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Peak To Average Power Ratio (Papr) Reduction In Mimo-Ofdm Systems Using Adaptive Active Constellation Extension (Adaptive Ace) Without Side Information

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Abstract:
One of the effective methods used for reducing Peak to Average Power Ratio (PAPR) in MIMO - OFDM systems is Adaptive Active Constellation Extension Algorithm. The proposed scheme is employed with Quadrature Amplitude Modulation (QAM). One of the big advantages is that the side information does not need to be sent to the receiver. The Adaptive ACE method is the most attractive scheme due to its good system performance and simplicity, also effectively reduces Peak-to-Average Power Ratio (PAPR) for different modulation formats and subcarrier sizes without any complexity increase and bandwidth expansion.

Key words: *peak to average power ratio (PAPR), orthogonal frequency division multiplexing (OFDM), multi input multi output (MIMO), Active constellation, extension (ACE), adaptive. Partial transmit sequence (PTS), Selected mapping (SLM)*

1.Introduction

Orthogonal frequency division multiplexing (OFDM) is an attractive technique for wireless communications because it supports robust reliability and high data rate in the frequency selective fading channel environments [1]. Moreover, multiple-input multiple-output (MIMO) is another attractive technology to improve the wireless system capacity. Therefore, the combination of MIMO and OFDM (MIMO-OFDM) could exploit the spatial dimension capability of a wireless communication system to improve the wireless link performance and system capacity by employing multiple antennas at both the transmitter and receiver ends [2]. MIMO-OFDM has attracted increasing attention because it is robust to time selective fading channels. However, MIMO-OFDM systems also inherit disadvantages from OFDM techniques, e.g., sensitivity to synchronization errors and high peak-to-average power ratio. Because in MIMO-OFDM wireless systems, independent OFDM signals are simultaneously transmitted from multiple-transmit antennas to multiple-receive antennas [2]. Therefore, similar to OFDM systems, MIMO-OFDM systems still suffer an inherent drawback of a high peak-to-average power ratio (PAPR).

2.Papr In OFDM

Let X *(0), X (1) . . . , X (N-1)* represents the data sequence to be transmitted in an OFDM symbol with subcarriers. The baseband representation of the OFDM symbol is given by:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X(n) e^{j\frac{2\pi nt}{N}}, 0 \le t \le T$$

Where x (t) is OFDM symbol at time t, T is the duration of the OFDM symbol [1]. The input information symbols are assumed to be statistically independent and identically distributed. According to the central limit theorem, when N is large, both the real and imaginary parts of x (t) becomes Gaussian distribution, each with zero mean and a variance of $E\,[|\,x\,(t)\,|^2]\,/\,2$, the amplitude, or modulus, of OFDM signal is given by

$$x_t = \sqrt{\mathrm{Re}^2\{x_t\} + \mathrm{Im}^2\{x_t\}}$$

In OFDM modulation technique, a block of N data symbols, $\{X_n, n = 0, 1, \ldots, N-1\}$, is formed with each symbol modulating the corresponding subcarrier from a set $\{f_n, n = 0, 1, \ldots, N-1\}$. The N subcarriers are chosen to be orthogonal, i.e., $f_n = n\Delta f$, where $\Delta f = 1/NT$ and T represents the original data symbol period [3]. The PAPR of the transmitted signal $x\,(t)$ can be defined as

$$PAPR(x(t)) = \frac{\max_{0\le t\le NT} |x(t)|^2}{E\left[|x(t)|^2\right]} = \frac{\max_{0\le t\le NT} |x(t)|^2}{\frac{1}{NT}\int_0^{NT} |x(t)|^2 \, dt}$$

Since most practical systems deal with discrete-time signals, instead of reducing the continuous-time peak max $|x(t)|$, the maximum amplitude of LN samples of $x(t)$ is reduced, where parameter L denotes the oversampling factor. To evaluate the PAPR performance from statistical point of view of the OFDM signals, the complementary cdf (CCDF) is used to describe the probability of exceeding a given threshold $PAPR_0$, i.e., $CCDF(PAPR_0) = Pr(PAPR > PAPR_0)$ [3].

3.Papr Reduction Techniques

Several techniques have been proposed to mitigate the high PAPR of MIMO-OFDM signals. Clipping is used to reduce the peak power by clipping the OFDM signals to the threshold level. Selective mapping (SLM) techniques the input data sequences are multiplied by each of the phase sequences to generate alternative input symbols sequences. Each of these alternative input data sequence is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission. Partial transmit sequence (PTS) schemes generate several alternative signal sequences representing the same OFDM signal sequence and select the one with the minimum PAPR among them. Tone reservation (TR), tone injection (TI), and active constellation extension (ACE) change constellation points for some subcarriers to reduce the PAPR [1].

Among various peak-to-average power ratio (PAPR) reduction techniques, the active constellation extension (ACE) technique is attractive because ACE allows the reduction of high-peak signals by extending some modulation constellation points toward the outside of the constellation without any loss of data rate [3]. The basic principle of clipping-based ACE (CB-ACE) algorithms involves switching between the time domain and the frequency domain. Filtering and applying the ACE constraint in the frequency domain, after clipping in the time domain, both require iterative processing to suppress the subsequent regrowth of the peak power [4].

However, the CB-ACE algorithms have a low clipping ratio problem in that they cannot achieve the minimum PAPR when the target clipping level is set below an initially unknown optimum value. Our approach combines a clipping-based algorithm with an adaptive clipping control, which allows us to find the optimal clipping level. Simulation results show that our proposed algorithm can achieve the minimum PAPR regardless of the low target clipping level [5].

The clipping of the peak signal results to distortion of the original OFDM signal. The distortion of the original signal can be assumed as the noise, which results to an unreliable communication between the transmitter and the receiver [5].

4.Proposed Papr Technique

The main objective of the Adaptive Active Constellation Extension (Adaptive ACE) algorithm for reducing the Peak-to-Average Power Ratio (PAPR) is to control both the clipping level and the convergence factor at each step and thereby minimize the peak power signal whichever is greater than the initial target clipping level. The Adaptive Active Constellation Extension (Adaptive ACE) algorithm can be initialized by selecting the parameters namely the target clipping level, denoted by A and the number of iterations, denoted by i. In the first step, the iteration is taken as two i.e., i = 2 and the initial target clipping level is to be taken as A [5].

The predetermined clipping level, denoted by A, is related to the target clipping ratio, $\gamma$and given as $\gamma = \dfrac{A^2}{E\{|x_n|^2\}}$

Where, γ – Target Clipping Ratio, A – Predetermined Clipping Level, x_n – Oversampled OFDM signal The clipping of the peak signal results to distortion of the original OFDM signal. The signal obtained after filtering the clipped signal is given as $x^{(i+1)} = x^{(i)} + \mu \tilde{c}^{(i)}$, Where, $\tilde{c}^{(i)}$ – Anti-Peak Signal at the i^{th} iteration, μ – convergence factor. The Convergence Factor (CF), denoted by μ can be estimated by $\mu = \dfrac{\Re[\langle c^{(i)}, \tilde{c}^{(i)} \rangle]}{\langle c^{(i)}, \tilde{c}^{(i)} \rangle}$,Where, μ– convergence Factor, $\Re$ – Real Part, $C^{(i)}$ – Peak Signal above the Pre-Determined Level, $\tilde{c}^{(i)}$ – Anti-Peak Signal at the i^{th} iteration, $\langle , \rangle$ – Complex Inner Part.

The anti-peak signal at the i^{th} iteration generated for the PAPR reduction, denoted by $\tilde{c}^{(i)}$, is given by $\tilde{c}^{(i)} = T^{(i)} c^{(i)}$ Where, $\tilde{c}^{(i)}$ – Anti-Peak Signal at the i^{th} iteration, $T^{(i)}$ – Transfer Matrix at the i^{th} iteration, $C^{(i)}$ – Peak Signal above the Pre-

Determined Level. The transfer matrix at the i^{th} iteration, denoted by $T^{(i)}$, used for generating the anti-peak signal is given as

$T^{(i)} = \hat{Q}^{*(i)} \hat{Q}^{(i)}$ Where, $T^{(i)}$ – Transfer Matrix at the i^{th} iteration, $\hat{Q}^{*(i)}$ – Conjugate of Constellation Order, $\hat{Q}^{(i)}$ – Constellation Order.

The original Orthogonal Frequency Division Multiplexing (OFDM) signal, denoted by x_n, is to be clipped in order to reduce the peak signals. The clipping signal is given by

$$c_n^{(i)} = \begin{cases} (|x_n^{(i)}| - A)\, e^{j\theta_n}, & |x_n^{(i)}| > A \\ 0, & |x_n^{(i)}| \le A \end{cases}$$

Where, $c_n^{(i)}$ – Clipping Sample, A – Predetermined Clipping Level, θ_n – arg(- $x_n^{(i)}$). The clipping level, denoted by A, for the next iteration is given by $A^{(i+1)} = A^{(i)} + \mu \nabla_A$,Where, $A^{(i+1)}$ – Next Iteration Level, $A^{(i)}$ – Present Iteration Level , μ – Convergence Factor, ∇_A – Gradient with respect to A. The gradient with respect to the target clipping ratio, denoted by ∇_A ,is given

$$\nabla_A = \frac{\sum_{n \in I_1^{(i)} \cup I_3^{(i)}} |c_n^{(i+1)}|}{N_p}$$

Where, ∇_A – Gradient with respect to A, N_p – Number of peak samples larger than A.

The Peak-to-Average Power Ratio by the Adaptive Active Constellation Extension (Adaptive ACE) algorithm is to be calculated for the Orthogonal Frequency Division Multiplexing (OFDM) signal which is obtained after filtering the clipped signal [5]. The clipped and filtered OFDM signal obtained by using Adaptive Active Constellation Extension (Adaptive ACE) algorithm is to be transmitted via an Additive White Gaussian Noise (AWGN) channel, in order to calculate the Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER).

5.Simulation Results

The Peak-to-Average Power Ratio (PAPR) of the Orthogonal Frequency Division Multiplexing (OFDM) system is equal to 10 dB without using any algorithm i.e., by using the basic formula of PAPR for the original OFDM signal. The existing techniques for reducing the high Peak-to-Average Power Ratio (PAPR) of the OFDM systems are Partial transmit sequence (PTS) and Selected Mapping (SLM).

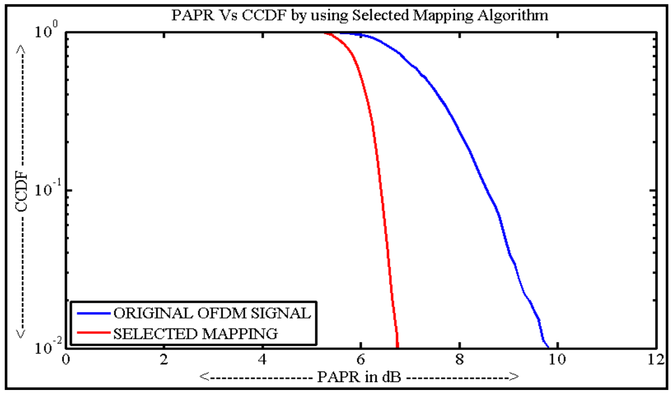

Figure 1: PAPR Result for PTS Algorithm

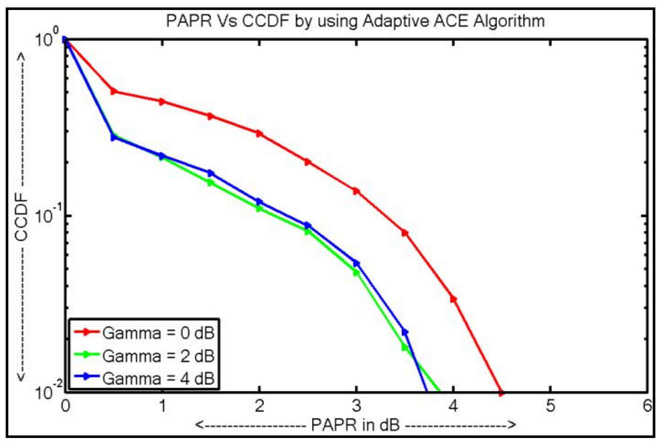

Figure 2: PAPR Result for SLM Algorithm

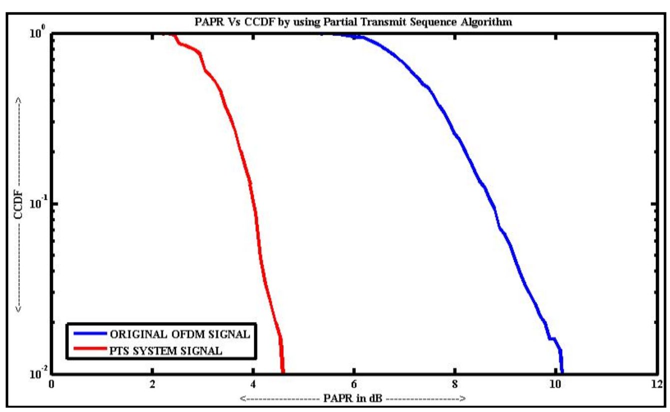

Figure 3: PAPR Result for Adaptive ACE Algorithm

Then, the PAPR basic formula is used for different values of target clipping ratios ($\gamma = 4$, 2, 0). The Peak-to-Average Power Ratios (PAPR) for the Selected mapping is 6.5 dB. The Peak-to-Average Power Ratios (PAPR) for the Partial transmit sequence is 4.6 dB.

The Peak-to-Average Power Ratios (PAPR) for the target clipping ratios of 0 dB, 2 dB and 4 dB are 4.5 dB, 3.9 dB and 3.8 dB respectively. From the PAPR values for different target clipping ratios, it is very clear that the PAPR increases when the value of the target clipping ratio is reduced, which results to low clipping ratio problem. The low clipping ratio problem means minimum PAPR cannot be achieved for low target clipping ratios.

The proposed method i.e., the Adaptive Active Constellation Extension (Adaptive ACE) algorithm reduced the Peak-to-Average Power Ratio (PAPR) to 3.8 dB for all the target clipping ratios, which says that the low target clipping ratio problem faced by the CB-ACE algorithm is eliminated completely.

The Signal-to-Noise Ratio (SNR) of the original Orthogonal Frequency Division Multiplexing (OFDM) signal is equal to 16 dB at a Bit Error Rate of 10^{-1}. In other words, a total of 100-bits are in error when a stream of 1000-bits is transmitted via a communication channel or medium for the original OFDM signal.

The Signal-to-Noise Ratio (SNR) of the Orthogonal Frequency Division Multiplexing (OFDM) signal obtained by the Adaptive Active Constellation Extension (Adaptive ACE) Algorithm is 1.2 dB at a Bit Error Rate of $10^{-0.4}$. In other words, a total of 398-bits are in error when a stream of 1000-bits is transmitted via a communication channel or medium for the original Orthogonal Frequency Division Multiplexing (OFDM) signal.

6.Conclusion

The major drawback of the Orthogonal Frequency Division Multiplexing (OFDM) system is the high Peak-to-Average Power Ratio (PAPR) or Peak-to-Average Ratio (PAR) or Crest Factor [1]. The high PAPR results to the increase in the complexity of Analog-to-Digital Convertors (ADCs) & Digital-to-Analog Convertors (DACs) and also reduces the efficiency of the power amplifiers [3].

The Peak-to-Average Power Ratio (PAPR) or Peak-to-Average Ratio (PAR) or Crest Factor of the original OFDM signal is equal to 10 dB at a Complimentary Cumulative Distribution Function (CCDF) of 10^{-2} or 0.01.

The Signal-to-Noise Ratio (SNR) and Bit-Error Rate (BER) are the other two important parameters for evaluating the PAPR reduction techniques. The Signal-to-Noise Ratio (SNR) of the original OFDM signal is equal to 16 dB at a Bit Error Rate of 10^{-1}.

The high Peak-to-Average Power Ratio (PAPR) or Peak-to-Average Ratio (PAR) or Crest Factor can be reduced by using various reduction techniques like Partial transmit sequence (PTS) Algorithm, Selected mapping (SLM), Adaptive Active Constellation Extension (Adaptive ACE) Algorithm.

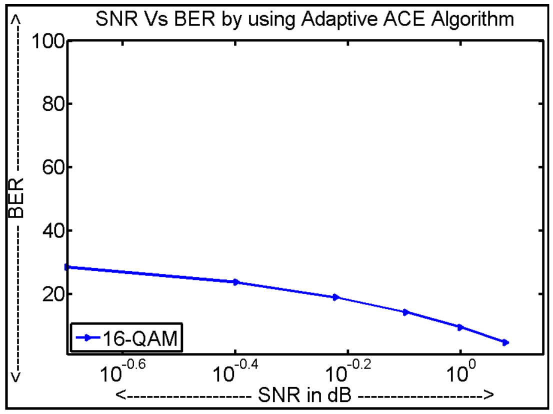

Figure 4: SNR Result for Adaptive ACE Algorithm

The Active Constellation Extension (ACE) Algorithm provides the minimum Peak-to-Average Power Ratio (PAPR), even when the initial target clipping ratio is set below the unknown optimum clipping point. Hence, the proposed algorithm avoids the problem of low clipping ratio, which is caused in the process of reducing the PAPR by using the Clipping-Based Active Constellation Extension (CB-ACE) Algorithm [5].

Hence, by reducing the Peak-to-Average Power Ratio (PAPR), the complexity of the Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) can be reduced. The reduced Peak-to-Average Power Ratio (PAPR) also increases the efficiency of the Power Amplifiers.

7.Reference

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