PAPR Reduction Using SFBC Based SLM in MIMO-OFDM

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Abstract: In this paper, Selected Mapping (SLM) Scheme for Peak to Average Power Ratio (PAPR) reduction in Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Systems with Space Frequency Block Coding (SFBC) is implemented. The main idea is to keep the advantage of the Space Frequency Block Coding (SFBC) structure to generate some multi-sequences, i.e., combining the signals at different transmit antennas. Specifically, when the proposed scheme is employed in SFBC MIMO-OFDM systems with Quadrature Amplitude Modulation (QAM), one of the advantages is that the side information does not need to be sent to the receiver. Theoretical analysis and simulation results validate that the proposed scheme has the ability to provide large PAPR reduction, low bit error rate and low computational complexity without side information in SFBC MIMO-OFDM systems.

Keywords: CCDF, DMT, IDFT, ISI, MIMO, OFDM, PAPR, PII, PTS, SFBC, SLM, QAM,

I. INTRODUCTION

The basic idea of multicarrier modulation is to divide the transmitted bit stream into many different sub streams and send over many different sub channels. Typically the sub channels are orthogonal under ideal propagation conditions, in this case multicarrier modulation is often referred to an OFDM. The data rate on each of the sub channels is much less than the total data rate, and the corresponding sub channel bandwidth is much less than the total system bandwidth. The number of sub streams is chosen to insure that each sub channel has a bandwidth less than the coherence bandwidth of the channel, so the sub channels experience relatively flat fading. Thus, the Inter Symbol Interference (ISI) on each sub channel is small. Moreover, in the discrete implementation of OFDM, often called Discrete Multi Tone (DMT), the ISI can be completely eliminated through the use of a cyclic prefix. The sub channels in OFDM need not be contiguous, so a large continuous block of spectrum is not needed for high rate multicarrier communications. Recently, various algorithms of the PAPR reduction have been proposed for Single Input Single Output (SISO) OFDM systems in the literature including Clipping, Nonlinear Commanding Transform, Coding Technique, Selected Mapping (SLM), Golay sequence and the weighting factor estimation method. When these methods are employed directly to reduce the PAPR in MIMO-OFDM systems[3], it results in increasing of the complexity and redundancy with the increasing number of antennas. Therefore, several new schemes have been proposed specially for MIMO-OFDM systems, such as the method of the Polyphase Interleaving and Inversion (PII). The best advantage of both the PTS/SLM and PII schemes is that they could provide a good PAPR reduction without signal distortion. However, the computational complexity of the PTS/SLM and PII schemes is very high because they need to implement some extra Inverse Discrete Fourier Transform (IDFT) operations and iterations of phase optimization. Obviously, the computational complexity of the scheme proposed in is reduced, which is at the cost of losing PAPR reduction.

Figure 1: OFDM Block Diagram

Moreover, its optimal phase rotation vectors also need to be transmitted as side information to the receiver, resulting in loss of the data rate. In this paper, we propose Partial Transmit Sequences (PTS) scheme to reduce the PAPR of MIMO-OFDM signals, for convenience and simplicity, the Space Time Block Coding (STBC) are employed in MIMO-OFDM systems, for the proposed SLM method, original data sequences at two antennas are partitioned into several pairs of sub blocks, and each pair of sub blocks multiplies by different factors to generate different pair of sub blocks. The obtained new sub blocks are combined to generate PTS, which keep the structure and the diversity capability of the STBC. Finally, the pair of alternative sequences with the smallest PAPR is chosen to be transmitted. The factors of the selected pair of sequences have to be transmitted as side information. However, if the factors are chosen particularly, the transformed pair of the constellation points corresponds to only one pair of original constellation points. As a result, the received pair of the constellation points could determine its corresponding original data without side information at the receiver. Simulation results show that the proposed SLM scheme could provide good PAPR reduction, and the STBC-SLM method without side information could provide the same Bit Error Rate (BER) performance as that of the PTS scheme with perfect side information in SFBC MIMO-OFDM with 4-QAM and 16-QAM, respectively.

Peak To Average Power Ratio In OFDM System[3]:

It is defined as the large variation or ratio between the average signal power and the maximum or minimum signal power. Theoretically, large peaks in OFDM system can be expressed as Peak-to Average Power Ratio (PAPR) and it is usually defined as

$$PAPR = \frac{P_{Peak}}{P_{Average}} = 10\log_{10}\frac{\max[|x_n|^2]}{E|x[n]|^2}$$

……..eq 1

Where P peak represents peak output power, P average means average output power E. Denotes the expected value, represents the transmitted OFDM signals which are obtained by taking Inverse Fast Fourier Transform (IFFT) operation on modulated input symbols as shown in Figure 1. Mathematically, is expressed as[2]

$$x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k \; W_N^{nk}$$

……..eq 2

For an OFDM system with sub-carriers as shown in eq 2, the peak power of received signals is N times the average power when phase values are the same. The PAPR of baseband signal [2] will reach its theoretical maximum at PAPR(db) =10logN. Another commonly used parameter is the Crest Factor (CF), which is defined as the ratio between maximum amplitude of OFDM signal x(t) and Root Mean Square (RMS) of the waveform.

II. PAPR REDUCTION TECHNIQUES

Different algorithms that have been proposed to solve the high PAPR problem of OFDM system. PAPR reduction solutions can be categorized as

(i) **Signal Distortion Techniques**:- To implement this signal distortion techniques there are different approaches like

- ❖ Peak Windowing
- ❖ Envelope Scaling
- ❖ Peak Reduction Carrier
- ❖ Clipping and Filtering

One of the easiest approaches is clipping and filtering[4], which can snip the signal at the transmitter so as to eliminate the appearance of high peaks above a certain level.

(ii) **Signal Scrambling Techniques[1]**:- The basic fundamental principle of this technique is to scramble each OFDM signal with different scrambling sequences and select one which has the smallest PAPR value for transmission. Apparently, this technique does not guarantee reduction of PAPR value below to a certain threshold, but it can reduce the appearance probability of high PAPR to a great extent.

- ❖ Block Coding Techniques
- ❖ Block Coding Scheme with Error Correction
- ❖ Selected Mapping (SLM)
- ❖ Partial Transmit Sequence (PTS)

Research on Signal Scrambling Techniques

The high PAPR or PAR or Crest Factor of the OFDM systems can be reduced by using various PAPR reduction techniques namely:-

1. Partial Transmit Sequence (PTS).
2. Selective Mapping (SLM)[6].

1. **Partial Transmit Sequence (PTS)**

Partial Transmit Sequence (PTS)[7] algorithm is a technique for improving the statistics of a multicarrier signal. The basic idea of partial transmits sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen.

From the left side of Figure 2, the data information in frequency domain X is separated into V non-overlapping sub-blocks and each sub block vectors has the same size N. So for each and every sub-block it contains N/V nonzero elements and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other. The sub-block vector is given by

$X=\sum v=1 \text{ to } V\ b_v X_v$

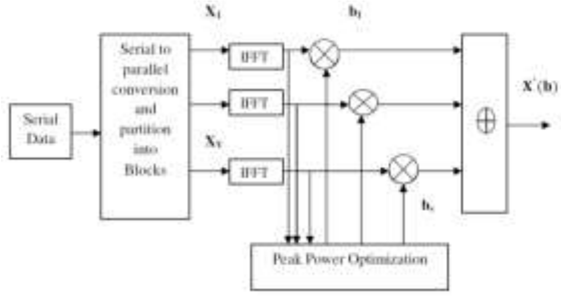

Figure 2: Block Diagram of Partial Transmit Sequence Technique

In this method, input data block X is partitioned in M disjoint sub blocks. Xm=[Xm,0; Xm,1; Xm,2...... Xm, N-1] T; m=0,1,2...M-1; such that ∑m-1 to M Xm=X and sub blocks are combined to minimize PAPR in time domain. Here S times Over sampled time domain signal of Xm (m=0, 1, 2....m-1); is obtained by taking the IDFT length of NS on Xm concatenated with (S-1) N Zeros.Complex Factorbm=∑∑¢jøm,(m=0,1,2...M-1) are introduced to combine PTS. The set of Phase factors is denoted as vector b= [b0.b1.....bM-1]T.

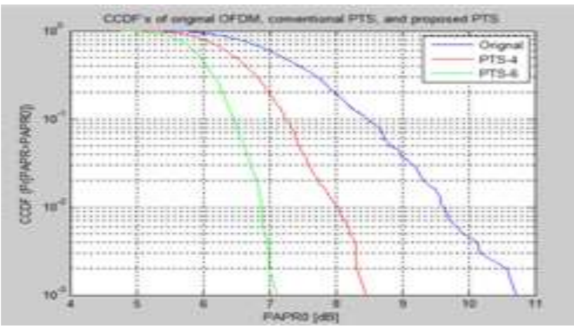

Figure 3: 128 Bit Process on PTS-PAPR Reduction in MIMO-OFDM Channel

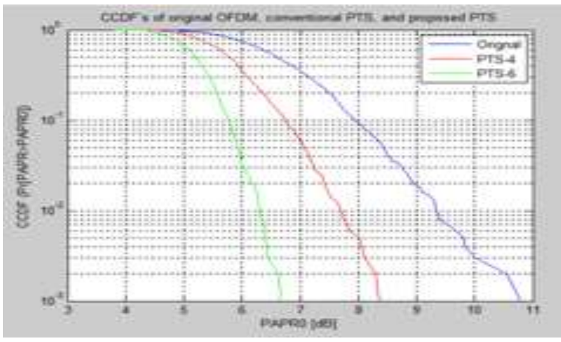

Figure 4: 64 Bit Process on PTS-PAPR Reduction in MIMO-OFDM Channel

2. **Selective Mapping Method**

The Complementary Cumulative Distributive Function(CCDF) of the original signal sequence PAPR above threshold PAPR0 is written as Pr {PAPR > PAPR0}.

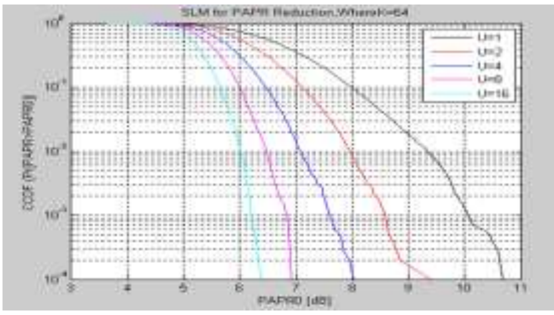

Figure 5: PAPR's CCDF using SLM method with N=64

Thus for K statistical independent signal waveforms, CCDF can be written as Pr {PAPR > PAPR0}, so the probability of PAPR exceed the same threshold. The probability of PAPR larger than a threshold Z can be written as

P (PAPR<Z) =F (Z) N=1-(exp (-Z)) N……..eq 3

Assuming that M-OFDM symbols carry the same information and that they are statistically independent of each other. In this case, the probability of PAPR greater than Z is equals to the product of each independent probability. This process can be written as

$P(PAPR_{low}$<Z) = (P (PAPR>Z)M=1-(exp (-Z) N …eq 4

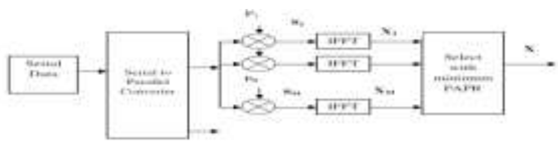

Figure 6: Block Diagram of Selected Mapping Technique

In selected mapping method as shown in Figure 6, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks $S_m=[S_{m,o};S_{m,1};S_{m,2}\ldots S_{m,n-1}]$, for m=1,2,...,M are then forwarded into IFFT operation simultaneously $X_m=[x_1,x_2,x_3\ldots x_n]T$ in discrete time-domain are acquired and then the PAPR of these M vectors are calculated separately. Eventually, the sequences x_d with the smallest PAPR is selected for final serial transmission.

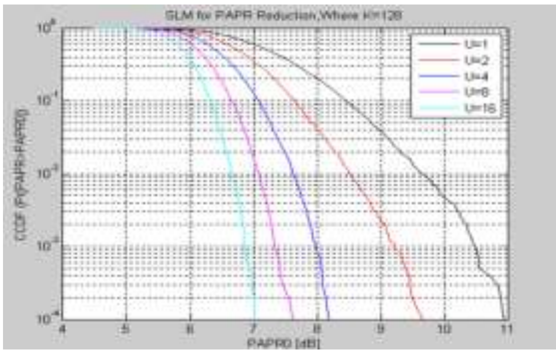

Figure 7: PAPR's CCDF using SLM method with N=128

III. STBC Using Partial Transmit Sequence

The most well known transmit diversity technique was introduced by SFBC where the proposed orthogonal code ensures full diversity in Figure 8, the Block code pre-coding can be implemented with SFBC. In order to simplify the descriptions of our proposed method, we consider a SFBC System with two transmits and one receives antennas. For other systems with more transmit antennas, our proposed method can be easily extended.

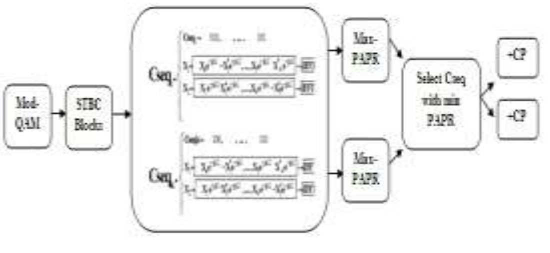

Figure 8: Basic STBC MIMO-OFDM Systems

Principle of Our Proposed Technique

Our proposed technique follows these steps:

1) Multiply the original data X by independent phase sequences and obtain X_,

2) Each couple (X_ 2k,X_ 2k+1) will be encoded according to the pre-coder code book M, The resulted sequence with the lowest PAPR will be kept and transmitted.

Basically, this method uses a predefined set E of possible phases. This set E consists of two subsets: E1 leaves unchanged the OFDM signal constellation whereas E2 is the set of its rotated constellation with a specific _opt angle. If the constellation points (in set E) are very close, the rate of errors detection phase will be increased. That is why we propose to calculate a minimum distance, dmin, separating two different types of constellation (E1 and E2), the selected one _opt is the one having the biggest dmin. We illustrate in Table I the corresponding _opt for 4, 16 and 64 QAM. Denote all possible combinations of the factors where V denotes the number of choices for the factor combinations. At the receiver is obtained after decoding of the SFBC. Then, a hard decision is made to each elements of X with the minimum distance of the constellation used at the transmitter, and the sequence X = { $=k = 0, 1,\ldots, N-1$} without channel noise is obtained.

$$\begin{cases} Z^m_{v,2l} = \bar{\bar{X}}_{pl}, \\ Z^m_{v,2l+1} = \bar{\bar{X}}_{2l+1}, \end{cases} v=0, \quad \begin{cases} Z^m_{v,2l} = \frac{a_v \bar{\bar{X}}_{2l} - b_v \bar{\bar{X}}_{2l+1}}{a_v^2+b_v^2}, \\ Z^m_{v,2l+1} = \frac{b_v \bar{\bar{X}}_{2l} + a_v \bar{\bar{X}}_{2l+1}}{a_v^2+b_v^2}, \end{cases} 1 \le v \le \frac{V}{2}, \quad \begin{cases} Z^m_{v,2l} = \frac{a_v \bar{\bar{X}}^*_{2l} - b_v \bar{\bar{X}}_{2l+1}}{a_v^2+b_v^2}, \\ Z^m_{v,2l+1} = \frac{b_v \bar{\bar{X}}_{2l} + a_v \bar{\bar{X}}^*_{2l+1}}{a_v^2+b_v^2}, \end{cases} \frac{V}{2}+1 \le v \le V. \quad \text{eq 5}$$

The sequence X is divided into M sub blocks for each sub block as shown in eq 5, we could obtain (V + 1) partial transmit sequences.

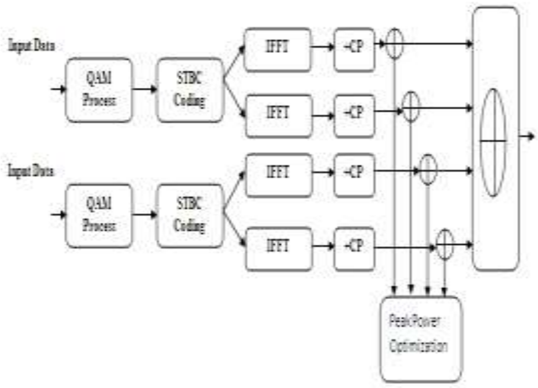

Figure 9: STBC-OFDM System Using SLM Process

Table 1: The Corresponding _opt for 4, 16 and 64 QAM.

	k=128	K=64
SLM U=1	10.98db	10.78db
SLM U=2	9.53db	9.43db
SLM U=4	8.25db	8.00db
SLM U=8	7.45db	6.97db
SLM U=16	7.00db	6.32db
Original	11.75db	11.12db
PTS V=4	9.52db	9.00db
PTS V=6	7.52db	7.43db
Without STBC	8.12db	5.25db
With STBC	4.85db	4.35db

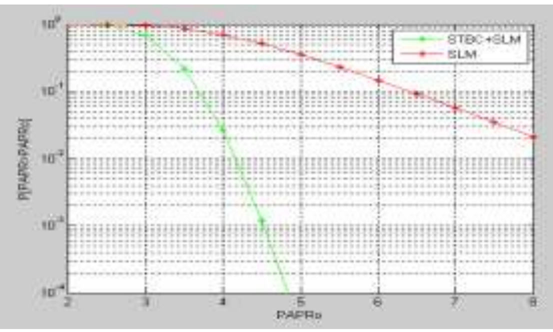

Figure 10: 64 Bit Process on Comparison Between PTS and STBC-SLM PAPR Reduction in MIMO-OFDM Channel

IV. CONCLUSION

In this paper, we observed an efficient PAPR reduction technique dedicated to MIMO-OFDM systems using STBC codebook. The main feature of our proposed method is that it induces an embedded signaling through the advanced pre-coders code book that leads to a powerful recovery of the transmitted signal and guarantees a very low failure decision rate. To further improve the decision process, we proposed an additional embedded signal that consists of a set of rotated and un-rotated QAM constellations and when Used in the decision process (using a hard decision deduced from a Max Log MAP decoding), it significantly improves the MIMO-OFDM system performances in terms of CCDF of the PAPR, SIER and BER. This decision criterion ensures a good decision performance when the absolute LLR value is greater than a certain threshold. But when it is close to zero (for very low SNR values), the decision can be biased. To overcome this issue, conceiving a soft decision process would be an appropriate solution: this is a research aspect that we are currently investigating.

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