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A Hybrid Approach to improve PAPR in MIMO-OFDM systems

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Abstract
The multiple input multiple output (MIMO) with orthogonal frequency division multiplexing (OFDM) has came into view as a promising solution to augment the channel capacity and multiplicity of wireless communication system without any increase in bandwidth. In this paper, an amalgam or hybrid combinational scheme is proposed to reduce peak-to-average power ratio (PAPR) in MIMO–OFDM system under Rayleigh fading environment. The proposed method intelligently slots in both clipping sequence and partial transmit sequence schemes. The results show that the proposed method not only reduces the PAPR but also maintains the bit error rate (BER) compared to other schemes.

I. Introduction

Until now we all are familiar and household with 3G technologies. However in the present circumstances this is not enough as the ever growing demands of multimedia services, online gaming and other services needs advanced speed of data. More suave technology for higher and faster data transmission and reception is now needed. This can be achieved by 4G wireless proficiencies. Antennas can be improved by applying a method known as MIMO, or multiple-input multiple-output, and the caveat sign can be improved by the modulation technique of OFDM, or orthogonal frequency division multiplexing. This concept, as a whole, is known as MIMO-OFDM, and is used as the basis of the 4G technology. Orthogonal frequency division multiplexing (OFDM) is widely used technique due to its robustness and higher data rate transmission over frequency selective fading channel [1]. Multiple input multiple output (MIMO) with OFDM is an alternative approach to achieve higher spectrum efficiency and data throughput for broadband wireless communication system without any expansion in the bandwidth [2, 3]. To further improve the overall system performance over channels with large delay spread, the space time block coding (STBC) technique [4] is also applied in MIMO–OFDM. Though, the MIMO–OFDM [5–7] offers multitudinous benefits, but when the large peak signals enter into amplifier saturation region, deformation occurs. This increases the peak-to-average power ratio (PAPR) of the system and reduces its recital and performance in terms of bit-error rate (BER). In the literature, various conventional [8–11] and hybrid [12–16] techniques have been proposed for reducing the PAPR of MIMO–OFDM system. Each straight scheme possesses its own merits and demerits in terms of the out-of-band interference, and data rate loss. Though, the hybrid method combines a couple of conventional schemes together and accumulates their remuneration and benefits in a combinational approach, but the computational complexity in combinational method is also a major issue of apprehension. Therefore, in this paper, a parallel combination of clipping and partial transmit sequence (PTS) schemes are prudentially applied to augment the performance of MIMO–OFDM system. The proposed method not only reduces the PAPR of MIMO–OFDM signals but also maintains the data rate and provides low in-band ripples and out-of-band radiations. Moreover, the proposed schemes also offers less computational complexity compared to an alike combinational scheme. Orthogonal frequency division multiplexing (OFDM) has become a prevalent and widespread technique for the broadcast and transmission of signals over wireless channels and has been adopted in many wireless standards. OFDM may be united with antenna arrays at the transmitter and receiver side to improve the diversity gain and to improve the system competence on time-variant along with the frequency-selective channels, resulting in a multiple-input multiple-output (MIMO) composition.

II. MIMO-OFDM System

Multiple Input Multiple Output Orthogonal Frequency division multiplexing is a technique that uses multiple antennas to transmit and receive radio signals. The block diagram of intended scheme for MIMO–OFDM system is shown in figure 1 which has number of antennas at transmitter and receiver side.

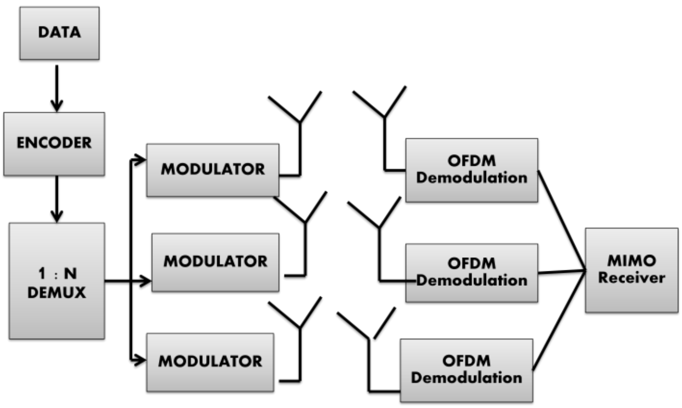

Figure 1 MIMO OFDM BLOCK DIAGRAM

When much higher throughputs are aimed at, the multipath character of the environment causes the MIMO channel to be frequency-selective. OFDM can transform such a frequency-selective MIMO channel into a set of parallel frequency-flat MIMO channels and also increase the frequency efficiency. Therefore, MIMO-OFDM technology has been researched as the infrastructure for next generation wireless networks. MIMO wireless systems, combined with OFDM, have allowed for the easy transmission of symbols in time, space and frequency. MIMO-OFDM takes advantage of the multipath properties of environments [17] using base station antennas that do not have LOS and uses both the advantages of MIMO and OFDM. Combination of MIMO and OFDM techniques will impact the evolution of wireless LANs, and is a leading candidate for future fourth generation (4G) wireless communications

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systems. Therefore, MIMO-OFDM [18] system has become a welcome proposal for 4G mobile communication systems. Advantage is very high competence, spectral efficiency and improved communications reliability i.e., reduced bit error rate (BER) [19] achieved at reasonable computational complexity.

III. System model

Considering MIMO OFDM system with a configuration in which the input data stream is the mapped into N number of orthogonal symbols. The space time block coding [20] is used to improve the overall performance of MIMO–OFDM system. The time domain signal $\tilde{x}_i(n)$ is obtained by IFFT operations

$$\tilde{x}_i(n)=1\frac{1}{\sqrt{N}}\sum_{k=0}^{LN-1}\hat{x}_i(k)e^{\frac{j2\pi nk}{LN}} \quad (1)$$

where i=1,...,N_T and n=0,1,…,LN−1. L is the oversampling factor. PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power, and it is written as,

$$\text{PAPR}=\max_{0\le n\le LN-1}\frac{|\tilde{x}i(n)|^2}{E[|\tilde{x}i(n)|^2]} \quad (2)$$

where E[.] symbolizes the expectation. The PAPR performance is describe by using complementary cumulative distribution function (CCDF), which is defined as the chance of the transmitted signal exceeding a given PAPR threshold λ and is given by

$$\text{CCDF}=1-\Pr\{\text{PAPR}\le\lambda\}=1-(1-e^{\lambda})^N \quad (3)$$

IV. Selection of PAPR reduction schemes

In general, the PAPR reduction schemes are broadly classified into four main categories:

a) **Signal distortion** The PAPR reduction is possible by distorting the OFDM signal non-linearly in time domain. The clipping and filtering [20], peak windowing and non-linear companding are a few methods of this sort. Performance of clipping scheme is easy, but its BER presentation degrades due to in-band signal distortion [21]. The Non-linear Companding mainly focuses on enlarging small amplitude signals whilst keeping peak signals unchanged, and so it increase the average power of the transmitted signals and possibly results in degradation of the BER performance with the increase in value of μ. Hence, the companding is efficient only for small number sub-carriers, and not suitable for high data transmission situations.

b) **Coding methods** The concept behind the coding schemes is to lessen and cut the occurrence probability of the same phase of *N* signals [22]. The coding method reduces the PAPR, but it suffers from bandwidth efficiency, in particular for a large number of sub-carriers.

c) **Scrambling techniques** The Selective Mapping (SLM) and Partial Transmit Sequence (PTS) are two admitted schemes of this category which partitions different scrambling sequences and selecting that sequence which gives smallest PAPR.. The major drawbacks of these schemes are computational complexity and requirement of side-information to recover original data block at the receiver side.

d) **Pre-distortion method** These methods are based on the re-orientation or spreading the vigour and energy of data symbol, which include DFT spreading, pulse shaping or pre-coding and constellation shaping schemes. The Tone Reservation (TR), Active Constellation Extension (ACE), and Tone Injection (TI) are two fit techniques for PAPR reduction which are based on the reorientation (shaping) of constellation. The Active Constellation Extension (ACE) practice is used to obtain good performance including PAPR reduction and low complexity [23]. The main advantage of ACE is that it does not require any side information to recover original sequence.

The hybrid/combinational methods seem to be a better choice for PAPR reduction because it possesses the merits of both techniques used in combination. Therefore, in this paper, a hybrid schemes based on clipping and partial transmit sequence (PTS) is selected. In this section, we present the proposed hybrid PAPR reduction technique which has been obtained by the alliance of PTS method with clipping method. One performs linear conversion or transformation by rotating the vectors from the frequency-domain signal, and the other one performs a non-linear alteration represented by signal limitation. The block diagram of the proposed method is presented in Figure 2.

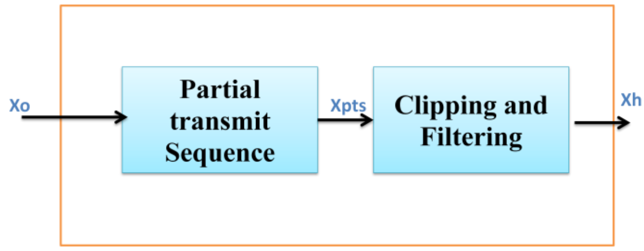

Figure 2 Hybrid PTS-Clipping Scheme

The presentation and performance of the proposed PAPR reduction technique is hereby analyzed with a MATLAB simulator as presented in Figure 3.

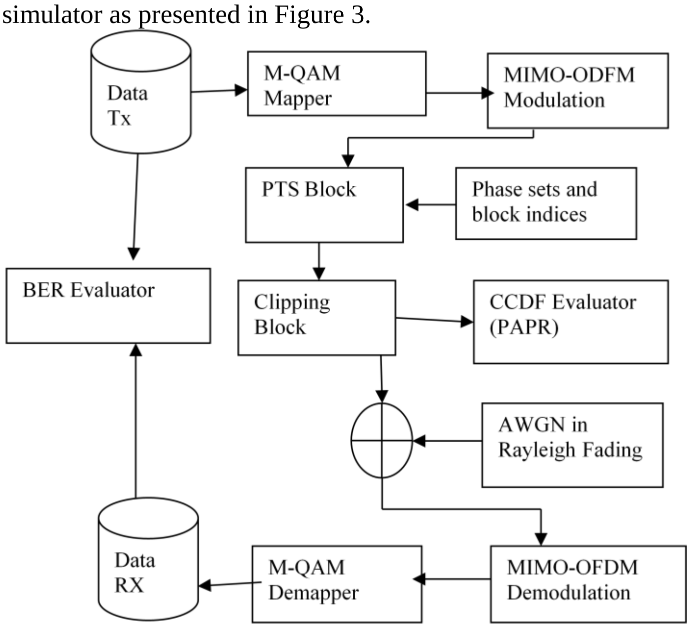

Figure 3 Proposed model for the analysis of hybrid PAPR reduction technique

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Within this simulator, the samples from the generated signal are mapped from binary representation to the M-QAM constellation points. The obtained complex values are grouped in blocks of *N* elements each, forming the MIMO-OFDM symbols using Constant Modulus Algorithm. Similar to [24] we consider a generic MIMO-OFDM/A downlink scenario with one base station (BS) employing antennas. An OFDM block with subcarriers is transmitted from each antenna. The subcarriers comprises of useful subcarriers surrounded by two guard bands with zero energy. The useful subcarriers are assemblage into resource blocks (RBs) each consisting of subcarriers. Data of one or many users is placed in these RBs and mapped into the space-time domain using an inverse discrete Fourier transform (IDFT) and space-time block coding (STBC). To allow channel inference at the receivers (mobile stations), each RB also contains several pilot subcarriers that act as training symbols. The transmit signal model which shows the data structure of an OFDM block for a MIMO-OFDM/A is shown in figure 4.

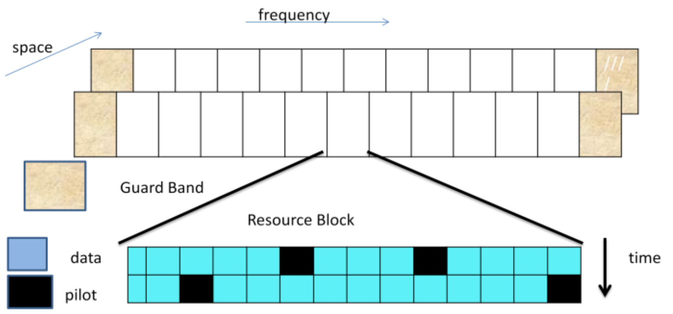

Figure 4 Structure of data of an OFDM block for MIMO system

The obtained MIMO-OFDM frames are applied sequentially to PTS block and then to clipping block. Also for a better valuation of the proposed method, the results obtained only from clipping are also considered. The parameters of the resulting signal change according with the signal processing applied by the two PAPR reduction methods. The PTS method operates on the frequency-domain signal iteratively until the best signal derivate is actually found. The main idea of this approach is to alter the phases of the vectors composing the signal. This method considers the signal's vectors as being grouped in disjoint blocks. The vectors from a block may have a nearby displacement, or they may be interleaved with the vectors representing another block. The algorithm applies one phase shift for each block iteratively until the signal variant having the lowest PAPR is found. In the present work, the PTS method was implemented considering contiguous or nearby blocks of same length each. To add on, for a better PAPR reduction, the proposed PTS method performs position swap between these blocks.

V. Partial Transmit Sequence (PTS) It is one of the most wanted techniques for PAPR reduction in OFDM. Here the input frequency domain data block is first partitioned into disjoint sub-blocks. Then each of the sub-blocks are then padded with zeros appropriately and weighted by complex phase factors. The data vector $X=[x_o,x_1,x_2....x_{N-1}]^T$ is divided in V disjoint sets, { X_v, v = 1,2..V }, using same number of carrier for each group.

$$X' = \sum X_v b_v \quad v= 1 \text{ to } V, \qquad (4)$$

Where $b_v = e^{j\emptyset v}$ are the phase factors. Select one suitable factor amalgamation $\mathbf{b}=[b1,b2,\ldots,bv]$ which makes the result achieve optimum. The combination can be given by:

$$b= [b_1,b_2\ldots\ldots,bv] = argmin_{\,b1,b2\ldots\ldots,bv}\left(max_{1\le n\le N}\left|\sum_{v=1}^{V} b\, vXv\right|^2 \right) \qquad (5)$$

Where argmin (·) is the verdict condition that output the minimum value. This way one can find the finest 'b' so as to optimize the PAPR performance. The added cost one has to pay is the extra *V*-1 times IFFTs manoeuvres. At receiver to recuperate the signal, some side information about phase weighting sequences are required, this side information needs $\log_2 W^V$ bits to be transmitted separately.

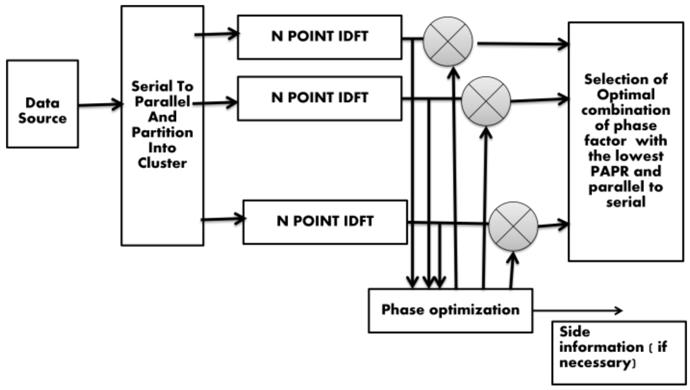

Figure 5 PTS Block Diagram

VI. Clipping and filtering This is simplest technique used for PAPR reduction of OFDM signal. A Clip is also called as non linear saturation which is employed about the peaks to reduce the peaks before high power amplifier to lessen PAPR and so is called Clipping Technique. This is simple technique but it yet commences Out Of Band Radiation and In Band Distortion in OFDM Signal. It also obliterates the Orthogonality of OFDM subcarriers. The part of the signal which is above the allowed region is clipped in a simple clipping technique. Joint filtering and clipping technique reduce the OOB radiation but IB distortion are still there since this method degrades OFDM system performance e.g. spectral efficiency and BER. Envelop scaling is used for PAPR reduction due to equality envelop properties of all subcarriers input [**25**] Clipping means the amplitude of the signal is clipped at the predefined values which limit the peak value of the input signal to a predetermined value. Let Y[n] denote the input signal and Yc [n] denote the clipped signal of Y[n], which can be represented as,

$$[n] = \begin{cases} -Z & [n] \le -Z \\ [n] & |[n]| < Z \\ Z & [n] \ge Z \end{cases} \qquad (6)$$

Where Z is the threshold or predetermines value of clipping level. Clipping is simple but yet it has some drawback. Clipping cause signal distortion which increase bit-error-rate performance. After the filtering operation performed on the clipped signal clipping level may exceed to the signal specified for the clipping operation.

VII. Results

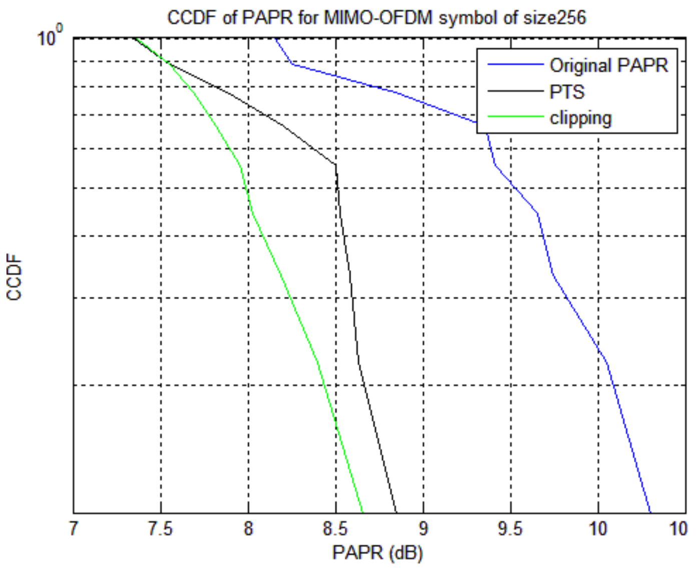

Figure 6 CCDF of MIMO-OFDM System with N=256

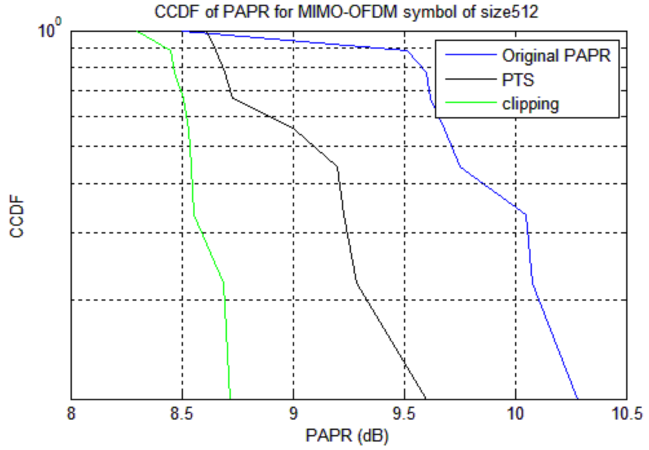

Figure 7 CCDF of MIMO-OFDM system with N=512

The PAPR calculation have been done for N= 256 and N=512 symbol size having CR ratio as 12. The blue coloured graph is the CCDF for the original signal. Once PTS technique in accordance with the block diagram is applied to the original signal then, PAPR is further reduced which is shown as in black colour. Now to the signal which comes after PTS block based upon the phase and block indices is sent for the clipping which actually clips the signal based upon some defined threshold value and PAPR is further reduced which the final hybrid (Clipping) signal is shown in green colour. The results can be understood from Table1.

Table 1: PAPR values for N=256 and 512

CCDF (PAPR)	Original	PTS	Hybrid
N=256	10.2	8.9	8.6
N=512	10.3	9.6	8.7

The values clearly show that the PAPR reduced by 1.6 dB for both N=256 and 512 FFT size. The PAPR value reduces after applying the hybrid PTS-Clipping technique in MIMO-OFDM system.

VIII. Conclusion

Though all the techniques in individual and hybrid effects gives good results but still every method is having certain flaws. Here in this paper the hybrid PTS and clipping techniques have been implemented on MIMO-OFDM system with the number of subcarriers as 256 and 512 as to OFDM system. The significant difference is a reduction in PAPR value by approximately 2dB.

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