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An Improved Adaptive Iteration Clipping and Tone-Reservation PAPR Reduction with Fast Convergence OFDM

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Abstract: Orthogonal frequency division multiplexing (OFDM) has been a crucial problem a high peak to average power ratio (PAPR). In all PAPR reduction scheme, 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, much iteration is need which have a high computer complexity. In this letter, A novel effective tone reservation method is proposed to reduce the PAPR, which based on the fast convergence adaptive least squares approximation (FCALSA-TR) algorithm can get the optimal peak-canceling signals with less iterations, Simulation results show that the proposed algorithm can achieve almost the same PAPR reduction as that of the clipping control method and just need few iterations.

Keywords: Clipping control, Least squares approximation, OFDM, Peak-to-average power ratio (PAPR), Tone reservation, Fast convergence.

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], compounding 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 much iteration to reduction PAPR. In [12], use a optimal convergence factor scale the filtered first-iteration clipping noise to compensate for peaks that are above the threshold and can achieve a lager PAPR reduction, but also need high iteration complexity In [13], based on the adaptive least squares approximation with fast convergence reduction PAPR, only need a few iterations can achieve the same performance and reduced computational complexity. The ALSA-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. The fast convergence factor β can improve the efficiency of iterative.

In this letter, an improved TR method based on the fast convergence adaptive least squares approximation (ALSA) algorithm, called as the FCALSA-TR scheme. With LSA we could obtain good PAPR reductions with low complexity. Fast convergence factor β can get a better iteration step which has optimal iterative efficiency.

The paper is organized as follows. In Section II , the system model based on the TR method and the adaptive least squares approximation(ALAS-TR) algorithm is introduced III, proposes the novel scheme the fast convergence least squares approximation (FCALAS-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 System and ALSA-TR Scheme

2.1. 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:

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

where N is the subcarrier number of an OFDM system, Xk is the modulated data carried by the k^{th} subcarrier, is the nth sample of a time-domain symbol. The PAPR of x is defined as the ratio of the maximal instantaneous power to the average power, that is:

$$R_{PAPR}(x_n) = \frac{\max\limits_{0 \le n \le LN-1} |x_n|^2}{E[|x_n|^2]} , \quad (2)$$

where L is the oversampling factor. This factor must be large enough (L≥4) to process all the continuous-time peaks and thus to better approximate the analog PAPR of the OFDM signal [13].

The complementary cumulative distribution function (CCDF) is evaluated the PAPR reduction performance, representing the probability that the PAPR of an OFDM symbol exceeds the given threshold PAPR, which is denoted as γ.

$$P_{CCDF} = pr[R_{PAPR}(x_n) > \gamma] , \quad (3)$$

2.2. ALSA-TR Scheme

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

$$P = \min_{p,A} \{ \sum_{n \in \mathrm{P}} [p|c_n| - |f(n)|]^2 \} , \quad (4)$$

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

$$g(p) = \sum_{n \in \mathrm{P}} [p|c_n| - |f_n|]^2 , \quad (5)$$

Than

$$\begin{aligned} \frac{\partial g(p)}{\partial p} &= \frac{\partial \left(\sum_{n \in \mathrm{P}} [p|c_n| - |f_n|]^2 \right)}{\partial p} \\ &= \frac{\partial \left(\sum_{n \in \mathrm{P}} [p^2 |c_n|^2 + |f_n|^2 - 2p|c_n||f_n|] \right)}{\partial p} , \\ &= 2p \sum_{n \in \mathrm{P}} |c_n|^2 - 2 \sum_{n \in \mathrm{P}} |c_n||f_n| \end{aligned} \quad (6)$$

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

$$p = \frac{\sum_{n \in \mathrm{P}} |c_n||f_n|}{\sum_{n \in \mathrm{P}} |c_n|^2} , \quad (7)$$

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 fast convergence adaptive least squares approximation (FCALAS-TR) algorithm. To identify different P depending on the initial clipping ration R. Join the Fast convergence factor in each iteration

3. Proposed FCALSA-TR Scheme

From the second part, good PAPR need many iterations when the amplitude of the peak-canceling signal is made to approximate the amplitude of the clipping noise. From [14], optimal convergence factor *β* define:

$$\beta \triangleq \frac{\textit{total filtered clipping noise after K iteration}}{\textit{filtered clipping noise generated in the first iteration}} , \quad (8)$$

when need a quick iterations to reduce the PAPR, we propose an adaptive iterations tone-reservation algorithm instead of using optimal convergence factor such that fast convergence. Thus, the optimization problem is

$$P' = \min\{\sum_{n\in P}[p|c_n| - \beta|f(n)|]^2\}, \qquad (9)$$

we define

$$g(p) = \sum_{n\in P}[p|c_n| - \beta|f(n)|]^2, \qquad (10)$$

Than

$$\frac{\partial g(p)}{\partial p} = \frac{\partial\left(\sum_{n\in P}[p|c_n| - \beta|f_n|]^2\right)}{\partial p} = \frac{\partial\left(\sum_{n\in P}[p^2|c_n|^2 + \beta^2|f_n|^2 - 2p\beta|c_n||f_n|]\right)}{\partial p} = 2p\sum_{n\in P}|c_n|^2 - 2\beta\sum_{n\in P}|c_n||f_n| \qquad (11)$$

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

$$p = \frac{\beta\sum_{n\in P}|c_n||f_n|}{\sum_{n\in P}|c_n|^2}, \qquad (12)$$

We could conclude that the amplitude of the new iterative convergence signal, which the distance between $p|c|$ and $\beta|f|$ is the smallest, after a few iterations is the best square approximation of peak-canceling.

$$2\times(T\times\Theta(LN\log_2 LN) + \Theta(2K+1))$$

Therefore, $|x(n)+\beta f(n)|$ approximates to $|x(n)+pc(n)$, and the good PAPR reduction could be achieved after the first servers iterations.

4. Simulation Result

To show the advantage of the novel FCALSA-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 tone 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.

In Fig. 1, the proposed FCALSA-TR scheme reduction PAPR performance. FCALSA-TR need only 4 iterations to obtain about 5 dB PAPR reduction when CCDF=10-5. Moreover, after 4 iterations, the PAPR reduction during each iteration is very small. That is the ALSA-TR method just need a litter iterations can achieve the effect of CC-TR method. And less iterations means the computational complexity reduction.

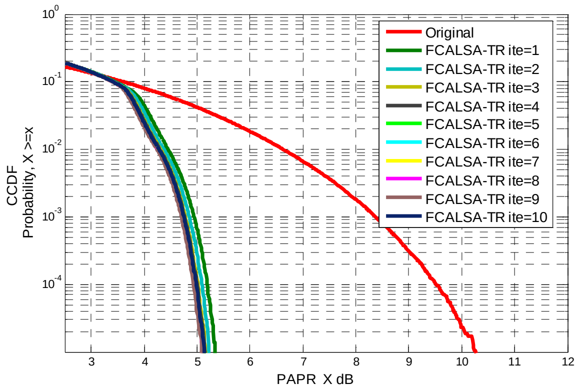

Fig. 1. FCALSA-TR method reduction performance with PAPR.

In Fig. 2, we compare the PAPR reduction performance of the CC-TR, ALSA-TR method with our FCALSA-TR method, the maximum number of iterations is 3, and the clipping threshold A=1.1, 1.3, 1.5. When CCDF=10-5, when A=1.1, FCALSA-TR method have 0.2 dB PAPR reduction with ALSA-TR. Obviously, the ALSA-TR algorithm is 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.

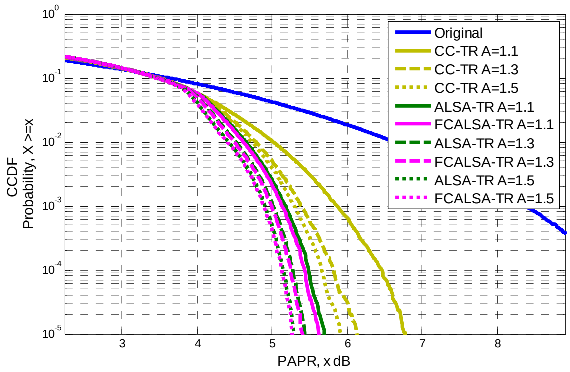

Fig. 2. Comparison of PAPR reduction between FCALSA-TR, ALSA-TR and CC-TR with different clipping threshold.

In Fig. 3, the bit-error-rate (BER) performance evaluate with CC-TR, ALSA-TR, FCALSA-TR method, we consider additive white Gaussian noise (AWGN) with high power amplify (HPA). The input back off (IBO) is set to be 5 dB. The number of iterations is 15. The proposed FCALSA-TR scheme can offer better BER performance compare with original method. Moreover, the FCALSA-TR scheme can offer nearly the same BER performance with CC-TR scheme and ALSA-TR method. When the BER=10^{-6}, the SNR can get 0.3 dB gains the FCALSA-TR scheme compare with ALSA-TR scheme.

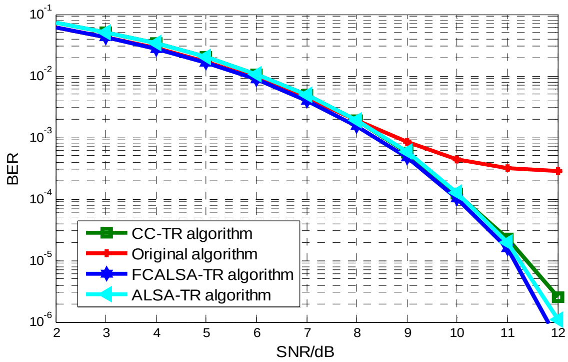

Fig. 3. BER performance of OFDM system over AWGN with CC-TR, ALSA-TR, FCALSA-TR method.

5. Conclusions

In this paper, the tone reservation scheme for PAPR reduction is investigated in this paper. With the introduction of the adaptive fast convergence least squares approximation (FCALSA-TR) algorithm. The proposed FCALSA-TR scheme makes the amplitude of the generated new peak-canceling signals approximate to that of the original clipping noise. Simultaneously, the FCALSA-TR scheme can have a better PAPR gains compare with ALSA-TR scheme. FCALSA-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 FCALSA-TR scheme can offer nearly the same BER performance with ALSA-TR scheme in the same computational complexity.

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