Performance of PAPR Reduction Techniques for MIMO-OFDM Systems in 4G Wireless Communication

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Abstract**—**Now-a-days reliable communication is necessary for wireless networks. In urban areas due to building and other manmade structures signal propagation became a complex phenomenon. Thus the range of non line of sight communication is restricted using existing techniques. Reliability and high data rate transmission possibilities achieving extended NLOS communication based on combined OFDM and space time coding MIMO at reasonable power levels. MIMO-OFDM is the promising wireless technology which is responsible for high performance 4G broadband communication. The main disadvantage of MIMO-OFDM is high peak-to-average power ratio (PAPR), which results in power inefficiency and non-linear distortion at the transmitter on different antennas. Many PAPR reduction techniques have been used to reduce PAPR. In this paper we presented three different techniques: Iterative clipping and filtering modified PTS and SLM methods which provides better PAPR reduction performance. Simulation results shows that modified PTS method improve the PAPR performance in MIMO-OFDM.

Keywords—*MIMO-OFDM, PAPR, Iterative clipping and filtering, PTS, SLM, CCDF*

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I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques [8] that transmit signals through multiple carriers used for 4th Generation (4G) wireless communication. The carriers of OFDM signal have different frequencies and orthogonal to each other and these subcarriers overlap to each other. This overlapping property makes OFDM more spectral efficient. This technique offers high speed data transmission and it is used in Digital terrestrial mobile communication, Digital Video Broadcasting terrestrial (DVB-T), Digital Audio Broadcasting (DAB). OFDM has many advantages such as High spectral efficiency, immunity to intersymbol interference and capability to reduce multipath and frequency selective fading. The employment of multiple antenna's at transmitter and receiver is referred to as MIMO technology and it is capable of supporting high data rates and having capability of exploiting both transmitter and receiver diversity which provides reliable communication.

The implementation of MIMO assisted OFDM is an effective and more attractive technique for high data rate transmission and provides strong reliability in wireless communication. A space time coding system (STBC) with MIMO-OFDM [10] is deployed for transmit diversity and secure means for data propagation in the scenario where the mobility is required for the data transmission. MIMO-OFDM has many advantages which can decrease receiver complexity, provides robustness against narrowband interference and have capability to reduce multipath fading. The major drawback of MIMO-OFDM is high PAPR. In fact, the high PAPR is one of the most detrimental aspects in the OFDM system, as it decreases the SQNR (Signal-to-Quantization Noise Ratio) of ADC (Analog-to-Digital Converter) and DAC (Digital-to-Analog Converter) while degrading the efficiency of the power amplifier in the transmitter. Due to large number of subcarriers and their amplitude has large dynamic range, leading to non-linear characteristics which results in out-of-band radiation that effects signal in adjacent band, in band distortion i.e. inter-modulation distortion when passed through the power amplifiers. To overcome this, the power amplifiers should be operated in very large linear region which makes expensive and inefficient. A straightforward way to reduce the PAPR in STBC MIMO-OFDM systems is to apply the PAPR reduction approach to each antenna separately and the side information (SI) is required to recover the signal successfully at the receiver.

In MIMO-OFDM systems, several PAPR reduction schemes [1] have been used to solve this problem. These techniques can be broadly classified in three categories: Signal distortion techniques, Multiple signalling and Probabilistic techniques, and Coding techniques. In this paper we mainly focus on one of Signal distortion technique i.e., Iterative clipping and filtering, and Probabilistic techniques -Selective mapping (SLM), and modified Partial Transmit sequence (PTS) which results in better performance.

The rest of paper is organized as follows: In section II, the system model of STBC MIMO-OFDM and PAPR problem is described. In section III, various PAPR reduction techniques and their performances was analyzed. The simulation analysis and results are shown in section IV, followed by conclusion in section V.

II. System model

For the next generation, mobile communication requires high frequency spectrum utilization, but the function to improve the spectrum utilization is limited by OFDM. Exploring the space resources based on OFDM, i.e. MIMO-OFDM can provide a high data rate.

A. *STBC MIMO-OFDM:*

Consider the STBC MIMO-OFDM [4] system with two transmit antennas. The input data block $S=[X_0,X_1,\ldots X_{N-1}]^T$ is encoded with space time encoder with two vectors

$$S_1=[X_0,-X^*_1,\ldots X_{N-2},-X^*_{N-1}]^T,$$

$S_2=[X_1, X^*_0, \ldots X_{N-1}, X^*_{N-2}]^T$.

which are fed to IFFT block and sent simultaneously from antennas T_{x1} and T_{x2} respectively.

The input data block of N symbols $S=[X_0, X_1, \ldots X_{N-1}]^T$ is transmitted in parallel and each symbol modulates different subcarriers from a set of subcarriers $\{f_k, k=0,1,\ldots N-1\}$. The N carriers are orthogonal. $f_k=k\Delta f$ with $\Delta f=1/NT$ and T is the period. Then the resulting baseband OFDM signal

$$x(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_n e^{\frac{j2\pi kn}{N}} \qquad 0\leq t\leq NT \ldots\ldots(1)$$

where X_n is the transmitted OFDM signal at the N subcarriers of the m transmit antennas.

B. *PAPR in MIMO-OFDM:*

The PAPR is defined as ratio between the maximum power and the average power of the complex passband signal [9]. For the following transmit signal x(t),

$$\text{PAPR}=\frac{\max_{0\leq t\leq MT} |x(t)|^2}{\frac{1}{MT}\int_0^{MT} |x(t)|^2} \ldots\ldots(2)$$

Measurement of the PAPR for the continuous-time baseband signal is not straightforward. Therefore, there must be some means of estimating the PAPR from the discrete-time signal x[n]. Fortunately, it is known that x[n] can show almost the same PAPR as x[n] if it is L-times interpolated (oversampled) where $L \geq 4$.

Therefore, the PAPR of the STBC MIMO-OFDM is defined as the maximum of PAPRs among all transmit antennas i.e.,

$$PAPR_{MIMO\text{-}OFDM}=max_{1\leq t\leq MT}\, PAPR_i \ldots(3)$$

where $PAPR_i$ denotes the PAPR at the i^{th} transmit antenna.

C. *Complimentary Cummulative Distributive Function(CCDF):*

We can evaluate the performance of PAPR using cumulative distribution function(CDF) is one of the most regularly used parameters, which is used to measure the efficiency of PAPR techniques. The CDF of the amplitude of a signal sample is given by

$$CDF(\delta)=1-e^{-\delta} \ldots\ldots..(4)$$

The probability that the PAPR of the OFDM signal with N subcarriers is below a threshold δ is the probability that all the N samples are below the threshold. However, the complimentary CDF(CCDF)is used instead of CDF, CCDF provides an indication of the probability of the OFDM signals envelope exceeding a specified PAPR threshold within OFDM symbol. The CCDF of the PAPR in MIMO-OFDM is given as

$$CCDF[PAPR(x^n(t))]=prob[PAPR(x^n(t)>\delta)] \ldots(5)$$

$$CCDF[PAPR(x^n(t))]=1-(1-e^{-\delta})^{\alpha N} \ldots\ldots\ldots\ldots.(6)$$

For a given PAPR threshold, the appearance probability of OFDM symbols which above this threshold δ will decrease with the increase of sub-carriers number *N*.

III. PAPR Reduction techniques

PAPR reduction techniques [3] vary according to the needs of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system.

A. *Iterative Clipping and Filtering(ICF):*

Clipping and filtering is the simplest way for PAPR reduction. The OFDM signal is deliberately clipped at a particular threshold value before amplification in this method. But clipping cause important in-band distortion and out-of-band noise which severely interferes with communications in adjacent frequency bands. CF techniques eliminate the out-of-band radiation by clipping the time-domain signal to a predefined level and subsequently filtering it. To suppress peak regrowth due to filtering, iterative clipping and filtering [2] techniques can be used.

In this paper, we use a new CF technique that, in one iteration, obtains the same PAPR reduction as that of Iterative Clipping and Filtering with several iterations. The clipping noise generated in the first iteration to approximate that obtained after several iterations. The same PAPR reduction can then be obtained with several FFT/IFFT, which significantly reduces the computational complexity. The clipped signal can be written as

$$\hat{x}(t)=\begin{cases} Ae^{j\phi(t)}, & |x(t)|>A \\ x(t), & |x(t)|\leq A \end{cases}$$

where ϕ(t)represents the phase of x(t), and A is the clipping level. When A is large, the clipping occurs rarely, and the clipping noise $x(t)-\hat{x}(t)$ is a series of pulses.

The new CF algorithm can be stated as follows.

1) Convert the OFDM symbol to time domain as x_n=IFFT(X_k).

Note that oversampling is needed

2) Clip x_n to the threshold A and calculate the clipping noise f_n.

3) Convert f_n to frequency domain to obtain F_k by doing FFT(f_n) and keep the first and last N/2 items of F_k to obtain the in-band distortion $\hat{F}_k$.

4) The clipped OFDM signal then becomes $\hat{X}_k=X_k-\bar{\beta}\hat{F}_k$

5) Convert $\hat{X}_k$ to time domain and transmit it.

B. *Selective mapping(SLM):*

SLM [7] is relatively simple approach to reduce PAPR. The actual transmit signal selects lowest PAPR from a set of sufficiently different signals which all represents the same information. Let us consider a STBC MIMO-OFDM system that employs Alamouti scheme. During the first symbol period, the OFDM symbol transmitted from antenna

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1 is denoted by X_1 and from antenna 2 by X_2. During the next symbol period, $-X_2^*$ and X_1^* are transmitted from antennas 1 and 2 respectively. Therefore, with orthogonal STBC,[11] the PAPR reduction needs to be done only for the first symbol period. Block diagram of SLM technique in MIMO-OFDM system is shown in Fig 1.

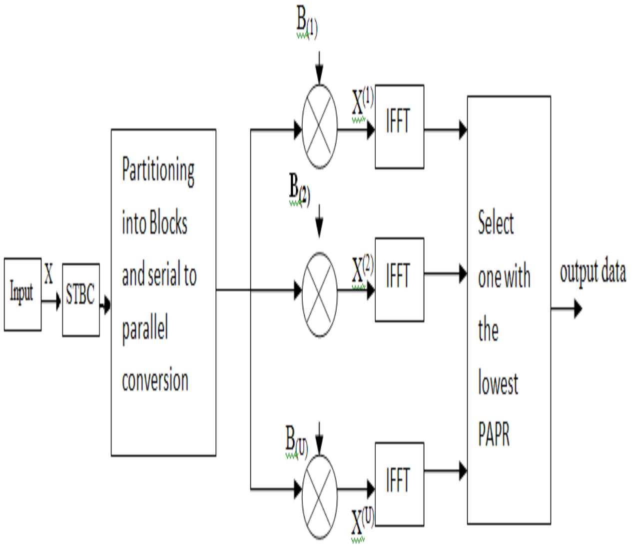

Fig:1 . Block diagram of MIMO-OFDM system with SLM technique

The OFDM symbols set can be generated by multiplying the original data block $X=[X_1\ X_2\ .....X_{N-1}]^T$ element-by-element with M different phase sequences $B^{(u)}$,

$$x_n^{(u)}=x_n.b_n^{(u)}.....(7)$$

$B^{(u)}$ can be written as

$$B^{(u)}=[e^{j\phi m,1},e^{j\phi m,2},.....e^{j\phi m,N}],0\leq m\leq M-1,..(8)$$

where $\phi_{m,N}$ takes values between 0 and 2π,excluding 2π. Then the modified OFDM symbol x_n is the IFFT of element-by-element multiplication of X and $B^{(u)}$.

$$x_n=IFFT[X_1\ e^{j\phi m,1},X_2\ e^{j\phi m,2},\ldots X_{N-1}\ e^{j\phi m,N}]..(9)$$

The phase sequences $B^{(u)}$ can be set to $\{\pm1,\pm j\}$ as these values can be implemented without multiplication. Information about the selected phase sequence should be transmitted to the receiver as side information to allow the recovery of original symbol sequence at the receiver. The transmitted OFDM symbol $\tilde{x}$ is represented as

$$\tilde{x}=\text{argmin}_{0\leq m\leq M-1}[PAPR(x(n))].....(10)$$

C. *Partial Transmit Sequence(PTS):*

The ordinary PTS scheme is simple and distortion less. In partial transmit sequence (PTS), an input data block of length N is partitioned into a number of disjoint sub-blocks. The sub-blocks are multiplied by phase weighting factors (±1, $\pm$ j) and then added together to produce OFDM symbols or number of candidate signals which ensures the low PAPR. It requires an exhaustive search over all the phase factor combinations, which results in the search complexity increasing exponentially with the number of subblocks. The modified PTS [6] scheme is proposed to lower the computational complexity which maintains the similar PAPR reduction performance compared with the conventional PTS scheme, in which real and imaginary parts are separately multiplied with phase factors, moreover PAPR is conjointly optimized in real and imaginary parts. Block diagram for STBC MIMO-OFDM with modified PTS is shown in Fig 2.

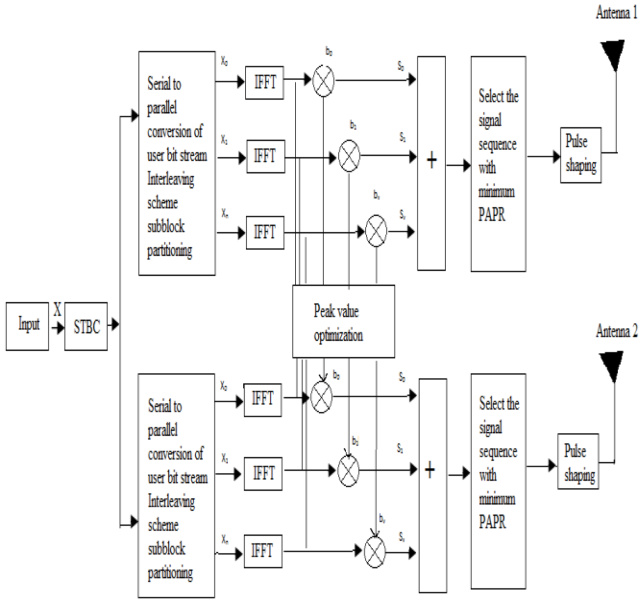

Fig:2 . Block diagram of MIMO-OFDM system with modified PTS technique

At the transmitter, the serial input data fIrst passes through the serial to parallel converter. Then the parallel signal is mapped with QPSK modulation to generate the data block $S=[S_1, S_2, ..., S_N]$ It is further partitioned into M disjoint subblocks $S_m=[S_{m,1},S_{m,2},......S_{m,N}]$ such that any two of these subblocks are orthogonal.

$$S=\sum_{m=1}^{M} Sm......(11)$$

Then IFFT of each subblock, s_m is computed and weighted by the phase factor $b_m=e^{j\phi\,(v)}$.

$$s=\sum_{m=1}^{M} bm.s_m\ ......(12)$$

Each alternate transmit signal is stored in memory and the process is repeated again with a different phase rotation value. After a set number of phase rotation values, W, the MIMO- OFDM symbol with the lowest PAPR is transmitted as given by

$$\tilde{s}=\text{argmin}_{0\leq m\leq M-1}[PAPR(s(n))]....(13)$$

The weighting rotation parameter set is chosen to minimise the PAPR. The computational complexity of PTS method depends on the number of phase rotation factors allowed. The phase rotation factors can be selected from an infinite number of phases $\phi^{(v)}=(0,2\pi)$.

IV. SIMULATION ANALYSIS AND RESULTS

The analysis of the PAPR reduction techniques have been carried out using MATLAB 7.0.The simulation parameters considered in MIMO-OFDM system are summarized in Table 1. The performance evaluation is done in terms of complimentary cumulative distributive function(CCDF) of

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the PAPR which indicates the probability that the PAPR is larger than $PAPR_0$.

Parameters	Values
System Subcarriers	128,256
Modulation scheme	QPSK
Phase factor	1,-1,j,-j
Random OFDM symbols generated	1000
FFT size	64
Clipping ratio	0.6
Number of routes used in SLM	V=8
Number of subblocks used in PTS	V=8

Fig:3 . Parameters used in Clipping and filtering, PTS, SLM

The simulation results of different methods iterative clipping and filtering, selective mapping and partial transmit sequence for 2x2 STBC MIMO-OFDM system are shown in figures

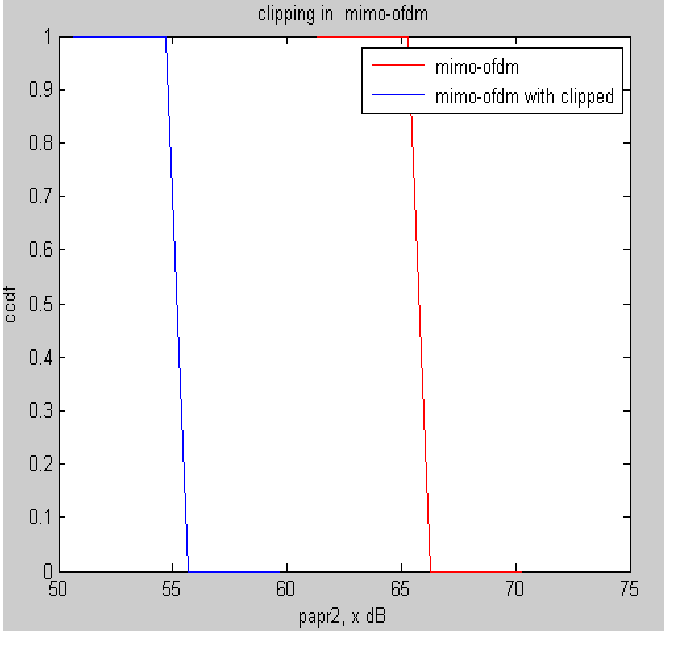

Figure4. PAPR Reduction with clipping and filtering STBC MIMO-OFDM

From the above result we see that the reduction of 10db by using clipping and filtering while in some literatures of clipping and filtering, only a 4dB reduction of PAPR is achieved. This confirms that the STBC coding helps in ways beneficial to reduce fluctuations in the envelope of the MIMO-OFDM. Clipping and filtering may cause data rate reduction

From the results of SLM and PTS shown in figures 5,6 the PAPR is reduced to 4dB respectively. In SLM method PAPR increases with increase of number of sub-carriers

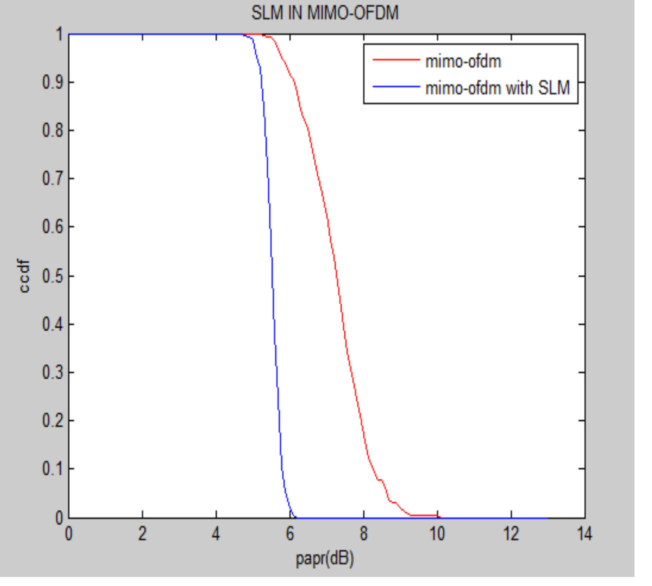

Figure5. PAPR Reduction with SLM in STBC MIMO-OFDM

The better PAPR performance will be obtained when the number of sub-block V is fixed. The PTS method provides a superior performance on PAPR reduction. We can say that SLM algorithm is more suitable if system can tolerate more redundant information, otherwise, PTS algorithm is more acceptable when complexity becomes the first considering factor.

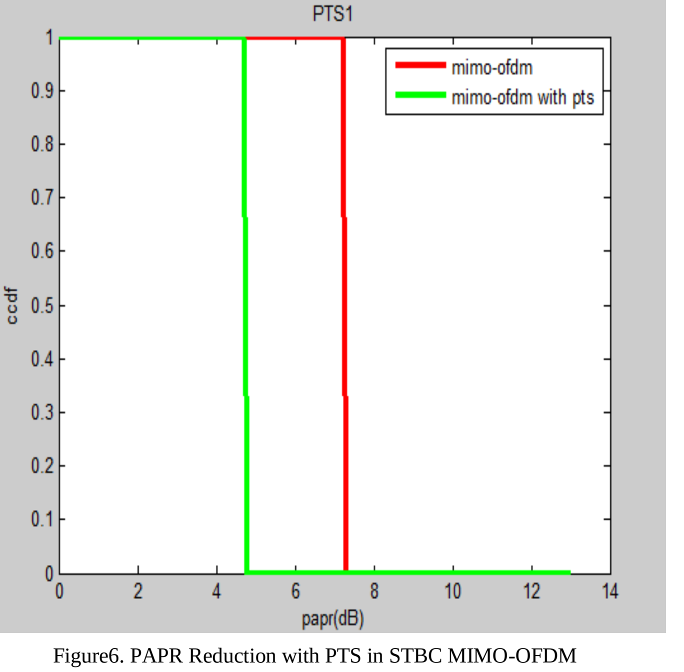

Figure6. PAPR Reduction with PTS in STBC MIMO-OFDM

V.CONCLUSION

MIMO-OFDM is a very attractive technique for wireless communications due to its spectrum efficiency and channel robustness. One of the serious drawbacks of in OFDM systems is that the composite transmit signal can exhibit a very high PAPR. Various major PAPR reduction techniques such as Iterative clipping, Selected mapping and modified Partial Transmit sequence has been studied. Simulation results have shown that clipping and filtering technique gives a better reduction PAPR (10 dB) compared to the others methods but the better PAPR performance will be obtained by modifies PTS method.

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