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PAPR Reduction in Multi-Tone Modulated OFDM using Constellation Diagram Improvement

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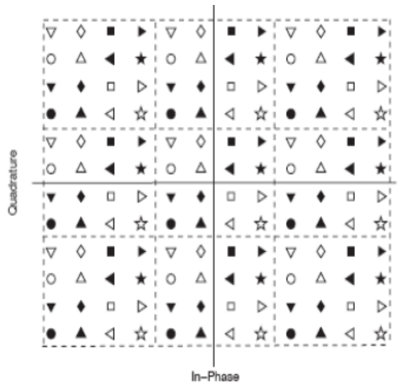
Abstract:- Orthogonal Frequency Division Multiplexing (OFDM) is a very powerful system but having a drawback of peak to average power ration (PAPR), which leads to a significant reduction in performance and power efficiency. The method of PAPR reduction is explained here with the help of clipping projection. Constellation cycle improvement is a PAPR reduction technique that cyclically extends QAM constellations to allow an alternative encoding with lower PAPR at the transmitter. The method consists of introducing a cycles with proper frequency and phase in the symbol that corresponds to replacing original constellation points with one of these equivalent points. OFDM with reduce PAPR is a demand of new working systems which is fulfilled by fast growing clipping projection with constellation cycle improvement. This method is most suitable for multicarrier communication.

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has been widely popular among various wire line and wireless applications. The main advantage of OFDM systems over single-carrier modulation is that they enable high-rate data transmission and combat multipath fading by a simple equalization scheme at the receiver. However, the approximately Gaussian-distributed output samples lead to a high peak-to-average power ratio (PAPR) of the transmit signal, which becomes the major drawback of OFDM systems. The large dynamic range of the OFDM signal requires an expensive high-power amplifier (HPA) with substantial back-off to avoid the nonlinear distortion caused by clipping, which results in poor power efficiency. One class of PAPR reduction techniques called nonobjective constellations introduces new constellations so that each symbol can be mapped to a set of constellation points to tackle large peaks. Cycle improvement (CI) uses a cyclically extended QAM constellation, allowing an alternative encoding with a lower PAPR. In this paper, we introduce a computationally very efficient, suboptimal algorithm that extends the TI technique to the complex-baseband case by using fast growing clipping, for which it is possible to reach very low PAPR levels, converging to the same PAPR as single-carrier modulation for large constellations, particularly. For 64-channel 16-QAM OFDM, a PAPR reduction of up to 5.1 dB at a 10−5 symbol-clip probability is obtained for the approximated analog signal. The results are very promising for commercial use in wireless OFDM systems

II. CONSTELLATION CYCLE IMPROVEMENT (CI)

The main idea behind CI is to extend the original QAM constellation cyclically so that the same information can be carried by several equivalent points from the cyclically extended constellation. The method consists of introducing a cycles with proper frequency and phase in the symbol that corresponds to replacing original constellation points with one of these equivalent points. Hence, these extra degrees of freedom can be used to generate OFDM symbols with low PAPR.



. Fig1. The cyclically extended 16-QAM constellations diagram. Any of the nine replications denoted by given symbol can be used for PAPR reduction

The extended constellation for 16-QAM, where the original constellation is duplicated cyclically onto its surrounding region in the complex plane. The resulting constellation includes nine 16-QAM sub constellations in which the equivalent points are spaced by the extension-size *D* along the real and/or imaginary axes. Thus, the same information can be carried by one of nine equivalent values to obtain time signals with lower PAPR. The use of a larger constellation increases the transmitted power. However, very large peaks occur Occasionally enough that these tone modifications will not have a significant effect on the overall average power. For an OFDM system, the effect of using a larger constellation is to add co sinusoidal and/or sinusoidal signals at a certain sub channel's frequency to the transmitted signal to generate a peak-compensation signal. Hence, TI does not reduce data rate as long as the extension-size *D* is known at the receiver.

The modified transmit signal after tone injection is

$$\overline{x}[n] = x[n] + c[n] \quad (1)$$

$$= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} (X_k + C_k) e^{j2\pi kn/N} \quad (2)$$

where the extension vectors *Ck* are defined precisely as

$$Ck = D(pk + jqk) \quad (3)$$

due to the cyclic extension of the nominal constellation. Since it is sufficient to use the first set of neighboring subconstellations, *pk* and *qk* take values from the set *{*−1, 0, 1*}*, where the horizontal and vertical translations between subconsellations are *D*. However, finding the optimal solution for the values of *pk* and *qk* to obtain the lowest PAPR for *x*[*n*] becomes an integer-programming problem that is known to be an NP-hard problem. Therefore, it is sufficient to reach very good but suboptimal solutions efficiently for a real-time system.

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable

III. CI WITH FAST GROWING CLIPPING PROJECTION

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We describe a new approach to the TI technique for the complex-baseband case, which we call CI with fast clipping projection (CI-FCP). The goal is to achieve a very good and fast, suboptimal solution for finding preferred sub channels and extension vectors for tone injection. The new approach is an iterative quantized-gradient method with fast convergence toward a low-PAPR solution. CI-FCP is formulated as an approximate gradient-project method by considering the clipped-off portion of a time signal to be the gradient descent direction, maximally reducing the peak magnitude and projecting it onto the allowable extension vectors to obtain the low-PAPR complex-baseband time signal. A clipped signal *x*clip[*n*] is defined alternatively as-

$$x_{clip}[n] = x[n] + c_{clip}[n] \quad (4)$$

where $c_{clip}[n]$ denotes the clipped-off portion of the signal. Hence, this formulation can be assumed as an approximate gradient-descent algorithm [5] where *c*clip[*n*] is chosen as the gradient-descent direction with the gradient step size $\mu = 1$. In the frequency domain, *C*clip[*k*] is projected onto the extension vectors to determine *Ck* in (2) to obtain the peak reduction signal *c*[*n*].

The iterative signal update can be written as

$$xi+1[n] = xi[n] + c[n] \quad (5)$$

To determine the exact extension direction, *C*clip[*k*] is projected onto the allowable extension vectors, and the extension vector *Ck* is chosen to be the projection with the largest magnitude. This procedure can be regarded as quantized clipping where *C*clip[*k*] is quantized into the nearest extension vector located in the same quarter-plane. Therefore, the TI-ACP algorithm approximates an iterative quantized gradient-descent method, and the possible values of *pk* and *qk* in Equation (3)
are given by

$$pk = \{0, \text{sgn}(\text{Re}(C\text{clip}[k]))\} \quad (6)$$

$$qk = \{0, \text{sgn}(\text{Im}(C\text{clip}[k]))\} \quad (7)$$

where sgn denotes the sign-function, and the resulting allowable extension vectors are

$$C_k = \{Dp_k,\ jDq_k,\ D(p_k + jq_k)\} \quad (8)$$

The maximum achievable peak reduction per single-tone Modification can be computed as:

$$|x[n]| - |\overline{x}[n]| \leq |c[n]| \quad (9)$$

$$= \left| \frac{D}{\sqrt{N}} (p_k + jq_k) e^{j2\pi kn/N} \right|$$

$$= \frac{D}{\sqrt{N}} \sqrt{p_k^2 + q_k^2} \quad (10)$$

Thus, choosing |*pk*| = 1 and |*qk*| = 1, we obtain the maximum peak reduction per tone injection for the complex baseband case as

$$\delta_{\max} = \sqrt{2} \frac{D}{\sqrt{N}} \quad (11)$$

For some values of *pk* and *qk*, secondary peaks may grow above the current peak level, resulting in a higher-PAPR signal. However, it can be easily shown that δmax is also the maximum possible growth for a time-sample magnitude after a single-tone injection. At each iteration, it is thus sufficient to consider only the time samples which exceed 2δmax below the largest peak level in magnitude, since only these samples can cause an increase in PAPR. Therefore, we discard the tones that might cause these time samples to increase above the largest-magnitude sample, and choose the sub channel which yields the maximum peak reduction among the other candidates for tone injection.

IV. FAST GROWING CLIPPING PROJECTION (FGCP)

The clip level *A* in (12) plays a key role in finding the preferred subchannels to reach the desired PAPR level. For instance, the extension vectors *Ck* are generally larger than *Cclip*[*k*] in magnitude, which can be considered as a quantization error, making it impossible to achieve the clip-level *A*. In addition, if *A* is chosen to be equal or close to the saturation or clip level of a HPA, secondary peaks may easily grow above this physical level, causing PAPR increase and convergence problems. Instead, choosing a clip level to be aggressively lower than the desired peak level allows secondary peaks to influence the tone injection by tending to penalize their growth, reducing the possibility of time samples of *xi*[*n*] to exceed the target peak level each iteration.

V. Simulation Result

Randomly generated 106 complex-baseband OFDM symbols which were tested for the CI-FCP algorithm with 64 and 128 sub channels employing QSPK, 16-QAM, and 64-QAM. Oversampling prior to CI-FCP is applied to approximate the analog PAPR, and $L = 4$ is found to be a very tight approximation to the analog signal. CI-FCP was applied whenever the PAPR of the symbol block exceeded 7 dB to obtain the PAPR complementary cumulative distribution function (CCDF). The results for oversampling to $L = 4$ followed by CI-FCP processing for $N = 64$ 16-QAM OFDM time-signal are shown in Fig. 2. The projection clip level A was chosen to be 1.1 dB above the average power, and the PAPR reduction reaches 5.13 dB at 10−5 clip probability after 5 tone injections. The average power increase was 0.21 dB over all OFDM blocks including blocks where CI-FCP is not needed. The constellation size does not play a key role in convergence of the CI-FCP algorithm because each point in the constellation is allowed to move along both axes. Fig. 3 shows the PAPR reduction results for OFDM systems using QPSK, 16-QAM and 64-QAM with $N = 128$ sub channels. A clip level $A = 3.0$ dB above the average power was used for QPSK, and $A = 3.5$ dB was used for 64-QAM. At a 10−5 clip probability, each system has approximately the same PAPR after eight iterations. Therefore, an advantage of the CI-FCP method is that it is well-suited for OFDM systems using large constellation sizes. The average power increases for the QPSK, 16-QAM, and 64-QAM results were 0.30 dB, 0.21 dB, and 0.20 dB, respectively.

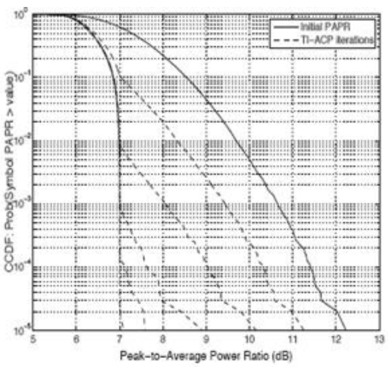

Fig.2. PAPR results of QPSK at L=4 to N=64, 64 QAM OFDM system.

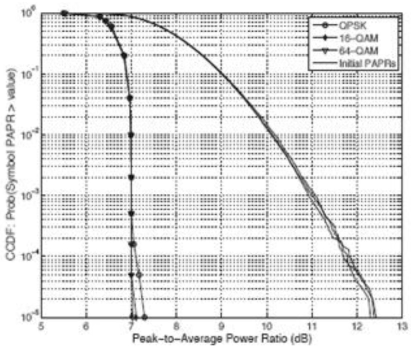

Fig.3. PAPR results of the CI-FCP method applied at L=4 to N=64, 64 QAM OFDM system

VI. Conclusion

The CI-FCP algorithm provides efficient PAPR reduction by introducing clipping-injection method for complex-baseband channels. The clipping injections are obtained by a low-cost computation without repeating IFFT operations. Thus, CI-FCP becomes an outstanding PAPR-reduction method for wireless systems, as sufficient results are achieved after a small number of clipping injections. The proposed CI-FCP makes use of alternate optimization to reduce computational complexity. At the same time, the number of candidate sequences is increased which improves PAPR reduction performance equivalently

A single-carrier system with a raised-root-cosine filter gives approximate analog PAPRs of 3.3 dB, 5.7 dB, and 6.7 dB with oversampling to sizes. CI-FCP thus largely eliminates the PAPR disadvantage of OFDM compared to single-carrier modulation while preserving the benefits of OFDM. $L = 8$ for QPSK, 16 QAM, and 64 QAM, respectively. At a clip probability of 10−5, the approximate analog PAPRs achieved by $L = 4$ CI-FCP processing are 7.29 dB, 7.11 dB, and 7.02 dB for the same constellations, respectively, which shows that the gap between single-carrier and OFDM is significantly reduced by CI-FCP, particularly for larger constellation.

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