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IMPLEMENTATION OF PAPR REDUCTION SCHEMES BY USING DCT AND SLM TECHNIQUES

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ABSTRACT

One of main disadvantage of Orthogonal frequency division multiplexing (OFDM) is high peak-to-average power ratio (PAPR). In this paper, two effective PAPR reduction schemes are proposed. These techniques combine the DCT and SLM techniques. The scheme 1 is composed of the DCT followed by the SLM technique, and the DCT is used followed by conventional SLM in proposed scheme 2. Simulation results show that the proposed schemes can obtain significant PAPR reduction performance with that of ordinary SLM techniques.

KEYWORDS: ***SLM, DCT Transform, PAPR, OFDM***

1. INTRODUCTION

Wireless communication is among technology's biggest contributions to mankind. Wireless communication involves the transmission of information over a distance without help of wires, cables or any other forms of electrical conductors. The transmitted distance can be anywhere between a few meters (for example, a television's remote control) and thousands of kilometers (for example, radio communication). Some of the devices used for wireless communication are cordless telephones, mobiles, GPS units, wireless computer parts, and satellite television.

Advantages:

Wireless communication has the following advantages:

- Communication has enhanced to convey the information quickly to the consumers.
- Working professionals can work and access Internet anywhere and anytime without carrying cables or wires wherever they go. This also helps to complete the work anywhere on time and improves the productivity.
- Doctors, workers and other professionals working in remote areas can be in touch with medical centers through wireless communication.

Disadvantages

The growth of wireless network has enabled us to use personal devices anywhere and anytime. This has helped mankind to improve in every field of life but this has led many threats as well

Wireless Medical Technologies

New wireless technologies, such as mobile body area networks (MBAN), have the capability to monitor blood pressure, heart rate, oxygen level and body temperature. The MBAN works by sending low powered wireless signals to receivers that feed into nursing stations or monitoring sites. This technology helps with the intentional and unintentional risk of infection or disconnection that arise from wired connections.

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

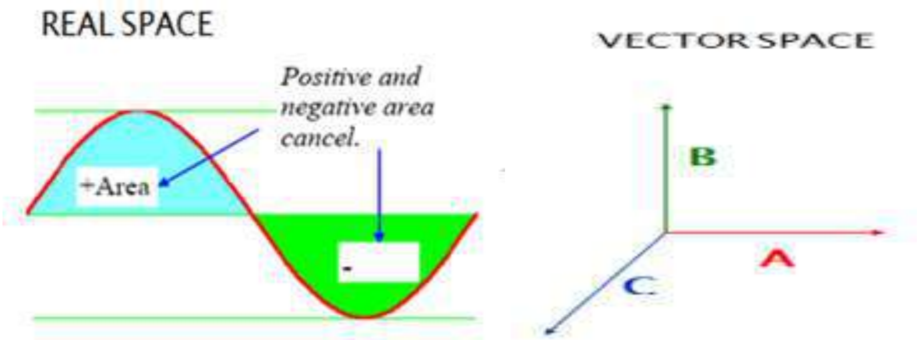
Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using subcarriers which are orthogonal to each other.

Fig 1: All cargo on one truck vs. splitting the shipment into more than one

Principle of Orthogonality

The condition for maintaining the orthogonality is that the frequency spacing between the carrier signals must be an integer multiple of the lowest carrier frequency.

In multi-carrier system, occupied bandwidth on the channel is minimized as possible. This minimization is possible by reducing the frequency space between carriers. The narrow space among the carriers is obtained when they are orthogonal to each other. To be orthogonal, the time averaged integral product of two signals should be zero.



(i) (ii)

Fig 2.(a): (i)Area under a sine wave over one period is always zero.

Mathematically, the orthogonality of two signals can be expressed as

$$\frac{1}{T}\int_{t_1}^{t_1+T} f_k(t) \times f_l(t)\,dt = 0 \quad if\ k \neq l \tag{2.1}$$

Where , f_k (t) and f_l(t) are any two signals over time interval [t_1, t_1+T],T a is signal time period. For orthonormal, the time averaged integral product of two signals should be one.

Mathematically, orthonormal of two signals can be expressed as

$$\frac{1}{T}\int_{t_1}^{t_1+T} f_k(t) \times f_l(t)\,dt = 1 \quad if \quad k = l \tag{2.2}$$

Using equation (2.1) and (2.2), orthogonality for OFDM system is expressed as-

$$\frac{1}{T}\int_0^T e^{j2\pi f_k t} \times e^{-j2\pi f_l t} dt = \frac{1}{T}\int_0^T e^{\frac{j2\pi kt}{T}} \times e^{\frac{-j2\pi lt}{T}} dt = \frac{1}{T}\int_0^T e^{\frac{j2\pi(k-l)t}{T}} dt \tag{2.3}$$

Solving equation (2.3), we get-

$$\frac{1}{T}\int_0^T e^{j2\pi f_k t} \times e^{-j2\pi f_l t} dt = \begin{cases} 0 & \forall\ k \neq l \\ 1 & \forall\ k = l \end{cases} \tag{2.4}$$

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Taking the discrete samples with the sampling instances at t=nTs=nT/N, n=0,1,2,…..N-1 . Equation (2.4) can be written in the discrete time domain as-

$$\frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi k}{T}nT_s} \times e^{\frac{-j2\pi k}{T}nT_s} = \frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi(k-l)}{N}n} = \begin{cases} 0 & \forall\ k \neq l \\ 1 & \forall\ k = l \end{cases} \quad (2.5)$$

OFDM communication systems are able to effectively utilize the frequency spectrum through overlapping subcarriers. Simulation of figure (2.2) for five sub-carriers shows that sub-carriers are able to partially overlap without interfering with adjacent sub-carriers because the maximum power of each subcarrier corresponds directly with the minimum power of each adjacent channel. In additional, different sub-carriers are orthogonal to each other and they are totally different from one another.

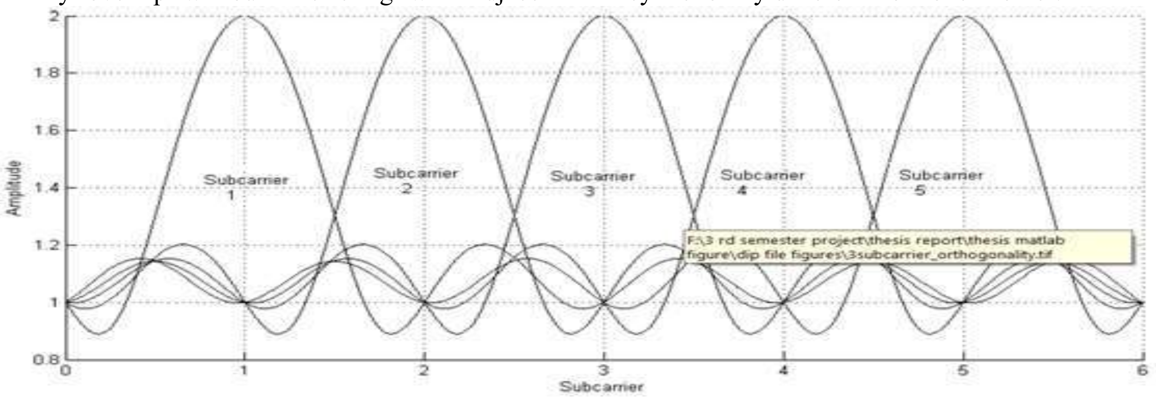

Fig 2.(b) frequency response of 5 sub carriers of OFDM signal

Block Diagram

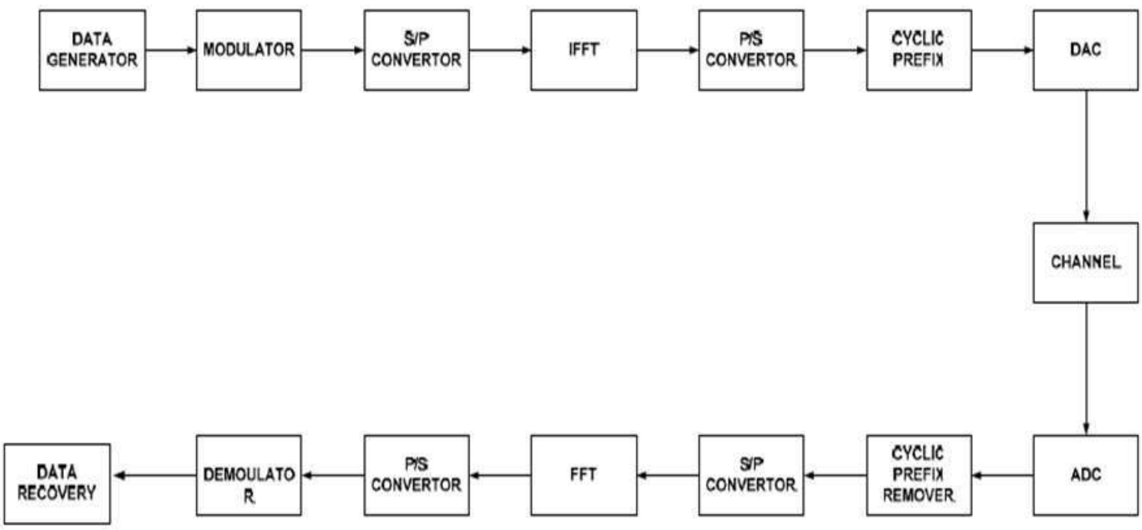

Fig 3: Block diagram of OFDM system

3. MODULATION TECHNIQUES

Modulation is defined as the process in which the characteristics of a carrier signal is varied in accordance with the instantaneous values of modulating signal. the modulation techniques are classified into two types.

They Are:

1. Analog Modulation Techniques
2. Digital Modulation Techniques

Analog Modulation Technique

The analog modulation is to transfer an analog low pass signal i,e. audio or video signals over the analog band pass channel i,e. limited radio frequency band.

analog modulation is three types.

They Are:

1. Amplitude Modulation
2. Frequency Modulation

3. Phase Modulation
4.

Digital Modulation Technique

The digital modulation is to transfer digital bit stream over the analog band pass channel. Digital modulation techniques are three types.

They Are:

1. **Amplitude Shift Keying**
2. **Frequency Shift Keying**
3. **Phase Shift Keying**
4.

5. PAPR REDUCTION TECHNIQUES

PAPR (PEAK-TO-AVERAGE POWER RATIO)

The Peak to Average Power Ratio (PAPR) of OFDM is defined as the ratio between the maximum instantaneous power and the average power.

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. At each instant they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio.

$$x(t) = \sum_{n=0}^{N-1} X_k e^{j2\pi f_k t}, \quad 0 \le t \le NT$$

PAPR is defined as:

$$PAPR = \frac{\max|x(t)|^2}{E\left[|x(t)|^2\right]}$$

Where $max[|x_n|^2]$ represents the maximum power of the signal and $E[|x_n|^2]$ is the average signal power. For an OFDM system with N sub-carriers, the peak power of received signals is N times the average power when phase values are the same. The PAPR of baseband signal will reach its theoretical maximum at (dB) =10log N.

PAPR in dB is given as:

$$PAPR = (P_{peak}/P_{average}) = 10\log_{10}[[\max|x(t)|^2]/E\{x(t)^2\}]$$

Criteria For PAPR Reduction Method Selection

The criteria of the PAPR reduction is to find the approach that it can reduce PAPR largely and at the same time it can keep the good performance in terms of the following factors as possible. The following criteria should be considered in using the techniques:

i) The high capability of PAPR reduction is primary factor to be considered in selecting the PAPR reduction technique with as few harmful side effects such as in-band distortion and out of band radiation.

ii) Low average power: Although it also can reduce PAPR through average power of the original signals increase, it requires a larger linear operation region in HPA and thus resulting in the degradation of BER performance.

iii) Low implementation complexity: Generally, complexity techniques exhibit better ability of

(i) PAPR reduction. However, in practice, both time and hardware requirements for the PAPR reduction should be minimal.

iv) Without additional power needed: The design of a wireless system should always take into consideration the efficiency of power.

Reduction Techniques

PAPR reduction techniques vary according to the requirement of the system and are dependent on various factors such as PAPR Spectral efficiency, reduction capacity, increase in transmit signal power, loss in data rate, complexity of computation and increase in the bit-error rate(BER) at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system. Many techniques have been suggested for PAPR reduction, with different levels of success and complexity. lot of techniques presents for the reduction of this PAPR.

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These Reduction techniques are divided into three groups:

1. signal distortion techniques
2. signal scrambling techniques
3. coding

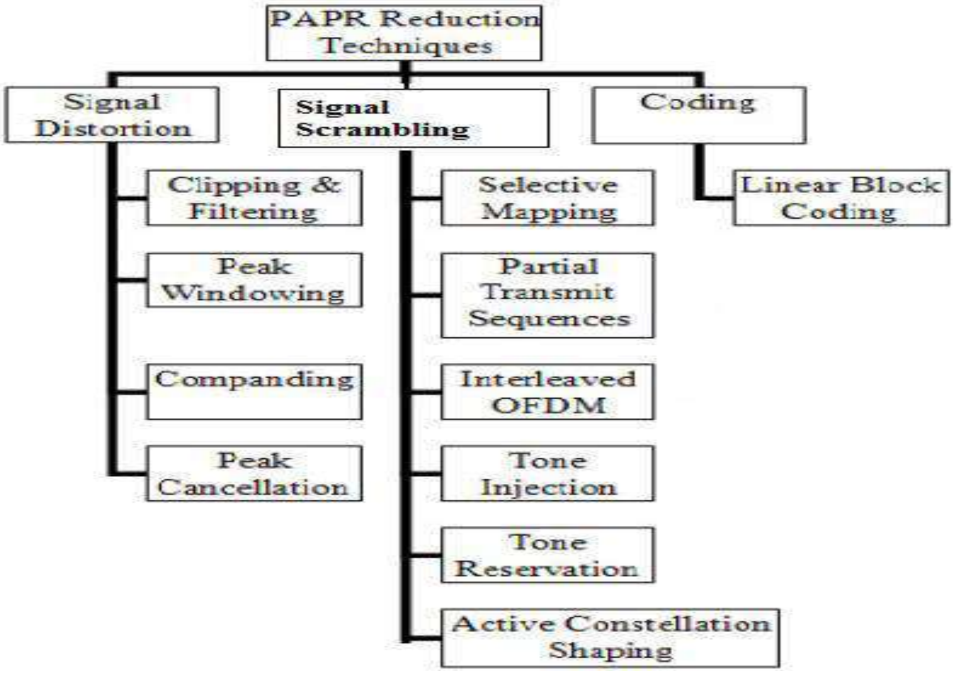

Fig.4. PAPR Reduction Techniques

5. COMBINATION OF SLM AND DCT SLM

SLM (Selective Level Mapping)

In the SLM, from a number of copies that represent the same information, one with lowest PAPR is chosen for transmission.

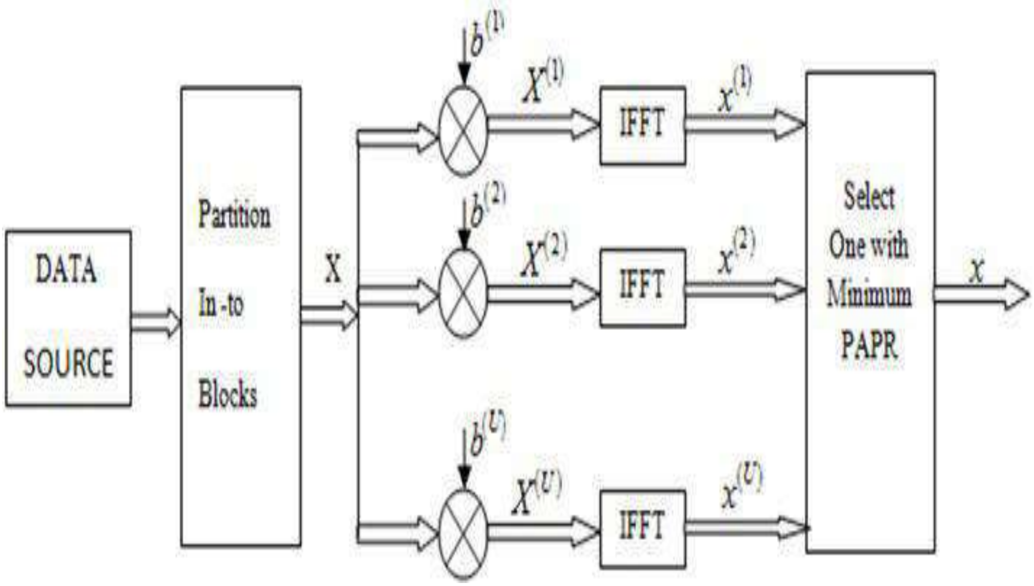

Fig.5 (a) :SLM Block diagram

X is the OFDM data block, is the phase vectors and is the modified data vectors in the frequency domain. So the time domain signal,

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$$X_U(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{k=N-1} X_k \, B_{u,k} \, e^{j2\pi K \Delta f t}$$
$$0 \leq t \leq NT$$

where u= 1,2…U ,and N is length of X, also the number of sub-carriers. Among the modified data blocks, the one with the lowest PAPR is selected for transmission. The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase sequences.

Construction of OFDM frames representing the same in-formation is by defining D distinct vectors:

$$\bar{B}^{(d)} = [B_1{}^{(d)},\ B_2{}^{(d)}, \dots \dots . B_u{}^{(d)}]$$

Figure 5.1 (a) shows the basic block diagram of selection mapping technique for suppressing the high PAPR.

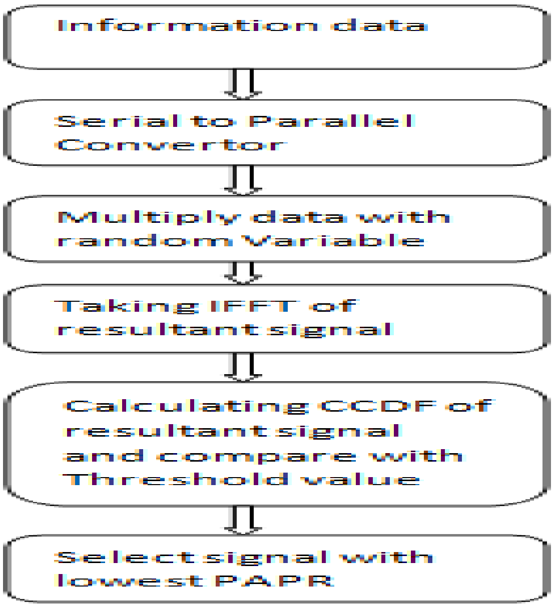

Fig.5.1 (b) Flow chart for SLM technique.

6. RESULTS AND ANALYSIS

CCDF Plots:

Cumulative distributive function is to describe the probability of the random variable with the given probability distribution function. Complementary cumulative distributive function is also called as tail distribution which is used to illustrate the PAPR of OFDM signal. The output curve is used to conclude the design parameters of the modulation system. Complementary cumulative distribution function (CCDF) is a method used to characterize the peak power statistics of a digitally modulated signal. CCDF object measures the probability of a signal's instantaneous power to be a specified level above its average power.

The CCDF of an OFDM system to measure the PAPR can be given as

$$\mathrm{CCDF} = \mathrm{P_r}\,(\mathrm{PAPR} > \mathrm{PAPR_0})$$

6.1.1 Comparison of original papr with different carriers

The vertical axis range of CCDF plots is from 10^0 to 10^{-1}, indicative of 0 db to -10 db respectively. The CCDF plots determine the probability of different orthogonal frequencies that can be modulated with different carriers like 64,128,256 & 4096 and the PAPR values as indicated in the below figures. Fig 6.1.1 (a) corresponds to BPSK. Fig 6.1.1 (b) corresponds to QPSK.

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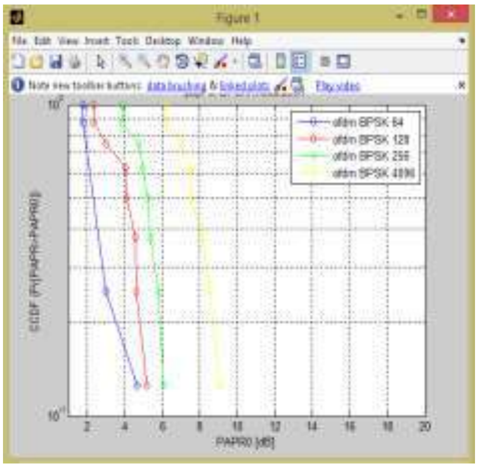

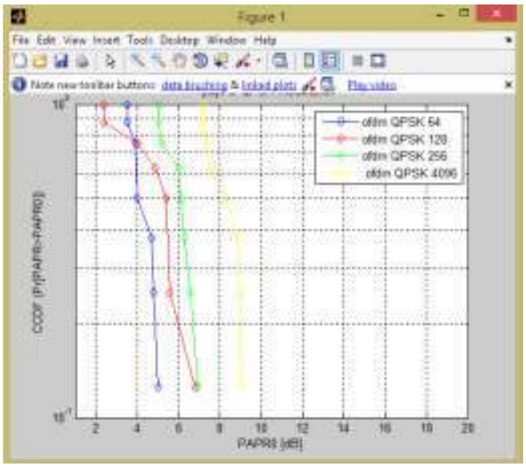

Fig 6.1.1 (a) Comparison of original papr using BPSK
Fig 6.1.1 (b) Comparison of original papr using QPSK

In the OFDM system the number of carriers increases the PAPR values also increases.

6.1.2 Comparison of Original PAPR with SLM [phases=2,4,8]

The vertical axis range of CCDF plots is from 10^0 to 10^{-3}, indicative of 0 db to -30 db respectively. The CCDF plots determine the probability of different orthogonal frequencies that can be modulated with carrier 4096 and the PAPR values as indicated in the below figures. Fig 6.1.2 (a) corresponds to BPSK. Fig 6.1.2 (b) corresponds to QPSK.

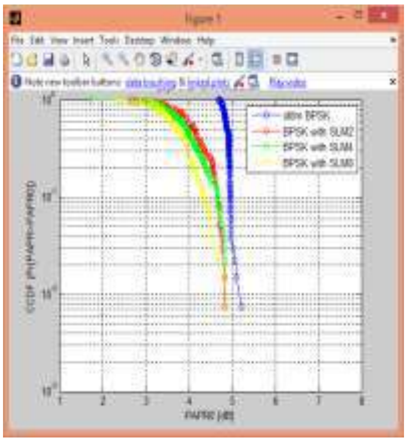

Fig 6.1.2 (a) Comparison of Original PAPR PAPR with SLM[phases=2,4,8] using QPSK

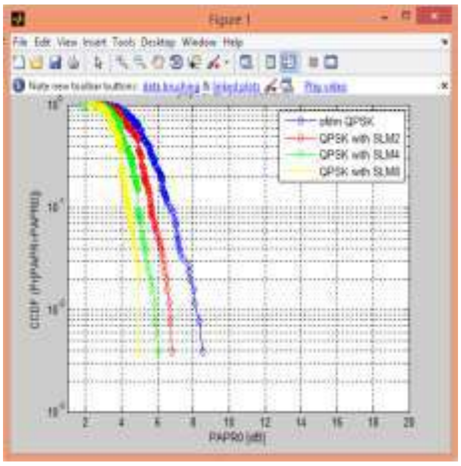

Fig 6.1.2 (b) Comparison of Original with SLM[phases=2,4,8] using BPSK

The original PAPR is comparatively more than the PAPR after the Selective Level Mapping is applied. In SLM techniques as the numbers of phase blocks increases the PAPR values are reduced.

6.1.3 Comparison between SLM and DCT combined with SLM [phase 4]

The vertical axis range of CCDF plots is from 10^0 to 10^{-3}, indicative of 0 db to -30 db respectively. The CCDF plots determine the probability of different orthogonal frequencies that can be modulated with carrier 4096 and the PAPR values as indicated in the below figures. Fig 6.1.3 (a) corresponds to BPSK. Fig 6.1.3 (b) corresponds to QPSK.

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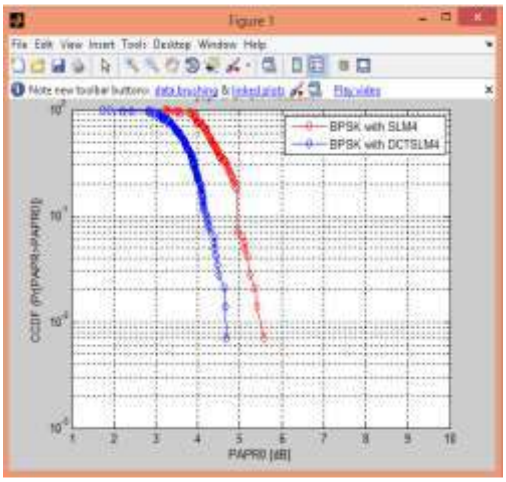


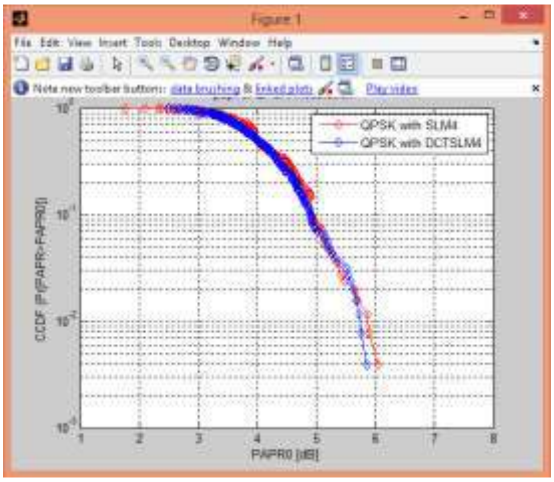
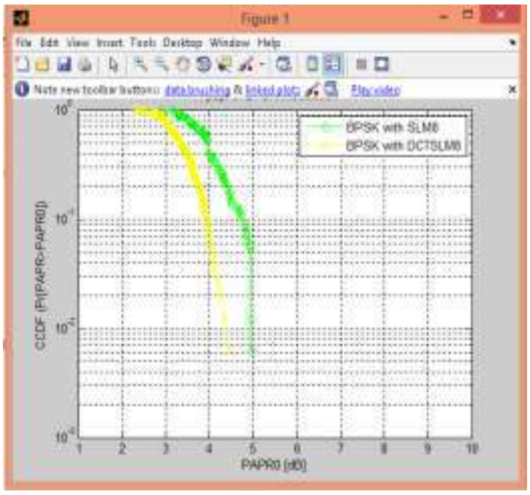


Fig 6.1.3 (a) Comparison of SLM and DCT SLM using BPSK
Fig 6.1.3 (b) Comparison of SLM and DCT SLM using QPSK

When the SLM technique is applied, the PAPR values are comparatively more than the PAPR values after the Combination of Selective Level Mapping (SLM) and Discrete Cosine Transform (DCT) applied. The above plots are taken when the number of phase blocks are 4.

6.1.4 Comparison between SLM and DCT combined with SLM [phase 8]

The vertical axis range of CCDF plots is from 10^0 to 10^{-3}, indicative of 0 db to -30 db respectively. The CCDF plots determine the probability of different orthogonal frequencies that can be modulated with carrier 4096 and the PAPR values as indicated in the below figures. Fig 6.1.4 (a) corresponds to BPSK. Fig 6.1.4 (b) corresponds to QPSK.



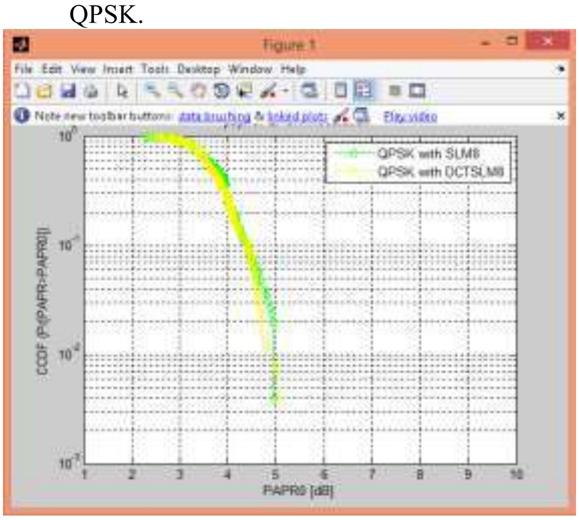


Fig 6.1.4 (a) Comparison of SLM and DCT SLM using BPSK
Fig 6.1.4 (b) Comparison of SLM and DCT SLM using QPSK

When the SLM techniques is applied, the PAPR values are comparatively more than the PAPR values after the Combination of Selective Level Mapping (SLM) and Discrete Cosine Transform (DCT) applied. The above plots are taken when the number of phase blocks are 8. here also as the number of phase blocks increases the PAPR is reduced.

In this thesis MATLAB simulation version used is "MATLAB R2009a". PAPR value is calculated for different data carriers with different phase blocks. In SLM and combination of DCT with SLM, this process is applied for different input data which are multiplied with phase blocks combined to minimize the PAPR.

In this thesis the PAPR performance of SLM and combination of DCT with SLM algorithms and conventional OFDM signal is evaluated with different modulation techniques such as BPSK, QPSK and is used for simulation. CCDF can be indicative of the figure of merit for the performance of PAPR. Some of the PAPR values of different modulation techniques with and without SLM and combination of DCT with SLM are as shown in tables 6.1 and 6.2.

PAPR OF OFDM USING BPSK

PAPR	N=2	N=4	N=8
ORIGINAL PAPR	5.212	5.212	5.212
PAPR WITH SLM	6.336	5.239	4.974
COMBINATION OF DCT WITH SLM	5.967	4.487	4.199

Table 6.1 comparison of papr using SLM and combined DCT SLM

PAPR OF OFDM USING QPSK

PAPR	N=2	N=4	N=8
ORIGINAL PAPR	7.816	7.816	7.816
PAPR WITH SLM	6.896	5.672	4.947
COMBINATION OF DCT WITH SLM	6.041	5.63	4.712

Table 6.2 comparison of papr using SLM and combined DCT SLM

CONCLUSION

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high – speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR. From the simulation results, it is observed that the reduction of PAPR is higher in the technique DCT combined with SLM compared to the conventional SLM technique when BPSK/QPSK modulation was used. The PAPR also reduced as the number of blocks of phases increased when BPSK/QPSK modulation was used.Use of QPSK allows higher transmission capacity due to the QPSK uses two bits per symbol. Hence QPSK is easily effected by the noise. Therefore OFDM with QPSK requires large transmit power. So BPSK is preferable for the OFDM systems.

FUTURE SCOPE

The following are some of the interesting extensions of the present work:

- The PAPR can be reduced further using different window techniques like hamming , Hann Peak Windowing etc are combined with PAPR reduction techniques likes SLM ,PTS.

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