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Hybrid Approach using PTS, Filtering and Companding Techniques to Reduce PAPR in OFDM System

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Abstract : ***In recent years, there is a rapid growth in multimedia based applications which require technology which support high data rate transmission. Orthogonal frequency division multiplexing (OFDM) is the efficient multiplexing and modulation technique adapted for 4G wireless communication applications. OFDM is high speed data transmission scheme in wireless communication. The one of the main disadvantage of the OFDM is peak to average power ratio PAPR. Mainly, because of non linearity of high power amplifier, these results intercarrier interference and degradation of bit error rate (BER). OFDM consist of large number of independent sub carriers as a result of which amplitude of such signal have high values. However, as the number of sub carrier's increase PAPR also increases. The different PAPR reduction techniques are available, such as Clipping, Compading, Selective Mapping (SLM), Tone Injection (TI), Tone Rejection (TR) and Partial Transmit Sequence (PTS). In this paper, a new approach is proposed in which hybrid techniques are used partial transmit sequence (PTS), filtering and compading.***

Keywords: OFDM (Orthogonal frequency division multiplexing) , BER (Bit error rate) , PAPR (Peak to average power ratio), PTS (partial transmit sequence) ,CCDF (Complementary cumulative distribution function) ,HPA (High power amplifier) ,SLM.(Selective mapping) ,TI (Tone injection), TR(Tone rejection).

I. INTRODUCTION

Though OFDM was introduced in 1960; but it was adopted recently in wireless communication due to high data rate, spectral efficiency and low susceptibility to multipath effects. OFDM is used in various communications like Audio Broadcasting, Video Transmission and communication system including Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), HDTV, WIMAX and Wireless Local Area Network (WLAN). [4] [8] There OFDM is a multicarrier modulation scheme, in which the bit stream is divided into several orthogonal subcarriers, each modulated at low rate. The main disadvantage of OFDM is high Peak-to-Average Power Ratio (PAPR) which causes distortion in the signal when it passes through Digital-to-Analog Converter and High Power Amplifier (HPA). [10]The PAPR is defined as the ratio of maximum peak power to the average power of signal. Hence PAPR reduction is necessary for efficient OFDM system.[2] [5]

To avoid the appearance of large PAPR of OFDM signal, different PAPR reduction methods have been proposed such as clipping and filtering, partial transmit sequence (PTS), selective mapping (SLM), Tone Injection (TI), tone rejection (TR), Interleaving, compading etc.[10][2] In order to reduce PAPR and improve BER performance paper introduced hybrid techniques using combination of different techniques like partial transmit sequence (PTS), Filtering and Compading. Among all the techniques the partial transmit sequence (PTS) is an attractive solution due to its good performance of PAPR reduction without any distortion in the signal. The concentration of this paper is partial transmit sequence (PTS) technique, which is one of the most efficient and an attractive solution due to its good performance of PAPR reduction without any distortion in the signal. This paper introduces combination of PTS technique with filtering and companding technique.

II. OFDM SIGNALS

In OFDM block of N symbol $\{X_k, k = 0, 1, 2, 3\ldots\ldots N\text{-}1\}$ is formed by modulating symbol with one of the set of the subcarrier $\{f_n, n = 0,1,2\ldots..N\text{-}1\}$ with equal frequency separation $\frac{1}{T}$, where T is the original time period. In discrete time domain OFDM x(n) signal is generated by taking N – point IDFT on frequency domain of X_k.

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi^{kn}/N} \quad ,0 \leq n \leq N-1 \qquad (1)$$

X_k is the data symbol with k^{th} subcarrier.[3] [5]

III. PAPR PROBLEM AND CCDF

One of the main disadvantages of the OFDM is its high peak to average power ratio (PAPR). PAPR occurs when different sub-carriers are out of phase with each other in multicarrier system. At each instant they are different with respect to each other at different phase values. When all points achieve the maximum value; simultaneously this will cause output envelope to suddenly shoot up which cause "a peak" in output envelope. Due to the presence of large number of independently modulated sub-carriers in OFDM system, the peak value of system is very high as compared to the average of the whole system. [9]PAPR is defined as the ratio of the maximum power of the sample in the given OFDM transmit symbol to the average power of the OFDM symbol.[10] [4]

$$\text{PAPR}(f_n) = \frac{\text{maximum power of the ofdm symbol}}{\text{averge power of the ofdm symbol}}$$

$$\text{PAPR}(f_n) = 10\, log_{10} \frac{\max\{|x(t)|^2\}}{E\{|x(t)|^2\}} \qquad (2)$$

Where x (t) is the original signal

max $\{|x(t)|^2\}$ is the peak signal power

$E\{|x(t)^2\}$ is the average signal power

where E[.] is the expectation operator.

Reducing the max |x (t)| is the principle goal of PAPR technique.

As in OFDM system, the main disadvantage of the OFDM system is PAPR. [4][2]It demands high power amplifier (HPA) to be operated in large linear region and it makes system inefficient and degrades system performance. It also causes non linear distortion and reduces power efficiency of high power amplifier. Also, a distortion of signal leads to degrade the bit error rate (BER) performance.

The complementary cumulative distribution function (CCDF) is used for measuring the performance of PAPR reduction technique. The CCDF denotes the probability that PAPR is below threshold level $PAPR_0$ which is expressed as –[8] [3]

$$CCDF(PAPR(x(n))) = Pr(PAPR(x(n))) > PAPR_0 \qquad (3)$$

IV. PAPR REDUCTION TECHNIQUE TYPES

PAPR reduction techniques are of different types. Here we are discussing the different types of techniques.

a) SIGNAL- SCRAMBLING TECHNIQUES-

In signal scrambling techniques the OFDM signal is modified by introducing phase shits, adding peak reduction carriers or changing constellation points. The modification parameters are optimized to minimize PAPR. The different signal–Scrambling techniques are selective mapping(SLM), partial transmit sequence(PTS), tone injection(TI) and tone rejection(TR).In this paper

symbol – scrambling techniques specially partial transmit sequence is used.PTS is one of the most important methods that are used to reduce PAPR in the OFDM system.[1]

1. Partial Transmit Sequence

A major disadvantage that arises in the multicarrier system like OFDM is the resulting non- constant envelope with peaks. When these independently modulated carriers are added, the instantaneous power will be more than average power. PTS technique has been proposed by Muller- Hubber in 1997. PTS is an attractive scheme due to its good performance PAPR reduction without any distortion of transmitted signal.[1] [2]

In PTS technique let "X" be the incoming data stream, N be the sub-carrier, then X=[X_1, X_2….X_n] will be signal after converting serial to parallel data. The input signal is partitioned into M disjoint block which is represented as-

$$X= \sum_{m-1}^{M} X_m \quad (3)$$

X_m is number of sub-blocks and these sub –blocks are transformed to time domain partial transmit sequence by using Inverse Fast Fourier Transform(IFFT) which is expressed as –

$$x_m = \sum_{m-1}^{M} IDFT\{X_m\} \quad , m= 0, 1, 2, 3…M-1 \quad (4)$$

These partial sequence are independently rotated by phase factors

$$b = \{b_m = e^{j\varphi_m} , m=0, 1, 2….M-1\} \quad (5)$$

The sub-block x_m is multiplied by the rotated phase factor and combined together to form a set of candidate. The candidate with the low PAPR is selected. After combination, the time domain signal is given by-

$$f_m= \sum_{m-1}^{m} b_m x_m \quad (6)$$

After finding the optimum phase factor the multiplied signal is applied to the adder whose output is

$$X'= \sum_{m=1}^{M} f_m \quad (7)$$

The process is repeated with different set of rotation values and the OFDM symbol with the lowest PAPR is transmitted.[3][11]

b) SIGNAL DISTORTION TECHNIQUES-

In the signal distortion techniques, the peaks of the signal are reduced before transmitting the same through power amplifier. Different signal distortion techniques are – clipping and filtering, companding techniques. These techniques reduce the peaks of the OFDM signal.[1]

2. Companding Technique-

One of the most attractive solutions for the PAPR reduction is companding technique in OFDM system due to its low complexity, low BER and no bandwidth expansion. In OFDM system the samples may have high and low peaks which may give low average power and it may cause high PAPR in the system. The first non linear companding is Mu-law of companding, which is based on speech processing algorithm. Mu-Law of companding is one of the methods to reduce PAPR. It generally enlarges the small signals power and leaves unchanged the higher peak power. This leads to increase in the power of the signal. The Mu-law of companding is given by-

$$F(X)= \text{sgn}(x) \frac{\ln(1+(x))}{\ln(1+\mu)} \quad -1<x<1 \quad (8)$$

Where mu- companding factor

x = normalized integer to be compressed[1] [3]

3. Filtering Technique-

In radio communication system, filtering is a desirable factor. As the signals are corrupted with the noise when they are transmitted through the channel, a good filtering is required to remove the noise from that electromagnetic signal while retaining the useful information. Filtering is used to remove the out of band distortion, interference noise and peak regrowth. [5]Different types of the filters may be used to remove distortion from the signal. Butterworth filter is used, in which ripples are intolerable and it also have monotonic response. Butterworth filter has maximally flat magnitude response. The equation of the filter is –

$$H(w)=\frac{1}{1+(\frac{w}{w_0})^{2n}} \quad (9)$$

Where n is the order of filter and w_0 is the frequency.The response of the Butterworth filter is monotonically decreasing.

V. Proposed Work

Many methods have been suggested to reduce PAPR. In order to reduce PAPR and improve BER performance new hybrid method is proposed by combining partial transmit sequence (PTS), Filtering and Compading (Mu- law) schemes. This method gives the best PAPR reduction than clipping and filtering, partial transmit sequence (PTS), companding & filtering techniques. This hybrid method provides best PAPR reduction and less BER.

Outline of the Propsed Work-

1. The input signal is applied and serial data is converted into parallel form by serial to parallel converter. The S/P converter divides the incoming data into parallel data stream and then input data is divided into blocks.
2. Each data is divided into blocks and then IFFT converts the input frequency domain into time domain signal.
3. The output of the IFFT time domain signal is multiplied with the different phase factor .The size of the phase factor is equal to the no of sub-blocks.
4. Each sub-block digital data PAPR is computed and search is carried out for the phase factor which gives minimum PAPR. This is optimum phase factor. Now total signal is multiplied with optimum phase factor.
5. The modulated signal is passed through the filters which generally removes the out of band distortion and reduce the peaks.
6. Then the modulated signal is passed through the compander block that compresses the signal. For that Mu-law is used.

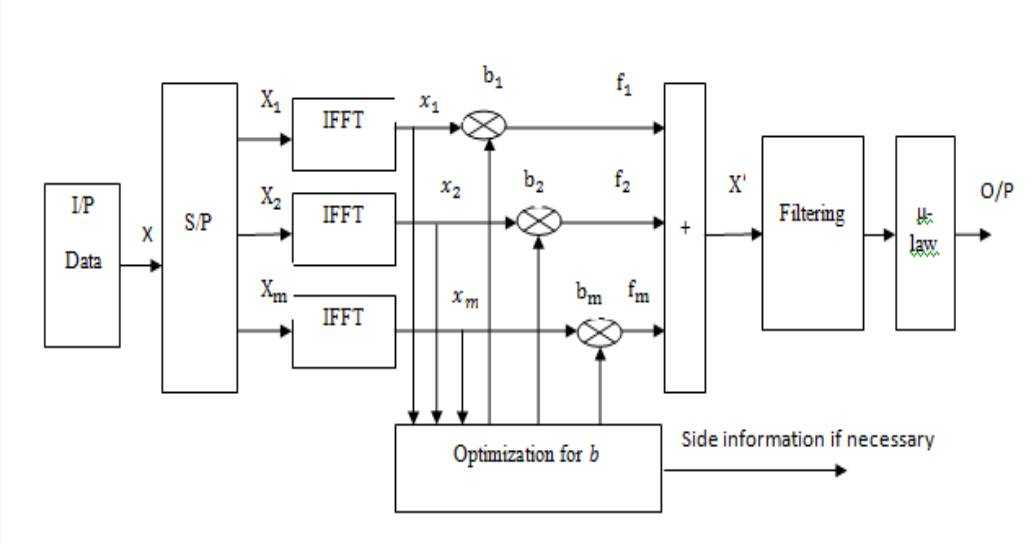

Fig. 1- Proposed method block diagram

VI. Simulation Results

This paper is based on Matlab simulation for validating analysis. In this section, we present numerical simulation for original OFDM symbol, clipping& filtering scheme, PTS scheme, filtering scheme, companding scheme and hybrid scheme of OFDM symbol CCDF comparison chart and BER comparison chart as shown in the figure. The simulation uses a QPSK modulation conditions, the no of subcarriers is 128,the simulation channel is additive white Gaussian noise(AWGN),no of the sub-blocks M=4 and set of weighting factor W=4 {-1,+1,-j,+j}.

Figure 2 shows PAPR curve for the clipping and filtering technique and original OFDM signal. The simulation uses the QPSK modulation condition, the number of the subcarriers are 128 and the simulation channel is additive white noise (AWGN).Figure shows the probability is 10^{-3} , the original signal of not clipping & filtering PAPR is 10.83 dB. In the same probability the clipping and filtering PAPR is 5.79 dB.

Figure 3 shows the PAPR curve for the proposed work and original signal. The proposed work is the combination of PTS, Filtering and companding technique. This hybrid method at CCDF=10^{-3} the PAPR value is 4.53 dB .Hybrid method provides better PAPR reduction than clipping and filtering method.

Figure 4 shows PAPR curves for the different techniques clipping& filtering scheme, PTS scheme, filtering scheme, companding scheme and proposed scheme. The figure shows that when we combine the PTS, filtering and companding technique the results are obtained well than individual techniques. The proposed method gives the least PAPR value. As shown in the figure the original curve has PAPR equals to 10.83 dB .After applying to the proposed algorithms, the PAPR value of the proposed model is approximately 4.5351 dB which is 5.036 dB , 4.566dB, 1.456 dB ,4.456and 6.2949 dB better than clipping & filtering, PTS technique, filtering technique and μ-law of companding technique respectively at CCFD= 10^{-3} . The comparison of CCDF of PAPR of proposed model with various techniques is given in table. This proves that the algorithm gives better results which are superior performance in PAPR reduction.

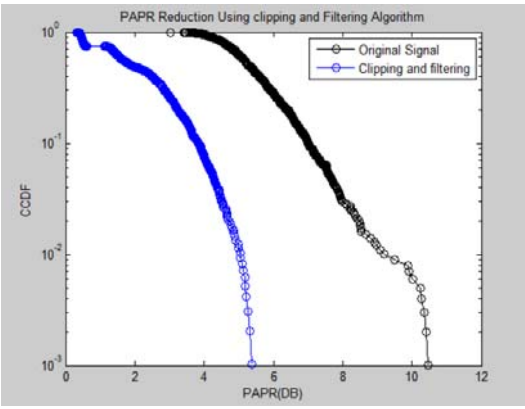

Figure 2.CCDF statistics of clipping & filtering technique and original signal.

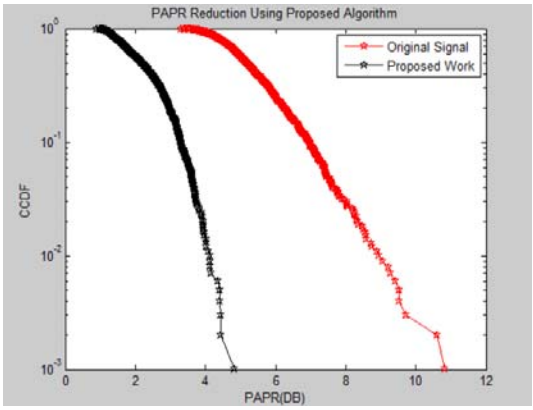

Figure 3-CCDF statistics of proposed technique and original signal.

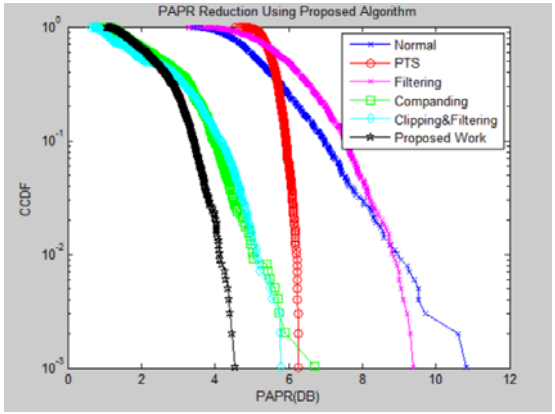

Fig 4– CCDF statistics of comparison of proposed model (PTS+ Filtering+Mu-Law) with various PAPR reduction and original signal.

Table1. Comparison of PAPR of proposed model with various PAPR techniques.

PAPR REDUCTION TECHNIQUES	PAPR at CCDF =10^{-3}
Original Signal	10.83 dB
Clipping& Filtering technique	5.794 dB
Partial Transmit Sequence Technique	6.264 dB
Filtering Technique	9.374 dB
Mu- Law of Companding	6.707 dB
Proposed Work (PTS+ Filtering+ Mu-Law)	4.5351 dB

Figure 5 shows the BER curve of the original signal and clipping &filtering technique through the AWGN channel. E_b/N_0 at BER =10^{-5} of the clipping and filtering technique is 0.030 dB. While figure 6 shows the BER curve for the proposed work where E_b/N_0 at BER =10^{-5} is 0.0031dB.Comparing both the curves of figure 5 and figure 6, it is observed that the SNR of proposed work is better than clipping & filtering technique. While clipping and filtering is the simplest approach, in which out of band radiation generated by clipping is eliminated by filtering operation but the filtering operation contributes to peak regrowth problem.

Figure 7 shows the BER versus SNR curves for OFDM case with no PAPR reduction scheme, clipping & filtering scheme, PTS scheme, filtering scheme, companding scheme and proposed method (modified).The proposed method offers better BER results than other individual techniques. The proposed methods offers less circuitry The reduction in the complexity of the circuit less to less power consumption which increases the battery life of the mobiles. Less hardware complexity leads to reduction in the cost.

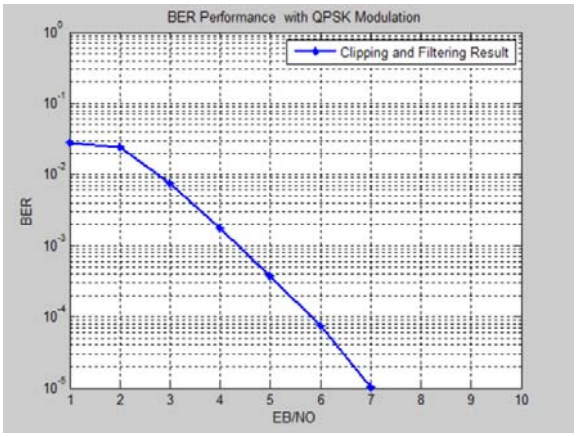

Figure 5.-BER versus $\frac{E_b}{N_0}$ of clipping & filtering.

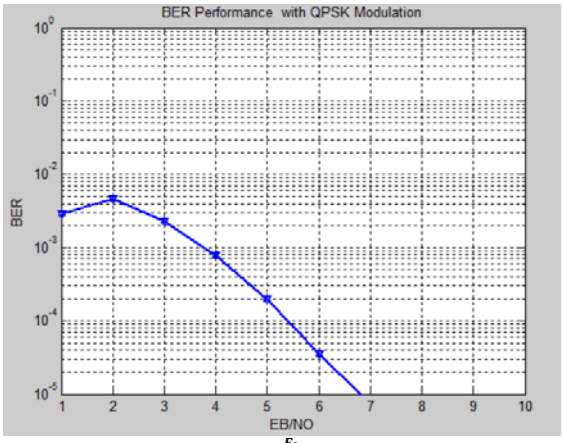

Figure 6.-BER versus $\frac{E_b}{N_0}$ of proposed work.

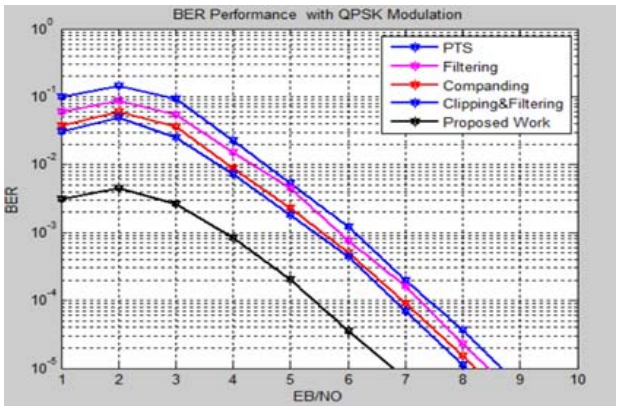

Fig.3 BER versus $\frac{E_b}{N_0}$ comparison of proposed model (PTS+ Filtering+ Mu-Law) with various PAPR reduction and original signal.

Table2. Comparison of BER performance of proposed model with various PAPR techniques.

PAPR REDUCTION TECHNIQUES	E_b/N_0 at BER =10^{-5}
Clipping& Filtering technique	0.030 dB
Partial Transmit Sequence Technique	0.101 dB
Filtering Technique	0.059 dB
Mu- Law of Companding	0.037 dB
Proposed Work (PTS+ Filtering+ Mu-Law)	0.0031dB

VII. Conclusion

OFDM is an efficient multicarrier modulation technique for the both wired and wireless application due to its high data rates and spectral efficiency .High PAPR of the transmitted signal is one major drawback of OFDM systems. In order to minimize the effects of high PAPR in OFDM system, hybrid approach is best solution to minimize the effects of high PAPR. The purpose of this paper is to reduce high PAPR of OFDM signal. A new PAPR reduction scheme is proposed by combining PTS, filtering and Mu-law of companding .From the above graphs it is concluded that the proposed method offers better PAPR reduction and better BER performance.

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