STUDY AND COMPARITIVE ANALYSIS OF PTS, ITERATIVE FLIPPING AND SLM SCHEME FOR PAPR REDUCTION IN OFDM NETWORKS

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Abstract - Orthogonal Frequency Division Multiplexing (OFDM) is an attractive and promising technique for fourth generation wireless communication. In the OFDM system, orthogonally placed sub-carriers are used to carry the data from the transmitter end to the receiver end. Presence of guard band in this system deals with the problem of ISI and noise is minimized by larger number of sub-carriers. But the large Peak to Average Power Ratio of these signal have some undesirable effects on the system.

High Peak to Average Power Ratio (PAPR) is the one of the major drawback of the Orthogonal Frequency Division Multiplexing (OFDM) transmitted signal. In this dissertation, some of the existing PAPR reduction techniques have been analyzed. The simulation results for the PAPR techniques are compared with some of the existing techniques like, Partial Transmit Sequences (PTS), Selective Mapping (SLM), Iterative flipping and new SLM. Although all the existing techniques can reduce the Peak to Average Power Ratio (PAPR), the computer simulation results is compared for various parameters. The results also show that the PAPR reduction techniques performs better when the numbers of subblocks in the OFDM transmitted signal increases.

Key Words: *OFDM, PAPR,CCDF, PTS, Iterative Flipping, SLM, HPA,SNR, BER.*

1. Introduction

1.1 Evolution of OFDM

Fourth generation wireless communication system has found its importance all around the globe due to its spectrum efficiency and high information rate of transmission. This is done by 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 multi-path channel environment known as multi-carrier communication system. This new 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 multi-carrier system, the available communication bandwidth is divided by many sub-carriers and transmitted on channel. One of the technique is Orthogonal Frequency Division Multiplexing (OFDM). The basis of OFDM is applied to all Fourth generation (4G) wireless communication systems because of its large number of sub-carriers, high information rate and universal coverage with high mobility capability.

In wireless communication which has to improve its 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, 4G and 5G wireless communication systems require further refined modulation scheme and data transmission structure. In earlier Frequency Division Multiplexing, the spectral overlapping among sub-carriers are allowed in OFDM since orthogonality of carriers will ensure the sub-carrier separation at the receiver end. This , provide better spectral efficiency and eliminate the steep band pass filter. OFDM transmission system provide possibilities for alleviating many of the problems encountered with single carrier systems. OFDM has the advantage of spreading out a frequency selective fade over many symbols. This effectively randomizes various burst errors caused due to fading so that instead of several adjacent symbols being Completely destroyed, many symbols are only slightly distorted. This allows successful reconstruction of majority of them even without forward error correction. Because of dividing an entire signal bandwidth into many narrow sub bands, the frequency response over individual sub bands is almost flat due to sub bands are smaller than coherence bandwidth of the channel. Thus, equalization is potentially simpler than in a single carrier system and even equalization may be avoided altogether if Differential encoding is implemented.

1.2 Principle of OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is an attractive multicarrier technique for high-bit-rate transmission nowadays. In OFDM, the data is transmitted simultaneously through multiple frequency bands so that the effects of multipath delay spread can be easily minimized. In a classical parallel data system, the total signal bandwidth can be divided into N non-overlapping frequency sub channels. After this each of the sub channel is under go modulation with a separate symbol and after this the N sub channels are frequency multiplexed. The earlier process of avoiding spectral overlap of sub channels was applied to ensure lower inter-carrier interference (ICI).

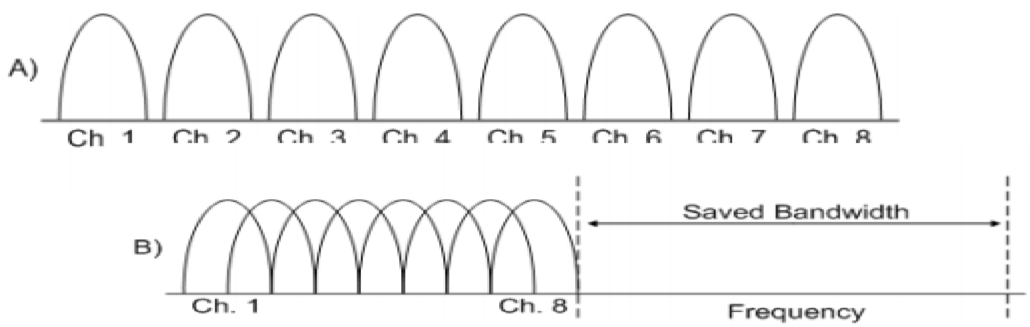


Figure1.1: A) The frequency spectrum of eight channel showing frequency utilizing division Multiplexing B) The frequency spectrum of OFDM where sub channels are orthogonal to each other.

This is shown in Fig 1 (A). due to this we have problem of insufficient utilization of the existing spectrum. To overcome this problem a scheme was proposed in the mid-1960s to overcome with this wastage of BW. This is done through the development of frequency division multiplexing (FDM) with idea of overlapping of sub channels. All the sub channels were arranged is such a way that the sidebands of the individual carriers overlap with each others and ensure no ICI between them. This principle is displayed in Fig 1 (B). To achieve this the carriers must be mathematically orthogonal. From this condition the idea of Orthogonal Frequency Division Multiplexing (OFDM) was born.

In digital communications, information is expressed in the form of bits. Please note that here symbol refers to a collection, in various sizes, of bits .In first step in OFDM various symbols are generated using the spectral space using M-PSK, QAM, etc, and this frequency domain spectrum is converted into the spectra to time domain by taking the Inverse Discrete Fourier Transform (IDFT). The implementation of inverse fast Fourier transform is more cost effective solution so it is usually used instead. The main features of a practical OFDM system are described as under.

1) In OFDM ,some processing is done on the source data, such as interleaving , coding for correcting errors, and mapping of bits onto symbols. Example of mapping is QAM
2) Then IFFT is used for the symbols modulation onto the orthogonal sub-carriers.
3) Orthogonality is maintained during channel transmission. This can be achieved by inserting a cyclic prefix (CP) to the OFDM frame to be sent. The cyclic prefix is of the L last samples of the frame, which are copied and placed in the starting of the frame. Please note that cyclic prefix (CP) must be longer than the channel impulse response.
4) Synchronization: cyclic prefix can be used to detect the start of each frame. This is done by using the fact that the in a particular frame first and last samples are the same and therefore correlated.
5) Demodulation of the received signal by using FFT.
6) Channel equalization: the channel can be estimated either by sending known so called pilot symbols at predefined sub-carriers or training sequence.
7) Decoding and de-interleaving.

1.3 Orthogonality in OFDM

It is very important to maintain orthogonality between the subcarriers. If no. of subcarriers are increases , the modulation, synchronization, and coherent demodulation produce a complicated OFDM circuit requiring additional hardware cost. This leads to an Orthogonal Frequency Division Multiplexing (OFDM) is really a multicarrier transmission technique, which usually divides the bandwidth straight into many carriers; each one is modulated by a decreased rate data stream. Inside term of multiple entry technique, OFDM is a lot like FDMA (frequency division multiple access) for the reason that the multiple user gain access to is achieved by subdividing the particular available bandwidth into multiple channels which can be then allocated to end users. Signals are orthogonal as long as they are mutually independent of each and every other.

Orthogonality is property allowing multiple information signals to become transmitted perfectly over a typical channel and detected, without having interference. Loss of Orthogonality end in blurring between these data signals and degradation with communications. Many common multiplexing system are inherently orthogonal. Time Division

Multiplexing (TDM) will allow transmission of multiple information signals on the single channel by working out unique time slots for you to each separate information indicate. During each time slot machine game only the signal from your single source is transmitted preventing any interference relating to the multiple information sources. Due to this of this TDM is orthogonal with nature. In the frequency sector most FDM systems are orthogonal as each one of the separate transmission signals are generally well spaced out inside Frequency preventing interference. If any two different functions in the set are multiplied, and integrated over a symbol period, the result is zero, for orthogonal functions. Equation (1.1) shows a set of orthogonal sinusoid, represent the subcarrier for un modulated OFDM signal.

$$S_k(t) = \begin{cases} \mathrm{Sin}(2\pi k f_0 t) & 0 < t < T \quad \text{where } k=1,2,3\ldots \\ 0 & \text{Otherwise} \end{cases} \qquad (1.1)$$

Where f_0 = carrier spacing, M = number of carrier ,T = symbol of period

Since the highest rate of recurrence component is Mf_0 the transmission bandwidth can also Mf_0 so that the frequency component are orthogonal to one other.[2][1]

1.4 Block Diagram of OFDM System

Consider an OFDM system consisting of N sub-carriers. Let us denote a block of N frequency domain sub-carriers as a Vector X, where X[X0,X1,X2……..XN-1] denotes the input data in an OFDM block. For an OFDM system each symbol in X is used to modulate a sub-carrier. Let, f_k, k = 0, 1……..N-1, denote the k^{th} sub-carrier frequency.

In the OFDM system, the sub-carriers must be Orthogonal to adjacent sub-carriers, i.e.fk = k.Δf, where Δf=1/(NT) and T is the symbol duration. Therefore, the complex envelope of the transmitted OFDM signal is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} Xke^{j2\pi k\Delta f} \quad 0 \le t, < NT \qquad (1.2)$$

Where j = $\sqrt{-1}$f is the sub-carrier spacing, and NT denotes the useful data block period. Further below is the detailed block diagram of a OFDM system.

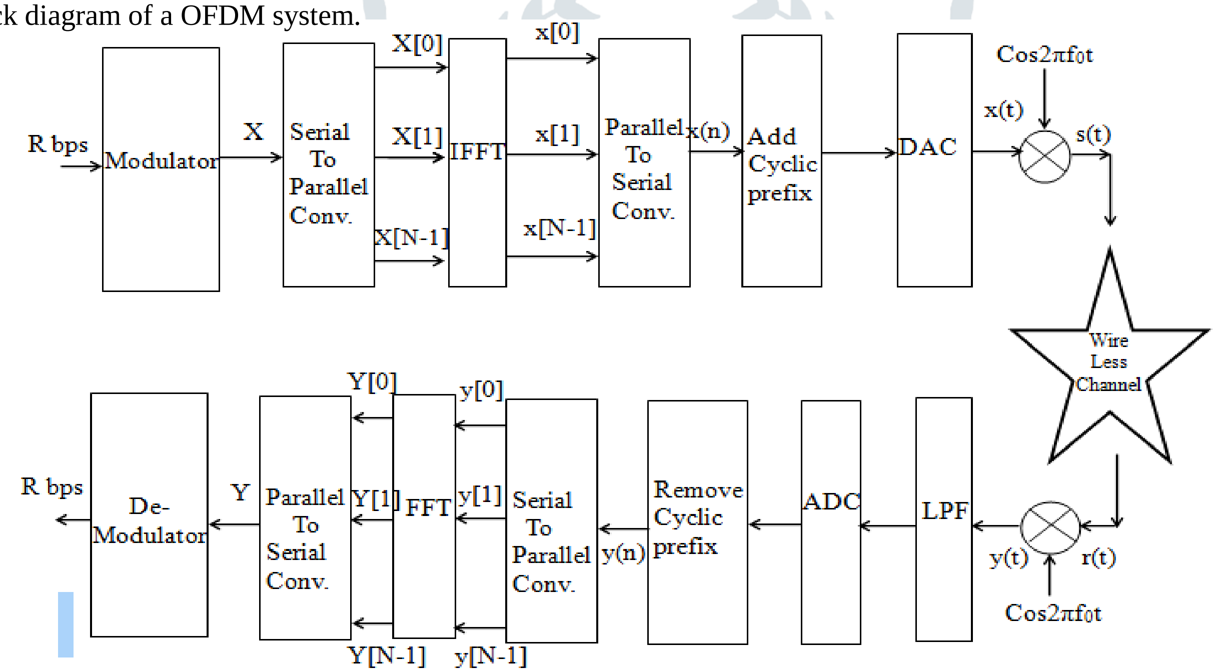


Fig 1.2 : Block diagram of OFDM system[1]

Data bits stream are converted from serial to parallel and each subcarrier is modulated using phase or amplitude modulation. Modulation process is called as symbol mapping. Each subcarrier is independently modulated using. Then, all the modulated signal are carried by OFDM carrier use IFFT module to create complex signal containing all subcarrier. Data parallel stream is converted to serial stream and real and imagine signal respectively are processed on Digital to Analog Converter (DAC). Both analog signal are multiplied by radio frequency with shift it's phase 90 degree and summing both. This signal will transmit over antenna.

Figure 1.2 shows the diagram of OFDM system. The receiver will receive real and imagine signal separately and they are processed by low pass filter to eliminate mirrored frequencies. Then, they are quantized by Analog to Digital Converter (ADC) block and the signal is calculated by Fast Fourier Transform (FFT) module. The data symbols demodulation is done by symbol mapping block according to the modulation scheme used. Parallel data stream is converted into data serial to obtain the desired data Received signal will be received many times due multipath propagation specially in urban environment or mobile device are moving high speed. Multipath signal and Line of sight have difference arrival time. It is called delay spread which results in Inter Symbol Interference (ISI).

OFDM scheme proposed to overcome the problem of ISI effect provided that can preserve orthogonality. This Orthogonality OFDM subcarrier can be achieved by inserting of guard time (guard interval). The OFDM guard time can be do by insert zero padding (ZP) or cyclic prefix (CP). CP is to enhance the OFDM symbol by copying the last samples of the OFDM symbol into its front. CP is introduced before the OFDM symbol. Let T_G denote the length of CP and T_{sub} denote the duration of OFDM symbol without guard time. So, the new extended OFDM symbols now have the duration of $T_{sym}=T_{sub}+T_G$. Guard time is selected longer than multipath delay so as not to cause interference with the next OFDM symbol. The other advantage of CP is combating Inter Carrier Interference (ICI) which is crosstalk between subcarriers. OFDM system needs synchronization in the receiver side to find the beginning of each symbols correctly. Synchronization parameters include finding the right time delay, frequency deviation and phase shift of each symbols in the subcarrier. These parameters can be determined with addition redundancy in some of the subcarriers which transmitted. The redundancy is called pilot symbol or preamble. The parameters are known by looking pilot signal from data received and will be calculated for synchronization and channel estimation process. The density of pilots determine quality of synchronization but decrease of data rate transmission.

1.5 Advantages of OFDM

Optical OFDM has several advantages and some of the advantages are shown below:

1. A large amount of data can be transmitted and at receiver simple equalizer is used to detect that data.
2. Robust against inter symbol interference (ISI), inter carrier interference (ICI), chromatic dispersion. Cyclic prefix is used to nullify ICI and ISI.
3. Optical OFDM, without complex equalization can easily adjust to severe channel conditions.
4. Efficient implementation by means of FFT.
5. Low sensitivity to time synchronization errors.
6. Capable of power overloading and dynamic bit.
7. Ease of dynamic channel estimation.
8. Extra resistance to fading.
9. High bandwidth (spectral) efficiency since carrier spacing is reduced as the subcarriers in optical OFDM is orthogonal and overlaps with each other.
10. Tolerance to linear impairments - Alike coherent detection QPSK, OFDM can compensate to linear impairments in the electrical field. This is one of the advantages of OFDM, which enables a better tolerance towards PMD and dispersion.
11. Oversampling One of the important advantages of OFDM is that oversampling can be realized using unmodulated subcarriers.

1.6 Disadvantages of OFDM

On the other hand, OFDM offers some disadvantages. The complexity is one of the effective disadvantages of OFDM, where OFDM is a multicarrier modulation (MCM) that is more complicated in comparison to single-carrier modulation and along with this more linear power amplifier is required by OFDM. Some of the disadvantages of OFDM are shown below:

1. Accuracy of the synchronization is very high
2. In order to avoid the orthogonality mismatch, multipath fading should be minimized
3. Superposition of information signals results in distortion problem due to peak-to-mean power ratio.
4. More compound than single-carrier Modulation.
5. Requires a more linear power amplifier. In the RF systems, the main problem is at the transmitter end in the power amplifiers, here amplifier gain will saturate on large input power. The power amplifier needs to be operated at which the signal power is lesser in comparison to the amplifier saturation power, so to avoid comparatively “peaky” OFDM signal. But for the power amplifier, we needs an excess high saturation power that is responsible for low power efficiency.
6. It is more sensitive to carrier frequency offset and drift than single carrier systems are due to leakage of the DFT. The two major disadvantages of OFDM are frequency offset sensitivity and phase noise which leads to (ICI) due to its long symbol length in comparison to that of the single carrier. Frequency compensation and estimation are used for removing frequency offset sensitivity. This frequency offset is compensated by the use of adaptive frequency correction (AFC), and also the phase noise sensitivity is mainly resolved by the careful and proper use of RF local oscillator design that will satisfy the necessary phase noise specification.
7. One of the most important drawbacks of the OFDM is high PAPR. An OFDM signal is created by addition of a number of independent subcarriers. This can result in a PAPR as soon as all the subcarriers are added coherently.

1.7 Peak To Average Power Ratio (PAPR)

The OFDM technique split the total bandwidth into no. of narrow sub-channels and sends data in parallel. OFDM has various advantages, such as immunity to impulse interference, high spectral efficiency and frequency selective fading without having powerful channel equalizer. High PAPR is the one of the major drawback of OFDM. This PAPR problem is arises due to presence of lots of modulated sub carriers. We cannot send this high peak amplitude signals to the transmitter without reducing peaks. So we have to reduce high peak amplitude of the signals before transmitting.

OFDM is a special case of multicarrier modulation technique in which the high bit stream is divided over several orthogonal subcarriers, each modulated at a lower rate. These Subcarriers have minimum frequency separation. This frequency separation maintains orthogonality of their corresponding time domain waveforms. Hence, this available bandwidth (BW) in OFDM ,is used very efficiently & effectively. Peak-to-average power ratio (PAPR) is very important term used in OFDM systems. Basically, PAPR is the ratio of peak power to the average power of the signal and it can be written as

$$\text{PAPR} = \frac{PeakPower}{Avg.Power} \qquad (1.4)$$

$$PAPR = \frac{\max\limits_{0 \le n \le LN-1}\left[|x_n|^2\right]}{E\left(|x_n|^2\right)} \qquad (1.5)$$

Where E[.] is the expectation operator, i.e. average power. Basically peak-to-average power ratio (PAPR) is the most popular parameter used to evaluate the dynamic range of the time-domain OFDM signal or signal envelop variation or the crest factor (CF) where PAPR = $(CF)^2$. Crest factor is another parameter which is widely used in the literature, and defined as the square root of the PAPR.

1.8 Relation Between CCDF & PAPR

The Cumulative Distribution Function (CDF) is one of the most frequently used parameters, CDF is used to measure the efficiency of any PAPR reduction technique. Normally, the this Complementary CDF (CCDF) is used in place of CDF, which helps us to measure the probability of the PAPR of a certain data block exceeds the given threshold. The CCDF is simply defined as the plot of relative power levels against their probability of occurrence Complementary Cumulative Distribution Function (CCDF) curves provide critical information about the signals encountered in communication systems. CCDF curves also provide the peak-to-average power data which is required by component designers. A CCDF curve shows probability of the signal spends at or above a given power level. The signal power level is expressed in dB relative to the average power. The percentage of time the signal spends at or above each line defines the probability for that particular power level. A CCDF curve is a XY plot of relative power levels in dB versus probability.

CCDF plots can also be used to analyze the impact of non-linearity of the communication system. CCDF also demonstrates the compression of the amplified signal measured at the transmitter output. You can consider a simple XY plot. Here, the x-axis is scaled to dB above the average signal power, which means we are actually measuring the peak-to average ratios as opposed to absolute power levels. The y-axis is the percent of time the signal spends at or above the power level specified by the x-axis. The position of the CCDF curve indicates the degree of peak-to-average deviation, with more stressful signals further to the right. [5]

The CCDF is a performance measuring index which indicates the probability of PAPR exceeding a specified threshold. For M subcarriers, the PAPR values depend on the nature of the wavelet basis used. Hence by properly selecting the wavelet basis, PAPR can be reduced. The CCDF is given as by equation (1.6)

$$\text{Probability}\ (\text{PAPR} > Z) = 1 - P(\text{PAPR} \le Z) \qquad (1.6)$$

Where Z is the PAPR threshold

From the central limit theorem, for large number of values of N, the real and imaginary values of $x(t)$ becomes Gaussian distributed. The amplitude of the OFDM signal, therefore, has a Rayleigh distribution with a variance of N times zero mean and the variance of one complex sinusoid. The cumulative distribution function (CDF) of the PAPR is among the most frequently used performance measures for PAPR reduction techniques. The complementary cumulative distribution function (CCDF) is the probability that the PAPR exceeds a certain threshold $PAPR_0$

$$\text{CCDF}(\text{PAPR}(x(n))) = P_r(\text{PAPR}(x(n))) > \text{PAPR}_0 \qquad (1.7)$$

Due to the random nature of the N samples, the CCDF of the PAPR of a data block having Nyquist rate sampling is given by

$$P = P_r(\text{PAPR}(x(n)) > \text{PAPR}_0) = 1 - (e^{\text{PAPR0}})^N \qquad (1.8)$$

In equation (1.8) we assumes that the N time domain signal samples are mutually independent and uncorrelated and it is not accurate for a small number of subcarriers. Therefore, there have been many attempts to derive more accurate distribution of PAPR.

2. LITERATURE SURVEY

High peak-to-average power ratio of the transmit signal is a major drawback of multi-carrier transmission such as OFDM or DMT. We described here some of the important PAPR reduction techniques for multi-carrier transmission. These techniques are tone reservation, amplitude clipping and filtering, coding, partial transmit sequence, interleaving, , selected mapping ,tone injection, and active constellation extension. Also, we concluded with some remarks for the criteria for PAPR reduction technique selection and briefly address the problem of PAPR reduction in OFDMA and MIMO-OFDM. **Seuang, H. [2005] [1] et.al** concluded that Multi-carrier transmission is a very attractive technique for high-speed transmission over a dispersive communication channel. The PAPR problem is one of the important issues to be addressed in developing multi-carrier transmission systems. In this paper they described some PAPR reduction techniques for multicarrier transmission. Many promising techniques to reduce PAPR have been proposed, all of which have the potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase, and so on. There is no any specific PAPR reduction technique is the best solution for all multicarrier transmission systems. The PAPR reduction technique should be carefully selected according to various system requirements. In practice, the effect of the transmit filter, D/A converter, and transmit power amplifier must be taken into consideration to choose an appropriate PAPR reduction technique. **LaSorte, N. [2008] [2] et.al** gave the idea about the development of Orthogonal Frequency Division Multiplexing from a historical perspective. A summary of major research milestones are noted that contributed to modern-day OFDM. These contributions include the use of discrete Fourier transforms replacing the analog implementation and addition of cyclic extensions to ensure orthogonality among the sub-channels. Also, channel equalization algorithms to suppress inter-symbol interference and inter-carrier interference, channel estimation through the insertion of pilot tones among data blocks, peak-to-average power ratio reduction, and synchronization techniques are discussed. After that Lim, **D.W. et.al [2009] [3]** reviewed the conventional PAPR reduction schemes and their modifications for achieving the low computational complexity required for practical implementation in wireless communication systems. Through this paper provided an overview of the conventional PAPR reduction schemes such as clipping, SLM, PTS, TR, TI, and ACE, and their modifications for achieving a low computational complexity. Although many PAPR reduction schemes have been developed, none of them satisfies commercial requirements or has been adopted as a standard for wireless communication systems. But, the modified PAPR reduction schemes with low computational complexity can be applied to high data rate OFDM systems. Future studies on PAPR reduction may include a combination of different schemes. **Kamal et.al [2011] [4]** told about the OFDM is one of the promising techniques for achieving high downlink capacities in future cellular and wireless networks. The major problem of orthogonal frequency division multiplexing (OFDM) signals is high peak to average power ratio (PAPR) of the transmitted signal. A high PAPR brings disadvantages like an increased complexity of the A/D and D/A converters and reduced efficiency of radio frequency (RF) power amplifier. The high peak of OFDM signal can be reduced by PAPR reduction techniques. In this paper partial transmit sequences (PTS) and iterative flipping schemes are discussed to reduce PAPR and compared with original scheme (without PAPR reduction scheme). Computer Simulations results show that the both schemes achieve PAPR reductions, but the result shows that PTS scheme can offer better PAPR reduction performance than the iterative flipping.. **Bhardwaj. M et.al [2012] [5]** Orthogonal frequency division multiplexing (OFDM) is a special case of multicarrier transmission where a single DataStream is transmitted over a number of lower rate subcarriers. In July 1998, the IEEE standardization group decided to select OFDM as the basis for their new 5-GHz standard aiming a range of data stream from 6 up to 54 Mbps. This new standard is the first one to use OFDM in packet-based communications. In wireless communication, concept of parallel transmission of symbols is used to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal subcarriers in order to transmit the symbols using these subcarriers in parallel. In this paper we will discuss the basics of OFDM techniques , role of OFDM in this era, its benefits and losses and also some of its application. **Arora, N. [2013] [6]** gave the idea to reduce the complexity of the IFFT architecture is used for complexity reduction of PTS PAPR reduction scheme in OFDM systems is investigated in this paper. In this IFFT architecture of PTS OFDM scheme, there are many multiplications and additions with zero involved , which are obviously unnecessary. By eliminating these additions and multiplications with zero from the architecture, we can efficiently reduce the computational complexity without changing the resulting signal or degrading the performance of PAPR reduction Through this paper PTS SUB-BLOCKS PAPR reduction techniques have been proposed and analyzed. A new PTS OFDM scheme is introduced having low complexity IFFT implement architecture. It is shown that the new proposed scheme is similar to the traditional PTS OFDM scheme, hence its performance of PAPR reduction is also same as the traditional PTS OFDM scheme. The new scheme reduces the computational complexity significantly. **Sudharani, V. et.al [2013] [7]** presented that OFDM is a promising technique for the present generation communication systems where high data rate and fading channels are of major concern. However still some challenging issues remain unresolved in the design of OFDM systems. One of the major problem is high PAPR. The high PAPR of transmitted systems reduces the system efficiency and hence increases the cost of Radio Frequency(RF) Power Amplifier and also degrades the BER. In this paper, a Dummy Signal Hybrid (DH) SLM-PTS scheme is proposed to obtain the better PAPR reduction performance with reduced computational complexity. The simulation results are examined with other hybrid schemes and found that DH scheme provides better PAPR reduction performance compared to other hybrid schemes but at the cost of computational speed, because each time it compares the PAPR of the signal with threshold value and generates dummy signal accordingly with reduced PAPR. **Aggarwal, S. et.al [2014] [8]** Orthogonal Frequency Division Multiplexing (OFDM) has been adopted as a predominant access technique to meet the challenges offered by next generation broadband wireless mobile systems. OFDM has gained a lot of interest in recent years because of its robustness against multipath fading. Despite many potential advantages offered by OFDM system, it suffers from major drawback of high Peak-to-Average Power Ratio (PAPR) which leads to inefficiency of radio frequency (RF) power amplifiers. In this paper, some of the important PAPR reduction techniques are reviewed and their analysis is done on the basis of their computational complexity, BER performance, spectral efficiency etc. After that **Geetha, M.N. et.al [2017] [9]** Orthogonal frequency division multiplexing (OFDM) has gained attention recently ever since it has been adopted as a standard for various high data rate wireless communication systems due to the high spectral bandwidth adaptability, sturdiness to frequency selective fading channels, well suited for mimo technology, Facilitate frequency-domain scheduling supports flexible bandwidth deployment etc. However, implementation of this system encompass several difficulties. One of the major setback is the high peak-to-average power ratio(PAPR) snag in multicarrier transmission system. This leads to power inefficiency in RF section of the transmitter, inter carrier interference and bit error rate performance degradation. Minimum PAPR will allow a higher average power to be transmitted for a fixed peak power which in turn improves overall SNR at the receiver. This report looks through various procedures proposed for PAPR reduction schemes for actualizing the low computational complexity which is necessary for real time applications in wireless communication systems.

3. Problem Formulation and Methodology

3.1 Introduction

Many approaches have been proposed to resolve with the PAPR problem in OFDM. These PAPR reduction techniques are clipping and filtering, active constellation extension (ACE), coding, tone reservation (TR),amplitude clipping, tone injection (TI), and multiple signal representation techniques such as partial transmit sequence (PTS) , selected mapping (SLM), and interleaving. PAPR reduction techniques achieve PAPR reduction at the expense of transmitting high signal power , high bit error rate (BER), loss in data rate, high computational complexity, and so on. Many PAPR reduction techniques to reduce high PAPR of OFDM signals are proposed in the literature The PAPR reduction techniques for OFDM signal in DVB-T system can be broadly classified into three main categories.

1. Signal distortion less techniques.
2. Coding techniques.
3. Signal distortion techniques.

1) Signal Distortion-less Techniques

In Signal distortion-less techniques Peak power of OFDM signal reduced but causes distortion of signal before to passing it through the Power Amplifier (PA). These techniques are useful after the generation of OFDM signal (after the IFFT operations). The signal distortion techniques are as

a) PTS Technique

The PTS technique is a very good PAPR reduction technique. The block diagram of the PTS scheme is shown in figure In the PTS scheme, the input data X is partitioned into M disjoint sub-blocks. Then phase factors are used to weight each sub carrier for that sub block. These phase factors are selected so that the PAPR of the combined signal is reduced . The input data X divided into M disjoint sunblocks is

$$X^{(m)} = [X_0^{(m)}, X_1^{(m)}, X_2^{(m)}, \ldots\ldots\ldots\ldots X_{N-1}^{(m)}] \quad , \qquad (3.1)$$

Where m =0 ,1 , 2 ,3 ……...M

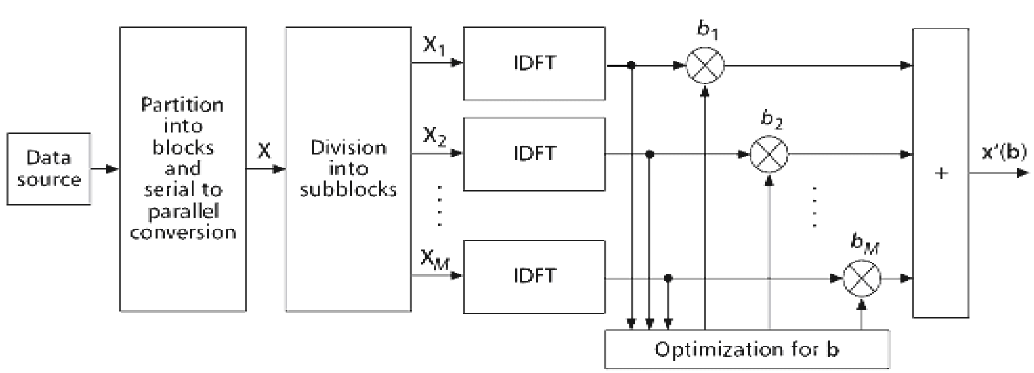


Figure 3.1: The block diagram of PTS technique

All the sub-carrier positions which are presented in other sub-blocks must be zero so that the sum of all the sub-blocks constitutes the original signal,

$$X = \sum_{m=1}^{M} X^m \quad (3.2)$$

The Complex phase factors b(m) are introduced to combine the PTSs. The set of phase factors is denoted as a vector b = [b_1, b_2, b_3…………b_M]. Each sub block $X^{(m)}$ is multiplied by a phase factor $b^{(m)}$ and then added together. This operation can be represented by

$$X' = \sum_{m=1}^{M} IFFT(b^m.X^m) = \sum_{m=1}^{M} b^m.IFFT(X^m) = \sum_{m=1}^{M} b^m.X^m \quad (3.3)$$

Where $x^{(m)}$ is the so-called Partial Transmit Sequence Now the objective is to find the optimum set of phase factors, which minimizes the PAPR of the resulting signal. However, the search complexity increases exponentially with the number of sub-blocks In general, The selection of the phase factors is limited to a set with a finite number of elements to reduce the search complexity. The set of allowed phase factors is written as P = [$e^{j2\pi L/W}$,L= 0, 1, …………..W-1], where W is the number of allowed phase factors. Also we can set $b^{(1)} = 1$ without any loss of performance. So, it is recommended to perform an exhaustive search for (M -1) phase factors. From this we can say that $W^{(M-1)}$ sets of phase factors are found to find the optimum set of phase factors. The amount of PAPR reduction depends on the number of sub-blocks M and the number of allowed phase factors W. Another factor that may affect the PAPR reduction performance in PTS is the sub-block partitioning, which is the method of division of the sub-carriers into multiple disjoint sub-blocks. The PTS technique works with a modulation scheme and an arbitrary number of sub-carriers. As discussed above, the ordinary PTS technique has exponentially increasing search complexity. To reduce the search complexity in PTS , various methods to reduce the number of iterations are purposed. These methods results in significant reduction in search complexity with minimal PAPR performance degradation. The phase factors must then be transmitted as side information to the receiver. It is required to send side information to the receiver end to recover the original required data block. This can be done by transmitting these side information bits with a separate channel other than the data channel. We can also include the side information within the data block, however, this can reduce our data rate .

b) Iterative Flipping Technique

Cimini and Sollenberger's Iterative flipping technique is developed as a sub-optimal technique for the PTS algorithm. In PTS technique, to find the optimum set of phase factor, we need to evaluate all the combinations of phase factors. Due to this search complexity is increased. Cimini's method is conducted with the condition that the number of the possible phase factor is W = {1, −1}. The algorithm starts after dividing the input data sequence into V subblocks and then assuming the initial phase rotation factor vector $b_v = 1$ for all v to compute the initial PAPR value, where v = {1, 2, ... , V}. Next, the first phase factor $b_1 = 1$ is inverted and the PAPR value is recomputed and compared with the initial PAPR value, if the new PAPR is lower than the initial PAPR value.

As discussed in previous scheme, the optimization process of the PTS scheme needs to evaluate all the combinations of phase factors. In , a simplified scheme called iterative flipping algorithm has been introduced and the computation complexity reduces to be linear with the number of sub blocks M. The iterative flipping algorithm can be described as the following steps:

1.Partition the input data X into M disjoint sub blocks to form the partial transmit sequences as described in the PTS scheme.

2. is initialized to 1 for all m and the PAPR is computed.

3.The first bit is changed, i.e. and the resulting PAPR is recomputed. If the new PAPR is smaller than that in the previous step, is updated with -1, otherwise, is reverted back to 1.

4.The algorithm repeats in this fashion until all M bits have been explored. Obviously, in the iterative flipping scheme as discussed in , the search complexity of this algorithm reduces to the number of sub blocks.

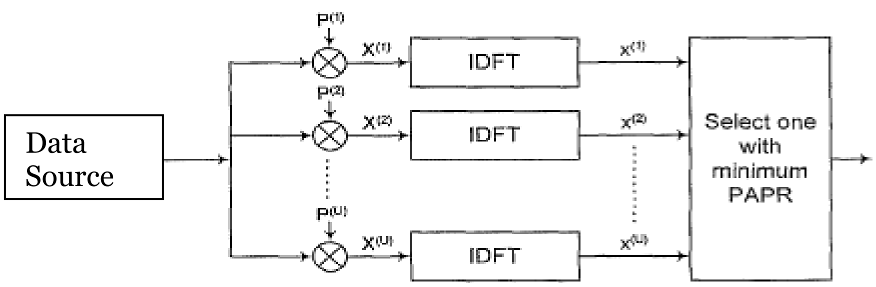
The iterative flipping with threshold method was introduced to depress the computational complexity for finding the optimum weighting factor. As mentioned in the previous section, this method increases the PAPR value, but the computational complexity is degraded. In contrast, the threshold-PTS method that has been proposed in works to terminate the weighting factors optimization as soon as the PAPR value of OFDM signal falls below the threshold value. The procedure of the is based on setting the number of the processing levels equal to the number of the phase factor vector bits. In each level, the optimum bit of the phase rotation factors which leads the PAPR value to be lower than that of the previous state must be fixed at the next levels processing. After wards, each PAPR value is compared with the threshold value. Hence, if the PAPR value is lower than the threshold value, the weighting factors optimization is terminated, as shown in Figure 3.3. This fashion continues until the last level; with the consideration that the optimum bit of the weighting factors is fixed at the current level. The ICF algorithm clips the amplitude of x(n) to a threshold say T if the amplitude, |x(n)|, exceeds T.

c) Selective Mapping (SLM) Technique

Bauml purposed this Selective Mapping (SLM). Block diagram of SLM Technique is shown in Figure 3.3. Selective Mapping (SLM) method is used for minimization of peak to average transmit power of multicarrier transmission system with selected mapping. In selective mapping (SLM) technique, from the set of sufficiently different signals the signal having lowest PAPR is selected. These all signals represents the identical information. In SLM a complete set of original signal is generated signifying the identical information. After this most favorable signal is selected as consider to PAPR and transmitted over the channel. We can say that input data structure is multiplied with a random series and resultant series with the lowest PAPR is identified and chosen for transmission. multiplying sequence is required to sent as side information , it helps to recover the original data, the multiplying sequence is termed as side information. Selective mapping (SLM) is a reliable PAPR reduction technique of OFDM system. Figure 3.4 shows the basic principle of Selective Mapping.

In simple words in SLM same data source is used to produce an alternative transmit sequences and then signal exhibiting the lowest PAPR is selected and transmitted over channel. The main principle of this technique is the fact that sequence of the transmit data vectors, Xm multiplying the data vectors by some random phase will change the PAPR properties after the IFFT. The result from multiplication will generate the data block of an OFDM system that has different time domain signals.

Symbol scrambling is used in this SLM technique . In Symbol scrambling ,information is represented with the help of a set of candidate signals & then from the set signal having lowest PAPR is selected and transmitted over the channel. The side information about the selection of these candidate signals required to be transmitted for recovering exact information .This side information plays an important role and used for recovering information signal. Evolution of any error in the received information, can increase difficulty level for the receiver to recover the information from the transmitted selected signal. To overcome this problem a strong protection is needed regarding side information. This side information signal helps in the process of decoding required information signal . It also helps to reduce the complexity level at receiver end of the OFDM system. SLM PAPR reduction technique can be employed for larger number of sub-carriers with moderate complexity .



From the fig 3.4 it is clear that in SLM technique whole set of signal represent the same signal but form it most favorable signal is chosen related to PAPR transmitted. The side information required to be transmitted with the selected signal. SLM technique is probabilistic based approach & will not remove the peaks but prevent it from frequently generation. This scheme is very efficient but main drawback is to retain and transmit side information along with the chosen signal. Plesae refer figure 3.4 , The input data sequences of each user (d^K_1, d^K_2, d^K_3 ………………d^K_M) with length M , first converted into M parallel data sequences $C^{(k)}$ =[C^K_1 , C^K_2 , C^K_3 ………………C^K_L]. and then all S/P symbols converted output is multiplied with the spreading code with length *L*. Multiplexed symbol sequences.

$$X = \sum_{k}^{k-1} X^k = [\, X^0, X^1, X^2 \ldots\ldots\ldots\ldots X^{N-1}] \qquad (3.4)$$

are multiplied by *U*-1 different phase sequences $b^M=(b_0^M, b_1^M, b_2^M \ldots\ldots\ldots b_{N-1}^M)$ whose length is equal to the number of carriers before IFFT process resulting in *U*-1 modified data blocks. Below is the flow chart of SLM technique.

Below are the important steps involved in SLM algorithm.

a) Divide the input data in to number of sub blocks and converted into parallel form by using convertor.

b) Then the input data sequences are multiplied by phase sequence to generate input symbol sequence.

c) Each of input resultant symbol sequence is undergo IFFT operation.

d) CCDF of resultant signal is calculated and compared with threshold value ($PAPR_0$).

e) Data with lowest PAPR is selected for transmission.

Table 3.1 : Comparison of PAPR reduction techniques

S.No.	PAPR Reduction Technique	BER Increase	Bit Rate reduction	Implementation Complexity
1	Clipping & Filtering	Yes	No	Low
2	Compading	Yes	No	Low

3	Selective Mapping	No	Yes	High
4	Partial Transmit Sequence	No	Yes	High
5	Interleaving	No	Yes	High
6	Tone Injection	No	No	High
7	Tone Reservation	No	Yes	High
8	Active constellation Shaping	No	No	High
9	Constrained Constellation Shaping	Yes	No	High
10	Linear Block Coding	No	Yes	Low
11	Golay Sequence	No	Yes	High

4. Result Analysis

4.1 Simulation Parameters

In 3rd chapter we have discussed various PAPR reduction techniques. In this chapter we will further compare and analyze best PAPR reduction technique for various values of N. PAPR reduction is a well-known signal processing topic in multi-carrier transmission and large number of techniques appeared in the literature during the past decades. In this chapter the graphs for the complement cumulative distribution function (CCDF) of PAPR in original (without reduction technique), PTS techniques , Iterative flipping technique and SLM technique for the different values of M = 2, 4, 8 ,16 sub-blocks respectively. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given fixed threshold PAPR.

Table 4.1: Simulation parameters of various PAPR reduction techniques.

Simulation Parameter	**Type /value**
Number of sub carriers (N)	256,512
Number of sub-blocks (M)	2, 4, 8 , 16
Oversampling factor(L)	4
Modulation Scheme	BPSK
Phase factor	[1 , -1]

4.2 Matlab Simulation

Figure 4.1 shows the CCDF's of PAPR in original, Iterative flipping, SLM & PTS techniques when M = 2 sub-blocks. In this case, SLM technique is compared with PTS & Iterative flipping techniques and PAPR
of original signal, and simulation results show that all these three PAPR reduction techniques reduce the PAPR of the OFDM signal. It is also seen that when the value of threshold PAPR is low, the performance of Iterative flipping technique and SLM technique is almost same, but for higher value of threshold PAPR, SLM technique gives better performance than the PTS & Iterative flipping techniques.

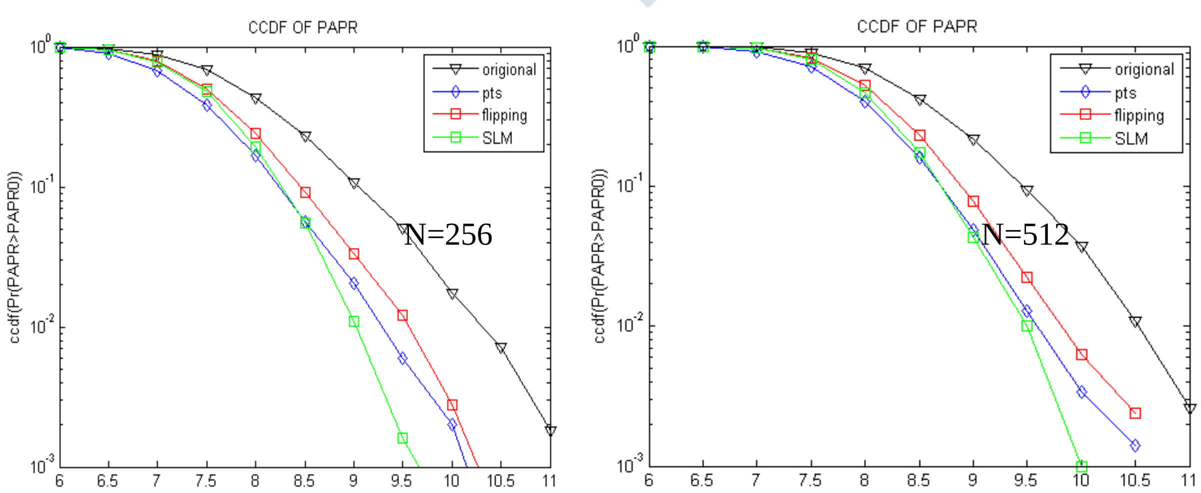


Figure 4.1: CCDF's of PAPR in SLM, Iterative, PTS and original techniques with M = 2 sub-blocks (N = 256, N=512, L = 4, BPSK modulation)

From the Figure 4.1 it can be easily observed that all these three techniques can reduce the PAPR of OFDM Signals, but SLM technique offer better performance than the PTS and Iterative flipping techniques. Although the SLM technique offer better PAPR reduction performance than the PTS and Iterative techniques, but SLM technique is more computationally complex than the PTS & Iterative techniques. It is also seen that when the value of threshold PAPR is low, the performance of Iterative flipping technique and SLM technique is almost same, but for higher value of threshold PAPR, SLM technique gives better performance than the PTS & Iterative flipping techniques.

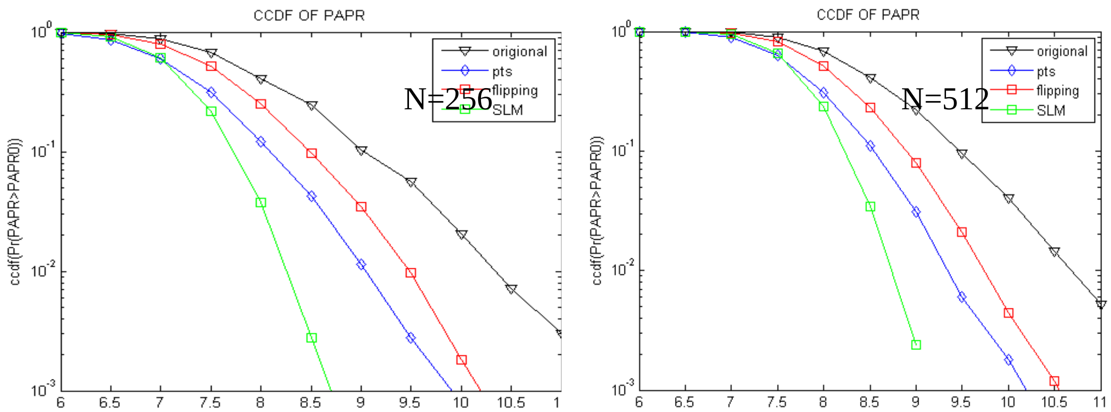


Figure 4.2: CCDF's of PAPR in SLM, Iterative, PTS and original techniques with M = 4 sub-blocks (N = 256,512 L = 4, BPSK modulation)

Figure 4.2 shows the CCDF's of PAPR in PTS, Iterative, SLM techniques for M = 4 sub-blocks. As expected, the performance of SLM, PTS and Iterative techniques has improved when compared to case with M = 2. The graph also shows that for higher value of threshold PAPR, SLM technique yields the best performance amongst all the previously discussed techniques.

Further for M=8 , as illustrated by figure 4.3 It can be seen that SLM technique shows a significant improvement in PAPR reduction performance when compared to M=2 & 4 respectively. Though PTS and Iterative techniques also show improvement in their PAPR reduction as M increases, but the amount of performance increase is comparatively lesser. Thus performance of SLM technique continuously increases as the number of sub blocks increase.

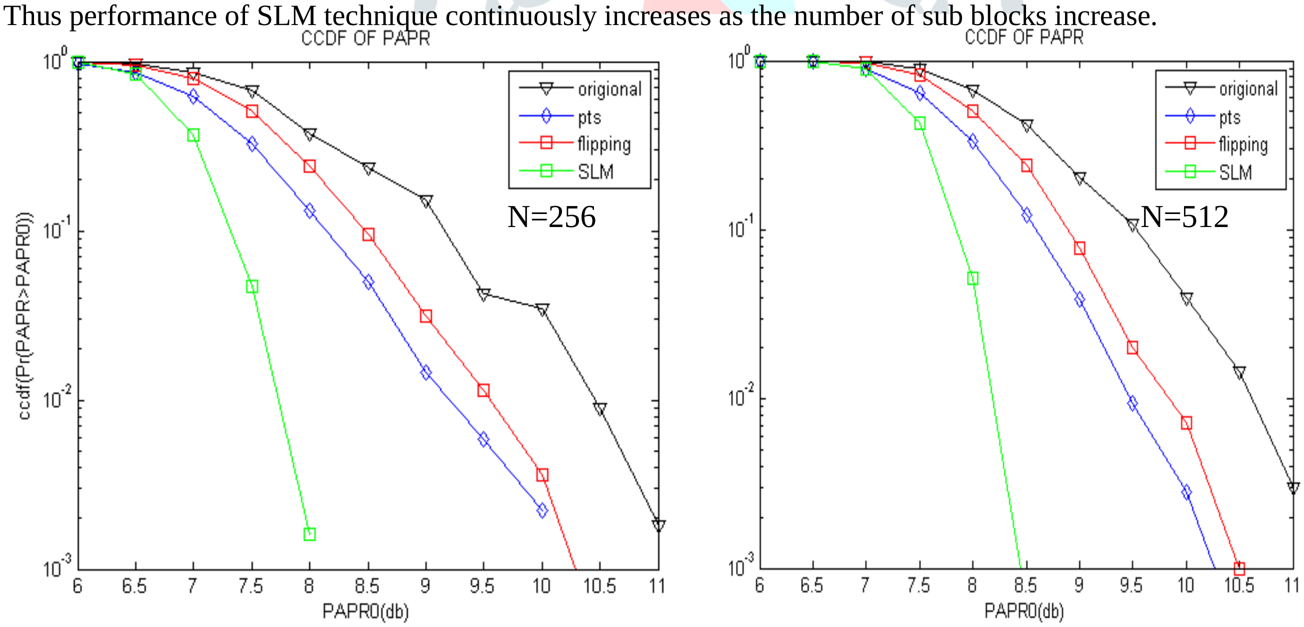


Figure 4.3: CCDF's of PAPR in SLM, Iterative, PTS and original techniques with M =8 sub-blocks (N = 256,N=512, L = 4, BPSK modulation)

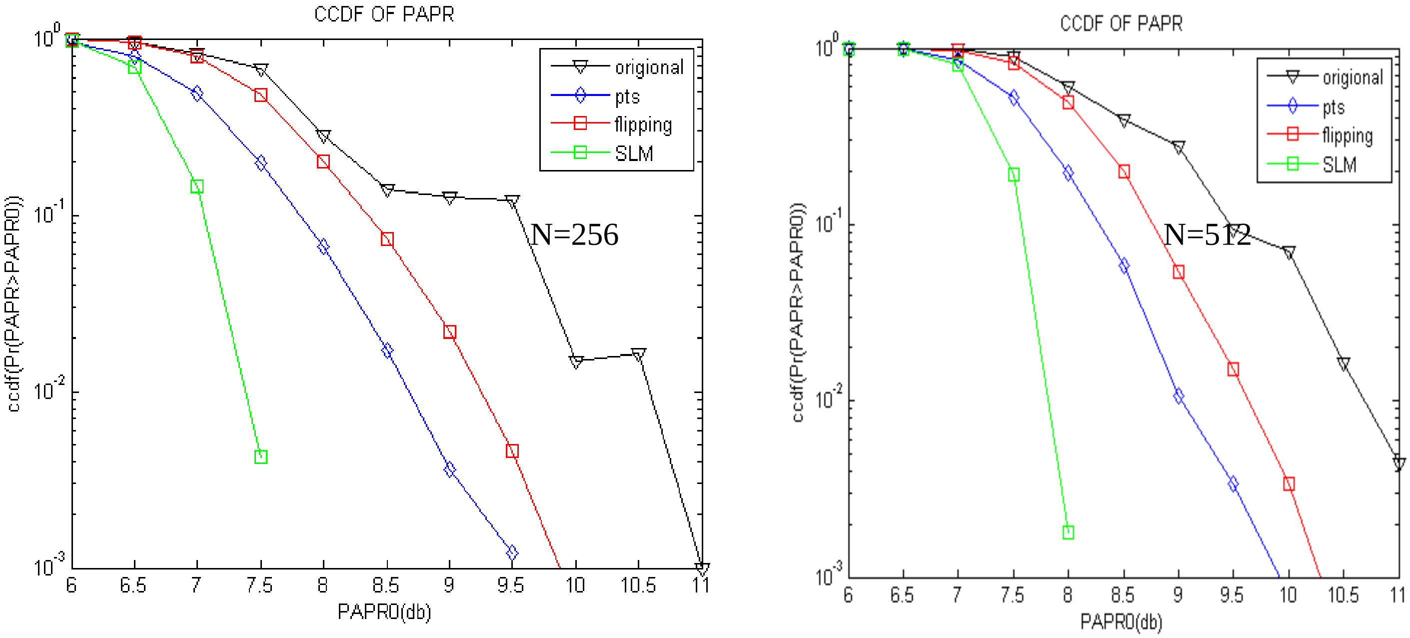


Figure 4.4: CCDF's of PAPR in SLM, Iterative, PTS and original techniques with M =16 sub-blocks (N = 256, N=512, L = 4, BPSK modulation)

Further for M=16, as illustrated by figure 4.4 , Thus by analyzing the simulation results from the Figure 4.1 to Figure 4.4 it can be concluded that as the number of sub-blocks increase the performance of SLM technique is continuously improved. The simulation results show that the SLM technique exhibits better PAPR reduction performance than the PTS & Iterative flipping techniques. It can be concluded that as the number of sub-blocks increase from M = 2 to M = 16 the performance of the SLM, PTS and Iterative techniques also increase, but SLM technique offer better PAPR reduction than the PTS and Iterative flipping techniques, especially for higher value of threshold PAPR. However, SLM technique is more computationally complex as discussed in Section 3.

5. Conclusion and Future Scope

5.1 Conclusion

In this Paper, different PAPR reduction techniques are discussed and simulated . PAPR reduction techniques are also compared for different 2 parameters. The PAPR reduction performance of these techniques is compared with another PAPR reduction techniques discussed in chapter 4. The concluding remarks are as follows.

The simulation results of different PAPR reduction techniques, discussed in Chapter 3, show that all of these existing techniques can reduce the PAPR of OFDM signals by different amounts. By analyzing the existing techniques, it can be seen that, in general, the PAPR reduction performance of these techniques becomes better & better as the number of sub-blocks increases. We also come to know that with increase iin no of sub carrier there is a increase in PAPR for same techniques. The order of better performace with increase in sub-blocks is SLM (Best), PTS(better), ITR Flipping(Good).The Riemann matrix based SLM technique i.e. new Selection of technique to be used depends upon the application and various important requirements of the communication system.

5.2 Future Scope

In this dissertation, performances of some of the existing PAPR reduction techniques have been evaluated. PAPR reduction techniques are simulated for different parameters.

Further research work can be carried out in the following areas , In this thesis, BPSK modulated signal have been considered for PAPR evaluation of OFDM signals.

The PAPR reduction algorithms can be extended for higher order modulations and for higher number of sub-carriers to be utilized in other wireless standards. Although the SLM offer better PAPR reduction, but the computational complexity issues of the PAPR techniques have not been addressed in this dissertation. Logically, the computational complexity of the PAPR techniques seem to be higher than the techniques on which the modifications have been carried out. Further research work can be carried out to reduce the computational complexity and also a combination of two technique can give better performance.

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