An Optimized OFDM System with Reduced PAPR

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) has become the popular modulation technique in high speed wireless communications. Despite the advantages of OFDM signals like high spectral efficiency and robustness against ISI, the OFDM signals have some disadvantages among which the main one is the high peak-to-average-power-ratio (PAPR). There are lots of methods and techniques intended to reduce PAPR. This paper presents the various PAPR reduction techniques, and concludes with an overall comparison of these techniques. Simulation results show that the partial transmit sequences with recoverable clipping reduces the PAPR problem in OFDM systems.**

Keywords— OFDM, PAPR, SLM, PTS, CCDF.

I. INTRODUCTION TO OFDM

Orthogonal frequency division multiplexing (OFDM) technology is one of the most attractive candidates for next generation wireless communication. It effectively combats the multipath fading channel and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission. OFDM uses the principles of Frequency Division Multiplexing (FDM), but in much more controlled manner, allowing an improved spectral efficiency. It is used in broadband wireless communication systems like WiMAX, DVB-T, or wire line systems like ADSL. The basic principle of OFDM [1] is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other, because the symbol duration increases for lower rate parallel subcarriers, so the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) can be eliminated almost completely by introducing a guard time in every OFDM symbol.

One of the main issues of the OFDM based systems is the Peak-to-Average Power Ratio (PAPR) of the transmitted signal. Due to the time-domain superposition of the many data subcarriers which composes the OFDM signal, the PAPR may reach high values. Due to the large number of subcarriers, the resulting time-domain signal exhibits Rayleigh-like characteristics and large time domain variations.

Large peak-to-average-power-ratio distorts the signal if the transmitter contains nonlinear components such as power amplifiers (PA). The nonlinear effects on the transmitted OFDM symbols are spectral spreading, inter modulation and changing the signal constellation. In other words, the nonlinear distortion causes both in-band and out-of-band interference to signals. Therefore the PAs requires a back off which is approximately equal to the PAPR for distortion-less transmission. This decreases the efficiency of amplifiers. Therefore, reducing the PAPR is of practical interest.

Many PAPR reduction methods have been proposed. Some methods are designed based on employing redundancy, coding [6], selective mapping with explicit or implicit side information [2], or tone reservation. PAPR reduction may also be achieved by using extended signal constellation, such as tone injection, or multi-amplitude CPM. The associated drawback is the increased power and implementation complexity. A simple PAPR reduction method can be achieved by clipping the time-domain OFDM signal. In this Paper, a comparison of the PAPR reduction techniques for OFDM is done and also a PAPR reduction technique based on Partial transmits sequences with clipping is proposed.

The remaining of this paper is organized as follows. In section II, some basics about PAPR problem in OFDM is given. Section III describes PAPR reduction techniques. In Section IV the overall analysis of different techniques is given. Section V describes the simulation results. Conclusions are given in section VI.

II. PAPR PROBLEM IN OFDM

PAPR is the main problem of OFDM, which also degrades the BER of OFDM signal. Let us consider the total number of subcarriers in the OFDM system is ‘N’ and x (k), $0\leq k\leq N$ represents the input Sequence. Then IFFT is taken for x (k) and the output is time domain complex signal x (t) which is expressed as

$$X(t) = \sum_{k=0}^{N-1} x(k) \exp(j2\pi f_k\, t)\,, t \in (0,T) \qquad (1)$$

And x (t) is sampled at t=T/N, then sampled time domain signal x (n) can be written as,

$$X(n) = \sum_{k=0}^{N-1} x(k) exp(j2\pi nk/N)\,, 0 \leq k \leq N \qquad (2)$$

Where x (k) is the signal on the kth sub-channel and x (n) is OFDM signal.

The PAPR (dB) of the OFDM signal x(n) is defined as the ratio between Maximum power at a particular sampling instant and average power of the OFDM signal.

$$\text{PAPR (dB)} = \frac{\max|x(n)|^2}{E\{|x(n)|^2\}} \quad (3)$$

PAPR can be measured using Complementary Cumulative Distribution Function (CCDF).It is defined as the Probability that PAPR greater than the threshold value (PAPRo).

CCDF=Pr (PAPR>PAPR0) (4)

For OFDM signals with different number of sub carriers i.e. N=64,128,256,512, given the threshold value of PAPR, the CCDF gradually increases, when the number of subcarriers (N) becomes larger.

III. PAPR REDUCTION TECHNIQUES

In order to reduce the PAPR of an OFDM signal, many techniques are proposed. A brief detailed description of various techniques is as follows:

A. *CLIPPING AND FILTERING:*

The clipping technique is the simplest PAPR reduction scheme, which limits the maximum of the transmit signal to a pre-specified level. And with filtering, out-of-band radiation can be reduced from the clipped signal. However, clipping [5] yields distortion power, which is called clipping noise, and expands the transmitted signal spectrum, which causes interfering. Since clipping is a nonlinear process, it causes in-band noise distortion and degradation regarding system performance.

To avoid out-of-band noise, repeated clipping and filtering should be done. Fig.1 shows the block diagram of repeated C&F technique where filtering is done repeatedly so as to avoid peak re-growth of the OFDM signal.

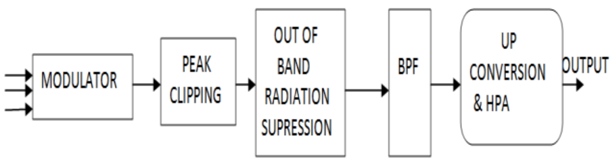

FIG1: Block diagram of repeated Clipping and filtering technique

B. *SELECTIVE MAPPING*

In selected mapping method, firstly *M* statistically independent sequences which represent the same information are generated and next the resulting *M* statistically independent data blocks are then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols $x_m = [x_1, x_2\ldots, x_N]^T$in discrete time-domain are acquired, and then the PAPR of these M vectors are calculated separately. Eventually, the sequences with the smallest PAPR will be eventually selected for transmission.

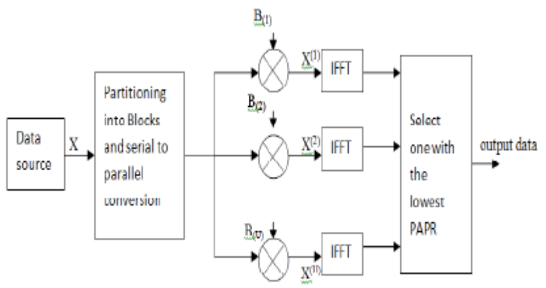

FIG 2: Block Diagram of Selective Mapping Technique

The key point of selected mapping (SLM) method lies in how to generate multiple OFDM signals when the information is same. Fig.2 shows the detailed block diagram of SLM technique. SLM Technique is very flexible as it does not impose any restriction on modulation applied in the subcarriers or on their number. But it has higher system complexity and computational burden. This complexity can be reduced by reducing the number of IFFT blocks.

C. PARTIAL TRANSMIT SEQUENCE

A block diagram of PTS technique is shown in fig.3 below

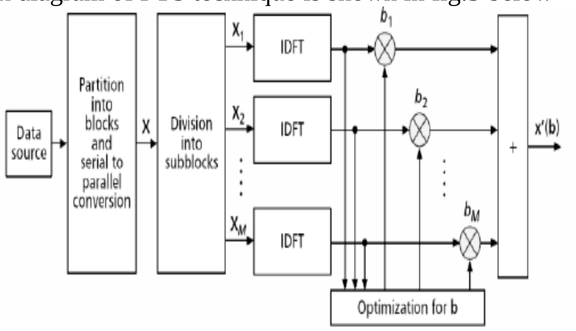

FIG 3: Block Diagram of PTS Technique

The idea of partial transmit sequences (PTS) is to divide the original OFDM sequence into several sub-sequences and for each sub-sequence, multiplied by different weights until an optimum value is chosen. In the PTS approach, the input data block is partitioned into V non overlapping sub blocks x(v) which are combined to minimize the PAPR. Each carrier in the sub blocks x (v) is multiplied with the same rotation factor b(v) = $e^{-j\varphi(v)}$, $-\infty < x < \infty$ The time domain vector can be composed by the IFFT.

$$X = \text{IFFT}(x'(b)) = \sum_{v=1}^{V} b(v)x(v) \quad (5)$$

In a typical OFDM system with a PTS scheme to reduce PAPR, the input data is partitioned into smaller disjoint sub blocks, which are represented by the vector X_m. It is assumed that each sub block consists of a set of subcarriers of equal size. Next, the partitioned sub blocks are converted from the frequency domain to the time domain using then N-point inverse fast Fourier transform (IFFT). The time domain sequences are combined with complex phase factors $b = [b_1, b_2, \ldots b_M]^T$ to minimize the PAPR. That is, the PAPR is reduced by the weighted combination of sub blocks. The resulting time domain signal after combination is given by equation (5). It is obvious that finding a best phase factor set is a complex and difficult problem. Therefore, we propose the implementation of PTS scheme combined with the Clipping method. When PTS block uses a reduced set of phase arrays, its smaller PAPR reduction can be compensated by the clipping block. The simulation results show that the proposed scheme brings higher PAPR reduction than the component methods.

IV. ANALYSIS OF DIFFERENT TECHNIQUES

The PAPR reduction techniques must be chosen in accordance with the various system requirements, such that system should acquire better performance.

Table1: Comparison of various PAPR reduction techniques.

Reduction technique	Distortion	Data loss	complexity
Clipping and filtering	YES	NO	NO
SLM	NO	YES	YES
PTS	NO	YES	YES

V: SIMULATION OF PTS WITH RECOVERABLE CLIPPING

To compare and evaluate the performances of PAPR reduction schemes for the generated OFDM signals, Simulations were done using MATLAB and the results are shown in fig 4.

From the simulated results, it is observed that the original OFDM signal without any PAPR reduction scheme suffers from very large PAPR. Clipping and filtering technique reduces the PAPR subsequently, but its PAPR reduction performance is lower than that of SLM and PTS with clipping.

Upon Comparison of PAPR reduction performance of these schemes, it is found that the proposed PTS with clipping technique provides better PAPR reduction than the other methods. It is evident from the graph that the proposed scheme produces better PAPR reduction.

The proposed PTS with recoverable clipping method reduces the complexity of PTS and produces better results than the other methods. The results are shown below in fig 5. It shows the comparison of CCDF of the proposed method with other methods.. It can be observed that the PAPR reduction for the proposed clipped PTS scheme improves with increase in complexity.

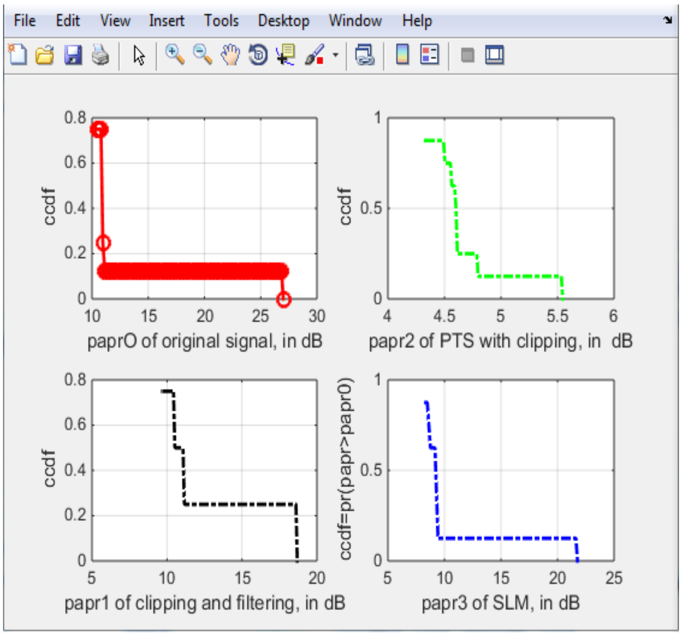

FIG 4: Simulation results of original OFDM signal without PAPR reduction, PAPR reduction with 1.clipping and filtering, 2.PTS method and 3.SLM method.

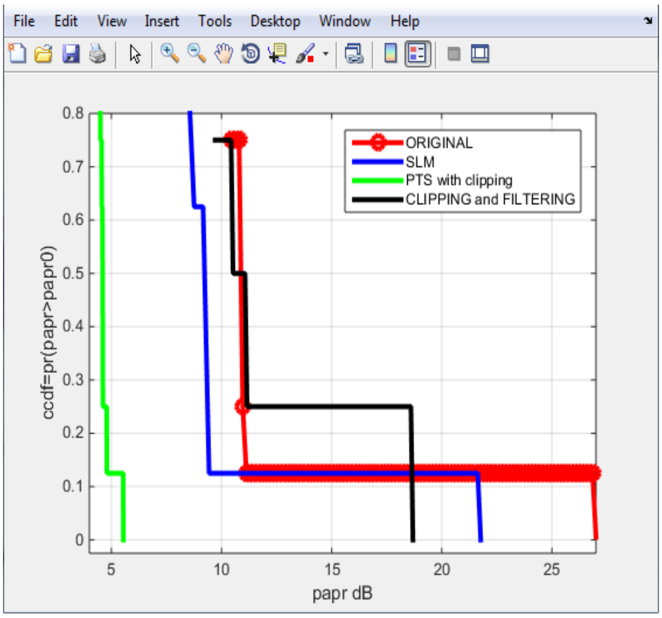

FIG 5: Comparison of the simulation results.

The above result shows a comparison of the CCDF of the proposed method with the other methods.It is clear that the proposed methos provides better optimization of PAPR but, it is achieved with an expense of increase in the complexity of the system.

VI. CONCLUSION AND FUTURE WORK

Different PAPR reduction schemes have been discussed in this paper. A comparison was made and PTS with clipping technique has been proposed. This technique can be applied to future wireless communication networks to support high data rate and can also be implemented in Optical systems by intensity modulation.

The future scope aims to implement the PAPR optimized OFDM signal in optical system to provide huge bandwidth for the contending high speed applications.

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