel. Fig (4.3) shows the clipping technique is better than partial transmit and selective mapping. Forth compared original signal without any technique, with clipping, with partial transmit and selective mapping to OFDM system with 16QAM symbol modulated and fading channel. Fig (4.4) shows the clipping technique is better than selective mapping and partial transmit. But all techniques in AWGN channel is better than fading channel in both modulation QPSK and 16QAM.

Table 4.1: Comparison of Clipping, PTS, and SLM using AWGN channel and QPSK modulation

Modulation	Original signal	With clipping	With PTS	With SLM
QPSK	12dB	5.25 dB	7.1 dB	9 dB

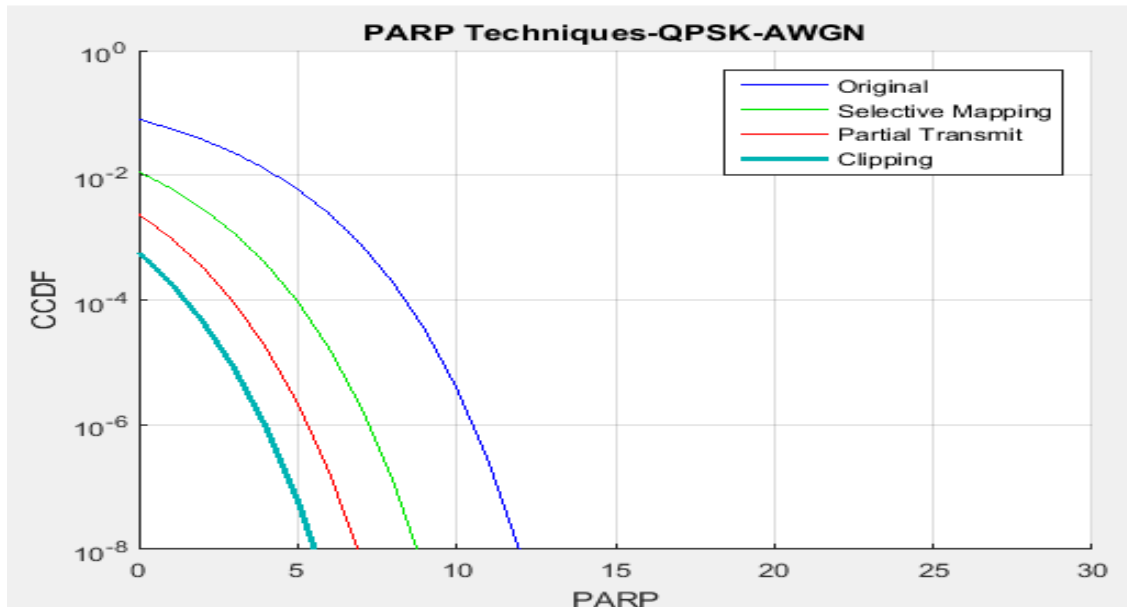


Figure (4.1): PAPR results of clipping, SLM and PTS methods over AWGN channel, QPSK OFDM systems.

Table 4.2: Comparison of Clipping, PTS, and SLM using fading channel and QPSK modulation

Modulation	Original signal	With clipping	With PTS	With SLM
QPSK	15 dB	9.1 dB	10.2 dB	12 dB

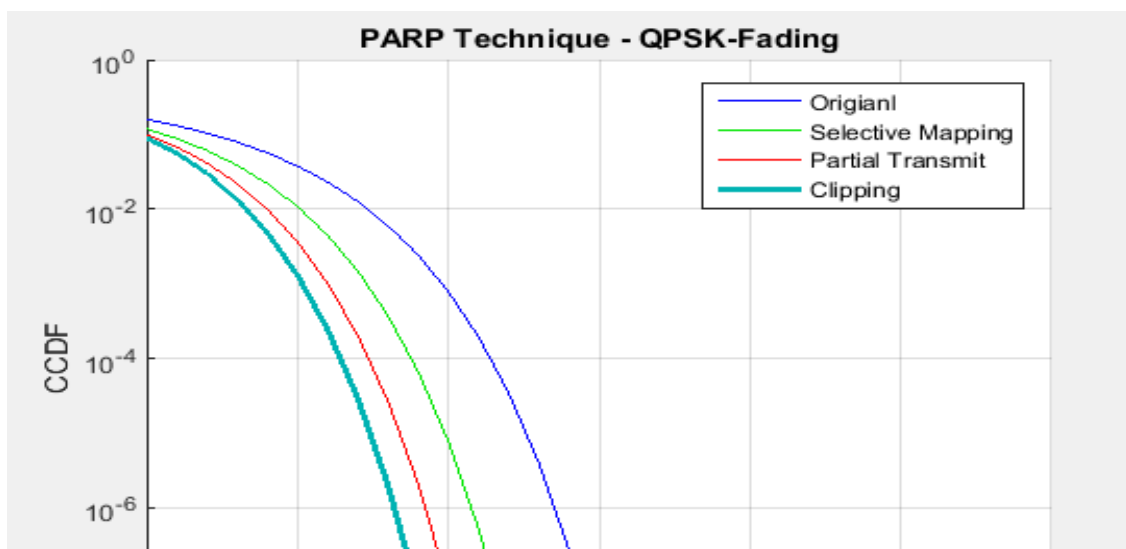


Figure (4.2): PAPR results of clipping, SLM and PTS methods over fading channel, QPSK OFDM systems.

Table 4.3: Comparison of Clipping, PTS, and SLM using AWGN channel and 16QAM modulation

Modulation	Original signal	With clipping	With PTS	With SLM
16QAM	25 dB	12 dB	16 dB	20 dB

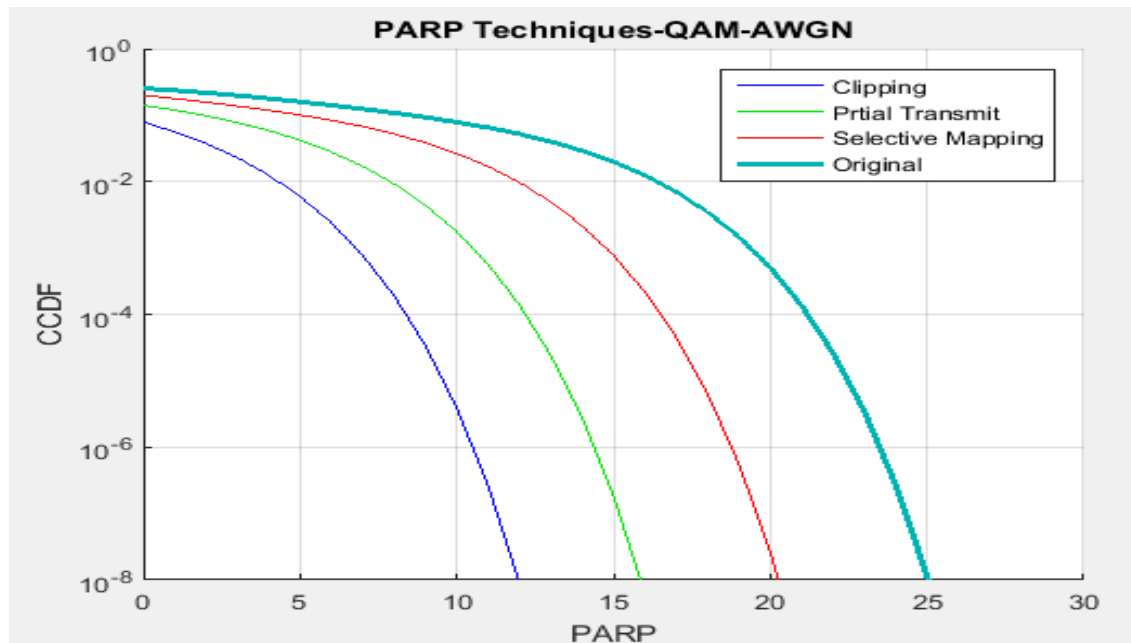


Figure (4.3): PAPR results of clipping, SLM and PTS methods over AWGN channel, 16-QAM OFDM systems.

Table 4.4: Comparison of Clipping, PTS, and SLM using fading channel and 16QAM modulation

Modulation	Original signal	With clipping	With PTS	With SLM
16QAM	>30 dB	18 dB	23 dB	28 dB

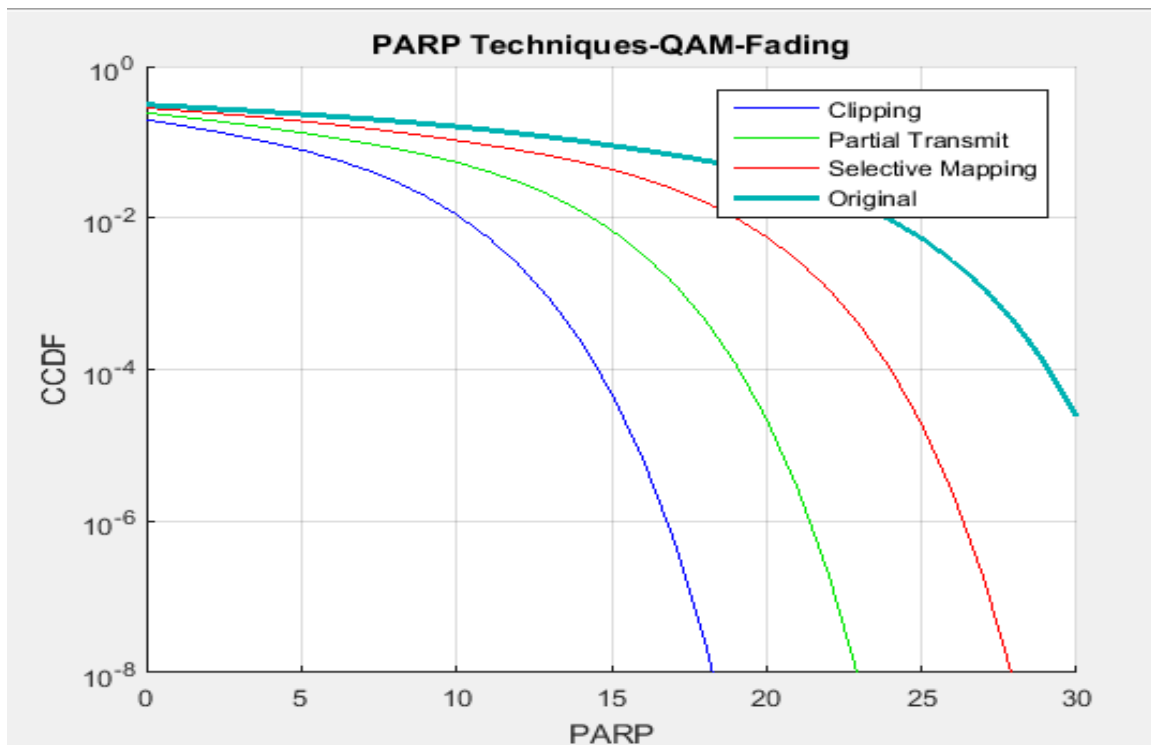


Figure (4.4): PAPR results of clipping, SLM and PTS methods over fading channel, 16-QAM OFDM systems.

S

Chapter Five

Conclusion and Future Work

5.1 Conclusion

The clipping algorithm provides efficient PAPR reduction in LTE OFDM system by applying different modulation and different channel environment. The clipping is obtained by a low-cost computation without repeating IFFT operations. But clipping technique by applying 16QAM and QPSK modulations and AWGN environment is best reduction than use fading channel. The SLM algorithm provides efficient PAPR reduction in LTE OFDM system by applying different modulation and different channel environment. But SLM technique by applying 16QAM and QPSK modulations and AWGN environment is best reduction than use fading channel. The PTS algorithm provides efficient PAPR reduction in LTE OFDM system by applying different modulation and different channel environment. But PTS technique by applying 16QAM and QPSK modulations and AWGN environment is best reduction than use fading channel. Thus clipping technique by applying QPSK modulation and

AWGN channel is best than SLM and PTS in different modulation and different environment.

5.2 Future work

- 1- Design and implement an adaptive PAPR block in the LTE structure to detect and evaluate the performance and use different algorithms.
- 2- Design and implement hybrid reduction method to increase the performance.
- 3- Compare between other methods.

Appendix

Clear all

```
M = 16; % Size of signal constellation
k = log2(M); % Number of bits per symbol
n = 30000; % Number of bits to process
numSamplesPerSymbol = 1; % Oversampling factor

%Create a binary data stream as a column vector.
rng default % Use default random number generator
dataIn = randi([0 1],n,1); % Generate vector of binary data

%Plot the first 40 bits in a stem plot.
stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');

%Perform a bit-to-symbol mapping.

dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix); % Convert to
integers

%Plot the first 10 symbols in a stem plot.

%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));
%title('Random Symbols');
```

```

xlabel('Symbol Index');
ylabel('Integer Value');

%Modulate using 16-QAM Apply modulation.

dataMod = qammod(dataSymbolsIn,M,0);           % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0

%Add White Gaussian Noise

EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(numSamplesPerSymbol);
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');

%Create a Constellation Diagram

sPlotFig = scatterplot(receivedSignal,1,0,'g. ');
%hold on
scatterplot(dataMod,1,0,'k*',sPlotFig)

% Demodulate 16-QAM

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:);                    % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:);                  % Return data in column
vector

figure()
EbNo = (0:10)';
M = 16;
%Generate theoretical BER data for QPSK modulation by using the
berawgn function.

%Generate equivalent data for DPSK and FSK.

berD = berawgn(EbNo,'qam',M);

%Plot the results.
semilogy(EbNo,berD)
xlabel('Eb/No (dB)')
ylabel('BER')
legend('16-QAM')
grid
%Create a binary data stream as a column vector.
rng default % Use default random number generator
dataIn = randi([0 1],n,1); % Generate vector of binary data

```

```

%Plot the first 40 bits in a stem plot.
%stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');
%Perform a bit-to-symbol mapping.
dataInMatrix = reshape(dataIn,length(dataIn)/k,k);    % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix);                % Convert to
integers
%Plot the first 10 symbols in a stem plot.
%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));
%title('Random Symbols');
%xlabel('Symbol Index');
%ylabel('Integer Value');
dataMod = qammod(dataSymbolsIn,M,0);                % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0
%Add White Gaussian Noise
EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(numSamplesPerSymbol);
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');

%Create a Constellation Diagram

%PlotFig = scatter plot(receivedSignal,1,0,'g. ');
%hold on
%scatterplot(dataMod,1,0,'k*',sPlotFig)
% Demodulate 16-QAM

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:);                        % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:);                      % Return data in column
vector
%Compute the System PAPR
[numErrors,ber] = biterr(dataIn,dataOut);
fprintf('\nThe binary coding bit error rate = %5.2e, based on %d
errors\n', ...
    ber,numErrors)
[numErrorsG,berG] = biterr(dataIn,dataOutG);
fprintf('\nThe Gray coding bit error rate = %5.2e, based on %d
errors\n', ...
    berG,numErrorsG)

%figure()
EbNo = (0:10)';
M = 16;

```

```

%Generate theoretical BER data for QPSK modulation by using the
berawgn function.

%Generate equivalent data for DPSK and FSK.

berD = berawgn(EbNo, 'qam', M);

%Plot the results.
%semilogy(EbNo,berD)
%xlabel('Eb/No (dB)')
%ylabel('BER')
%legend('16-QAM')
%grid
%% Mapping with QAM and AWGN
% Create a rectangular 16 QAM modulator, 64 QAM modulator, and an
AWGN Channel
    hQAM16 = comm.RectangularQAMModulator(16);
    hQPSK = comm.RectangularQPSKModulator(4);
    hChan = comm.AWGNChannel('NoiseMethod',...
        'Signal to noise ratio (SNR)', 'SNR', 15);
% Create a CCDF System object and request average power and peak
% power measurement outputs
    hCCDF1 = comm.CCDF('AveragePowerOutputPort', true, ...
        'PeakPowerOutputPort', true);
% Modulate signals
    sQAM16 = step(hQAM16,randi([0 16-1],20e3,1));
    sQPSK = step(hQPSK,randi([0 16-1],20e3,1));
% Pass signals through an AWGN channel
    hChan.SignalPower = 10;
    sQAMNoisy16 = step(hChan,sQAM16);
    hChan.SignalPower = 5;
    sQPSKNoisy = step(hChan,sQAM64);

% Obtain CCDF measurements
[CCDFy,CCDFx,AvgPwr,PeakPwr] = step(hCCDF1,[sQAMNoisy16
sQPSKNoisy]);
% plot CCDF curves using the plot method of the CCDF object

M = 16; % Size of signal constellation
k = log2(M); % Number of bits per symbol
n = 30000; % Number of bits to process
numSamplesPerSymbol = 1; % Oversampling factor
%Create a binary data stream as a column vector.
rng default % Use default random number generator
dataIn = randi([0 1],n,1); % Generate vector of binary data
%Plot the first 40 bits in a stem plot.
%stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');
%grid on
%Perform a bit-to-symbol mapping.
dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix); % Convert to
integers
%Plot the first 10 symbols in a stem plot.
%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));
%title('Random Symbols');
%xlabel('Symbol Index');
%ylabel('Integer Value');

```

```

%grid on
%Modulate using 16-QAM Apply modulation.
dataMod = qammod(dataSymbolsIn,M,0); % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');

%Create a Constellation Diagram

%Plot the received signal
sPlotFig = scatterplot(receivedSignal,1,0,'g. ');
%hold on
%scatterplot(dataMod,1,0,'k*',sPlotFig)
% Demodulate 16-QAM

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:); % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:); % Return data in column
vector
%Compute the System BER
[numErrors,ber] = biterr(dataIn,dataOut);
fprintf('\nThe binary coding bit error rate = %5.2e, based on %d
errors\n', ...
    ber,numErrors)
[numErrorsG,berG] = biterr(dataIn,dataOutG);
fprintf('\nThe Gray coding bit error rate = %5.2e, based on %d
errors\n', ...
    berG,numErrorsG)
%figure()
EbNo = (0:10)';
M = 16;
%Generate theoretical BER data for QPSK modulation by using the
berawgn function.
%Generate equivalent data for DPSK and FSK.

berD = berawgn(EbNo,'qam',M);

%Plot the results.
%semilogy(EbNo,berD)
xlabel('Eb/No (dB)')
ylabel('BER')
legend('16-QAM')
%grid on

M = 4; % Size of signal constellation
k = log2(M); % Number of bits per symbol
n = 30000; % Number of bits to process
numSamplesPerSymbol = 1; % Oversampling factor
%Create a binary data stream as a column vector.
rng default % Use default random number generator

```

```

dataIn = randi([0 1],n,1); % Generate vector of binary data

%Plot the first 40 bits in a stem plot.
%stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');
%grid on
%Perform a bit-to-symbol mapping.
dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix); % Convert to
integers

%Plot the first 10 symbols in a stem plot.

%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));
%title('Random Symbols');
%xlabel('Symbol Index');
%ylabel('Integer Value');

%grid on
%Modulate using QPSK Apply modulation.

dataMod = qammod(dataSymbolsIn,M,0); % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0

%Add White Gaussian Noise

EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(numSamplesPerSymbol);
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');
%Create a Constellation Diagram

%PlotFig = scatterplot(receivedSignal,1,0,'g. ');
%hold on
%scatterplot(dataMod,1,0,'k*',sPlotFig)

% Demodulate QPSK

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:); % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:); % Return data in column
vector

```



```

%Compute the System BER

[numErrors,ber] = biterr(dataIn,dataOut);
fprintf('\nThe binary coding bit error rate = %5.2e, based on %d
errors\n', ...
    ber,numErrors)
[numErrorsG,berG] = biterr(dataIn,dataOutG);
fprintf('\nThe Gray coding bit error rate = %5.2e, based on %d
errors\n', ...
    berG,numErrorsG)

%figure()
EbNo = (0:10)';
M = 16;
%Generate theoretical BER data for QPSK modulation by using the
berawgn function.

%Generate equivalent data for DPSK and FSK.

berD = berawgn(EbNo, 'qam',M);

%Plot the results.
%semilogy(EbNo,berD)
%xlabel('Eb/No (dB)')
%ylabel('BER')
%legend('16-QAM')
%grid on

% Partial Transmit Sequence is one of the effective techniques for
% peak-to-average power ratio (PAPR) reduction in OFDM systems.
% In this .m file it is simulated for a QPSK modulated, 64-subband
% OFDM symbols.

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% All permutations of phase factor B
p=[1 -1 j -j]; % phase factor possible values
B=[];
for b1=1:4
for b2=1:4
for b3=1:4
for b4=1:4
B=[B; [p(b1) p(b2) p(b3) p(b4)]]; % all possible combinations
end
end
end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

load ofdm_100000 % this is a .mat file contaaining 100000 QPSK
modulated,
                % 64-element OFDM symbols. It is available for free
                % download at the 'file exchange' web page.

NN=1000; % the test is achieved on 10000 OFDM symbols only. It is
        % possible to use all of the 100000 symbols, but it will
        % take more time.
N=64; % number of subbands
L=4; % oversampling factor

```

```

for i=1:NN

    % calculate papr of original ofdm
    time_domain_signal=abs(iff([ofdm_symbol(i,1:32) zeros(1,(L-1)*N) ofdm_symbol(i,33:64)]));
    meano=mean(abs(time_domain_signal).^2);
    peako=max(abs(time_domain_signal).^2);
    papro(i)=10*log10(peako/meano);

    % Partition OFDM Symbol
    P1=[ofdm_symbol(i,1:16) zeros(1,48)];
    P2=[zeros(1,16) ofdm_symbol(i,17:32) zeros(1,32)];
    P3=[zeros(1,32) ofdm_symbol(i,33:48) zeros(1,16)];
    P4=[zeros(1,48) ofdm_symbol(i,49:64)];

    % Transform Pi to Time Domain
    Pt1=abs(iff([P1(1:32) zeros(1,(L-1)*N) P1(33:64)]));
    Pt2=abs(iff([P2(1:32) zeros(1,(L-1)*N) P2(33:64)]));
    Pt3=abs(iff([P3(1:32) zeros(1,(L-1)*N) P3(33:64)]));
    Pt4=abs(iff([P4(1:32) zeros(1,(L-1)*N) P4(33:64)]));

    % Combine in Time Domain and find papr_min
    papr_min(i)=papro(i);
    for k=1:256 % 256 is the number of possible phase factor combinations
        final_signal=B(k,1)*Pt1+B(k,2)*Pt2+B(k,3)*Pt3+B(k,4)*Pt4;
        meank=mean(abs(final_signal).^2);
        peak=max(abs(final_signal).^2);
        papr=10*log10(peak/meank);

        if papr < papr_min(i)
            papr_min(i)=papr;
            sig=final_signal;
        end
    end

end

end

% plot the CCDF of original and pts systems
% N.B. the CCDF function is available for free download at the 'file
% exchange' web page.
%[cy,cx]=ccdf(papro,0.2);
%semilogy(cx,cy,'k')
%hold on
%[cy,cx]=ccdf(papr_min,0.2);
%semilogy(cx,cy,'r')
%grid on
%% Mapping with QAM and AWGN
% Create a rectangular 16 QAM modulator, QPSK modulator, and an AWGN
Channel
hQAM16 = comm.RectangularQAMModulator(16);
hQAM64 = comm.RectangularQAMModulator(64);
hChan = comm.AWGNChannel('NoiseMethod',...
                        'Signal to noise ratio (SNR)', 'SNR', 15);
% Create a CCDF System object and request average power and peak
% power measurement outputs
hCCDF = comm.CCDF('AveragePowerOutputPort', true, ...
                  'PeakPowerOutputPort', true);

% Modulate signals

```

```

    sQAM16 = step(hQAM16,randi([0 16-1],20e3,1));
    sQAM64 = step(hQAM64,randi([0 16-1],20e3,1));
% Pass signals through an AWGN channel
    hChan.SignalPower = 2;
    sQAMNoisy16 = step(hChan,sQAM16);
    hChan.SignalPower = 4;
    sQAMNoisy64 = step(hChan,sQAM64);
% Obtain CCDF measurements
    [CCDFy,CCDFx,AvgPwr,PeakPwr] = step(hCCDF,[sQAMNoisy16
sQAMNoisy64]);
% plot CCDF curves using the plot method of the CCDF object
    %plot(hCCDF)

M = 16; % Size of signal constellation
k = log2(M); % Number of bits per symbol
n = 30000; % Number of bits to process
numSamplesPerSymbol = 1; % Oversampling factor
%Create a binary data stream as a column vector.
rng default % Use default random number generator
dataIn = randi([0 1],n,1); % Generate vector of binary data
%Plot the first 40 bits in a stem plot.
%stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');

%Perform a bit-to-symbol mapping.

dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix); % Convert to
integers

%Plot the first 10 symbols in a stem plot.

%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));
%title('Random Symbols');
%xlabel('Symbol Index');
%ylabel('Integer Value');

%Modulate using 16-QAM Apply modulation.

dataMod = qammod(dataSymbolsIn,M,0); % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0
%Add White Gaussian Noise
EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(numSamplesPerSymbol);
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');
%Create a Constellation Diagram

%subplot(2,1,1);
%hold on
%scatterplot(dataMod,1,0,'k*',sPlotFig)

```

```

% Demodulate 16-QAM

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:); % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:); % Return data in column
vector

%figure()
EbNo = (0:10)';
M = 16;
%Generate theoretical BER data for QPSK modulation by using the
berawgn function.

%Generate equivalent data for QPSK and FSK.

berD = berawgn(EbNo,'qam',M);

%Plot the results.
%semilogy(EbNo,berD)
%xlabel('Eb/No (dB)')
%ylabel('BER')
%legend('16-QAM')
%grid

%% 64

M = 4; % Size of signal constellation
k = log2(M); % Number of bits per symbol
n = 30000; % Number of bits to process
numSamplesPerSymbol = 1; % Oversampling factor

%Create a binary data stream as a column vector.
rng default % Use default random number generator
dataIn = randi([0 1],n,1); % Generate vector of binary data

%Plot the first 40 bits in a stem plot.
%stem(dataIn(1:40),'filled');
%title('Random Bits');
%xlabel('Bit Index');
%ylabel('Binary Value');

%Perform a bit-to-symbol mapping.

dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data
into binary k-tuples, k = log2(M)
dataSymbolsIn = bi2de(dataInMatrix); % Convert to
integers

%Plot the first 10 symbols in a stem plot.

%figure; % Create new figure window.
%stem(dataSymbolsIn(1:10));

```

```

%title('Random Symbols');
%xlabel('Symbol Index');
%ylabel('Integer Value');

%Modulate using QPSK Apply modulation.

dataMod = qammod(dataSymbolsIn,M,0); % Binary coding, phase
offset = 0
dataModG = qammod(dataSymbolsIn,M,0,'gray'); % Gray coding, phase
offset = 0

%Add White Gaussian Noise

EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(numSamplesPerSymbol);
%Pass the signal through the AWGN channel for both the binary and
Gray coded symbol mappings.

receivedSignal = awgn(dataMod,snr,'measured');
receivedSignalG = awgn(dataModG,snr,'measured');

%Create a Constellation Diagram

sPlotFig = scatterplot(receivedSignal,1,0,'g. ');
%hold on
scatterplot(dataMod,1,0,'k*',sPlotFig)

% Demodulate QPSK

dataSymbolsOut = qamdemod(receivedSignal,M);
dataSymbolsOutG = qamdemod(receivedSignalG,M,0,'gray');

%Convert the Integer-Valued Signal to a Binary Signal

dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:); % Return data in column
vector
dataOutMatrixG = de2bi(dataSymbolsOutG,k);
dataOutG = dataOutMatrixG(:); % Return data in column
vector
%Compute the System BER

[numErrors,ber] = biterr(dataIn,dataOut);
fprintf('\nThe binary coding bit error rate = %5.2e, based on %d
errors\n', ...
    ber,numErrors)
[numErrorsG,berG] = biterr(dataIn,dataOutG);
fprintf('\nThe Gray coding bit error rate = %5.2e, based on %d
errors\n', ...
    berG,numErrorsG)

%figure()
EbNo = (0:10)';
M = 16;

```

```

%Generate theoretical BER data for QPSK modulation by using the
berawgn function.

%Generate equivalent data for DPSK and FSK.

berD = berawgn(EbNo, 'qam',M);

%Plot the results.
%semilogy(EbNo,berD)
%xlabel('Eb/No (dB)')
%ylabel('BER')
%legend('16-QAM')
%grid

% -----
% C:  %   +++++   clipping as a PAPR reduction method   +++++
% -----

avg=0.4;
clipped=receivedSignal;
for i=1:length(clipped)
    if clipped(i) > avg
        clipped(i) = avg;
    end
    if clipped(i) < -avg
        clipped(i) = -avg;
    end
end
%figure()
%plot(real(clipped)); xlabel('Time'); ylabel('Amplitude');
%title('clipped Signal');grid on;

%% Mapping with QAM and AWGN
% Create a rectangular 16 QAM modulator, QPSK modulator, and an AWGN
Channel

hQAM16 = comm.RectangularQAMModulator(16);
hQPSK = comm.RectangularQPSKModulator(4);
hChan = comm.AWGNChannel('NoiseMethod',...
                        'Signal to noise ratio (SNR)', 'SNR', 15);
% Create a CCDF System object and request average power and peak
% power measurement outputs
hCCDF = comm.CCDF('AveragePowerOutputPort', true, ...
'PeakPowerOutputPort', true);
% Modulate signals
sQAM16 = step(hQAM16,randi([0 16-1],20e3,1));
sQPSK = step(hQPSK,randi([0 16-1],20e3,1));
% Pass signals through an AWGN channel
hChan.SignalPower = 1;
sQAMNoisy16 = step(hChan,sQAM16);
hChan.SignalPower = 3;
sQPSKNoisy64 = step(hChan,sQPSK);
% Obtain CCDF measurements
[CCDFy,CCDFx,AvgPwr,PeakPwr] = step(hCCDF,[sQAMNoisy16
sQPSKNoisy]);
% plot CCDF curves using the plot method of the CCDF object
%% Mapping with QAM and AWGN
% Create a rectangular 16 QAM modulator, QPSK modulator, and an AWGN
Channel

hQAM16 = comm.RectangularQAMModulator(16);
hQPSK = comm.RectangularQPSKModulator(4);
hChan = comm.AWGNChannel('NoiseMethod',...

```

```

                                'Signal to noise ratio (SNR)', 'SNR', 15);
% Create a CCDF System object and request average power and peak
% power measurement outputs
    hCCDF = comm.CCDF('AveragePowerOutputPort', true, ...
                    'PeakPowerOutputPort', true);
% Modulate signals
    sQAM16 = step(hQAM16,randi([0 16-1],20e3,1));
                                sQPSK = step(hQPSK,randi([0 16-1],20e3,1));
% Pass signals through an AWGN channel
    hChan.SignalPower = 2;
    sQAMNoisy16 = step(hChan,sQAM16);
    hChan.SignalPower = 4;
                                sQPSKNoisy = step(hChan,sQPSK);
% Obtain CCDF measurements
    [CCDFy,CCDFx,AvgPwr,PeakPwr] = step(hCCDF,[sQAMNoisy16
                                                sQPSKNoisy]);
% plot CCDF curves using the plot method of the CCDF object
%plot(hCCDF)

```

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