

An Improved Tone Reservation Scheme in OFDM Systems for Adaptive Amplitude Clipping

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Abstract

Orthogonal frequency division multiplexing (OFDM) suffers from a high peak to average power ratio (PAPR). Tone reservation (TR) technology is considered as one of the most promising methods because of no additional distortion, no side information, and low implementation cost. However, in all PAPR reduction schemes, determining the optimal target clipping level is difficult. In this paper, we consider an adaptive amplitude least squares approximation (AALAS-TR) algorithm. Adjust adaptive optimal convergence factor for initial clipping threshold. That is results an approximately PAPR reduction performance with a low computational complexity. Simulation results show that the proposed algorithm can achieve better PAPR reduction as that different clipping threshold.

Keywords: high peak-to-average power ratio (PAPR), tone reservation (TR), adaptive amplitude least squares approximation (AALAS-TR), OFDM, clipping control

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1. Introduction

Orthogonal frequency division multiplexing (OFDM) is one of the most popular technologies in current high-rate wireless communication systems which is for multi-carrier modulation techniques [1]. However, OFDM systems have high peak to average power ratio (PAPR) problem which is inefficient requires a linear high power amplifier (HPA). To study this problem, various PAPR reduction techniques have been proposed. Such as clipping and filtering [2-4], coding [5-6], companding scheme [7], active constellation extension [8] and tone reservation [9-10]. As one of tone reservation (TR) techniques, clipping control (CC-TR) [11] method is to repeatedly generate peak-canceling signals by clipping, but CC-TR method requirement of many iterations to reduction PAPR. In [12], uses a optimal convergence factor scale the filtered first-iteration clipping noise to compensate for peaks that are above the threshold and can achieve a larger PAPR reduction, but also need high iteration complexity. In [13], based on the least squares approximation with fast convergence reduction PAPR, only need a few iterations can achieve the same performance and reduced computational complexity. The LSA-TR scheme is employed to calculate the optimal constant P but different clipping threshold A results in different PAPR reduction. In other words, Each iteration should correspond to an optimal constant P but not the same P.

In this letter, a clipping algorithm is developed to obtain good PAPR reduction performance regardless of the initial target clipping level. This improved TR method based on the adaptive amplitude least squares approximation (AALAS-TR) algorithm. The fast convergence factor P with the iterative changes obtain a good PAPR reduction with low complexity. And different clipping threshold have an approximately PAPR reduction performance.

The paper is organized as follows. In Section II, the system model based on the TR method and the adaptive least squares approximation (LAS-TR) algorithm is introduced III, proposes the novel scheme the adaptive amplitude least squares approximation (AALAS-TR) algorithm. In Section IV, the simulated results are shown and the convergence of such a novel algorithm is compared with the other methods. In the end, a conclusion is given.

2. OFDM Systems and Tone Reservation Technique

2.1. OFDM Systems and PAPR Tone-Reservation Technique

In OFDM systems, the transmitted signal consists of a great number of orthogonal subcarriers. The baseband samples of an OFDM symbol can be written as:

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi nk/N}, 0 \leq k \leq N-1 \quad (1)$$

Where N is the subcarrier number of an OFDM system, X_k is the modulated data carried by the kth subcarrier, is the nth sample of a time-domain symbol.

The tone-Reservation technique reserves Nr tones for PAP reduction and don't carry any data information, the remaining (N- Nr) tones for data transmission. Obviously, the tone-reservation ration $R = Nr / N$ is small. The peak-canceling signal $c(t)$ is generated based on reserved tone, and the peak-reduced signal is given by:

$$\tilde{x}(t) = x(t) + c(t) = \frac{1}{\sqrt{N}} \sum_{k=-N/2}^{N/2-1} (X_k + C_k) e^{j2\pi kt/T} \quad (2)$$

2.2. Proposed LSA-TR Scheme

The LSA-TR algorithm is employed to calculate the optimal constant P, the objective of optimization problem is formulated as [13]:

$$P = \min_{p,A} \left\{ \sum_{n \in P} [p|c_n| - |f(n)|]^2 \right\} \quad (3)$$

For the least squares approximation (LSA) algorithm, we define:

$$g(p) = \sum_{n \in P} [p|c_n| - |f_n|]^2 \quad (4)$$

Then,

$$\begin{aligned} \frac{\partial g(p)}{\partial p} &= \frac{\partial \left(\sum_{n \in P} [p|c_n| - |f_n|]^2 \right)}{\partial p} \\ &= \frac{\partial \left(\sum_{n \in P} [p^2 |c_n|^2 + |f_n|^2 - 2p|c_n||f_n|] \right)}{\partial p} \\ &= 2p \sum_{n \in P} |c_n|^2 - 2 \sum_{n \in P} |c_n||f_n| \end{aligned} \quad (5)$$

Make $\frac{\partial g(p)}{\partial p} = 0$, we have:

$$P = \frac{\sum_{n \in P} |c_n||f_n|}{\sum_{n \in P} |c_n|^2} \quad (6)$$

From the above we can know, $|x(n) + pc(n)|$ approximates to $|x(n) + f(n)|$, and the good PAPR reduction could be achieved after the first servers iterations. But when P is uniquely determined, in the iterative process, different clipping threshold A results in different PAPR reduction performances. However, the optimal target clipping level or clipping ratio not be predetermined at the initial stage. In the next section, proposes a novel scheme the adaptive amplitude least squares approximation(AALAS-TR) algorithm. To identify different P depending on the initial clipping ration R.

3. Proposed AALSA-TR Scheme

In this section, we propose an adaptive amplitude least squares approximation algorithm for TR-based OFDM systems. The main objective is to control both the target clipping level A and convergence factor P at each iteration. that is:

$$P = \min_{A, p} \left\{ \sum_{n \in P} |p^{(i)} |c_n^{(i)}| - |f_n^{(i)}|^2 \right\} \quad (7)$$

$$\begin{aligned} \frac{\partial g(p)}{\partial p} &= \frac{\partial \left(\sum_{n \in P} |p^{(i)} |c_n^{(i)}| - |f_n^{(i)}|^2 \right)}{\partial p^{(i)}} \\ &= \frac{\partial \left(\sum_{n \in P} |p^{(i)2} |c_n^{(i)}|^2 + |f_n^{(i)}|^2 - 2p^{(i)} |c_n^{(i)}| |f_n^{(i)}| \right)}{\partial p^{(i)}} \\ &= 2p^{(i)} \sum_{n \in P} |c_n^{(i)}|^2 - 2 \sum_{n \in P} |c_n^{(i)}| |f_n^{(i)}| \end{aligned} \quad (8)$$

Make $\frac{\partial g(p)}{\partial p} = 0$, we have:

$$\hat{p}^{(i)} = \frac{\langle |c_n^{(i)}| |f_n^{(i)}| \rangle}{\sum_{n \in P} |c_n^{(i)}|^2} \quad (9)$$

Where $\langle \dots \rangle$ represents the real inner-product. This implies that the calculation of P involves real domain, rather than complex domain. From the above we can know, $|x(n) + \hat{p}c(n)|$ approximates to $|x(n) + f(n)|$. For the complexity comparison, in the CC-TR method need two FFT/IFFT operations during every iteration. Thus, CC-TR method complexity is $2 \times (T \times \Theta(LN \log_2 LN) + \Theta(2K+1))$, the LSA-TR method just need few iterations which we set T can achieve the same PAPR reduction. In [13], We LSA-TR method compute complexity is obtained $2 \times I \times \Theta(LN \log_2 LN)$. The AALSA-TR algorithm is modified in the iteration process step size and the threshold value A, so the computational complexity of the algorithm is the same with LSA-TR.

4. Simulation Results

To show the advantage of the novel ALSA-TR algorithm, computer simulations are performed in China Mobile Multimedia Broadcasting (CMMB) system. In this simulation, 4096

subcarriers are performed for FFT/IFFT operation. This distribution means that all data subcarriers are symmetric about the central frequency and the reserved tones is randomly generated. Quadrature Phase Shift Keying (QPSK) is used for the simulation system. The PAPR reduction performance is evaluated by the PAPR CCDF function. 4 time oversampling is used in all simulations.

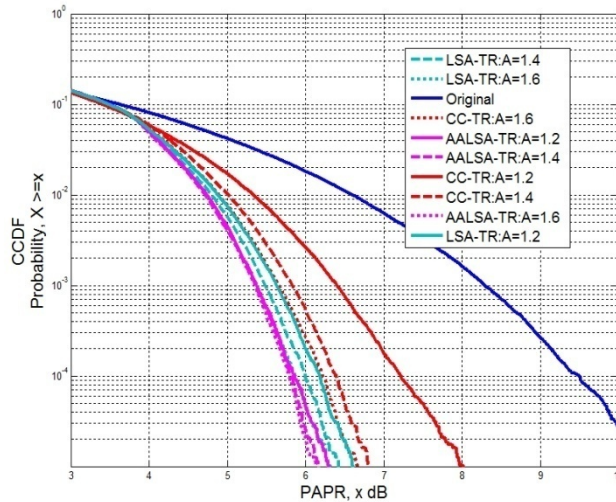


Figure 1. Comparison of PAPR Reduction between AALSA-TR, LSA-TR and CC-TR with Different Clipping Threshold

In Figure 1 , we compare the PAPR reduction performance of the CC-TR, LSA-TR method with our AALSA-TR method, the maximum number of iterations is 10, and the clipping threshold $A=1.2, 1.4, 1.6$. When $CCDF=10^{-5}$, when $A=1.2$, AALSA-TR method have 0.5dB PAPR reduction with LSA-TR. As $A=1.6$, have 0.3dB gains. Obviously, the LSA-TR algorithm in different clipping threshold have different PAPR reduction performance. Contrary to our new method, can be in different clipping threshold, CCDF curves was better, and no increase in computational complexity.

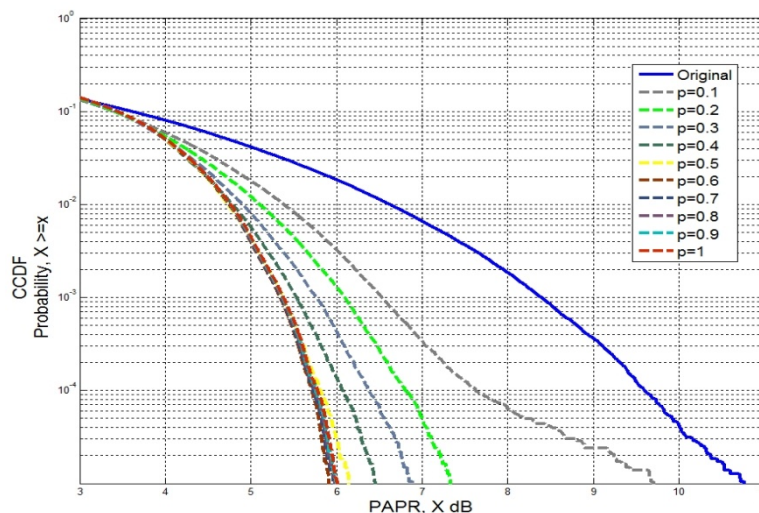


Figure 2. Comparison of PAPR Reduction with Different Step Size p

In Figure 2, the proposed AALSA-TR scheme reduction PAPR performance with different step size, We chose step size respectively from 0.1 to 1 range. When $p=0.1,0.2,0.3,0.4$, the PAPR are 9.8dB to 6.5dB. For the other choices on p the different of the PAPR are very small and that is about 6dB. Moreover, that is the smaller p can not effectively adjust the clipping level A , and choose a bigger step size p to gain better PAPR performance for the AALSA-TR algorithm.

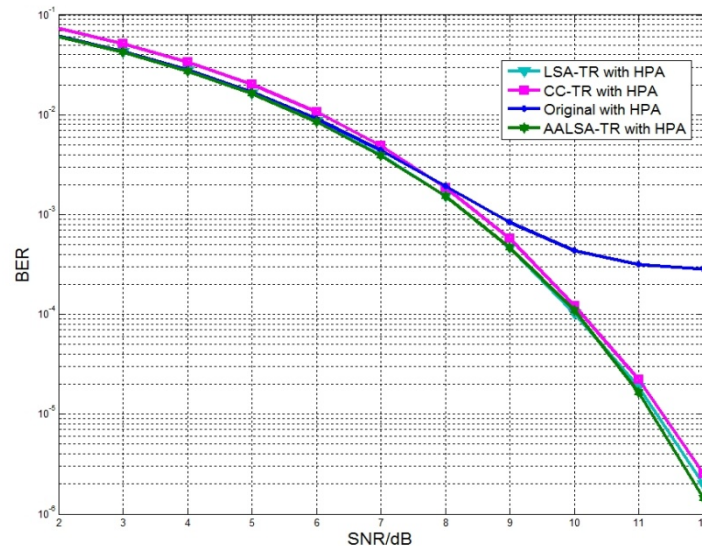


Figure 3. BER Performance of OFDM System over AWGN with CC-TR, LSA-TR, AALSA-TR Method

In Figure 3, the bit-error-rate (BER) performance evaluate with CC-TR, LSA-TR, AALSA-TR method, we consider additive white Gaussian noise (AWGN) with high power amplify (HPA). The input backoff (IBO) is set to be 5 dB. The number of iterations is 15. The proposed AALSA-TR scheme can offer better BER performance compare with original method. Moreover, the AALSA-TR scheme can offer nearly the same BER performance with CC-TR scheme and LSA-TR method. When the $BER=10^{-6}$, the SNR can get 0.2dB gains the AALSA-TR scheme compare with LSA-TR scheme.

5. Conclusion

In this paper, the tone reservation scheme for PAPR reduction is investigated in this paper. With the introduction of the adaptive amplitude least squares approximation (AALSA-TR) algorithm. The Proposed AALSA-TR scheme makes the amplitude of the generated new peak-canceling signals approximate to that of the original clipping noise. simultaneously, the AALSA-TR scheme can have a better PAPR gains compare with LSA-TR scheme. AALSA-TR method in different clipping threshold have an approximately PAPR reduction performance. Simulated results are shown that require a large step size to get the steady CCDF curve. Through the OFDM system, the AALSA-TR scheme can offer nearly the same BER performance with LSA-TR scheme in the same computational complexity.

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