Computationally Efficient Modified PTS for PAPR Reduction in MIMO-OFDM

Busireddy Venkata Subba Reddy

Department of Electronics and Communication Engineering
National Institute of Technology Rourkela-769008

Computationally Efficient Modified PTS for PAPR Reduction in MIMO-OFDM

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Busireddy Venkata Subba Reddy

(Roll No: 214EC5220)

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Prof. Sarat Kumar Patra

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Department of Electronics and Communication Engineering

National Institute of Technology Rourkela-769008

Department of Electronics and Communication Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Odisha, India.

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Roll Number: *214EC5220*
Name: *Busireddy Venkata Subba Reddy*
Title of Dissertation: *Computationally Efficient Modified PTS for PAPR Reduction in MIMO-OFDM*

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Prof. (Dr.) Sarat Kumar Patra
Principal Supervisor

Department of Electronics and Communication Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Odisha, India.

Dr. Sarat Kumar Patra
Professor

May 31, 2016

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This is to certify that the work presented in the dissertation entitled *Computationally Efficient Modified PTS for PAPR Reduction in MIMO-OFDM* submitted by *Busireddy Venkata Subba Reddy*, Roll Number *214EC5220*, is a record of original research carried out by her under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology* in *Electronics and Communication Engineering*. Neither this thesis nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Prof. (Dr.) Sarat Kumar Patra

Dedicated to My Loving Parents and Friends...

Department of Electronics and Communication Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Odisha, India.

Declaration of Originality

I, ***Busireddy Venkata Subba Reddy***, Roll Number ***214EC5220*** hereby declare that this dissertation entitled ***Computationally Efficient Modified PTS for PAPR Reduction in MIMO-OFDM*** presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections "Reference" or "Bibliography". I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

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May 31, 2016 Busireddy Venkata Subba Reddy
NIT Rourkela

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Busireddy Venkata Subba Reddy
busireddy25542@gmail.com

Contents

Abstract

Nowadays wireless communication has taken its leap for a high data rate using the multi-carrier transmission technique. Orthogonal frequency division multiplexing (OFDM) is one of such popular method for achieving this high information rate. OFDM has several advantages, but one of the main drawback is its high peak-to-average power ratio (PAPR).This is due to a large number of the subcarrier, which leads to distortion problem at receiver. An OFDM signal with the high PAPR requires power amplifiers (PAs) with large dynamic ranges. Such PAs are less efficient, costly to manufacture and very much difficult to design. There have been large number of techniques are available in the literature to reduce the PAPR, such as Partial transmit sequence, Selective mapping, Block Coding, Tone rejection, etc. However, the challenging part is that most of the PAPR reduction schemes come with high computational complexity. Recent PAPR reduction techniques such as partial transmit sequence (PTS) has been considered as most popular for PAPR reduction. This research work explores to find a solution for the PAPR reduction by using PTS technique, which has been implemented by using sub-blocks partitioning. In sub-block partition consists of OFDM data frame which is partitioned into several sub-blocks. An adjacent partitioning (AP) method can be perceived as the best of the existing partitioning method when the cost and PAPR reduction performance are considered together.

In this thesis, PTS technique is applied in MIMO-OFDM. Here, on each transmit antenna we have applied the existing PTS techniques, although the overall PAPR has reduced but it leads to a high computational complexity. A new technique is based on modified PTS using phase rotation and circular shifting to attain the overall reduction of PAPR in MIMO-OFDM system, but computational complexity does not decrease for the same. A Co-operative PTS technique which is mainly based on alternative PTS technique is applied. Here, half of the sub-blocks are only required for optimising the phase weighting factors compared to modified PTS. In this technique although slight loss of PAPR reduction performance is there but with much lower computational complexity.

Keywords: OFDM, PAPR, Partial transmit sequence(PTS), Adjacent partitioning.

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List of Acronyms

Acronym	Description
ACE	Active Constellation Extension
ADC	Analog to Digital Converter
AWGN	Additive White Gaussian Noise
BPSK	Binary Phase Shift Keying
CCDF	Complementary Cumulative Distribution Function
CDMA	Code Division Multiple Access
CP	Cyclic Prefix
CS	Cyclic Suffix
DAB	Digital Audio Broadcasting
DAC	Digital to Analog Converter
FFT	Fast Fourier Transform
HPA	High Power Amplifier
ICI	Inter-Carrier Interference
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LOS	Line of Sight
LTE	Long Term Evolution
MCM	Multi-Carrier Modulation
MISO	Multiple Input Single Output
MIMO	Multiple Input Multiple Output

NLOS	Non-line of Sight
OFDM	Orthogonal Frequency Division Multiplexing
PAPR	Peak to Average Ratio
PTS	Partial Transmit Sequence
QAM	Quadrature Amplitude Multiplexing
QPSK	Quadrature Phase Shift Keying
SER	Symbol Error Rate
SFBC	Space Frequency Block Coding
SI	Side Information
SIMO	Single Input Multiple Output
SISO	Single Input Single Output
SLM	Selective Mapping
SNR	Signal to Noise Ratio
SSCP	Spatial Sub-block Circular Permutation
TDMA	Time Division Multiple Access
TI	Tone Injection
VLSI	Very Large Scale Integration
ZP	Zero Padding
4G	Fourth Generation

Nomenclature

Nomenclature	Description
N	Number of sub-carriers
T_s	Symbol period
τ_{max}	Maximum channel delay
R	Data transmission rate
b_m	m^{th}allowed phase factor
B	Bandwidth of OFDM signal
L	Oversampling factor
W	Number of allowed phase factors in PTS
X_N	Data symbols on N^{th} sub-carrier
σ^2	Variance
$x^{(m)}$	m^{th} Partial Transmit Sequence
$n(t)$	Additive white Gaussian noise
M	Number of sub-blocks in PTS
P_{peak}	Peak power
P_{avg}	Average power
$X^{(m)}$	m^{th} sub-block
$P_r(d)$	Received power
$\tilde{x}_{opt}$	Optimized transmitted symbol
G_r	Gain at receiver antenna

P_t	Transmitted power
G_t	Gain at transmitter antenna
λ	wavelength
N_r	Number of receive antennas
H	Channel matrix
C	System capacity
γ_o	SNR in dB
N_t	Number of transmit antennas
X_{i,n_t}^m	m^{th} sub-block of n_t transmitter
Cs_i	i^{th} Cyclic shifting factor

1
Introduction

Fourth generation (4G) wireless communication system has found its importance all around the globe due to its spectrum efficiency and high information rate of transmission and utilizing advance techniques. This requirement of multimedia data service where the users are in large number and with bounded spectrum, modern digital wireless communication system adopted technologies which are bandwidth efficient and robust to multipath channel environment known as multicarrier communication system. This system provide high information rate at minimum cost for many users as well as high reliability. In a single carrier system, the entire communication transmission depends on only one carrier but in a multicarrier system, the available communication bandwidth is partitioned by many sub-carriers and transmitted. One of the technique is Orthogonal Frequency Division Multiplexing (OFDM).

The basis of OFDM is implied to all Fourth generation (4G) wireless communication systems because of its large number of subcarriers, high information rate and universal coverage with high mobility. In wireless communication which has to improve the performance, it uses promising technology such as Multiple-input multiple-output (MIMO) system. In 4G and 5G wireless communications which has general air interface is Multiple input multiple output - orthogonal frequency division multiplexing (MIMO-OFDM). The restriction of modulation schemes in prevailing communication systems has became an obstruction in further increasing the information rate. Hence, next generation wireless communication systems require further refined modulation scheme and data transmission structure.

1.1 Overview

Multi-carrier system has the requirement for excessive consideration of high information rate. To operate efficiently be capable in the situation of the large information transmission rate, more carrier frequency, and mobility. OFDM fulfil us to study the multicarrier system requirements. In multi-carrier modulation (MCM) scheme which has complex information symbols, for example, M-PSK, M-QAM, etc. are modulated then this parallel transmission over orthogonality of a sub-carrier is known as Orthogonal Frequency Division Multiplexing (OFDM). In single carrier system involves that the entire complex information in one carrier over sub-carrier by parallel transmitted. Here the SC system has same as active data rate transmission of the scheme. The period of the parallel transmission symbol is high and then the multipath delay is decreased due to the amount of separation in time. The inverse Fast Fourier Transform (IFFT) is used be maintain orthogonality among subcarriers in OFDM system. Guard band is inserted in OFDM symbols; there are three types- zero padding, cyclic prefix (CP), and cyclic suffix (CS). OFDM symbols are added to a guard band and converted into wideband channel into narrowband channel, a single channel through each sub-carrier. Therefore, it eliminates Inter-Symbol Interference (ISI). Because of these features like high information rate transmission, more immune to multipath fading and necessity of equalizer complexity is less.

Multiple-input multiple-output (MIMO) system is a promising technology for the performance of wireless communication can be improved. MIMO technology transmits different signals over multiple antennas, it improves the capacity. Research directed throughout in the 1990s demonstrated and it has other well-known air interfaces, for example, Code division multiple access (CDMA) and Time division multiple access (TDMA). If MIMO and OFDM are combined then it is more useful for high information rate transmission. MIMO-OFDM is establishment of most growing for Digital video broadcasting (DVB), Digital audio broadcasting (DAB) and wireless local area network (Wireless LAN) criteria since it succeeds in highest spectral efficiency, in this way to convey the highest capacity and information throughput. Multiple antennas and pre-coding the information, diverse information streams might be sent over various ways. First, Raleigh proposed then later demonstrated MIMO is required to prepare for higher speeds and the most reasonable OFDM modulation is used, then the OFDM changes over a fast information channel into various lower-speed channels in parallel.

1.2 Orthogonality of OFDM System

In multi-carrier system, the channel bandwidth has promising to minimized. The frequency space between the carriers has been reducing the minimization. When the orthogonally among the carriers has to each other the narrow space is obtained. In orthogonality of OFDM system, the time integral product of two signals must be zero. Mathematically, the orthogonality and orthonormal of two signals can be expressed as

$$\frac{1}{T}\int_{t_1}^{t_1+T} f_m(t)f_n(t)dt = \begin{cases} 0 & ifm \neq n \\ 1 & ifm = n \end{cases} \tag{1.1}$$

In OFDM system, the symbol period at last T seconds which has a number of non-zero subcarriers. Hence, the convolution between the spectrum of rectangular pulse and a group of sub-carriers at different frequencies which implies the frequency spectrum of OFDM system. The duration of rectangular pulse is T. The spectrum of rectangular pulse is sinc(fT). The zero points of this function only take place at integer multiples of 1/T. For an assigned sub-carrier frequency point, only the corresponding sub-carrier can have a maximum value with all the other sub-carriers taking the value of zero at this point. Therefore, based on this special property, symbols of each sub-carrier can be extracted from a number of overlapped sub-carriers during the modulation process and without causing any interference effects. Eq.1.2 shows the mathematical expression for this phenomenon as shown in Figure1.1.

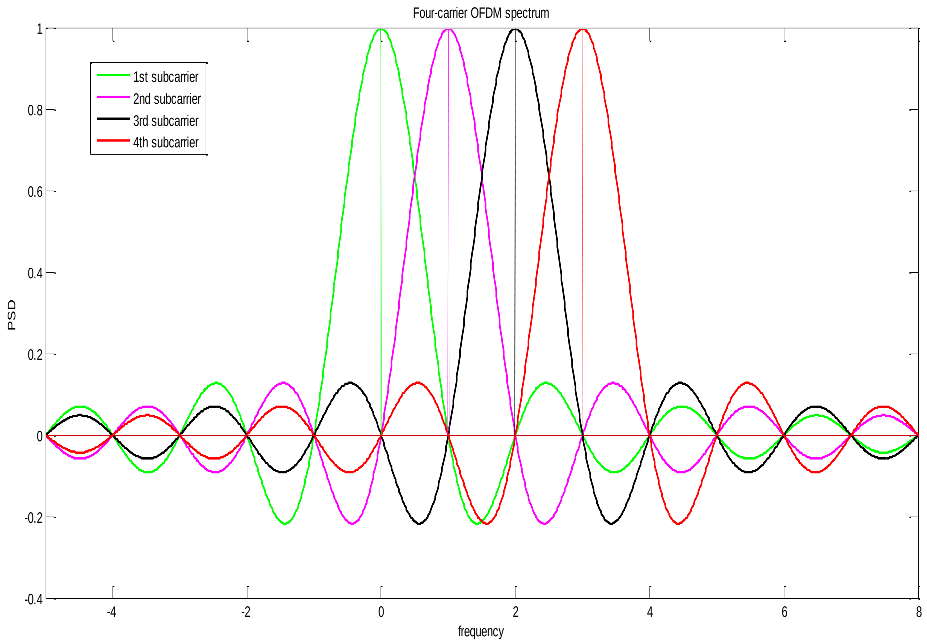

Figure 1.1: Four carrier OFDM system

$$\frac{1}{T}\int_0^T e^{j2\pi f_m t}e^{-j2\pi f_n t} = \begin{cases} 0 & if m \neq n \\ 1 & if m = n \end{cases} \tag{1.2}$$

The sampling of the discrete samples with an instances at t = n T_s = nT/N, $0 \leq n \leq N-1$ The discrete domain can be written as

$$\frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi kn}{N}}e^{-\frac{j2\pi ln}{N}} = \frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi(k-l)n}{N}} = \begin{cases} 0 & if k \neq l \\ 1 & if k = l \end{cases} \tag{1.3}$$

1.3 Advantages and Disadvantages of OFDM system

OFDM system is working as a principle of multipath distortion used for communication techniques. The applications of OFDM system have been prolonged from digital audio broadcasting (DAB), digital video broadcasting (DVB) and telephone networks at high radio frequency [1]. The OFDM multicarrier modulation technique has several advantages:

1. OFDM has high spectral efficiency as compared to other double sideband modulation scheme, because of the OFDM system the sub-carriers are orthogonal to each other and overlapping is allowed in channel spectrum. It is used maximum limited spectrum.

2. Low data rate transmitted in each sub-carrier. Robust against inter symbol interference (ISI) and fading caused by multipath propagation. In OFDM, high-speed serial data streams are transferred to parallel transmission which increases the duration of data symbols carried by corresponding sub-carriers.

3. OFDM system is easy to implement by using VLSI technology. It is because of using the IFFT block at modulation side and FFT block at demodulation side. The number of sub-carriers in OFDM is used for digital signal processing technology.

4. Robust against narrow band co-channel interference.

5. OFDM can use a different transmission rates has to provide different number of sub-channels between downlink and uplink. Present, wireless information services are usually non-symmetrical, that is, uplink channels transfer less traffic than downlink channels. This requires a physical layer that supports non-symmetric high-speed data transmission.

However, OFDM also has some disadvantages are

1. OFDM system has high PAPR requires dynamic transmitter circuitry and it is suffers from poor power efficiency.When the peak power is too large,

then the linear power amplifiers will be out of range. It offers non-linear distortion and the signal spectrum will change. Orthogonality of sub-carrier abolishes and the performance also reduces.

2. Loss of efficiency caused by cyclic prefix or guard interval and sensitivity to Doppler shift.

1.4 Problem Statement

OFDM system has a major drawback with high PAPR. In OFDM system, the output is the superposition of the multiple subcarriers. When these sub-carriers have the same phases, it increases instantaneous power at the output while the mean power of the system should be less. This is also known as large Peak-to-Average Power Ratio (PAPR). We have divided the wide band width into a set of narrow band carriers, by modulating data on this sub carriers and transmitted. Adding the large number of sub-carriers results to PAPR increase and in turn decreases the efficiency of the power amplifiers, because of low efficiency these amplifiers are very expensive. In large peak power, it could be the non-linear power amplifier. It provides the non-linear distortion which has to change the spectrum of resulting signal in performance degradation. PTS technique is used for reducing the PAPR but high computational complexity. In practical applications MIMO-OFDM system is intended to some major problems, if there is no reduction of the high PAPR [2]. To reduce the high PAPR which has some proposed techniques are used. Therefore, some promising PAPR reduction techniques are studied. By reducing the high PAPR the complexity of the system will increases. The reduction techniques proposed have good performance and are estimated by using Matlab software.

1.5 Motivation

In advance OFDM has been possible for the 4th generation wireless communication system. The modern wireless communication system desires to transfer the high data and speed which is especially all around to provided by OFDM.

The multi-carrier signal is used for the implementation of OFDM has lead to concern of high PAPR. Researchers are trying to reduce this PAPR by using several techniques, unwanted distortions or without reducing the information rates of the signal on last few decades. Some techniques are used for good PAPR reduction has to capable, but it offers computational complexity which is very high. While distortion are introduce by some techniques with the low complexity of the signal. Therefore, the method of PAPR reduction has chosen, there is a trade-off among different factors [14]. Among these techniques best one is the PTS technique which offered a specially reduces the PAPR but computational complexity increases. Thus, researchers are having great interest of the PAPR reduction by using this technique but it needs to overcome the effects of loss in data rate and high computational complexity. This technique while improving the disadvantages to keep its advantages is need to consider.

The main motive of this technology is to improve the performance of the PAPR reduction compare to the works. In this technique the implementation the number of IFFTs is used for PAPR reduction and due to the high computational complexity and this concept are based on the new technology has to be designed. MIMO technology provides more information transmission rate along with the diversity gain of the signal. The main motive which is derived from the implementation of the new technique in MIMO technology. Therefore, it can be provide very high information rates and some improvement of the drawbacks on the existing method. MIMO OFDM is a promising technology for reducing the PAPR and some techniques are used for reducing the computational complexity with slight loss of PAPR performance [3].

1.6 Thesis Outline

The thesis has been organised into five chapters. This chapter describes describes about the basics of the MIMO-OFDM system and discusses the problems associated. The following sections are discussed about orthogonality of OFDM system, advantages and disadvantages.The last section was the motivation of the work has been discussed.

Chapter 2: This topic explain about the background of OFDM system and includes their basic structure. Analysis of PAPR problems with the comparative evaluations and PAPR definition are given. It discusses about the different techniques in PAPR reduction and these techniques compare with the different parameters.

Chapter 3: This chapter describes about the ordinary Partial Transmit Sequence technique along with its advantages and disadvantages. Finally, the simulation results of PTS technique are discussed.

Chapter 4: This chapter describes the background of the MIMO technology. It also describes the ordinary PTS in MIMO-OFDM system compare with the proposed techniques are used for the performance of PAPR reduction and the computational complexity.

Chapter 5: In this chapter we describes about the my overall work is concluded and possible suggestions for future work.

2

PAPR Reduction Techniques in OFDM

2.1 OFDM System model

The aim of this chapter is to discuss about the background of the OFDM system which is general concept of the thesis. It briefs about the history of the OFDM system in the mid-1960s. This paper about bandlimited signals to the multichannel transmission. OFDM system which has input bit streams that are modulated by modulation techniques and serial to parallel conversion. The modulated date is given to IFFT block, it is converted to required spectrum into time domain signal. This signal is converted parallel to serial, then it is applied to add guard interval. In multipath radio channel the impairments to moderate for employing a guard interval in the OFDM system. Hardware properties which have to consider several design techniques and the transmitting data symbols are independent to each other through the bandlimited channel without inter-carrier interference and inter-symbol interference. A brief introduction to OFDM system model is given below and introduces the cyclic extension or cyclic prefix and problem of the orthogonal solution.

OFDM system model introduces ideal uncoded BERs for calculations. The Ricean and Rayleigh fading channels are evaluated by using coherent detection and differential schemes. The system offer under analysis, time-direction of the differential detection is much enhanced by frequency direction of the differential detection. The system model is extended to measure by using the channel estimation and Imperfect synchronization. Therefore, the SNR degradations are incorporated because of Inter symbol interference and Inter-Carrier Interference.

2.2 Single carrier and Multi carrier system:

2.2.1 Single carrier system

Single carrier communication system is an end-to-end configuration signal. In the Multipath channel to apply the transmitter, filter added with signals. At the receiver, to minimizing the signal-to-noise ratio (SNR) that receiving signals from a channel is passed through Receiver matched filter and as shown in the figure 2.1.

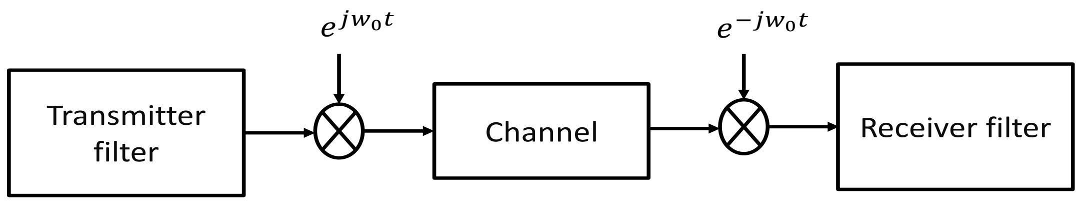

Figure 2.1: Single carrier system

2.2.2 Multi carrier system

Multi-carrier system is used for high data rate transmission, the frequency selectivity of the wideband channel is to overcome by single-carrier transmission. In the Multipath channel to apply the transmitter filter added with the input signals are isolated by a multiplexer. Similarly, the receiver end consists of N parallel paths. Receiver matched filter are used to each path, and incoming signals are delivered through a respective match filter to realize maximum SNR. The basic diagram of a multi carrier system is shown in the figure 2.2.

The multi-carrier system is separating the existing bandwidth into different sub-bands, and different subcarrier frequency has each operating point. In the channel coherence bandwidth must be greater than or equal to the signal bandwidth of each sub-band has to avoid the frequency selective fading, and it increases the information transmission rates when compared to single carrier system fundamentally. In the multi carrier system, wideband signals into several narrowband signals at the transmitter side of a system. The fundamental frequency has been an integral multiple of this carriers, and then this multi-carrier modulation scheme is also known as Orthogonal Frequency Division Multiplexing (OFDM)[4]. Different sub-carriers of the Spectrum can be overlapped, yet the matched filters are used for recovering the data on these sub-carriers without any Inter-Carrier Interference (ICI).

In conventional FDM, the carries are divided into the two sub-carriers and if increase the orthogonal of the sub-carriers has to saving the bandwidth, and finally, the data rate will increase the bandwidth. In a conventional wireless communication system model, at the receiver to receive the transmitted signal with different paths. Thus, the receiving end to removing the original signal come to be difficult. The transmitted signal at time intervals T, then the delay τ_{max} for longest path compare to shortest path while regarding the multipath channel. At the receiver, the previous signals $(\tau_{max})/T$ are influenced by the received signal. In single carrier system, the data transmission rate $R_{sc} = 1/T$ and maximum channel delay is τ_{max}. In the multicarrier system, the original data transmission rate R is multiplexed into N parallel data rate transmission $R_{mc} = R/N$. If N increases then the inter-symbol interference (ISI) will decreases.

2.3 Basic Structure of OFDM System

OFDM system is another type of multi-carrier system. In OFDM block diagram which contains the transmitter, channel, and receiver and is shown in the figure 2.3.

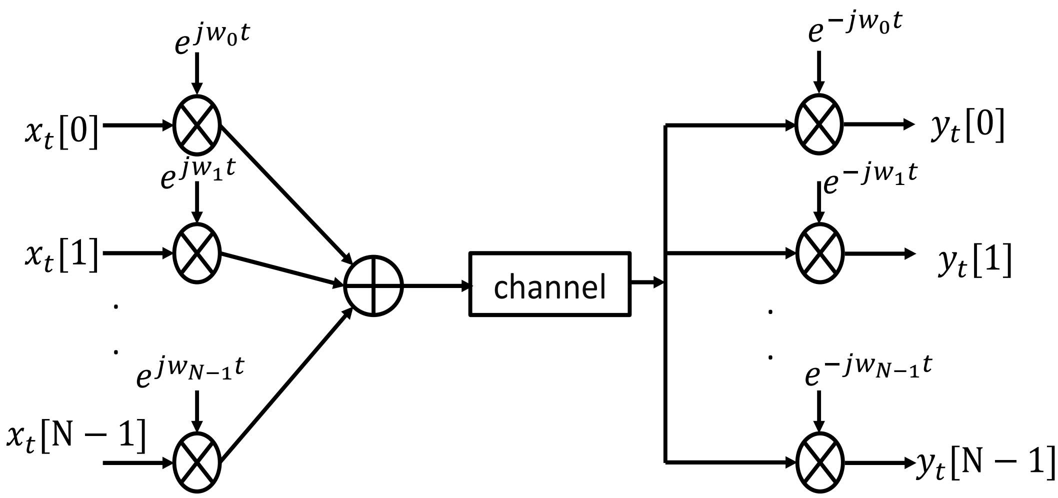

Figure 2.2: Multi carrier system

2.3.1 Transmitter

In OFDM transmission system, the orthogonal of the carriers has to maintain for controlling the relation of all the carriers are successfully generate the OFDM [5]. After generating the OFDM to choose the required spectrum by using based on the modulation technique and the input data. The input bit streams are modulated by different modulation techniques and such bits are transmitted by serial to parallel converter. These methods are used for modulation has some system requirement, for example, BPSK, QPSK, M-QAM, etc. and these modulation techniques are used for calculating the required amplitude and phases. Inverse Fourier Transform (IFT) is used to convert the required spectrum to its time domain signal and to obtain the multiple parallel data bits (X_n) are given to IFFT block. The IFFT performs very efficient transformation and produce the orthogonal of carrier signals are provide simple way to ensure the OFDM signals. The complex baseband transmitted OFDM signal has a block of N symbols $X_n(n = 0, 1, 2, ., N-1)$ is parallel to transmit, and modulates each of them has a group of N subcarriers $f_n(n = 0, 1, 2, ., N-1)$. The orthogonality of subcarriers are each other and $f_n = nf$, where $f = 1/T$. OFDM signal x(t) can be expressed as follows:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi f_n t}, 0 \leq t \leq T \tag{2.1}$$

The signal x(t) at sampling time $t = 1/B = 1/Nf$ is sampled and the bandwidth of OFDM signal is $B = Nf$, the discrete form of an OFDM signal can be expressed as

$$x(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi kn/N}, 0 \leq k \leq N-1 \tag{2.2}$$

Where n denotes the frequency domain of index and X_n is the frequency domain of the complex symbol.

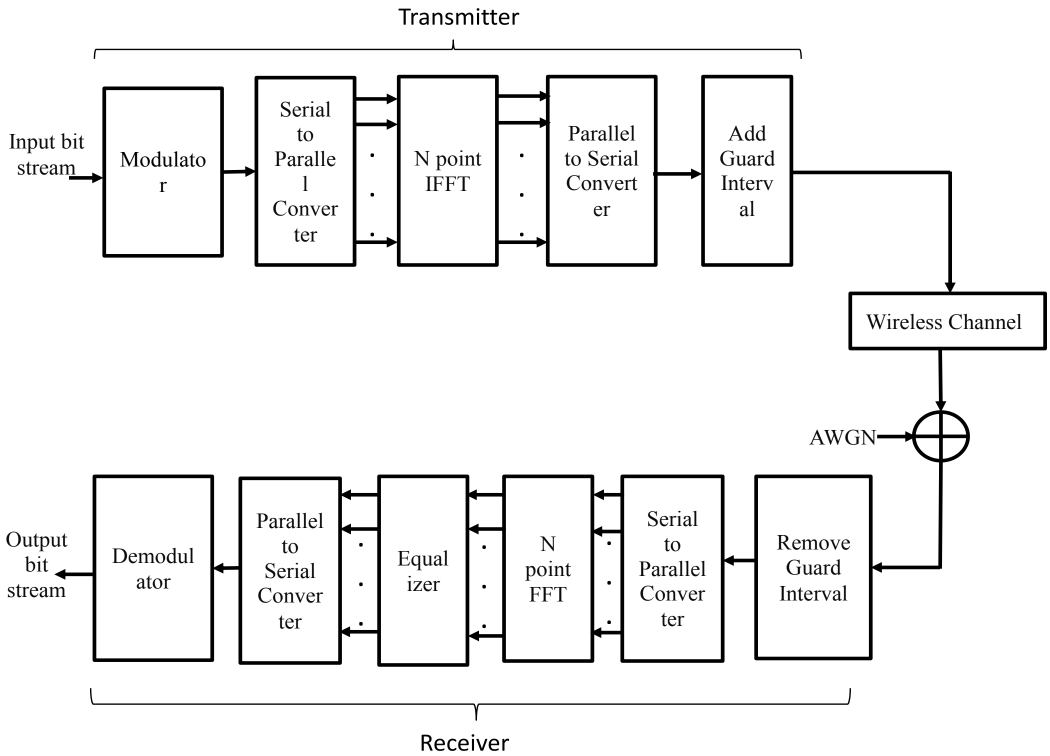

Figure 2.3: Block diagram of OFDM system

2.3.2 Addition of Guard Band

In general presented ISI in between consecutive OFDM symbols, Guard band is used to remove ISI. In OFDM symbols, ISI is causing the delay spread in the multipath channel. To eliminate ISI completely in a guard interval with no use of signal transmission but it is created ICI due to significant spectral components which have happened for fast change of waveform. Guard band consists of a cyclic prefix, zero padding, and cyclic suffix. Parallel to serial data sequence has to convert and then the last L samples copy in one symbol in front of cyclic prefix (CP).

(i). **Cyclic prefix:** In cyclic prefix, the transmitted symbols are occupied with a small portion and the prefix of transmitted symbol are repeated that small portion as shown in the figure 2.4. The delay spread should be less than the length of the cyclic prefix in a multipath channel. If the cyclic prefix length is less than the delay spread of the multipath channel, then the next OFDM symbol on starting portion will be altered by the end portion of previous OFDM symbol, prominent to ISI. The delay spread less than the length of the cyclic prefix of the multipath channel retains the orthogonal of the subcarriers.

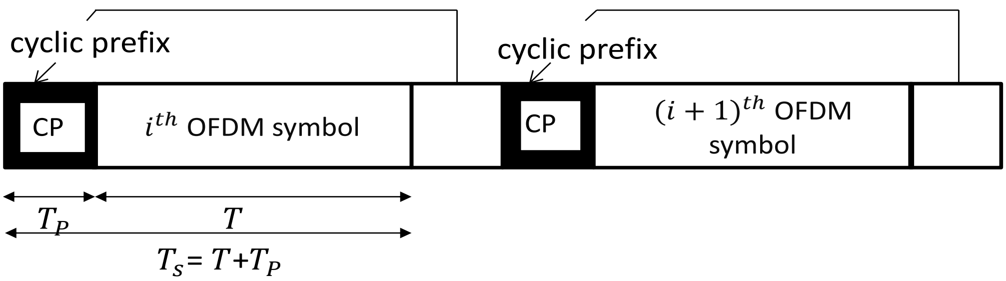

Figure 2.4: OFDM symbol with cyclic prefix

(ii). **Cyclic suffix:** In cyclic suffix, the transmitted symbols are occupied with a small portion and the suffix of transmitted symbol are repeated that small portionas shown in the figure 2.5. It copies OFDM symbol on starting portion to the end portion the symbol to moderate ISI. This method of insertion of guard band is used for radio frequency (RF) convergence and frequency hopping.

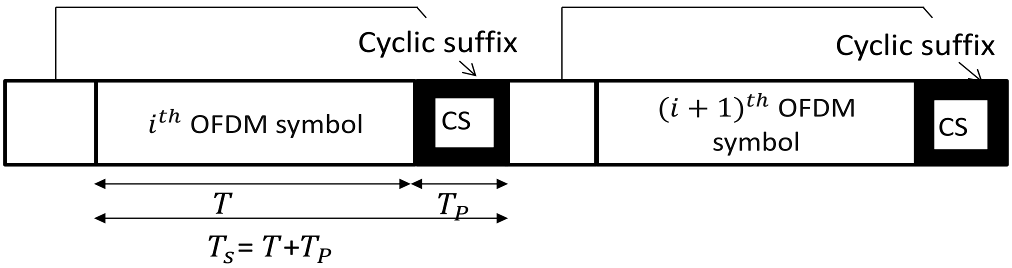

Figure 2.5: OFDM symbol with cyclic suffix

(iii). **Zero padding:** In zero padding (ZP) the starting portion and the end portion of the transmitted symbols are occupied with zeros as shown in the figure 2.6.

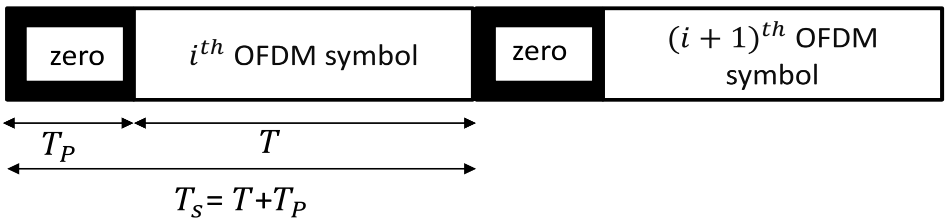

Figure 2.6: OFDM symbol with zero padding

2.3.3 channel

The multipath phenomenon can be estimated the noise by using channel model. In OFDM symbol has to add the random data then it will generate the noise, to add the attenuation then it will generate the multipath system and delayed copies of the OFDM signal. In wireless channel the impulse response $h(\tau - t)$ can be expressed as

$$h(\tau - t) = \sum_{l=0}^{L-1} h_l(t)\delta(t - \tau) \tag{2.3}$$

The tap coefficients h(t) are exhibited as complex Gaussian random variables have mean zero and variance one [5]. In wireless signal has to provide a proper location on Rayleigh fading model and Rayleigh distribution function amplitude follows due to multipath channel and its probability density function (pdf) is defined as

$$f(x) = \frac{x}{\sigma^2} exp\Big\{-\frac{x}{2\sigma^2}\Big\} \tag{2.4}$$

Where σ^2 is a variance and x is an envelope of a received signal. In Rayleigh distribution function, it is along with non-line of sight (NLOS) between the receiver and the transmitter on the propagation of the signal. After the fading of multipath channel $h(\tau, t)$, the received signal y(t) is

$$y(t) = \sum_{l=0}^{L-1} h_l(t) x_{ext}(t - \tau) + n(t) \tag{2.5}$$

Where n(t) is a Additive white Gaussian noise (AWGN).

2.3.4 Receiver

At the receiver, inverse operation of the transmitter side. The starting part of receiver removes the guard band of OFDM symbol. Then, these OFDM symbol is converted to serial to parallel are passed in FFT (Fast Fourier Transform) block, and N-Points FFT has to lead on left recover the sample points to the information in frequency domain. The FFT operation output can be expressed as

$$X(k) = P(k)x(k) + w(k), k = 0, 1, , N - 1 \tag{2.6}$$

Where w(k) is an AWGN component in frequency domain In multipath fading channel the FFT frequency response P(k) can be expressed as

$$P(k) = \frac{1}{\sqrt{N}} \sum_{l=0}^{L-1} h_l e^{\frac{-j2\Pi kn}{N}} \tag{2.7}$$

These FFT parallel OFDM data streams are passed through the equalizer. The complex received data symbol x(k)are recovered by the frequency response of the equalizer. The equalizer output is converted by parallel to serial converter and finally, the recover received symbols are converted into serial data stream by using some demodulation techniques, for example, BPSK, QPSK, M-QAM, etc. to baseband which ultimately recovers the original data.

2.4 PAPR in OFDM system

The system devices required that D/A converters and, A/D converters should have linearly large dynamic ranges in power amplifiers. OFDM system one of the main drawback is PAPR. OFDM symbol waveform produces PAPR because of linearly large dynamic range. At the transmitter side, if the peak signal enters into the non-linear region of the devices, then the inter-modulation distortion and out of band radiation are high when it is not satisfied come across a series of unwanted interference. The transmitted signal in OFDM system major issue is high PAPR, which reduces the performance by using the non-linear high power amplifiers (HPA). Therefore, OFDM systems have more importance for PAPR reduction methods at the transmitter side [6].

IFFT pre-processing fundamental advances high PAPR in OFDM system and this signal contains independent number of modulated subcarriers added with same phases then it produces significant peak value. If data symbols added across sub-carriers, it increases peak value signals. If signal swing is inadequate that linear or dynamic range then it is linearly related to input and output for example, voltage deviation is small then the amplification of the signal is confined to the linear range but signal swing has very high instant power in OFDM system compare to single carrier system. If it will enter into non-linear region then it is non-linear amplification [7]. All the properties of OFDM signals are lost because of non-linear amplification for example orthogonality is lost.

2.5 Impact of PAPR on the system

At the transmitter side, high power amplifier (HPA) is used in radio system to attain maximum output power efficiency. The operating point of HPA is generally near the saturation region. The high power amplifiers in nonlinear characteristics are very kind to the signal amplitudes difference. This difference is large in the OFDM amplitudes with the high PAPR. Therefore, the HPA with high PAPR introduces system interference and intermodulation between different sub-carriers. The linear amplification of a signal has more power back off due to the high PAPR forces the amplifier, and the power efficiency is poor.

Digital to Analog Converter (DAC) of the OFDM signals have to enough dynamic range to accommodate the massive peaks due to the high PAPR. Digital to Analog Converter (DAC) is support to high PAPR with less quantization noise has high accuracy, and more quantization noise has low accuracy. The signal follows Gaussian distribution for the number of subcarriers in OFDM system. Analog to Digital Converter (ADC) is no need for uniform quantization and this type of a distribution rarely occur for the average of the peak value signal. When the signal in power amplifier enters into non-linear region, then it causes Out-of-band radiation and Inter-carrier interference. The most significant impact of high PAPR on the system are-

1. Efficiency can be reduced in radio frequency amplifiers.

2. Complexity Increases in the DAC and ADC.

2.6 PAPR Definition

The variation of the signal envelope which is expressed in the form of a ratio of the peak power to the average power of the signal, and it is known as the peak-to-average power ratio. OFDM system is defined as Peak-to-Average Power Ratio with high peaks is denoted as PAPR, and it is also written as PAR. It is given by

$$PAPR = \frac{P_{peak}}{P_{avg}} = 10log_{10}\frac{max[|x_n|^2]}{E[|x_n|^2]} \tag{2.8}$$

Where $P_{peak}$is a peak power, $P_{avg}$is an average power. OFDM signal in continuous-time are considered can be represented as

$$x(t) = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n e^{j2\Pi f_n t}, 0 \leq t \leq NT \tag{2.9}$$

PAPR is measured by the envelope fluctuations of an OFDM signal. The PAPR of the transmitted OFDM symbol x(t) is the ratio of peak instant power to the average power of the signal, which can be mathematically represented as

$$PAPR = \frac{\max\limits_{0 \leq t \leq NT} |x(t)|^2}{E\left[|x(t)|^2\right]} \tag{2.10}$$

Where

$$E\left[|x(t)|^2\right] = \frac{1}{NT}\int_0^{NT} |x(t)|^2 \, dt \tag{2.11}$$

The above equation gives the PAPR of the analog signal. Nyquist criteria is used to obtaining the exact time domain signal which is consider that the OFDM signal is expanded with $(L-1)N$ zeros. Therefore, the L times oversampled data can be represented as

$$X = [x_0, x_1, x_2, .., x_{NL-1}]^T \tag{2.12}$$

OFDM signal in discrete-time of a representation can be considered as

$$x_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi kn/LN}, 0 \leq k \leq NL-1 \tag{2.13}$$

In the OFDM signal which has L times oversampling data of PAPR can be expressed as

$$PAPR = \frac{\max\limits_{0 \leq k \leq NL-1} |x_k|^2}{E\left[|x_k|^2\right]} \tag{2.14}$$

Where E[.] denotes expectation operation.

2.7 Analysis of PAPR

In PAPR analysis has to use one of the most prevalent parameters is the Cumulative Distribution Function (CDF) for measuring the efficiency of any PAPR reduction technique [8]. The performance is measure for PAPR reduction techniques used the Complementary Cumulative Distribution Function (CCDF) instead of CDF that helps to determine the probability that the PAPR of OFDM symbols of an information block greater than the threshold PAPR value and it is computed by Monte Carlo Simulation. In central limit theorem to implement the large number of sub-carriers (N) in the multi-carrier signal, the time domain signals of the real part and the imaginary part have a zero mean and a variance is 0.5. Therefore, In the multi-carrier signal of the amplitude is followed by Rayleigh distribution, where the system of the power distribution has the freedom of two degrees by using the central chi-square distribution. The signal amplitude of the CDF is given by $F(z) = 1 - e^{-PAPR_o}$. The data block has N symbols with the Nyquist rate sampling and then the CCDF of the PAPR can be expressed as

$$Pr(PAPR > PAPR_o) = 1 - (Pr(PAPR \leq PAPR_o)) = 1 - (1 - e^{-PAPR_o})^N \tag{2.15}$$

2.8 PAPR Reduction techniques

PAPR reduction methods can be generally classified into domain methods: frequency domain method and time domain method. In frequency domain method is to increase the cross correlation coefficient of the input signal before IFFT and decreases the output of the IFFT peak value or average value. In time domain method, PAPR is reduced to distortion signal before amplification and addition of extra signals to increase the average power. Time domain methods are very simple method because they require very low computational time but introduce distortion, increase out of band radiation. Time domain methods are also known as signal distortion techniques. On comparing these two methods, frequency domain PAPR Reduction Techniques is the efficient one because its ability to reduce the PAPR without distorting the transmitted signal, without out-of-band radiation and Inter-carrier interference of the OFDM signals. Frequency domain method is also known as Signal scrambling techniques. The main objective of each technique which has PAPR reduction of the signal can be transmitted before. These techniques are mainly two groups and is shown in the figure 2.7.

1. Signal scrambling techniques
2. Signal distortion techniques

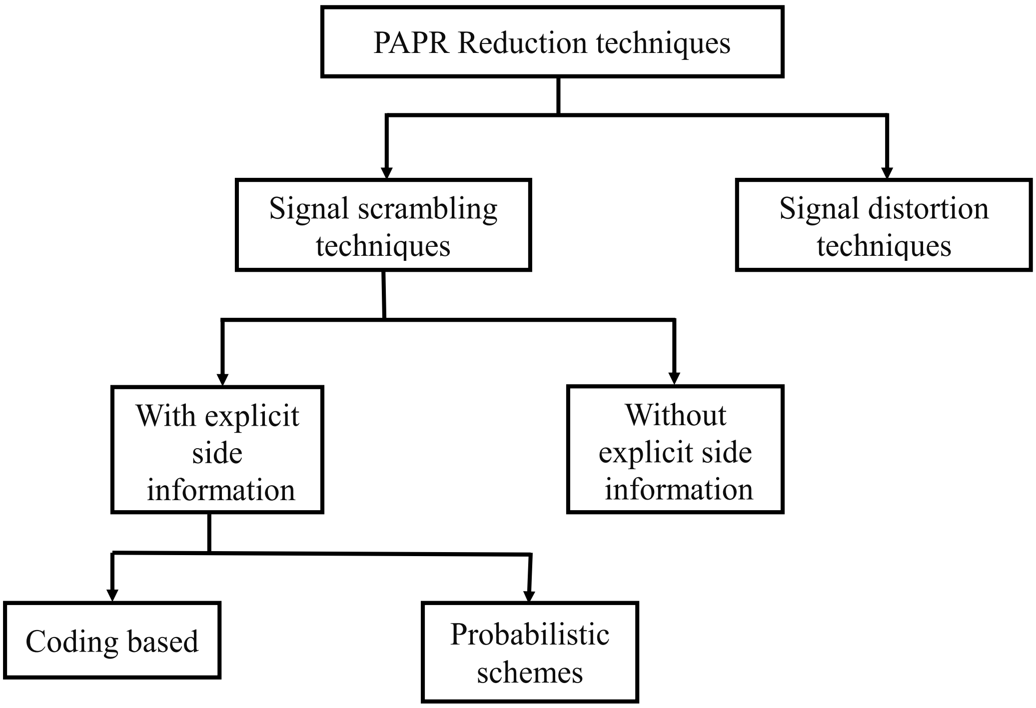

Figure 2.7: Classifications of PAPR reeduction techniques

2.8.1 Signal scrambling techniques

A signal scrambling technique has different scrambling techniques which are the scramble to each OFDM symbol, and the smallest PAPR value is selected in the sequence. Signal scrambling techniques are with explicit side information and without explicit side information. In with explicit side information are divided into two types: Coding based and Probabilistic schemes. In without explicit side information is divided into two types: Hadamard transform method and Dummy sequence insertion.

Coding based

- Block coding scheme
- Sub block coding scheme

- Block coding with error correction

Probabilistic schemes

- Active constellation extension (ACE) technique
- Interleaving
- Tone reservation (TR)
- Selective mapping (SLM) technique
- Tone injection (TI)
- Partial transmit sequence (PTS) technique
- Standard array of linear block coding

2.8.2 Signal distortion techniques

Signal distortion techniques can be PAPR reduction with distortion to the non-linear OFDM signal. These techniques can be applied to the OFDM signal after the generation (after the IFFT).

- Signal clipping
- Peak windowing
- Envelop scaling
- Random phase update
- Peak reduction carrier
- Companding

In the above PAPR reduction techniques, Signal scrambling techniques is selected because data loss is minimum. In these paper, among various probabilistic scheme PTS technique chosen due to compare with others complexity and computational time.

2.9 Selection of the criteria in PAPR Reduction techniques

There are many factors that must be considered to selecting before a specific for PAPR reduction in the OFDM signal[9]. All the parameters are listed below and if any of these techniques may not be satisfied, yet there is a requirement of trade-off among these factors of the method is selected.

- Computational complexity
- Capability of PAPR reduction
- Increase power in transmitted signal
- BER performance
- Data rate

2.9.1 Computational complexity

This technique of the hardware implemented that is related to Computational Complexity. It may satisfy the other limitations like computational complexity cost but in time process of the signal the complexity increases, the required power and also the system cost. Thus, the performance of the system has needed to speed up by reducing the computational complexity [10].

2.9.2 Capability of PAPR reduction

The OFDM signal is applied to the technique for PAPR reduction capability. The best technique is considered as high PAPR reduction and it is evaluated by using CCDF curves.

2.9.3 Increase power in transmitted signal

PAPR reduction techniques are used before transmitting the signal which has required to increase the power in Some techniques. If the signal power increases then the allowable limit must be within the range.

Technique	Distortion less	Power increase	Data rate loss	Computational complexity
Partial transmit sequence	Yes	No	Yes	Very high
coding	Yes	No	Yes	Moderate
Selective mapping	Yes	No	Yes	High
Tone injection	Yes	Yes	No	Moderate
Tone reservation	Yes	Yes	Yes	Moderate
Amplitude clipping and filtering	No	No	No	Less
Interleaving	Yes	No	Yes	Moderate
Active constellation extension	Yes	Yes	No	Moderate

Table 2.1: Differences between some techniques in PAPR reduction.

2.9.4 BER increases at receiver

The PAPR reduction is to attain better performance of the system including bit error rate (BER) than the original OFDM system. The distortion of the signal is caused by this technique when it is applied then the bit error rate increases at the receiver.

2.9.5 Data rate loss

These techniques are needed additional side information that is transmitted to the receiver and the received signal can be recover the information. Data rate is reduced by additional side information therefore, it is needed to consider that the side information are added for selecting the technique.

The performance of different techniques based on the table 2.1 lists above criterias mentioned [11].

3

PTS Technique for PAPR Reduction

3.1 Partial Transmit Sequence Technique

In this chapter, we discussed about the OFDM system for PAPR reduction by using Partial Transmit Sequence technique. The history of this technique in 1997, it is proposed by J. B. Huber and S. H. Muller about high data transmission. In OFDM framework caused a high PAPR is the negative part tended to various methods for decreasing the PAPR are prepared as critical impact. The PAPR reduction some methods has to moderate the low computational complexity and some methods has high computational complexity, but high PAPR improved performance. In Partial Transmit Sequence (PTS) technique has to conform excellent PAPR reduction performance at high computational complexity. A block diagram and numerical mathematical statements are supported to describe the current PTS method. In OFDM system, the problem of high PAPR sustained is given as the PAPR reduction methods are used to reducing the PAPR for particular threshold value that can eliminate the critical effects.

Partial Transmit Sequence technique, N symbols of data block in input is divided into several sub-blocks, and it is transmitted [12]. In sub-block partitioning has to affect the performance of PAPR reduction is another factor in PTS and in this method the number of subcarriers are divided into several sub-blocks. It is characterized into three types of sub-block partition methods namely pseudo-random,interleaved,and adjacent sub-block partition. The PTS methods work with any modulation technique and an arbitrary number of subcarriers [13]. Partial Transmit Sequence (PTS) technique of the main objective after the IFFT blocks is scramble the partitioned by using phase rotation factors that is $\pm 1, \pm j$ for QPSK are taken within the transmitter [14]. The minimum PAPR are selected in the optimal sequences. In PTS technique has two main drawbacks are the high computational complexity and to recover the side information. When PTS method needs to search completely for the overall arrangements of optimal phase factors are permitted and to explore the number of sub-blocks increased exponentially are caused by high computational complexity. At the receiver side has to recover the side information safely from the transmitter is also another problem.

3.2 PTS for SISO-OFDM system

In SISO-OFDM system, the PTS technique is promising technique compare to the remaining techniques of the PAPR reduction in the multi-carrier transmission. This technique is based on the data of sub-blocks are phase shifted then the data structure is multiplied by random vectors. PTS technique of the OFDM system is discussed below as shown in the figure 3.1

3.2.1 PTS transmitter

In OFDM system, the data source of serial input data is converted into parallel data is needed for transmission. The possible block of the parallel data is partitioned into disjoint sub-blocks with the same length of data for each sub-block in the original parallel block. The length of the parallel data block of the sub-carriers and the length of each sub-block will be N. These N subcarriers of input data are divided into several sub-blocks, then the every sub-block has some non-zero subcarrier values and some zero subcarrier values. The subcarriers are divided into several sub-blocks by using different sub-bock partitioning methods. Hence, if all the sub-blocks are effectively adding that gives the original parallel data block. Each sub-block is passed through each IFFT block which performs Inverse Fast Fourier transform and each IFFT block output is mentioned as Partial transmit sequence [15].

This technique is used for rotating the allowed phase factors are predefined, and it is characterized by approved set of phase values to select the predefined phase factors for one complete phase rotation PTSs added up to become a candidate signal in PTS. The process is repeated with the set of different phase vectors can be multiplied with PTSs, and it is repeated until to complete the all possible phase factor combinations. Therefore, the more candidate signals are generated, then the PAPR value is compared with all candidate signals, and one of the minimum PAPR value is selected for transmitting the required OFDM symbols.

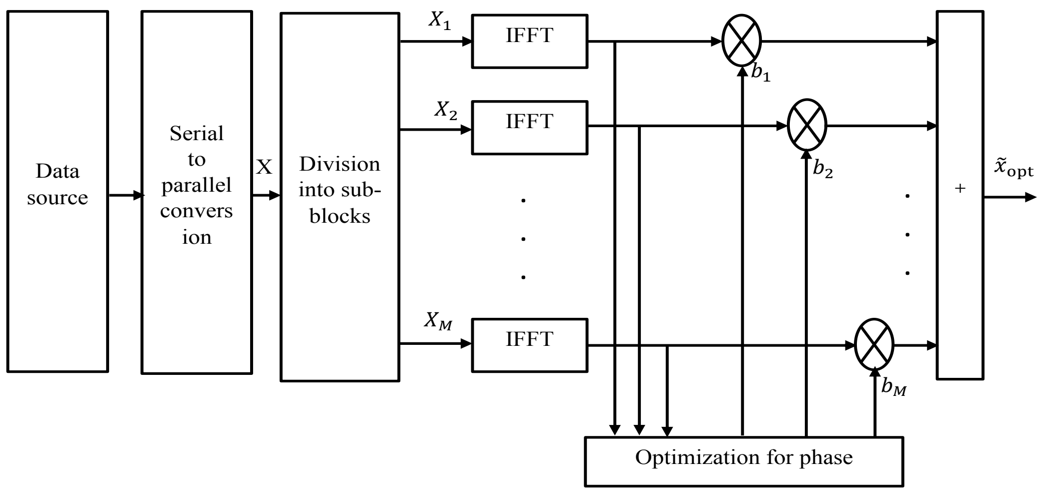

Figure 3.1: PTS technique for SISO OFDM

3.2.2 Mathematical analysis

In PTS technique, the N subcarriers of an input data block is separated into several sub-blocks and are filled the blank parts with zeros. Each sub-block has some subcarriers then the phase factor is weighted for particular sub-block. The selection of the phase factors has to minimize the PAPR on the combined signal.

The Complex Envelope of the transmitted OFDM signal is

$$x_n(t) = IFFT(X) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi f_n t}, 0 \leq t \leq NT \tag{3.1}$$

In the ordinary PTS technique the M disjoint sub-blocks is partitioned by input data block X is

$$X = \sum_{m=0}^{M-1} X^{(m)}, Where X^{(m)} = \left\{ X_0^{(m)}, X_1^{(m)}, ., X_N - 1^{(m)} \right\} \tag{3.2}$$

The time domain signal has L-times oversampled as $X^{(m)}$, m = 0,1,2 ,.,M-1, is attained by the IFFT has taken of the length NL on $X^{(m)}$ together in a series with $(L-1)N$ zeros. Therefore, the Sub-blocks $X^{(m)}$ are transform into Partial Transmit Sequences in Time-domain by IFFTs $x^{(m)} = IFFT(X^{(m)})$. The phase factors are used rotating independently the Partial transmit sequences can be expressed as

$$b_m = e^{j\theta_m}, \theta_m \epsilon \left\{ \frac{2\Pi k}{w} |_{k=0,1,2,\ldots,w-1} \right\} \tag{3.3}$$

Optimized transmitted symbol of PAPR reduction can be generated as

$$\tilde{x}_{opt} = \sum_{m=0}^{M-1} b_m x^{(m)} \tag{3.4}$$

In general, the selection of the allowed phase elements can be reducing the computational complexity and it has less number of elements. If set the value $b_1 = 1$ then the performance has no loss. Such that, the complete $M-1$ phase elements has to perform. Therefore, W^{M-1} collections of phase elements are looked to locate the set of phase elements are optimized. The number of sub-blocks M are increases exponentially to search complexity. The amount of reducing the PAPR mainly depends on the number of phase elements W and the number of sub-blocks M. The sub-block partition is also factor that might be influence on the PAPR reduction performance in PTS, these method is used for number of the subcarriers are divided into several sub-blocks.

3.2.3 PTS Receiver

OFDM communication system has transmitted decoded data are needed at the receiver. The signal is received form the transmitter is multiplied with conjugate receiving the phase factors. At the receiver side has to obtain the number of sub-blocks which is dependent on the phase arrangements are received. At the transmitter side these sub-blocks are indicated that the phase sequences are received. All the received data sub-blocks are transferred through the FFT block and each sub-block has to perform as Fast Fourier transform. If combining these sub-blocks to become a one parallel data block.

At the transmitter side the partition technique is used that is depended by the combination of these sub-blocks. The parallel data block is obtained which consists of the N information symbols and to perform the demodulation of the low pass signal. In every subcarrier the baseband demodulation is performed and the OFDM system which is transmitted the original information. The parallel to serial converter is used for the existing parallel information block is converted into serial information. Finally, it gives the required serial information.

3.3 Sub-block partitioning

The PTS technique works with any modulation scheme and the number of subcarriers. The sub-block partitioning is used for the performance of PAPR reduction in PTS it may affect, and this method is used of the subcarriers are divided into several sub-blocks [16]. It is characterized into three types of sub-block partition schemes.

- Interleaved sub-block partition

- Adjacent sub-block partition
- Pseudo-random sub-block partition

3.3.1 Interleaved Sub-block partition

Here every sub-block has fixed interval that are allocated the sub-carriers with non-zero values. If subcarriers are partitioned into M sub-blocks, then the first sub-block is allocated to every M_{th} sub-carrier will be non-zero. Likewise, remaining sub-blocks are also assigned the sub-carriers are significantly non-zero and the remaining sub-carriers are zeros [17]. The Interleaved Sub-block Partition is more arbitrary compared to adjacent sub-block partition but the sub-blocks has a certain level of affiliation exists because of fixed arrangement of sub-carriers are shown in the figure 3.2.

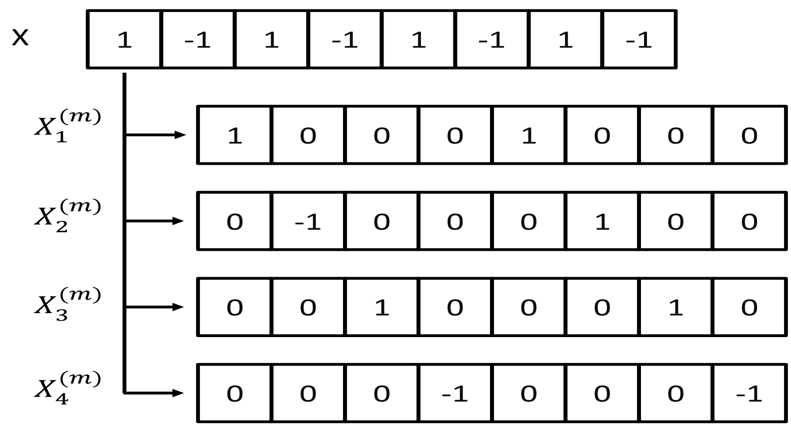

Figure 3.2: Interleaved partitioning

3.3.2 Adjacent Sub-block Partition

In this partitioning, the total number of N sub-carriers are divide into M sub-blocks and the primary sub-block are allocated by the starting N/M sub-carriers and remaining are allotted with zeros. Similarly, the second sub-block the following N/M sub-carriers are non-zero values and remaining are allocated with zeros are shown in the figure 3.3. Adjacent partitioning scheme offers the performance PAPR reduction is significant with relatively less computational complexity.

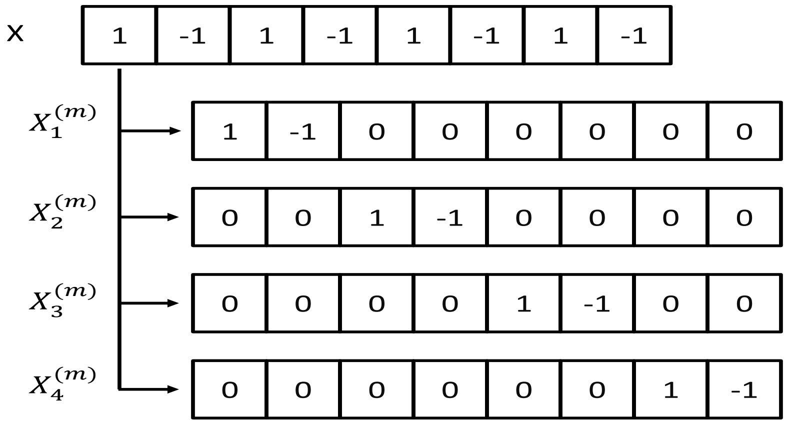

Figure 3.3: Adjacent partitioning

3.3.3 pseudorandom Sub-block partition

In pseudorandom partitioning, the total number of N subcarriers is assigned randomly into M sub-blocks. Every sub-block allocated by N/M subcarriers randomly and remaining subcarriers can be zeros. It is discussed that can achieve the good PAPR reduction performance but high computational complexity. This pseudorandom sub-block partitioning are shown in the figure 3.4.

3.4 Advantages and disadvantages of PTS technique

PTS technique has some advantages and disadvantages compare to the other techniques.

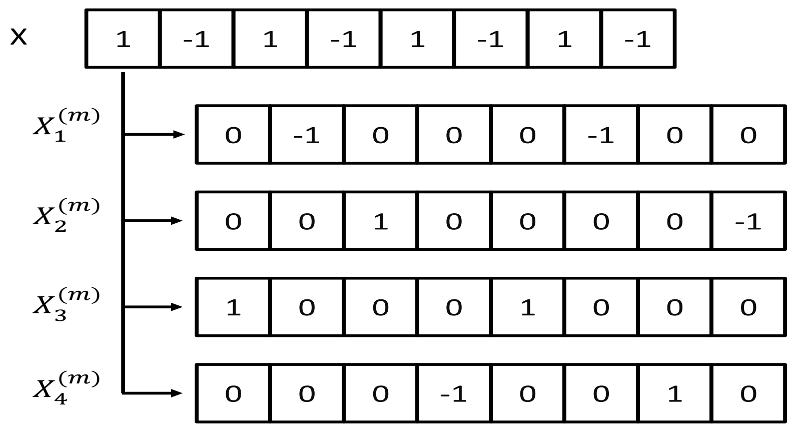

Figure 3.4: Pseudo-random partitioning

3.4.1 Advantages of PTS technique

(i). **Less distortion technique:** In OFDM system is processed by PTS technique without any distortions at the receiver. Therefore, it will not affect the performance of symbol error rate.

(ii). **Arbitrary number of sub-carriers it works:** In this system is to be use numbers of sub-carriers are not depending on the PTS technique. If the number of sub-carriers is increases then the system information rate also increases. Thus, it is possible for arbitrary number of sub-carriers by using PTS technique.

(iii). **Performance of PAPR reduction:** When compared to other techniques, PTS is the best technique for the performance of PAPR reduction. It offers that it is a best advantage compare to other advantages by this technique.

(iv). **Any modulation it works:** It is used for different sub-carriers on the PTS technique which has no restrictions on the modulation [18]. Therefore, in this PTS technique as including BPSK and QPSK has to possible the higher order modulation techniques can be used.

(v). **Flexibility:** The number of sub-blocks, type of modulations, the number of sub-carriers, and the allowed number of phase vectors are the parameters independent provided by the PTS technique. Hence, it is possible as per our requirement to implement and as per our need can modify.

3.4.2 Disadvantages of PTS technique

In the PTS technique has more advantages but some disadvantages also needed to be considered.

(i). **Computational complexity increases:** In the PTS technique which has the high computational complexity is main drawback of the system. This technique number of IFFT blocks is used for PAPR reduction but increases the computational complexity of the technology and needed number of iterations has to perform getting different candidates of the signal [13]. It needed number of iterations has to perform because of reducing the performance of PAPR mainly dependent on the number of candidate signals of the technique [19].

(ii). **Loss of information rate:** The information of the phases are needed for retrieving the OFDM signal, at the receiver side. In the side information, the data about the phase factors are needed to be transmitted with the OFDM symbol. The data rate of the system decreases by this side information. If less number of sub-blocks with more number of sub-carriers and allowed phase sequences are used to minimizing this drawback.

3.5 Simulation Results

3.5.1 Performance of CCDF curve

The simulations are evaluated in MATLAB R2013a of the OFDM signal for the PAPR reduction by using PTS algorithm. QPSK modulation is applied to both the interleaved and the adjacent sub-block partition schemes which has M=4 sub-blocks that Simulations are performed, and ± 1 *or* $\pm 1, \pm j$ the two phase factors are chosen. The performance curves of CCDF is plotted with the probability of PAPR signal is greater than the threshold PAPR on Y-axis and the reference

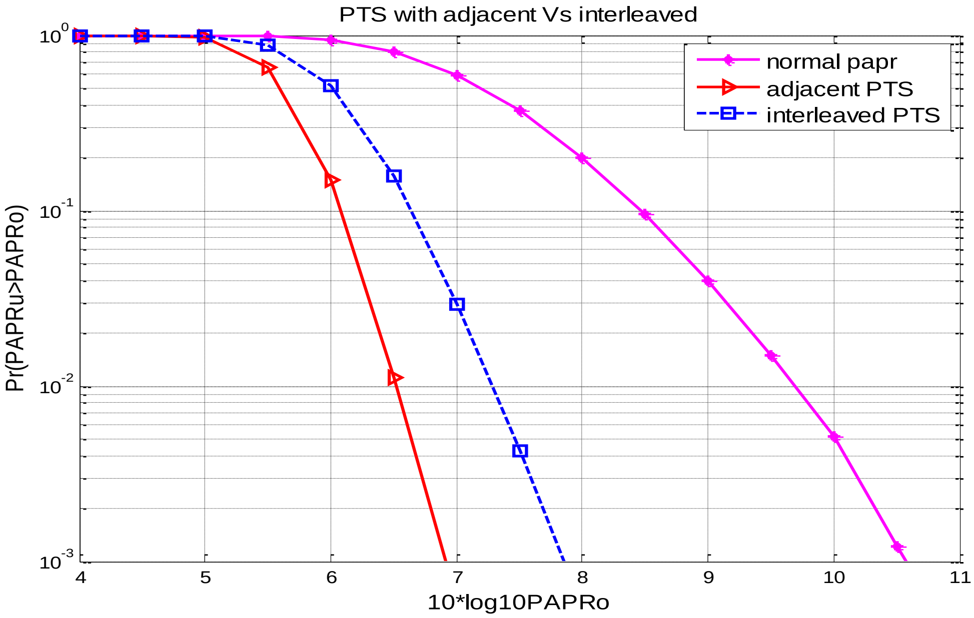

Figure 3.5: CCDF of the PAPR performance for PTS with adjacent Vs. interleaved

threshold PAPR on X-axis.

The performance of the PAPR reduction using PTS technique for different sub-block partition methods with N = 128 and M=4. As shown in figure 3.5, the CCDF curve which is represented by solid line is adjacent PTS and dotted line is based on the interleaved PTS. Therefore, the PAPR of the OFDM signal is observed that the adjacent partition is less when compared to the interleaved partition. The number of candidate signals is provided same for both the partitioning methods. The PAPR value is same for different candidate signals in interleaved partition scheme but the candidate signals having different PAPR values in adjacent partition scheme. Therefore, the resulting PAPR decreases in adjacent partition scheme.

The CCDF curve of PTS technique is based on the values mentioned in the above Table 3-1 and it is compared without using any technique to the CCDF curve of normal OFDM signal. The various factors are considered in the table 3.1 for Figure **??**.

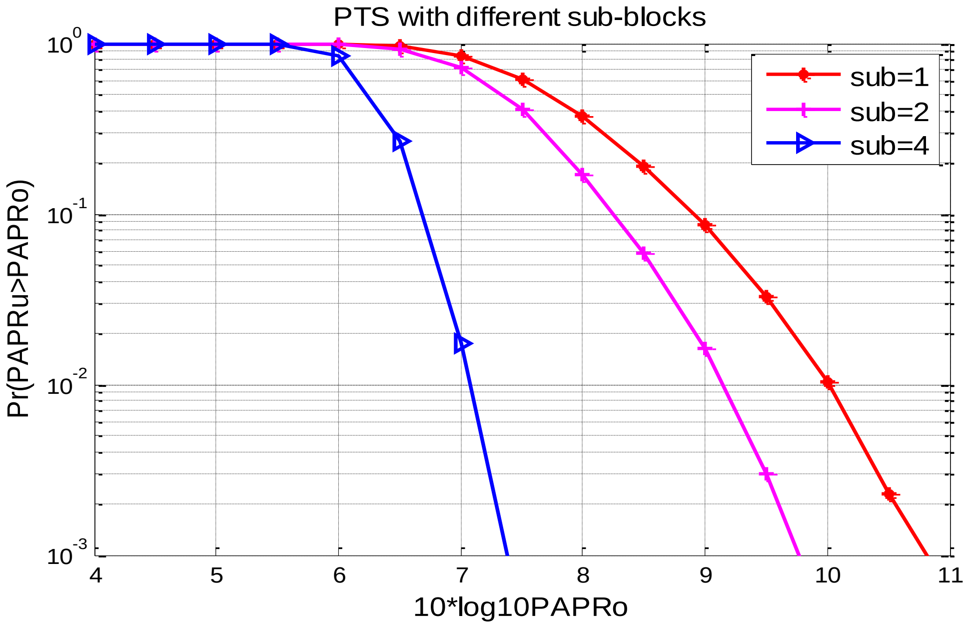

Figure 3.6: CCDF of the PAPR performance for different sub-blocks with N=256

Factors	**Value**
Type of partition scheme	Adjacent
Sub-carriers	256
Phase factors	4

Table 3.1: Various factors for simulating Figure 3.6

If the number of sub-blocks increases then it reduces the PAPR in PTS technique with N=256. Therefore, the CCDF curve is near to the origin as shown in the figure 3.6. It is observed that PAPR=7.4dB with M=4 and PAPR= 9.7dB with M=2 by using PTS technique but if M=1 means normal OFDM signal PAPR=10.8dB without using any method for the probability is 10^{-3}. When compared to PTS technique it is very high and it is improved around 3.4dB.

Here the same thing observed if N=128 subcarriers from the above concept. It is observed that PAPR=6.8dB with M=4 and PAPR= 9.6dB with M=2 by using PTS technique but if M=1 means normal OFDM signal PAPR=10.5dB without using any method for the probability is 10^{-3} and it is improved around 3.7dB as shown in the figure 3.7

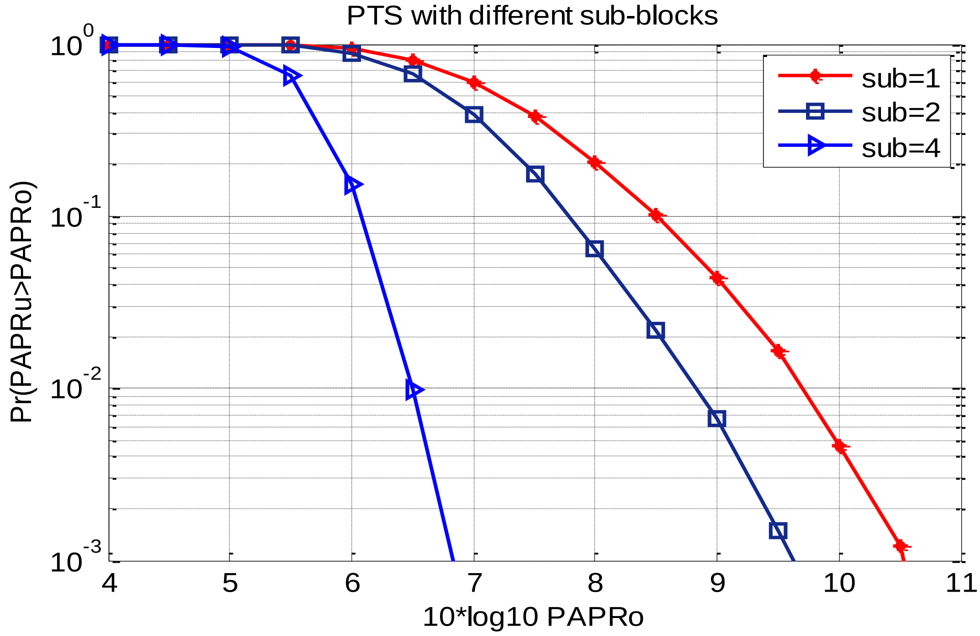

Figure 3.7: CCDF of the PAPR performance for different sub-blocks with N=128

Here as we known that in the OFDM system if increases the number of subcarriers then the PAPR also increases. In PTS technique, for different subcarriers i.e., N=64, 128, 256, 512, 1024, are observed as shown in figure 3.8. The PAPR performance curve is shifted to right side when increases the number of subcarriers.

3.5.2 BER Performance

The simulations are measured in PTS technique from the transmitter to receiver in the occurrence of the channel. To operate this system is made with repetitive then more data want to be collected. The simulation procedure are given below.

The symbol of OFDM when transmitted through channel of AWGN noise is added to transmitted OFDM symbol. The signal which is received undergoes decoding process by using appropriate design at the receiver. The data or signal received is compared by using data which is transmitted which will give us the number of received bits as error occurred due to the condition of the channel. In OFDM, for more number of symbols is repeated by this process and for various

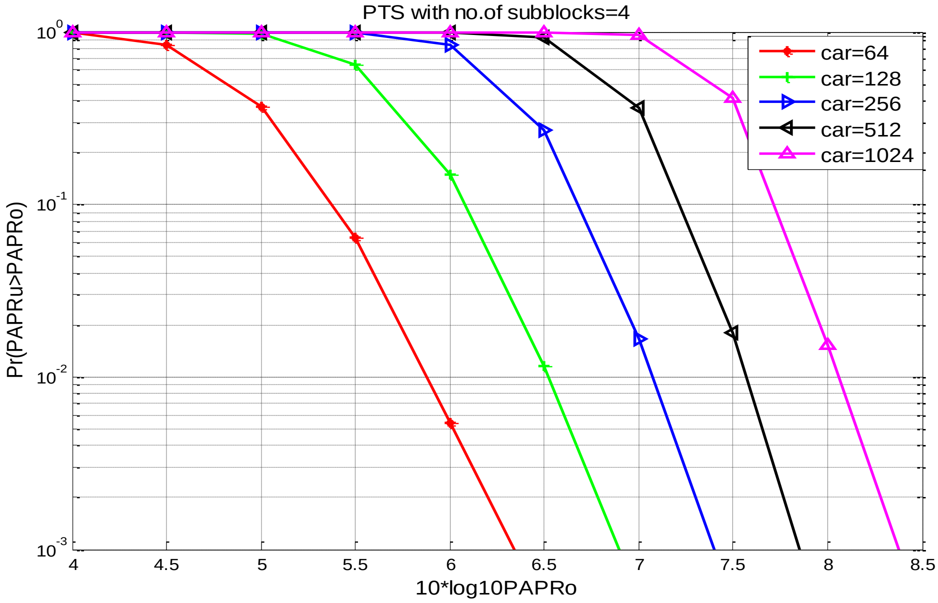

Figure 3.8: PAPR performance for different number of sub-carriers with M=4

values of SNR is repeated from starting 0dB to 15dB and in every time calculated SER and SNRn is plotted as shown in the figure 3.9.In this PTS technique the phase factors dose not give any effect compare with the normal OFDM signal in SER performance.

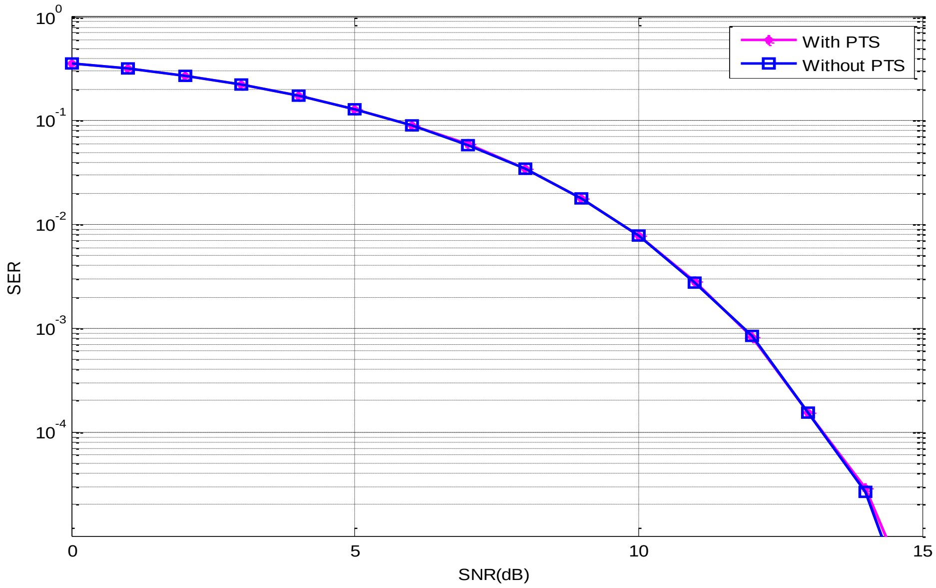

Figure 3.9: SNR vs SER graph for $(10)^{-5}$ OFDM symbols

4
PTS based MIMO-OFDM system

In high-speed wireless communication, MIMO is combined with the OFDM then it is known as MIMO-OFDM technology, to transform frequency-selective MIMO channel are applied to OFDM into parallel flat MIMO channel. The complexity at the receiver has to be reduced, through the fading of the multipath channel has robust transmission to achieve high information rate. Therefore, an MIMO-OFDM system has to achieve diversity gain and coding gain at the same time by using space-time coding, and then the OFDM system is designed with a simple structure. The signals of amplitude and phases are added to random in different paths has to occur deep fading and causes destructive interference in wireless communication. The probability of the symbol error rate is more in deep fade and produces the weak performance [20]. The performance is improved in the mobile communication system by using some fundamental techniques. Thus, in 4G mobile communication systems has been proposed by using MIMO-OFDM system.

4.1 MIMO system

4.1.1 MIMO system models

In MIMO system has different communication transmission models are shown in the figure 4.1.

(1). **Single Input single Output (SISO) system:** There is only one transmitting antenna, and one receiving antenna is used.

(2). **Multiple Input Single Output (MISO) system:** There are more transmitting antennas and one receiving antenna is used, and it is also known as transmitter diversity.

(3). **Single Input Multiple Output (SIMO) system:** There is only one transmitting antenna and more receiving antennas are used, and it is also known as receiver diversity.

(4). **Multiple Input Multiple Output (MIMO) system:** There are more transmitting antennas, and more receiving antennas are used, and it is also known as antenna diversity. It will not reduce the spectral efficiency by using the multiple transmitter and receiver antennas.

In MIMO communication systems use the transmitter, and distance separates the receiver of the multiple antennas are so far. These distances are ten times more than the carrier wavelength but in mobile communication antennas are separated by half of the carrier wavelength. In spatial diversity multiplexing space division, multiplexing independent channels are formed in between the transmitter and receiver end. MIMO can transmit parallelly several data streams then the data rate will increase with the same power [21].

4.1.2 MIMO channel

In wireless communication, there are different types of channel impairments.

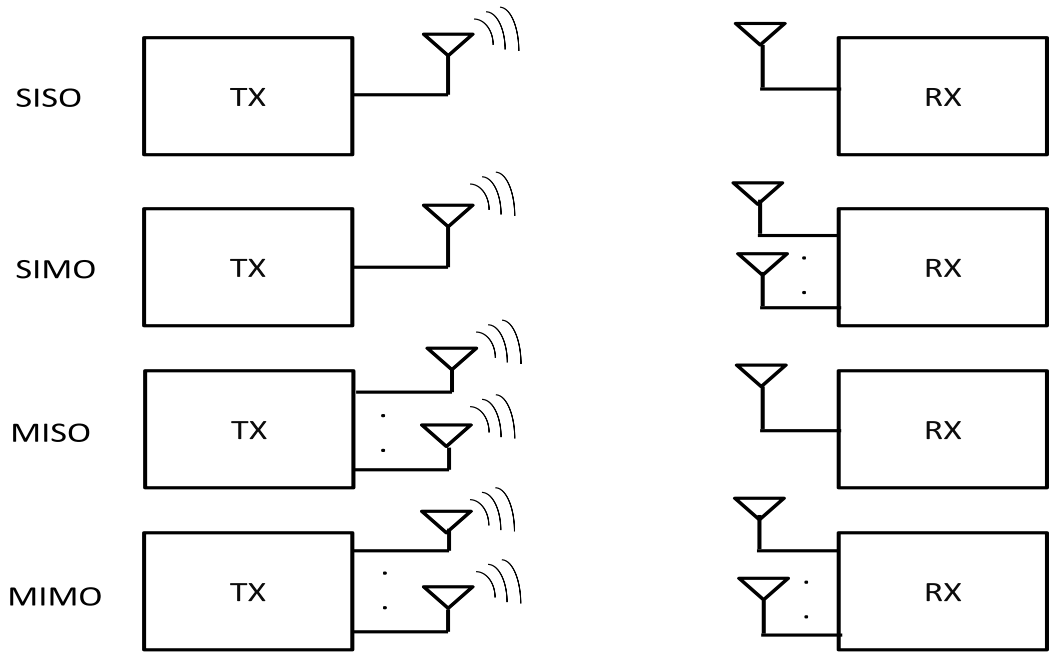

Figure 4.1: Different antenna configurations in space time systems

(i). **Shadow fading:** Actuality the path signals are mainly in between the transmitter and the receiver has significant obstacles, for example, large buildings or hills are obscure, which has to lead to amplitude fluctuation and shadowing of receiving signals. In fact that shadow and fading free-space path loss are belongs to slow fading or large-scale fading.

(ii). **Free-space path loss (FSPL):** When line-of-sight path occurs between receiver and transmitter with no obstacles and it discusses about the power loss of electromagnetic wave. At the receiver antenna can receive the free space power from the transmitting antenna which is separated by a distance d is defined as

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\Pi)^2 d^2 l} \tag{4.1}$$

Where $P_r(d)$ is a received power, G_r is gain at receiver antenna, P_t is a transmitted power, G_t is gain at transmitter antenna, λ is the wavelength in meters, d is the separated distance from transmitter to receiver in meters, and l is loss factor of the system ($l \geq 1$) it has propagation is not related.

The gain antenna is associated with its effective aperture can be expressed as

$$G = \frac{4\Pi A_e}{\lambda^2} \tag{4.2}$$

(iii). **Small-scale fading (multipath):** When Small-scale fading discusses about phase and amplitude with rapid fluctuation over a travel distance or period is less. It can be associated with the scattering, reflection, and diffraction. In some particular location, these three different propagation appliances of interaction fading are caused. Small-scale fading needs an applicable model is Rayleigh fading to describe the line of sight between receiver and transmitter along which is no dominant propagation. Rician fading is more suitable for the line of sight along with dominant distribution.

4.1.3 MIMO system capacity

System capacity is defined as maximum information rate transmission in the condition of probability error is small. In MIMO system, multiple space sub-channels which are connected between transmitter and receiver setting up linearly increases the system capacity.In MIMO wireless system, it is considered as the frequency response as existence to flat when the bandwidth of transmitted signal is narrow. The fading coefficients of the channel matrix elements are from the j_{th} transmitter antenna to the i_{th} receiver antenna. MIMO system with N_r receiving antennas, and N_t transmitting antennas, then the receiver transmission is defined as:

$$\bar{y} = H\bar{x} + n \tag{4.3}$$

Where $\bar{x}$ is $N_t * 1$ transmitted vector, H is $N_t * N_r$ channel matrix, $\bar{y}$ is $N_r * 1$ received vector, n is AWGN noise with autocorrelation $R_n = Enn^H = N_o I_{N_t}$ and I_{N_t} is identity matrix, N_o is a noise power at each receiving antenna. MIMO system capacity is defined as

$$C = max_{Tr(R_{ss})=N_t} \left\{ log_2 \left[det(I_{N_r} + \frac{E_s}{N_t N_o} H R_{ss} H^H) \right] \right\} \tag{4.4}$$

In system capacity the signals are transmitted equal power at each antenna, if channel is unknown for the transmitter such that $R_(ss) = I$, then system capacity(C bits/s/Hz) can be expressed as

$$C = log_2 \left[det(I_{N_r} + \frac{E_s}{N_t N_o} H H^H) \right] \tag{4.5}$$

The previous system capacity formulas are used in the multi-antenna system, and the channel capacity has to improve positively by multi-antenna system compared to the single-antenna system. In the above condition has to maintain the information transmission rate, the increased channel capacity is used to improve the consistency of the communications systems or raise the information transmission rate by improving data redundancy. MIMO system is characterized into two types: Spatial Multiplexing (SM) and Space-Time Coding (STC). Spatial multiplexing in MIMO wireless communication which is a transmission technique has independently transmitted, and encoded data signals are separated into data streams from each transmit antenna in the multi-antenna system. Hence, the space dimension is multiplexed more than one time. If the N_r antennas at receiver, and N_t antennas at transmitter, the maximum spatial multiplexing is

$$N_s = min(N_t, N_r) \tag{4.6}$$

If the receiver is to use linearly, then the N_s streams are parallel to transmit which increases the spectral efficiency. Space-time coding technique is used for time processing method and two-dimensional space [22]. In time-domain, similar antenna at the same time is used for different time slots which are transmitted by different signals. In space-domain, multiple antennas are used in receiver side and transmitter side to improve the information rate and system capacity. In various antennas which are transmitted the signals with the purpose of the receiver diversity can be realized at the receiver antennas by combining time and space domains. Hence, space-time coding is special for high coding gain without using large bandwidth which efficiently improves system capacity.

4.2 PAPR in MIMO OFDM system

The system which has a combination of the multiple-input-multiple-output(MIMO) and orthogonal frequency division multiplexing(OFDM)is MIMO-OFDM system to increase the system capacity and the diversity gain over the time modified frequency-selective channels. At each transmit antenna standard techniques has to apply separately for reducing the PAPR directly, and then the overall PAPR reduction is obtained in MIMO-OFDM systems [23]. This system which has input vectors are transmitted independently with N_t transmit antennas, then the transmitted system with the contribution vectors are equivalent to the i_{th} symbol, X_i is given as loading the N_t antennas of the input vectors at transmitter side,$X_i = [X_{i,1}^T, X_{i,2}^T, ..., X_{i,N_t}^T]^T$ where the input i_{th} vector of the n_t^{th} antenna at the transmitter side, $X_{i,n_t} = [X_{i,n_t,0}, X_{i,n_t,1}, ..., X_{i,n_t,N-1}]^T$, $n_t = 1, 2, .., N_t$. PAPR is defined as

$$PAPR_{i,N_t}(x_{i,N_t}) = \frac{max[|x_{i,N_t}|^2]}{E[|x_{i,N_t}|^2]} \tag{4.7}$$

In MIMO-OFDM signal of the data block has N symbols and N_t transmitting antennas with the Nyquist rate sampling and then the CCDF of the PAPR can be expressed as

$$Pr(\gamma > \gamma_o) = 1 - (1 - e^{-\gamma_o})^{N*N_t} \tag{4.8}$$

4.3 PTS for MIMO-OFDM system

In MIMO-OFDM systems can reduce the PAPR by using PTS technique is shown in figure 4.2. Each transmitting antenna has to apply the PTS-OFDM method. The ordinary PTS(O-PTS) for MIMO-OFDM system has to implement above method for the N_t transmitting antennas. The possible block of parallel data is partitioned into several sub-groups with the same length of data for each subgroup in the original parallel block. This $N * N_t$ subcarriers are divided into several sub-groups, then the every sub-group has some non-zero subcarrier values and some zero subcarrier values. If consider one transmitting antenna then it is similar to PTS for OFDM system. Hence, if all the sub-groups of the particular antenna are effectively adding that gives the particular transmitting antenna data. Each sub-group is transferring through N_t IFFT block which has Inverse Fast Fourier transform is performed and each IFFT blocks output is mentioned as Partial transmit sequence.

This technique is used for rotating the allowed phase factors are predefined, and it is considered before allowed set of phase values to select the predefined phase elements for one complete phase rotation PTSs added up to become a candidate signal in MIMO-OFDM system. The above process is repeated with the set of different phase factors can be multiplied with PTSs for every transmitting antenna, and it is repeated until to complete the all possible phase factor combinations.

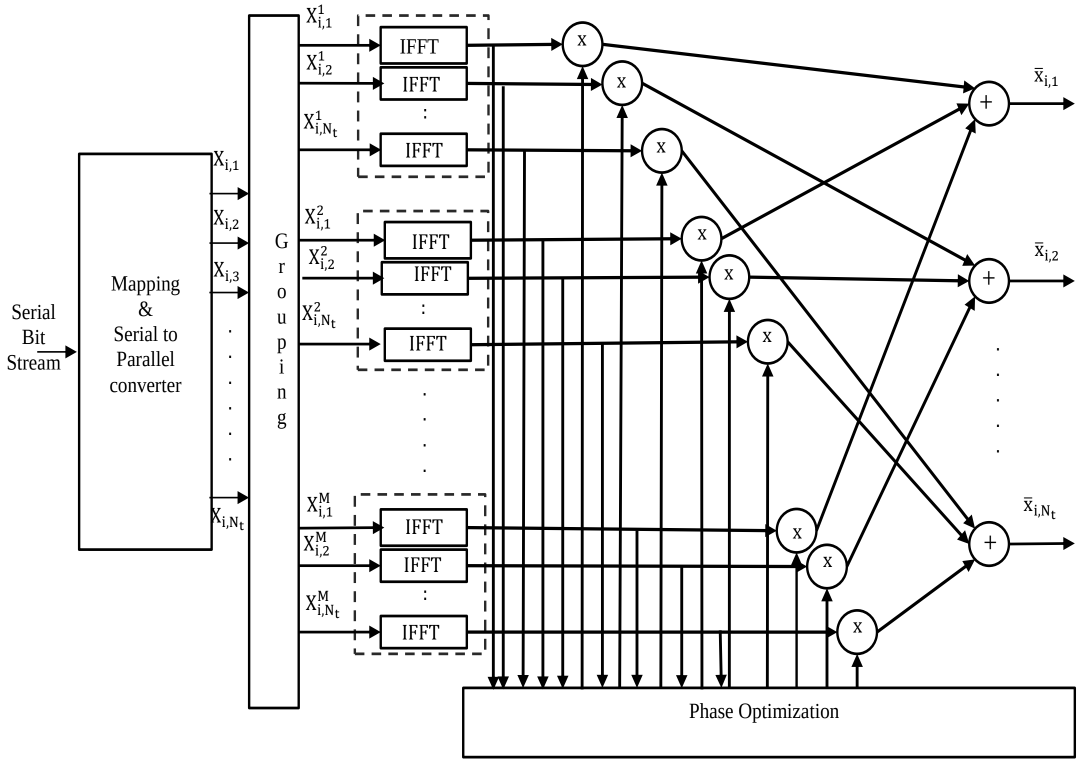

Figure 4.2: PTS technique for MIMO-OFDM system

4.3.1 Mathematical analysis

The i^{th} symbol of a input vector X_i is divided into several sub groups and then the $m^{(th)}$ group of the N_t transmitting antennas and N symbols can be formed as total NN_t elements can be expressed as

$$X_i^m = [X_{i,1}^{m\,T}, X_{i,2}^{m\,T}, ..., X_{i,N_t}^{m\;\;T}]^T, where\; m = 1, 2, ., M \tag{4.9}$$

Here, the N symbols in one transmitting antenna can be defined as $X_{i,n_t}^m = D^m X_{i,n_t}$ and Diagonal matrix is D^m with elements are N,$\sum_{m=1}^{M} D^m = I_N$. The vector X_{i,n_t}^m is applied to each IFFT in that group, then the resultant $m^{(th)}$ group can be defined as

$$x_i^m = [x_{i,1}^{m\,T}, x_{i,2}^{m\,T}, ..., x_{i,N_t}^{m\;\;T}]^T, where\; x_{i,n_t}^m = IFFT[X_{i,n_t}^m] \tag{4.10}$$

The M groups are applied to the phase optimization block and these partial sequence are rotated independently by using phase vector a is given by $b_i = [b_i^{1T}, b_i^{2T}, ..., b_i^{MT}]^T$, Where $b_i = [b_{i,1}^m, b_{i,2}^m, ..., b_{i,N_t}^m]$and the phase factor is defined as

$$b_{i,n_t}^m = e^{j\theta_{i,n_t}^m}, \theta_{i,n_t}^m \epsilon \left\{ \frac{2\Pi k}{W} |_{k=0,1,2,...,W-1} \right\} \tag{4.11}$$

To obtain the phase vector b_i of the OFDM signals that the M groups are combining optimally the overall PAPR performance is low. Finally, the optimized PAPR reduction of the transmitter vector for the n_t^{th} antenna is generated as

$$\bar{x}_{i,n_t} = \sum_{m=1}^{M} b_{i,n_t}^m * x_{i,n_t}^m \tag{4.12}$$

The optimization of the transmitting antennas has a phase vector is $b_i^{'}$ can be expressed as

$$b_i^{'} =_{b_i}^{argmin} (_{1<n_t<N_t}^{max} PAPR_{i,n_t}(\bar{x}_{i,n_t})) \tag{4.13}$$

Where argmin(.) estimates with the expression has to minimize of the argument.

In general, the phase elements are the selection which is reducing the complexity with less number of elements. If the possible set of phase elements can be expressed as $P = e^{j2\Pi K/W}$, $K = 0, 1, ..., (W1)$, where K is the number of allowable phase factor. The binary or quaternary elements are ± 1 *or* $\pm 1, \pm j$, then there is no multiplications have been performed, simply sign changes and interchange the imaginary and the real parts. The number of groups M are increases the complexity exponentially, then $N_t(W^{(M-1)})$) likely for the transmitting antenna has a phase vector is b_i that is used to estimate the phases optimization vector $b_i^{'}$. Each transmitted vector X_i has MN_t times to employ the IFFT operations, and at the receiver to send the essential number of side information bits are $log_2(W^{N_t(M-1)})$. In the data channel cannot be transmitted the side information bits and the separate channel can be transmitted the side information bits. In the data block, the side information (SI) bits are included as possible, yet the final result has some information rate loss occur [24]. The entire PAPR reduction mainly dependent on the number of phase elements W and number of sub-groups M.

4.4 Modified PTS for MIMO OFDM Systems

The proposed technique is a modified PTS(M-PTS), which has to attain for reducing the PAPR with better performance in MIMO-OFDM system as shown in the figure 4.3. The main concept of this method is circular shifting operation is used before applying the transmitting antennas, and phase rotation compare to the ordinary PTS. The possible block of parallel data is partitioned into several sub-groups with the same length of data for each sub-group in the original parallel block [25]. This $N * N_t$ subcarriers are divided into several sub-groups, then the every sub-group has some non-zero subcarrier values and some zero subcarrier values. Each sub-group is transferred through the N_t IFFT block which has Inverse Fast Fourier transform is performed and each IFFT blocks output is mentioned. After partitioning the sub-groups are applied to the circular shifting block and phase optimization block. In circular shifting is used for each group is shifted which has N_t possibilities. Before transmitting the each antenna, the shifted group is independently rotated by using the optimized phase vector. The above process is repeated with the set of different phase factors can be multiplied, and it is repeated until to complete the all possible phase factor combinations in this technique[26]. MIMO-OFDM symbols are required to transmitting the selection of minimum PAPR.In this operation can be shifted independently all the M groups then the circular shifting of this M groups has a vector is defined as

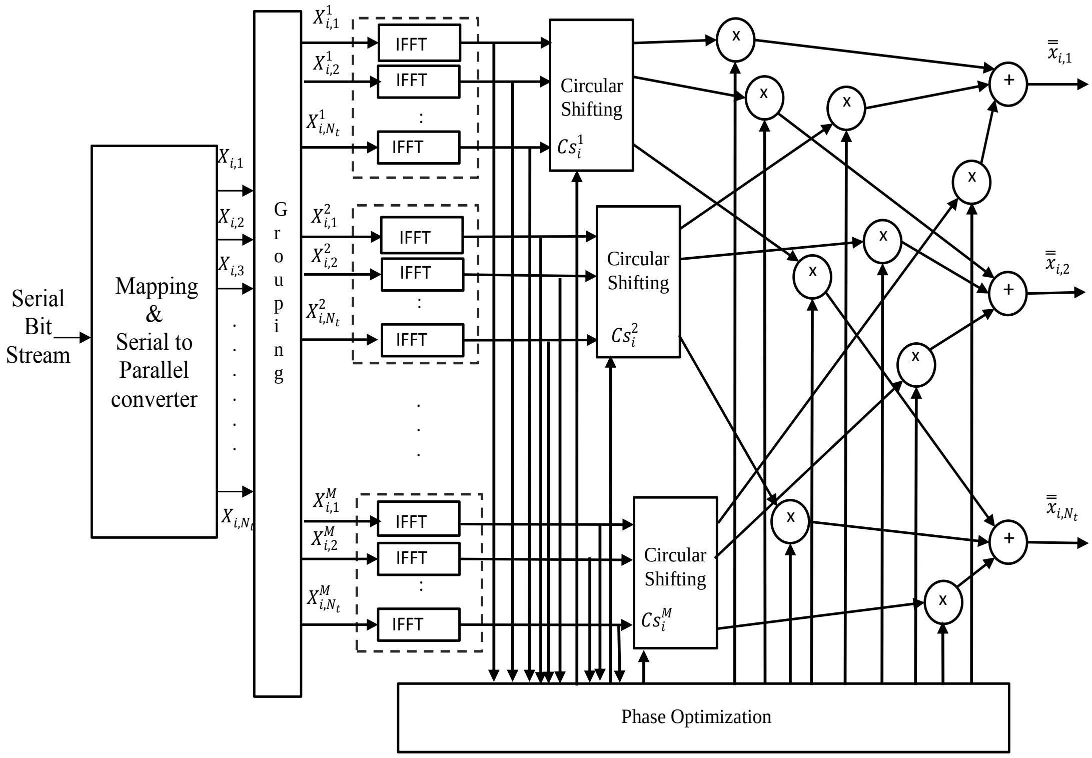

Figure 4.3: Modified PTS technique for MIMO-OFDM system

$$Cs_i = [Cs_i^1, Cs_i^2, ..., Cs_{i,}^M]^T \quad (4.14)$$

The factor of circular shifting Cs_i^m is used for the group vector x_i^m is shifted circular way then the optimized shifted vector is

$$\dot{x}_i^m = [{x_{i,N_t}^m}^T, {x_{i,1}^m}^T, ..., {x_{i,N_t-1}^m}^T]^T \quad (4.15)$$

Each group is possibly shifted by the total N_t probabilities, there is no performance loss if Cs_i is set to 0. Before transmitting the each antenna the M groups shifted of a partial sequence are rotated independently by using the phase vector

b_i, the final optimal transmitted vector at the each antenna is

$$\bar{\bar{x}} = \sum_{m=1}^{M} b_{i,n_t}^{m} * \dot{x}_{i,n_t}^{m} \tag{4.16}$$

The optimal phase rotating vector $b_i^{'}$ and circular shifting vector $Cs_i^{'}$ are designated from $N_t(KN_t)^{(M-1)}$possible vectors is given by

$$\left\{Cs_i^{'}, b_i^{'}\right\} =_{\{Cs_i,b_i\}}^{argmin} \left(_{1<n_t<N_t}^{max} \mathrm{P}APR_{i,n_t}(\bar{\bar{x}}_{i,N_t})\right) \tag{4.17}$$

Here, the number of side information bits are transferred from the transmitter to the receiver is $log_2(W^{N_t}N_t)^{(M-1)}$.

4.4.1 Sub - Optimal Solutions for Modified PTS

In modified PTS the solution has the side information and/, or computational complexity can be reduced to requiring the sub-optimal solution in MIMO-OFDM system. The above technique which has less performance loss for reducing the PAPR by two sub-optimal solutions[26]. The first solution before applying phase vector b_{i,n_t}^{m} then the optimized circular shifting is selected as vector can be expressed as

$$Cs_i^{'} =_{Cs_i}^{argmin} \left(_{1<n_t<N_t}^{max} \mathrm{P}APR_{i,n_t}(\bar{\bar{x}}_{i,N_t})\right) \tag{4.18}$$

After selecting the optimal circular shifting vector $Cs_i^{'}$, in these two steps $Cs_i^{'}$ is only applied to the phase vector, then the optimal rotation of the phase vector $b_i^{'}$ is defined as

$$b_i^{'} = {}_{b_i}^{argmin} \left(_{1<n_t<N_t}^{max} \mathrm{P}APR_{i,n_t}(\bar{\bar{x}}_{i,N_t})\right) \tag{4.19}$$

The two optimization steps which have the computational complexity can be reduced to $N_t(K)^{(M-1)} + Nt^{(M-1)}$,and the number of side information bits are same. In general all antennas the phase rotation is same which dependent on the second sub-optimal solution in the similar group. Hence the M elements only contains phase rotation vector b_i. The optimal phase rotating vector $b_i^{'}$ and circular shifting vector $Cs_i^{'}$ are chosen and then the reducing the number of side information bits is $log_2(KN_t)^{(M-1)}$. To obtain MIMO OFDM signals has to estimate the optimal phase rotation vector $b_i^{'}$ and circular shifting of a vector $Cs_i^{'}$ and that the M groups are combining optimally with the lowest overall PAPR.

4.5 Co-operative PTS for MIMO OFDM Systems

Co-operative PTS(Co-PTS) for MIMO-OFDM system have been attaining the low computational complexity for reducing the PAPR is proposed. In this technique which has to combine spatial sub-block circular permutation and alternate optimization, then the number of candidate sequences can be reduced for improving the PAPR reduction performance across all the transmitting antennas by using spatial sub-block circular permutation and the alternate optimization is used for reducing the computational complexity [27]. The co-operative PTS, which is mainly based on alternative PTS, in this alternative PTS half of the sub-blocks, are only required for optimizing the phase weighting factors is shown in the figure 4.4. In these sub-blocks, starting from every alternative sub-block (odd sub-blocks) is unchanged and the phase weighting factor are used for remaining sub-blocks are optimized. Then, the obtaining number of complex computational multiplication will be reduced for each candidate sequence. The number of candidate sequence being reduced with the same amount of phase factors W and number of subgroups M. Hence, the computational complexity will be reduced but the low-performance loss in PAPR reduction [28].

In co-operative PTS, if increases the candidate sequences then the starting alternative sub-groups (except the first one) for all the transmitting antennas by using spatial sub-block circular permutation. For example, with four sub-blocks and four transmitting antennas, consider the second sub-block is the original set $[x_{i,1}^{(2)}, x_{i,2}^{(2)}, x_{i,3}^{(2)}, x_{i,4}^{(2)}]$, then the spatial sub-block circular permutation has to obtain another three different ways are $[x_{i,4}^{(2)}, x_{i,1}^{(2)}, x_{i,2}^{(2)}, x_{i,3}^{(2)}]$,$[x_{i,3}^{(2)}, x_{i,4}^{(2)}, x_{i,1}^{(2)}, x_{i,2}^{(2)}]$, and $[x_{i,2}^{(2)}, x_{i,3}^{(2)}, x_{i,4}^{(2)}, x_{i,1}^{(2)}]$. After the starting alternative sub-blocks (odd sub-blocks) is transform has to perform the spatial sub-block circular permutation and remaining alternative sub-blocks (even sub-blocks) are weighted to increases the candidate sequences. Each transmitting antenna the candidate sequence has to

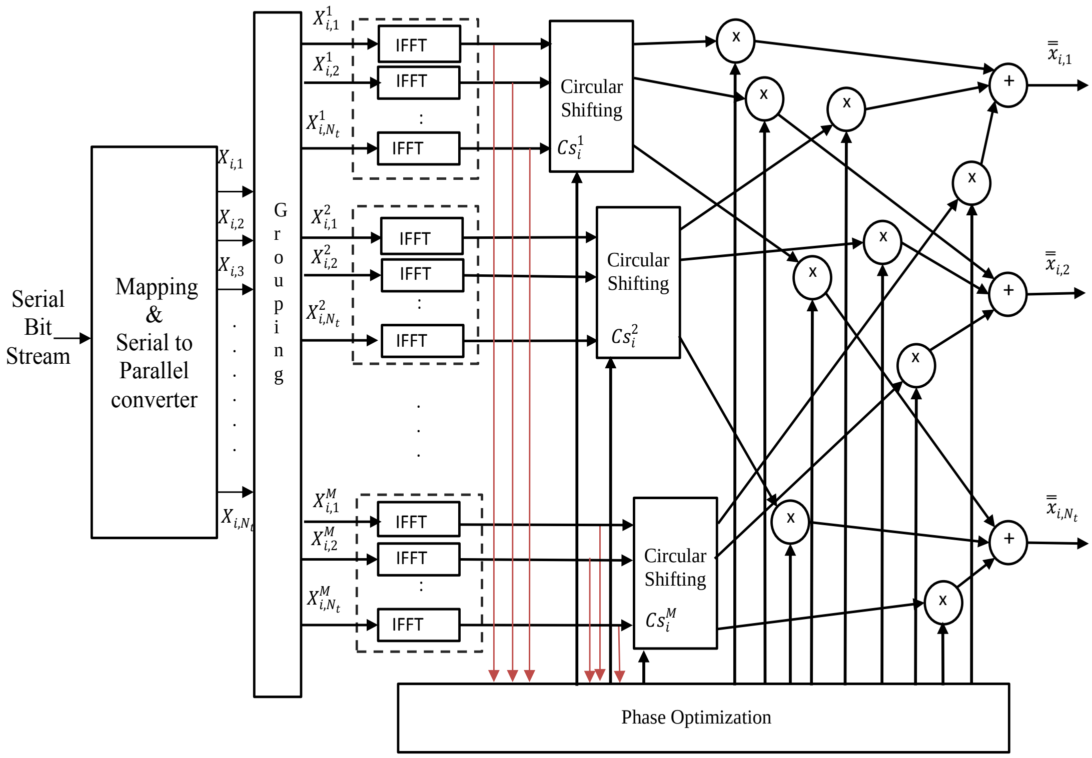

Figure 4.4: Co-operative PTS technique for MIMO-OFDM system

obtain the low PAPR performance and the set of candidate sequences are make up for all the antennas. Finally, the allowed min-max criterion is used to all the spatial sub-block circular shifting are completed, the optimum set of has to find for all the transmitting antennas. If the best PAPR reduction performance are required to eliminate the SSCP has increased the number of candidate sequences in phase weighting factors of starting alternative sub-blocks (odd sub-blocks) then there is no change on the complex multiplications but it essentially to increases the number of complex additions due to newly generated the candidate signals. The performance has to attain the reasonable PAPR reduction and to minimize the complex additions in spatial sub-block circular permutation (SSCP) factor is

	Number of complex multiplications	Number of complex additions
O-PTS	$N_t(M-1)LNW^{M-1}$	$N_t(M-1)LNW^{M-1}$
M-PTS	$N_t(M-1)LNW^{M-1}$	$N_t(SSCP+1)(M-1)LNW^{M-1}$
Co-PTS	$\frac{M}{2}N_tLNW^{M/2}(M\ even)$	$N_t(SSCP+1)(M-1)LNW^{M/2}(M\ even)$
	$\frac{M-1}{2}N_tLNW^{M-1/2}(M\ odd)$	$N_t(SSCP+1)(M-1)LNW^{M-1/2}(M\ odd)$

Table 4.1: Comparison of computational complexity for various PTS techniques

given by

$$SSCP = \begin{cases} \min\left\{\frac{M-2}{2}(N_t-1), \left\lfloor\frac{W^{M-1}}{W^{M/2}}\right\rfloor - 1\right\} \text{if } M \text{ is even} \\ \min\left\{\frac{M-1}{2}(N_t-1), \left\lfloor\frac{W^{M-1}}{W^{M-1/2}}\right\rfloor - 1\right\} \text{if } M \text{ is odd} \end{cases} \tag{4.20}$$

Where $\frac{M-2}{2}(N_t-1)$ (M is even) and $\frac{M-1}{2}(N_t-1)$ (M is odd) are the number of spatial sub-block circular permutation are maximum in co-operative PTS. $W^{M/2}$ (M is even) and $W^{M-1/2}$ (M is odd) are the number of candidate signals for every antenna at transmitter in alternative PTS. $\lfloor . \rfloor$ is the flooring of the element integers are near zero. In co-operative PTS has to obtain complex multiplication are reduce, and the complex addition of the computational complexity is considerably lower than the complex multiplication. Therefore, in co-operative PTS, the computational complexity is less than the conventional PTS. Co-operative PTS is also required the side information (SI) Like to ordinary PTS, then the number of SI bits is given by

$$\text{SI(bits)} = \begin{cases} N_t\left\lceil log_2[(\text{SSCP}+1)W^{M/2}]\right\rceil \text{if } M \text{ is even} \\ N_t\left\lceil log_2[(\text{SSCP}+1)W^{M-1/2}]\right\rceil \text{if } M \text{ is odd} \end{cases} \tag{4.21}$$

The above proposed techniques in MIMO-OFDM system has the computational complexity in terms of the number of complex multiplications and complex additions the combination of phase weighting are needed this operation [29]. Table 4.1 Computational complexity of ordinary PTS, Modified PTS and Co-operative PTS.

4.6 Simulation Results

The simulations are evaluated in MATLAB R2013a of the MIMO-OFDM signals by using the PTS technique. The QPSK modulation is used in the PTS technique with the adjacent partitioning scheme that can offer better performance with the phase factors (W=4) are selected as $\{\pm 1, \pm j\}$ and sub-blocks(M=4). The performance of CCDF are plotted with the probability of PAPR signal is greater than the threshold PAPR on Y-axis and reference threshold PAPR on X-axis.

It is concluded that various CCDF curves for multiple antennas. Here applying PTS technique different antennas due to different data is provided. The similar performances are getting from these all the four antennas. It is due the four antennas are carrying with the data is random and taken as a similar number of sub-carriers.

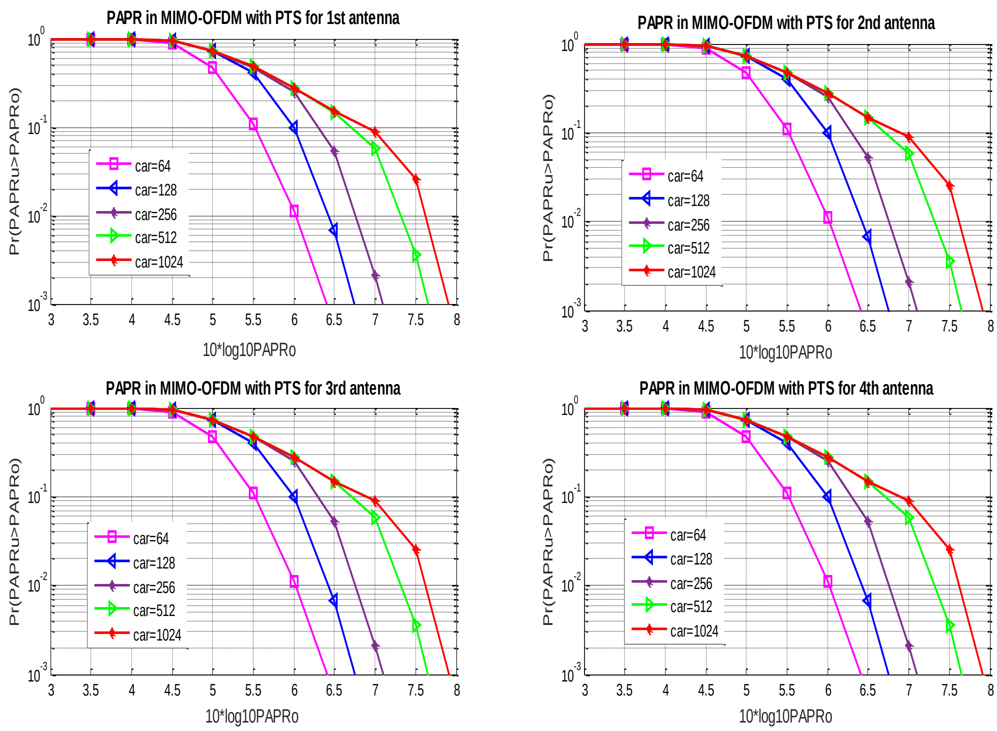

Figure 4.5: PAPR performance for M=4, MIMO OFDM with PTS by using different sub-carriers with four antennas

As we known that if an increase the number of subcarriers then the signal of PAPR is also increases and it is observed by using PTS technique. In this technique, for different subcarriers i.e., N=64, 128, 256, 512, 1024, are observed as shown in figure 4.5. The performance curve is shifted to right side when increases the number of subcarriers that shows the PAPR is going to increase.

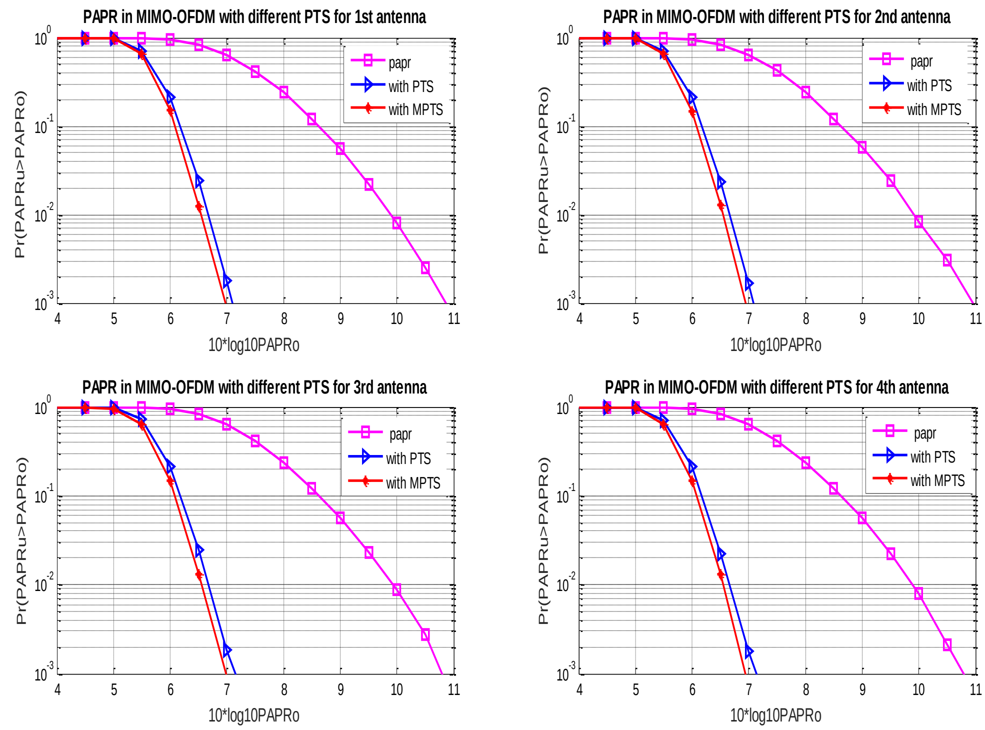

Figure 4.6: PAPR performance for M=4, MIMO OFDM with PTS and Modified PTS

Here it is observed that the number of subcarriers, N=256 for the PAPR is 7.1dB in PTS technique but in Modified PTS the PAPR is reduced and it is nearly 7dB is observed.Nearly, the similar performances are getting from these all the four antennas as shown in the figure 4.6.

Now the PAPR performance for M=4, Co-operative PTS technique can be compared with the PTS technique in MIMO-OFDM. The CCDF curve of the CO-operative PTS gives slight loss compare to the PTS technique for the number of

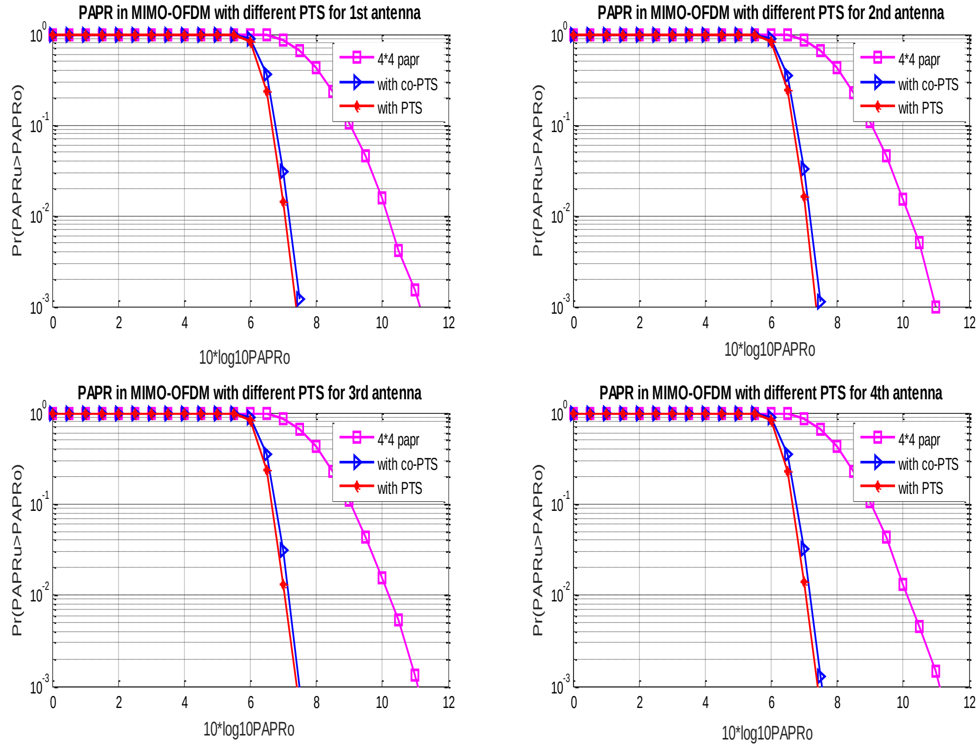

Figure 4.7: PAPR performance for M=4, MIMO OFDM with PTS and Co-operative PTS

subcarriers are N=512 as shown in the figure 4.7. Here computational complexity of the Co-operative PTS has very less compare to the PTS technique.

5 Conclusion and Future scope

5.1 Conclusion

In wireless communication, which is trending as the most important technology is OFDM system. This thesis provides an overview of OFDM and MIMO technology and MIMO-OFDM has been the promising technology in $4G$ wireless communication systems. At the same time, the advantages and disadvantages of OFDM system are concluded by analysing and comparing with other traditional modulation schemes. The main drawback of the OFDM system is high PAPR and to reduce the PAPR of the signal, many techniques have been proposed to provide a suitable limit. Among all these technologies, PTS can reduce PAPR more significantly but computational complexity will increase simultaneously. In present thesis, the simulation results are presented using the PTS technique of the performance is compared with the OFDM signals.Therefore, the performance of PTS technique is improved by 3.7dB with M=4 from the graph when compared to original OFDM system.

At the receiver end, the testing is needed for transmitted signal over the channel in wireless communication system. The AWGN channel is considered for simulation of complete communication system with the signal propagation environment. The Symbol Error Rate (SER) is plotted for various values of SNR. In PTS technique,SNR vs SER plot is compared with the normal OFDM signal. This technique which has phase factors does not effect SER performance due to that we are getting similar performances.

In MIMO-OFDM system which has to reduce the PAPR in multiple antennas and the PTS technique is used for every antenna to reducing the PAPR with adjacent sub-block partitioning. The conventional PTS technique is best technique for reducing the PAPR in MIMO-OFDM system but it provides high computational complexity, since more IFFT blocks are used. This technique is simulated to observe its performance for different number of sub-carriers. From the observation given in the figure 4.5 we conclude that as the increasing the number of sub-carriers,then performance curves of CCDF moving away from the origin. The proposed Modified PTS technique has been analysed after the ordinary PTS technique. In the Modified PTS technique used cyclically shifting block or spatial sub-block circular permutation compared to the PTS technique. It is observed that further reducing the PAPR performance from the CCDF curve but the computational complexity increases.

The proposed Co-operative PTS technique is mainly based on the alternative PTS in MIMO-OFDm system.The alternative optimization in co-operative PTS can be reduce the system computational complexity. Compared to the modified PTS with the co-operative PTS, only half of the sub-blocks are used with allowed phase factor. In co-operative PTS, it is observed that the computational complexity is low but the performance of this technique slightly reduced. The co-operative PTS technique for MIMO-OFDM system has number of complex multiplications and number of complex additions can be reduced. consider M=4 and W=4 in co-operative PTS the number of complex multiplications are decrease by 83 compare to the ordinary PTS but the number of complex additions are are nearly same. The CCDF curve of the PAPR performance at every antenna has been analysed in co-operative PTS. The performance is observed that in MIMO-OFDM system PAPR reduces as compared with SISO-OFDM system.

5.2 Future scope

MIMO-OFDM system is particularly suited for high speed ($4G$) wireless transmission. Here, we can use SFBC MIMO-OFDM system with low complexity PTS scheme for PAPR reduction of the transmitting signals. This technique uses the combination of Adjacent and Interleaved partition schemes for input data block, which is portioned into sub-blocks. At the receiver side which is required the decoded information for the analysis of removing the side information from the signal and it is needed to be done.

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