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The New Adaptive Active Constellation Extension Algorithm For PAR Minimization in OFDM Systems

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ABSTRACT
In this paper, the Peak-to-Average Ratio reduction in OFDM systems is implemented by the Adaptive Active Constellation Extension (ACE) technique which is more simple and attractive for practical downlink implementation purpose. However, in normal constellation method we cannot achieve the minimum PAR if the target clipping level is much below than the initial optimum value. To get the better of this problem, we proposed Active Constellation Algorithm with adaptive clipping control mechanism to get minimum PAR. Simulation results exhibits that the proposed algorithm reaches the minimum PAR for most severely low clipping signals to get minimum PAR.

I. INTRODUCTION

OFDM is a well known method for transmitting high data rate signals in the frequency selective channels. In OFDM system, a wide frequency selective channel is sub divided in several narrow band frequency nonselective channels and the equalization becomes much simpler [1]. However, one of the major drawbacks of multitone transmission systems, such as OFDM systems has higher PAR compared to that of single carrier transmission system.

To solve this problem, many algorithms have been proposed. In some of the algorithms, modifications are applied at the transmitter to reduce the PAR. In some of the algorithms like Partial Transmit Sequence and selective mapping (SLM) the receiver requires the Side Information (SI) to receive data without any performance degradation. In some other methods the receiver can receive the data without SI; example is clipping and filtering, tone reservation [2] and ACE [3]. In the ACE method, the constellation points are moved such that the PAR is reduced, but the minimum distance between the constellation points remains the same. Thus the BER at the receiver does not increase, but a slight increase in the total average power. To find the proper movement constellation points, an iterative Projection onto Convex Set (POCS) method has been proposed [3] for OFDM systems.

Among various peak-to-average (PAR) reduction methods, the active constellation extension (ACE) technique is more attractive for down-link purpose. The reason is that ACE allow the reduction of high-peak signals by extending some of the modulation constellation points towards the outside of the constellation without any loss in data rate. This favour, however, comes at the cost of slight power penalty. For practical implementation, low complexity ACE algorithms based on clipping were proposed in [3-4]. The elementary principle of clipping based ACE (CB-ACE) involves the switching between the time domain and switching domain [5]. Clipping in the time domain, filtering and employing the ACE constraint in the frequency domain, both require iterative process to control the subsequent regrowth of the peak power. This CB- ACE algorithm provides a suboptimal solution for the given clipping ratio, since the clipping ratio is predetermined at the initial stages. Even this method has the low clipping ratio problem in that it cannot achieve the minimum PAR when the clipping level is set below an unknown optimum level at the initial stages, because many factors, such as the initial PAR and signal constellation, have an impact on the optimal target clipping level determination [3]. To the best of knowledge, a practical CB-ACE algorithm cannot predetermine the optimal target clipping level.

In this method, to solve the low clipping problem, we introduce a new method of ACE for PAR reduction. The approach combines a clipping-based algorithm with an adaptive control, which allows us to find the optimal clipping level. The rest of the paper consist OFDM system with CB-ACE, proposed ACE algorithm. Finally the last section includes the simulation results for M-QAM.

II. PAR PROBLEM WITH CB-ACE

An OFDM, the input bit stream is interleaved and encoded by a channel coder. These coded bits are mapped into complex symbols using QPSK or QAM modulation. The signal consists of the sum of N independent signals modulated in the frequency domain onto sub channels of equal bandwidth. As a continuous-time equivalent signal, the oversampled OFDM signal is expressed as

$$X_n = \frac{1}{JN} \sum_{k=0}^{JN-1} X_k \, e^{j2\pi \frac{k}{JN} n} \quad (1)$$

where n=0,1,2,…….,JN-1, N is the number of subcarriers; X_k are the complex data symbols at kth subcarrier; J is the oversampling factor where J≥8, which is large enough to accurately approximate the peaks [6]. In matrix notation , (1) can be expressed as **x=Q*X**. where Q* is inverse discrete Fourier transform (IDFT) matrix of size JN x JN, ()* denotes the Hermitian conjugate, the complex time- domain signalvector x=$[x_{0,} x_1, x_2 \dots . x_{JN-1]}]^T$, and the complex symbol vector is denoted by 'X' and is given by as X=$[X_{0,} X_1, x_2 \dots . X_{\frac{N}{2}-1}, 0_{1x(j-1)N,} X_{\frac{N}{2}''} X_{\frac{N}{2}+1}, \dots X_{N-1}]^T$.

Here , we do not consider the guard interval, because it does not impact the PAR, which is defined as

$$PAR(x) \triangleq \frac{max_{\, 0 \le n \le JN-1} \; |x_n|^2}{E[\, |x_n|^2]} \quad (2)$$

Note that (2) does not include the power of the anti-peak signal added by the PAR reduction. Let £ be the index set of all data tones. Then '£' is given by

£= $\{\forall k \; s.t. 0 \le k \le N-1\} = \{£_a \cup £_a^c\}$,

where $£_a$ is the index set of active sub channels for reducing PAR. The PAR problem in ACE can be formulated as [5]. And is given as below

$min_c \; \|x + Q^* C\|$.

Subject to: $X_k + C_k$ be feasible for k $£_a$, (3)

C_k=0 , for k € $£_a$.

Where C is the extension vector whose components, $C_{k\,,}$ are non zero only if k ε $£_a$. However , this optimal solution for this ACE formulation of PAR reduction is not appropriate for practical implementation due to high combinational complexity. Then the CB-ACE algorithms are is the solution for this problem [1],[2].

The basic idea of the CB-ACE algorithm is to generate the anti-peak signal for PAR reduction by projecting the clipping in-band noise into the feasible extension area while removing the out-of-band distortion with filtering. Thus, the CB-ACE formulation is considered as a repeated-clipping-and- filtering (RCF) process with ACE constraint as follows;

$$x^{(i+1)} = x^i + \mu c^{\sim(i)} \quad (4)$$

Where µ is a positive real step size that determines the convergence speed, 'i' is the iteration index, the initial signal is $x^{(0)}$, and $c^{\sim(i)}$ is the anti-peak signal at the i^{th} iteration as follows:

$c^{\sim(i)} = \tau^{(i)} c^{(i)}$, where $\tau^{(i)}$ is the transfer matrix of size JN x JN and $\tau^{(i)} = Q^{*(i)} Q^{(i)}$. And $Q^{(i)}$ is determined by the ACE constraint that $X_k^{(i)} + C_k^{(i)}$ is feasible for k ϵ $£_a$. Here, $c^{(i)}$ is the peak signal above the predetermined clipping level A and $c_n^{(i)} = [c_0^{(i)}, c_1^{(i)}, c_2^{(i)}, \dots \dots c_{(JN-1)}^{(i)}]^T$, where $c_n^{(i)}$ is the clipping sample , which can be given as below.

$$c_n^{(i)} = (\,|x_n^{(i)}| - A) e^{j\theta_n} \quad \text{if } |x_n^{(i)}| > A$$
$$c_n^{(i)} = 0 \quad \text{if } |x_n^{(i)}| \le A \quad (5)$$

Where $\theta_n = \arg(-x_n^{(i)})$.

The clipping level A is related to the clipping ratio $'\gamma'$ and is given as

$$\gamma = \frac{A^2}{E\{\, |x_n|^2\}} \, .$$

In general we expect more PAR reduction gain a lower target clipping level. But this is not achieve the minimum PAR for low target clipping ratos, because the reduced power by low clipping decreases the PAR reduction gain in ACE. The original symbol constellations move toward the origin with the decreasing clip[ping ratio in [6], which places the clipped signal constellations outside the feasible extension region. The number of $£_a$,corresponding to the number of reserved tones in tone reservation (TR), as in [7],decreases with low clipping ratio, which in turn degrades the PAR reduction capacity in ACE.

III SUGGESTED ALGORITHM

The main objective of our proposed algorithm is to control both the clipping level and convergence factor at each iteration and to iteratively minimize the peak power signal greater than the target clipping level. The cost function is defined as

$$\xi(I^{(i)}) \triangleq \min_{\mu, A} \|\mathbf{x}^{(i)} + \mu \tilde{\mathbf{c}}^{(i)} - A e^{j\Phi^{(i)}}\|_2^2 \quad 6)$$

. where Φ(*i*) is the phase vector of **x**(*i*)+*µ*~**c**(*i*) at the *i th* iteration and *I*(*i*) represents the set of time indices at the *i*th iteration.

Now, we summarize the proposed algorithm.

Step 0: Initialize the parameters

. Select the target clipping level *A*.

. Set up the maximum number of iterations *L*.

Step 1: Set *i* = 0, **x** = **x** and (0) = *A*.

Step 2: Compute the clipping signal in (5);

if there is no clipping signal, transmit signal, $x^{(i)}$.

Step 3: transfer the clipping signal into the anti-peak signal subject to ACE constaint;

- convert $c^{(i)}$ into $C^{(i)}$.
- Project C^i onto the feasible region in ACE and remove the out-of-band of C^i .
- obtain $c^{\sim(i)}$ by taking the IDFT

Step 4: update $x^{(i)}$ in (4) and A minimizing (6).

. comp-ute the optimal step size μ,

$$\mu = \frac{\Re[\langle \mathbf{c}^{(i)}, \bar{\mathbf{c}}^{(i)} \rangle]}{\langle \bar{\mathbf{c}}^{(i)}, \bar{\mathbf{c}}^{(i)} \rangle}, \qquad (7)$$

where $\mathfrak{R}$ defines the real part and $<,>$ is the complex inner-product.

. adjust the clipping level A

$$A^{(i+1)} = A^{(i)} + \nu \nabla_A \qquad (8)$$

Where the gradient with respect to A is

$$\nabla_A = \frac{\sum_{n \in I_1^{(i)} \cup I_3^{(i)}} |c_n^{(i+1)}|^1}{N_p} \qquad (9)$$

And ν is the step size with $0 \leq \nu \leq 1$ and N_p is the number of peak samples larger than A.

Step 5: increase the iteration counter, i=i+1 . if i<L, go to step 2 and repeat; otherwise transmit signal, $x^{(i)}$.

Compared to the existing CB-ACE with complexity of order φ(JN x JN), the complexity of our proposed algorithm slightly increases whenever the adaptive control is calculated in (8). However, this additional complexity of the adaptive control is negligible compared to that of order φ(JN x JN)

IV SIMULATION RESULTS

In this section, we illustrate the performance of our proposed algorithm using computer simulations. In the simulations, we use an OFDM system with 2048 sub carriers and M-QAM constellation on each subcarrier. To approximate the continuous-time peak signal of an OFDM signal, the oversampling rate factor J = 8 is used in (1).

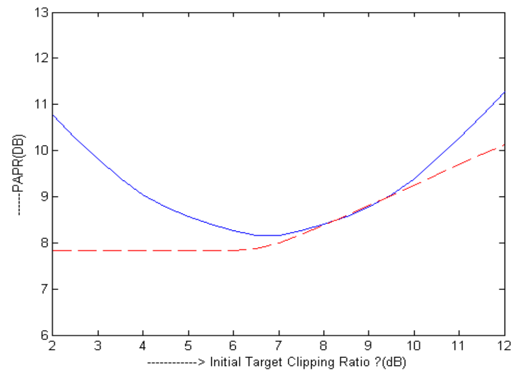

Figure1. The achievable PAR of CB-ACE and the proposed algorithm for an OFDM signal with a 12dB PAR, for different target clipping levels.

Fig. 1 compares the achievable PAR of CB-ACE with the optimal adaptive scaling with that of our proposed algorithm for an OFDM signal with an initial 11.7 db PAR and 16-QAM modulation, for different target clipping ratios from 0dB to 12dB. In the case when CB-ACE is applied, we find the minimum achievable PAR, 7.72Db, is obtained with a target clipping ratio of 6dB, which shows that CB-ACE depends on the target clipping ratio, as we mentioned in the previous section. The PAR reduction gain becomes smaller with a decreasing target clipping ratio from the optimal value of 6dB. Thus, we must carefully select the target clipping ratio for CB-ACE. On the other hand, we observe that our proposed algorithm can achieve the lower minimum PAR even when the initial target clipping ratio is set below the CB-ACE optimal value of 6.4dB, It is obvious that our proposed algorithm solves the low target clipping ratio problem associa`ted with the CB-ACE, as shown in Fig.1.

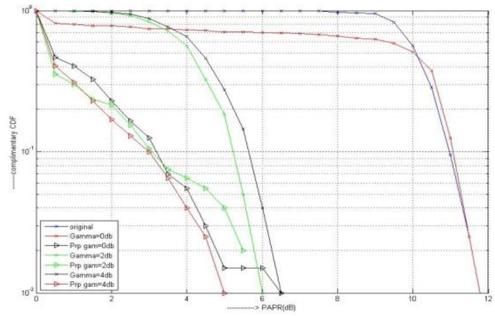

Figure2. PAR CCDF comparison of the CB-ACE and proposed method for different initial target clipping ratios:γ =0dB, 2dB, and 4dB, L=10.

Fig,2 considers two algorithms: CB-ACE and our proposed method for three different initial target clipping ratios, =0dB, 2dB, and 4db, in terms of their complementary cumulative density function (CCDF). The solid line curve at the right is plotted for the original OFDM signal. The marked lines correspond to the PAR reduced signals of CB-ACE and our proposed method after 10-iterations, which we have confirmed is sufficient for convergence. For a 10 CCDF, CB-ACE with initial target clipping ratios of =0dB, 2dB, and 4dB can be achieve a 0.14dB,0.89dB, and 2.95dB PAR reduction from the original PAR of 11.7dB,respectively. In other words, when the target clipping ratio is set low, the achievable gain in PAR reduction decreases, which is opposite to out general expectation, but is consistent with the trend shown in Fig.1.On other hand, our proposed algorithm shows about a 4dB reduction gain in PAR a t10^{-3} CCDF for all three of the initial low target clipping ratios.

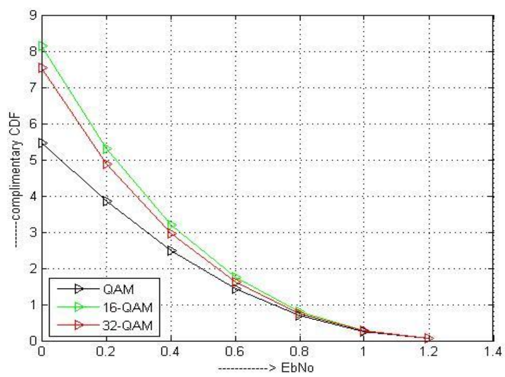

Fig.3.PAR for CCDF 10^{-3} vs loss in $\frac{E_b}{N_0}$ at the BER

of 10^{-3} for different QAM constellation orders of the suggested algorithm

Fig.3 plots the performance of our proposed algorithm considering both PAR and loss in $\frac{E_b}{N_0}$ over an AWGN channel for the different M-QAM symbols. The x-axis indicates the loss in $\frac{E_b}{N_0}$ with respect to $\frac{E_b}{N_0}$ of the original OFDM signal for a given target BER of 10^{-3} , and y-axis shows the required PAR at a CCDF of 10^{-3}. The tradeoff curves for M-QAM symbols is plotted as a function of the target clipping ratio γ , ranging from 10 dB to 0 dBin increments of -1 dB. The curve with triangles down is for QAM , the curve with triangles up is for 16-QAM, and the one with squares is for 64-QAM. For a clipping ratio of 10 dB, the three curves meet eachother at a PAR of 10dB. As the clipping ratio decreases,t he symbols move toward the bottom right direction; the achievable PARs for different constellation sizes are moving to the rminimum points with a decreasing clipping ratio. Our proposed algorithm reaches the minimum PARs :5.55dB, 6.42dB, and 7.07dB for QAM, 16-QAM ,and 64-QAM, respectively. These differen tminimum PARs come from thei nherent ACE constraint that the highe rthe order of the constellation, the less lexibility [1]. However, we observe that the loss in $\frac{E_b}{N_0}$ for each different constellation is about 1.06 dB, even though the achievable minimum PAR depends on the constellation size. It is clear that our proposed algorithm provides the tradeoff curve between PARs and the loss in $\frac{E_b}{N_0}$ for the M-QAM constellations as a function of the target clipping ratio.

V CONCLUSION

In this paper, we proposed a new CB-ACE algorithm for PAR reduction using adaptive clipping control. We observed that the existing CB-ACE depends on initial target clipping ratio. The lower the initial target clipping ratio is from the optimal clipping value, the smaller the PAR reduction gain. However, our proposed algorithm provided the minimum PAR even when the initial target clipping ratio was set below the unknown optimum clipping point.

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