An Optimized Clipping Technique for PAPR Mitigation in OFDM Systems

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Abstract: For Wireless broadband communications, Orthogonal Frequency Division Multiplexing (OFDM) is a frequently used method. However, OFDM systems have some disadvantages. The problem of high Peak-to-Average Power Ratio (PAPR) is one of the most serious restrictions. Some linear components, such as power amplifiers have distortions. A variety of methods have been used for the mitigation of PAPR in OFDM Signals. Among these methods, Clipping-based approaches have been developed for effective PAPR decrease and ease of deployment. The PAPR of OFDM Signals is reduced using a uniform distribution approach (UD) proposed in this paper. The proposed approach introduces three distinct approaches, each of which enables PAPR mitigation through Iterative Clipping and Filtering (ICF) without relying on clipping ratio (CR). We discovered that our method minimizes the PAPR of OFDM Signals much better than the traditional clipping and filtering techniques.

Keywords: OFDM, PAPR, UD, Mitigation, ICF.

1 Introduction

OFDM is an effective multicarrier communication technique across fading channels because of the narrow-bandwidths subtended in the frequency domain (FD). This characteristic protects against channel impulse response effects, making OFDM appealing for the effective management of finite radio frequency bandwidths in current communication systems. Using wavelets that can run OFDM in the absence of a cyclic prefix (CP) can improve spectral efficiency even more. Unfortunately, the high PAPR issue prevents it from being widely used in several communication devices. For example, while OFDM is used in mobile communication standards, downlink broadcasts, Due to PAPR constraints, it is not preferred in uplink broadcasts. Power amplifiers run in the saturation area due to the high PAPR, wasting a lot of system power and causing BER loss owing to signal blur.

Several PAPR-reduction strategies, such as multiple signaling, probabilistic techniques, coding techniques and signal distortion techniques, have recently been proposed in the literature. By selecting acceptable codewords, coding algorithms reduce PAPR, however, this often results in coding rate loss. Numerous signaling sequence (PTS) work by producing multiple candidate signals and transmitting the one with the lowest PAPR. They'd result in a lot of computation complexity and a lot of side information communication. Signal distortion techniques like ICF and companding works by lowering the PAPR by altering the transmission signal, which typically results in in-band and out-of-band distortion (IBD & OBD). They are, however, usually simple to execute and do not necessitate the exchange of side information.

The ICF is considered to be the most feasible option because of its low computational complexity, non-expansion of bandwidth and ease in implementation without receiver-side collaboration. After the introduction of the Clipping and Filtering method, many experiments have been conducted to perfect the scheme as an optimal PAPR mitigation technique for OFDM systems. All of these systems, however, are reliant on the specification of a CR.

A new strategy is used in this investigation, which does not require a predetermined CR. The amplitude distribution (AD) of a standard OFDM signal follows the Rayleigh distribution (RD). The high PAPR problem is caused by amplitudes spread above the average, which force the high-power amplifier (HPA) into a saturation state, where it uses a lot of power and blurs the signals, lowering the BER. This approach is founded on the assumption that changing the AD to a UD can result in perfect PAPR reduction. As a result, we devise the procedure for accomplish such distribution by clipping.

We present the chance of tackling the PAPR problem without using thresholds. The PAPR problem can be solved if the peaks of the signal amplitude can be adjusted to approach a UD. Rather than converting PDFs using various compression transforms, we limit this design to the average AD.

We calculated the average amplitude of OFDM signals and then clipped other amplitudes which were above the average amplitude; this is referred to as Approach 1. We discovered that this approach significantly lowered the system's PAPR but because many subcarriers have characteristic amplitudes that are larger than the average amplitude, there was a lot of IBD, which hurt the BER performance. We have developed another way that can improve the BER at the expense of the PAPR because the BER is severely damaged. This was accomplished by increasing the mean amplitude to reduce the amount of clipped signals, hence lowering IBD; we termed this as Approach2.We compared approach 2's PAPR results to the original signal and found that Approach 2 lowered the PAPR of the unclipped OFDM signal.

We can conclude from these two approaches that the PAPR issue can be addressed in two simple phases, yielding Approach 3; 1) Identify the amplitudes distributed below the average and use approach 2 to scale these lower amplitude signals up to equal or greater amplitude than the average amplitude.; 2) find out the amplitudes dispersed above the average and clip those excess amplitudes - this completes the PAPR reduction.

2 System Model

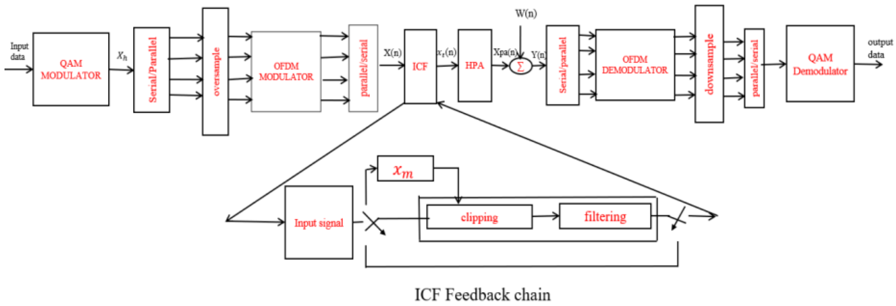

FIGURE 1. OFDM block diagram with ICF Scheme for PAPR Reduction

The data to be communicated in OFDM systems is typically translated to complex symbols using quadrature amplitude modulation (QAM). Without sacrificing generality, the QAM constellations are assumed to be scaled to an average power of 1.

$$E[|M|^2] = 1$$

$$M = [M_0, M_1, M_2, M_3, \dots, M_k, \dots.. M_{N-1}]$$

Oversampling techniques are commonly used in baseband processing to better represent continuous time-domain (TD) signals. The symbol vector can be enlarged by zero padding with D-time oversampling to generate the FD OFDM symbol as follows

$$Y = [M_0, M_1, M_2, M_3, \dots, M_k, \dots.. M_{N-1}, \underbrace{0,0,0, \dots..0}_{(D-1)\,N}]$$

The OFDM symbol can be converted from the FD to the TD using an inverse fast Fourier transform (IFFT).

$$y(n) = \frac{1}{\sqrt{DN}} \sum_{h=0}^{DN-1} Y_h e^{j\frac{2\pi nh}{DN}} \quad (1)$$

Where Y_h is the h^{th} subcarrier of the OFDM symbol. The predicted power of OFDM symbol can be normalized to 1 to simplify the study without losing generality.

$$E[|y|^2] = \left(\frac{1}{\sqrt{DN}}\right)^2 . DN . E[|Y|^2] = \frac{1}{D} E[|M|^2] = \frac{1}{D}$$

By scaling y(n) as, we can acquire the discrete TD OFDM signal p(n) with normalized power.

$$p(n) = \sqrt{D}.\text{y (n)}$$

$$p(n) = \frac{1}{\sqrt{N}} \sum_{h=0}^{DN-1} Y_h e^{j\frac{2\pi nh}{DN}}$$

The extensively used measure PAPR is used to analyze the amplitude envelope characteristic of the signal p(n), which is determined as

$$\text{PAPR} = 10 \log_{10} \frac{\underset{0 \le n \le DN-1}{MAX} (|p(n)|^2)}{Pavg}$$

Where Pavg is average power of the OFDM Symbol.

Since the random variable for OFDM symbols is PAPR, it's typically relevant to look at how frequently it's over a certain level. The complementary cumulative distribution function (CCDF) can be used to study this issue. The PAPR CCDF is defined as

$$\text{CCDF}\ (\varepsilon) = probability(PAPR > PAPR_0)$$

Where $\varepsilon_0$is the reference level.

3 Analysis of Proposed Approach

The AD of an OFDM signal resembles the RD. Because the amplitudes are Rayleigh distributed, the small parts of amplitudes spread above the average amplitude causes a high PAPR problem. Our motive is to transform the AD to a UD through clipping. The traditional ICF system, on the other hand, is typically constrained to a fixed clipping threshold and CR, which restricts the amount of PAPR that may be decreased.

It also needs many numbers of iterations, which can be reduced using an optimized ICF approach that uses convex optimization techniques to establish an ideal frequency response filter for each ICF iteration which consumes system power and increases processing time[1].A way to get around these restrictions by using an adaptive ICAF, scheme which clips the signal with an adjustable clipping threshold in every clipping operation [2].We suggest a technique that doesn't need the CR and threshold constraints in this study since OFDM symbols are not static with fluctuating AD.

Consider the traditional ICF approach, which is typically stated as

$$\hat{y}(n) = \begin{cases} T\exp(j\ \theta_n),\ |\text{y(n)}| > \text{T} \\ y(n), \qquad |\text{y(n)}| \leq \text{T} \end{cases} \qquad (2)$$

Where T is the required amplitude attained from T=$k_0\sqrt{P_{avg}}$,k_0 is the CR and P_{avg}=$\frac{1}{DN}\sum_{n=0}^{DN-1}|y(n)|^2$,$\theta_n = \arg\{y(n)\}$ is the phase of y(n) and $\hat{y}(n)$ is the output clipped

Signal. From the PDF of OFDM Signal, we emphasize that the clipping PAPR mitigation approach is a PAPR strategy based on amplitude that has no effect on the signal phase. A FD filter is also used to minimize IBD noise caused by excessively clipped signals. Peak regrowth occurs as a result, and the PAPR rises. The clipping is performed repeatedly until the required PAPR is attained to buffer this effect. The authors propose that in the adaptive instance, T should be adjusted in accordance with the amplitude of $\hat{y}(n)$rather than the fixed threshold that enhanced PAPR performance [2]. An OFDM signal frame, on the other hand, is defined by three separate amplitudes [3], namely

$$y_m = \frac{1}{DN}\sum_{n=0}^{DN-1}|y(n)| \qquad (3a)$$

$$y_{min} = \underset{y_{n=0,1,.....DN-1}}{\arg\min}\{|y(n)|\} \qquad (3b)$$

$$y_{max} = \underset{y_{n=0,1,.....DN-1}}{\arg\max}\{|y(n)|\} \qquad (3c)$$

In general, equation (2) can be rewritten as a vector of the form

$$|y(n)| = [|y(n)| < y_m, y_m, |y(n)| > y_m], \forall_n = 0,1, \ldots . DN - 1 \quad (4)$$

If (3a) is described as the average signal power, then (3c) and (3b) are the high and low power signals. Companding, a similar technique to ICF, compresses and expands the amplitude of (3c) and (3b) at the same time to reduce PAPR. One of the most well-known companding examples can be derived from (3), which involves splitting the characteristic amplitudes of (1) into (3a), (3b), and (3c) in order to build an amplitude transforming PDF model that modifies the RD into a near UD. The unsolvable PAPR problem arises from the central peaks of trapezoidal distribution used in that discussion, the obtained distribution is non-uniform. With the usage of the ICF PAPR reduction, these approaches provide some exploitative insights that have yet to be explored.

Approach 1 (Clipping above the Average amplitude)

We will now review the PAPR issue in OFDM systems in order to keep away from signal AD that is not uniform. We clip the amplitudes ($|y(n)| > y_m$)to make these peaks more evenly distributed. Now, we rewrite the ICF solution as

$$\hat{y}(n) = \begin{cases} y_{m'} \exp(j\ \theta_n), & |y(n)| > y_{m'} \\ y(n), & |y(n)| \leq y_{m'} \end{cases} \quad (5)$$

Consider y_{min} in (3b) to evaluate the approach 1. The clipped signal minimizes the energy in the signals rather than minimizing the noise which gives rise to IBD .In contrast, if we Consider y_{max} in 3(c) is so large, that nothing is clipped and smearing at HPA occurs, increases BER and requiring the HPA to dissipate more power. The AD of the clipped signal for a high number of subcarriers N = 1024 with D= 4 is shown as

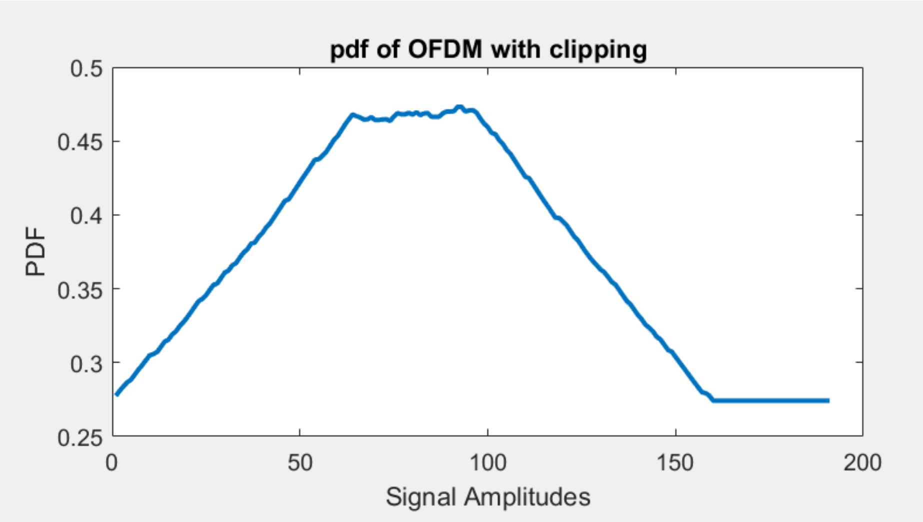

Figure3.PDF Distribution.

From fig.3, the clipped signals have an systematic even distribution, A $(-y_m, y_m)$.As will be seen in the Result Discussion section, this will drastically reduce the PAPR. However, because many of these signals are disfigured, the result is a high level of IBD, which results in poor BER performance. As a result, filtering must be used to improve the system's BER performance by eliminating the in-band distorting components. Approach 1 in this paper refers to the ICF model described above.

Approach 2 (Scaling up the Average amplitude)

Recollect the OFDM signal amplitudes illustrated in (3), then, evaluated (3c) and (3a) as

$$\Delta y = y_{max} - y_m (6)$$

As shown in figure 3, it can be analyzed that Δy is more. One of the technique to reduce(6) is by scaling up (3a) with reference to surplus amplitude in fig(3) as

$$y_{m'} = \sqrt{\frac{DN}{q}} y_m \quad (7)$$

Where q is from $y(q) = |y(n)| > y_m, \forall_n = 1, \dots \dots .., DN \ \forall_q = 1, \dots .., q$

Suppose q is the number of elements in $y(0 \leq q \leq q-1)$.Now registering (7) into (5) substituting for y_m,we demonstrate the new clipping standard as

$$\hat{y}(n) = \begin{cases} y_{m'} \exp(j\theta_n), |y(n)| > y_{m'} \\ y(n), \quad |y(n)| \leq y_{m'} \end{cases}$$

In general, equation (4) can be rewritten as a vector of the form

$$|y(n)| = [|y(n)| < y_m, y_m, |y(n)| > y_m], \forall_n = 0,1, \dots . DN - 1$$

The reason behind the second strategy is that, while the amplitudes are specifically increased, they are not inside the nonlinear zone of the HPA, avoiding nonlinear distortion of the input signal amplitudes, which would results in good BER performance, as shown in the results discussion.

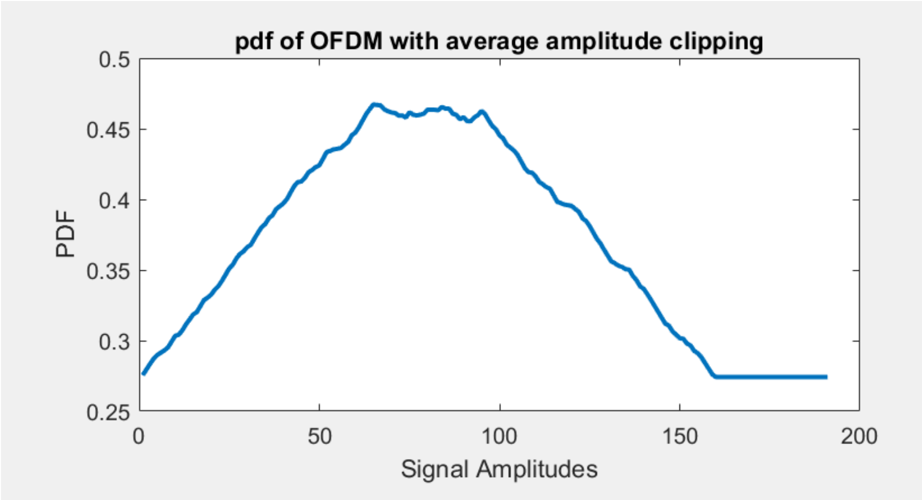

Figure4.PDF Distribution.

The PDFs depicting the AD of the two clipping styles are shown in Fig. 4. The amplitude of an unclipped OFDM signal follows the RD by default, with amplitudes spread above the average this is mainly what causes the high PAPR measure of unprocessed OFDM transmissions. PDFs with a higher concentration of amplitudes around the average have a more UD and achieve the best PAPR results. Approach 1 achieves this property; hence it performs better in terms of PAPR than Approach 2, but have good BER performance.

Approach 3(Proposed Optimized ICF Scheme)

Approach 2 presents two peaks, the smaller of which corresponds to the traditional AD generated by approach 1, and the upper of which corresponds to the peaks acquired by raising the average amplitude by $\sqrt{\frac{DN}{P}}$.As a result, achieving aideal PAPR reduction of 0dBrequires two simple steps: 1) scale up all amplitudes lower than y_m using (7) or compel them to y_m; and 2) clip amplitudes bigger than y using (5).By this the UD and perfect PAPR reduction can be achieved and which was illustrated in the results section.

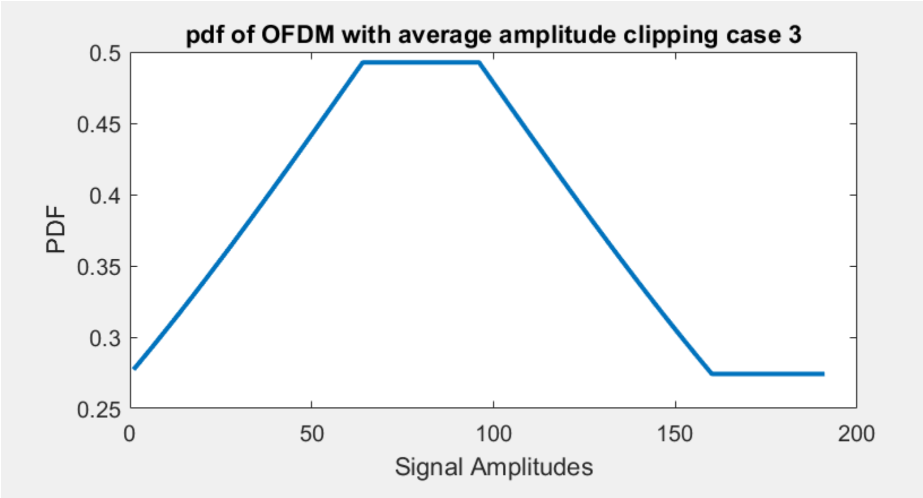

Figure 5.PDF Distribution.

4 Results Discussion

It is unfair to differentiate the proposed systems with ICF model, which aims to achieve a desired PAPR value, because the proposed approach does not require a predetermined CR. At the transmitter, however, we produce N = 128 random data and send it across a QAM modulator, as illustrated in Fig 1. As mentioned in (4a), we estimate the signal's average amplitude here and the signal amplitude above the average is removed using the average amplitude, which improves PAPR performance. We analogize the received signal, transmitted signal to estimate the BER by comparing the received data with the initially transmitted data.

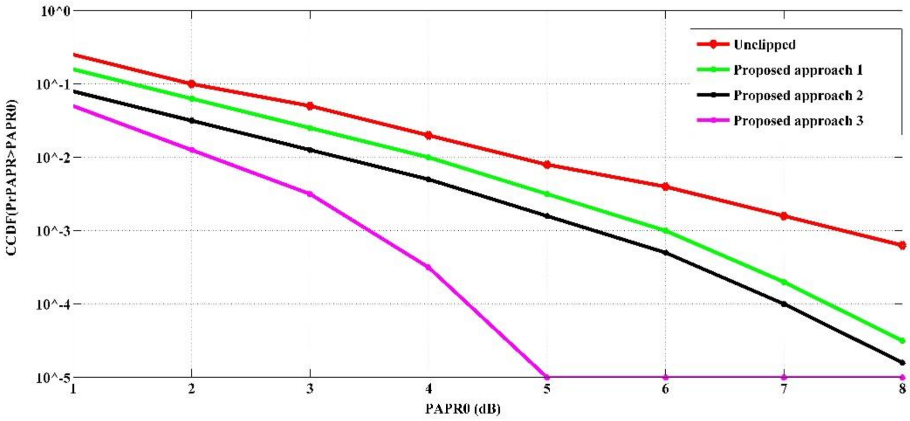

Figure 6. PAPR Comparison

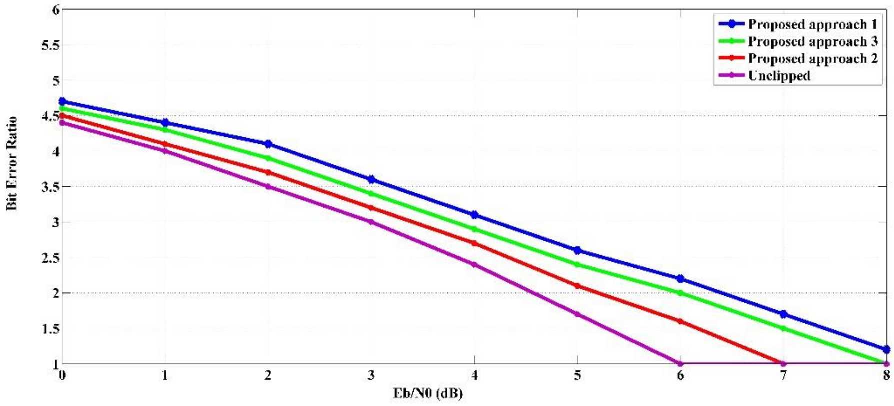

Figure 7.BER Comparison

Here, From fig 6 and fig 7 we have compared the PAPR and BER of OFDM signals which are obtained using the three approaches and the unclipped signal. Finally, from approach 3 the PAPR and BER of OFDM signals was slightly increased.

5 Conclusion

In this research, we describe three innovative clipping and filtering-based approaches for dealing with the PAPR reduction issue in OFDM systems. The proposed solutions are based on converting a standard OFDM system's AD to a UD. We clip excess amplitudes to approximate UD by making use of the average amplitude as a reference amplitude. A second technique, which yields greater BER performance than the first, increases the average with reference to the excess amplitudes. We presented a third strategy that boosts the amplitudes distributed lower than the average before clipping all amplitudes greater than the average to achieve 0dB PAPR by combining the principles from the first two approaches.

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