

# Clipping and Companding Technique for BER and PAPR Reduction in OFDM System

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## Abstract

Peak to Average Power Ratio (PAPR) is one of most detrimental aspects in any wireless communication system using multicarrier modulation technique like OFDM, which cause power degradation and spectral spreading. Due to the simplest way for PAPR reduction, clipping technique has been proposed and seems to be promising for use in commercial system. In this paper, we mainly focus on Amplitude clipping and filtering method. Later in this paper, simulation result shows the PAPR and BER performance with clipping and filtering with different clipping ratios. The BER of the original OFDM signal is approximate  $10^{-3}$  at SNR = 10 dB. With clipping, BER is increased to just higher than  $10^{-2}$  at the SNR = 10 dB and the BER performance improves a little bit with filtering.

## Keywords -

Power Spectral Density (PSD), Orthogonal Frequency Division Multiplexing (OFDM), Complementary Cumulative Distribution Function (CCDF), Probability Density Function (PDF), Peak-to-Average Power Ratio (PAPR).

## I. Introduction

Multi-carrier phenomena is considered to be one of the major developments in wireless communication and among them OFDM is becoming the important standard. Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique with bandwidth-efficient signaling schemes for use in high data rate communication systems. This technique received a lot of attention especially in the field of wireless communication because of its robustness to the multi-path fading and it has already been adopted as the standard transmission technique in the wireless LAN systems and the terrestrial digital broadcasting systems [1].

Since many subcarrier components are added via an IFFT operation the transmit signals in an OFDM system can have high peak values in the time domain. Therefore, OFDM systems are

known to have a high PAPR, compared with a Single-carrier system. The PAPR problem is more important in the uplink since the efficiency of power amplifier is critical due to the limited battery power in a mobile terminal. The main objective of this paper is to find best data compression technique that can reduce PAPR significantly [2,3]. To reduce the PAPR several techniques have been proposed, these techniques achieve PAPR reduction at the expense of transmit signal power increase, data rate loss, bit error rate (BER) increase, computational complexity increase, and so on. A simple PAPR reduction method can be achieved by clipping the time-domain OFDM signal. In this paper we first present PAPR characteristics using CCDF and secondary the BER performance for OFDM.

The remainder of the paper is organized as follows:

In section II, PAPR and BER problem in OFDM. While Reduction techniques are describes in section III, comparative simulation results are presented in section IV. Finally conclusions are given in section V.

## II PAPR and BER problem in OFDM System

The number of bit errors in digital transmission is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors.

Bit error rate BER is a parameter which gives an excellent indication of the performance of wireless channel. When data is transmitted over a channel, there is a possibility of errors being introduced into the system. The integrity of the system may be compromised if errors are introduced into the data. As a result, it is necessary for the performance of the system, bit error rate, BER, provides an ideal way in which this can be achieved [4].

The bit error rate or bit error ratio (BER) is the rate at which errors occur in transmission system. The definition of bit error rate can be translated into a simple formula

$$BER = \frac{\text{Number of errors}}{\text{Total number of bits sent}}$$

Bit Error Rate assesses the full end to end performance of a system including the transmitter, receiver and the channel between the two. Main reason for the degradation of a data transmitted through channel is noise and changes to the propagation path of radio signal. Signal to noise ratios (SNR) is parameter that is more associated with radio links and radio communications systems [5,6]. SNR can also define BER in terms of the probability of error.

### III Reduction Technique

Several techniques have been proposed to reduce PAPR. In this section, we mainly discuss two typical techniques companding and Amplitude clipping and filtering for PAPR reduction in OFDM system. Here, we have to discuss clipping and filtering technique

#### Amplitude Clipping and Filtering Technique

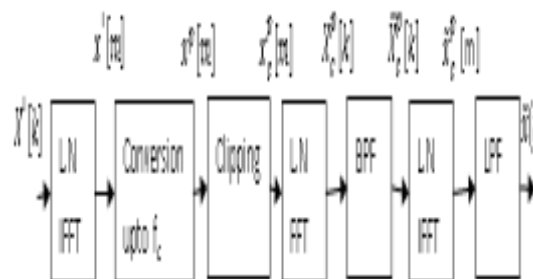
The clipping approach is the simplest PAPR reduction scheme, which limits the maximum of transmit signal to a pre-specified level [7,8]. However, it has the following drawbacks:

1. Clipping causes in-band signal distortion, resulting in BER performance degradation.
2. Clipping also causes out-of-band radiation, which imposes out-of-band interference

signals to adjacent channels. Although the out-of-band signals caused by clipping can be reduced by filtering, it may affect high-frequency components of in-band signal (aliasing) when the clipping is performed with the Nyquist sampling rate in the discrete-time domain. However, if clipping is performed for the sufficiently-oversampled OFDM signals (e.g.,  $L \geq 4$ ) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF), the BER performance will be less degraded [9,10].

3. Filtering the clipped signal can reduce out-of-band radiation at the cost of peak re-growth. The signal after filtering operation may exceed the clipping level specified for the clipping operation [11].

Figure 1 shows a block diagram of a PAPR reduction scheme using clipping and filtering, where  $L$  is the oversampling factor and  $N$  is the number of subcarriers. In this scheme, the oversampled discrete-time signal  $x'$  [m] is generated from IFFT of  $X'$  [k] with  $N(L-1)$  zero-padding in the frequency domain and is then modulated with carrier frequency  $f_c$  to yield a passband signal  $x^p$  [m] [12,13].



**Figure 1:** Generalized block diagram of PAPR reduction using clipping and filtering Technique.

Let  $x_c^p$  [m] denote the clipped version of  $x^p$  [m]

$$x_c^p[m] = \begin{cases} -A & x^p[m] \leq -A \\ x^p[m] & |x^p[m]| < A \\ A & x^p[m] \geq A \end{cases} \quad (1)$$

where,

$x_c^p$  [m] = passband clipped signal

$x^p$  [m] = pass band signal

$A$  = pre-specified clipping level

Or

$$x_c^p[m] = \begin{cases} x^p[m] & \text{if } |x^p[m]| < A \\ \frac{x^p[m]}{|x^p[m]|} \cdot A & \text{otherwise} \end{cases} \quad (2)$$

Here A is the pre-specified clipping level. Note that Equation (2) can be applied to both Baseband complex-valued signals and pass band real-valued signals, while Equation (1) can be applied only to the pass band signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS value  $\sigma$  of OFDM signal[14];

$$CR = \frac{A}{\sigma}$$

It is known that  $\sigma = \sqrt{N}$  and  $\sigma = \sqrt{N/2}$  in the baseband and passband OFDM signals with N subcarriers, respectively. Filtering after clipping is required to reduce out-of-band distortion as shown in figure (3.1). The L times oversampled frequency domain signal  $X_c^p[k]$  is generated from FFT of  $x_c^p[m]$  and then it passes to the BPF to generate  $\tilde{x}_c^p[k]$  signal, again time domain signal is generated with IFFT of the filtered signal  $\tilde{x}_c^p[k]$  [15]. The BER performance will be less degraded, if clipping is performed for the sufficiently-oversampled OFDM signals (e.g.,  $L \geq 4$ ) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF).

#### IV Simulation Result

In general, the performance of PAPR reduction schemes can be evaluated in terms of following three aspects:

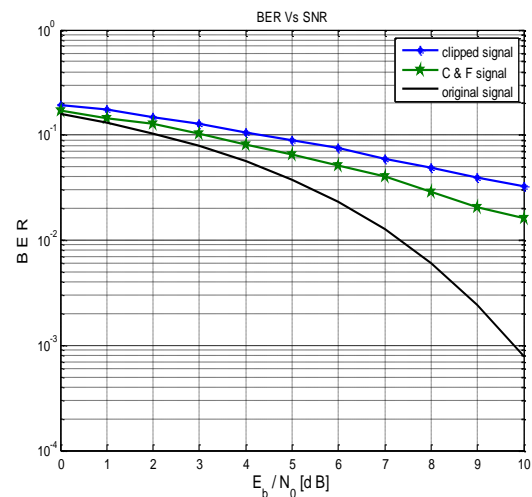
- In-band ripple and out-of-band radiation that can be observed via the power spectral density (PSD).
- Distribution of the crest factor (CF) or PAPR, which is given by the corresponding CCDF.
- Coded and uncoded BER performance.

In this section, we calculate the PAPR reduction in terms of the CCDF of PAPR, BER and PSD with the different clipping ratios.

#### CCDF of PAPR, BER and PSD of ACF Technique with CR = 1

Figure 2 shows the PAPR performance of the clipping and filtering of OFDM signal with clipping ratio (CR) 1. The ‘‘C & F’’ in all figures stands for clipping and filtering. It has been observed from the figure 3.3, that the PAPR of the OFDM (original) signal is approximate 15 dB

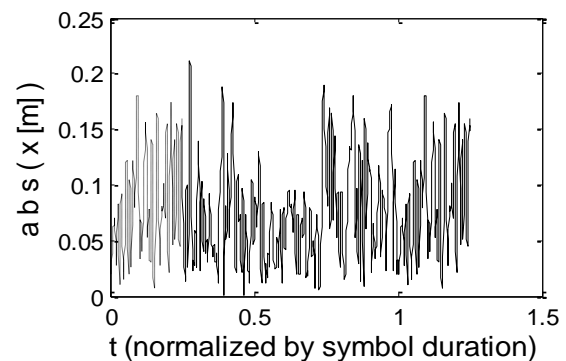
and it reduce to 5.2 dB after clipping the high peaks with CR = 1, and PAPR increases to 9.1 dB after filtering due to the peak re-growth.



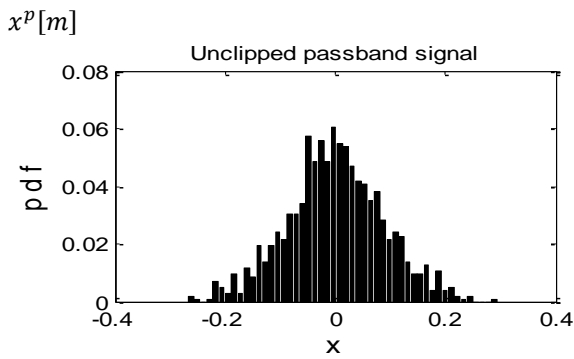
**Figure 2:** PAPR performance with clipping ratio (CR = 1)

Figure 3 shows the BER performance after clipping and filtering of OFDM signal with clipping ratio (CR) 1. It has been observed from the figure 3 that the BER of the original OFDM signal is approximate  $10^{-3}$  at SNR = 10 dB. With clipping, the BER is increased to just higher than  $10^{-2}$  at the SNR = 10 dB and the BER performance improves a little bit with filtering.

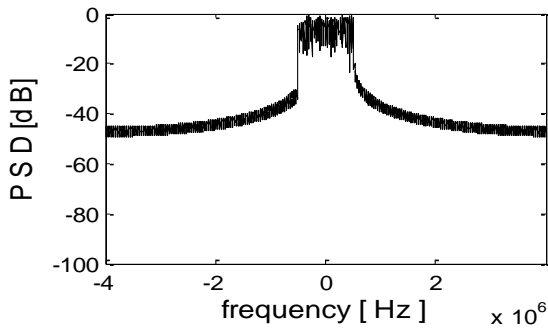
**Figure 3:** BER performance with clipping ratio (CR=1)



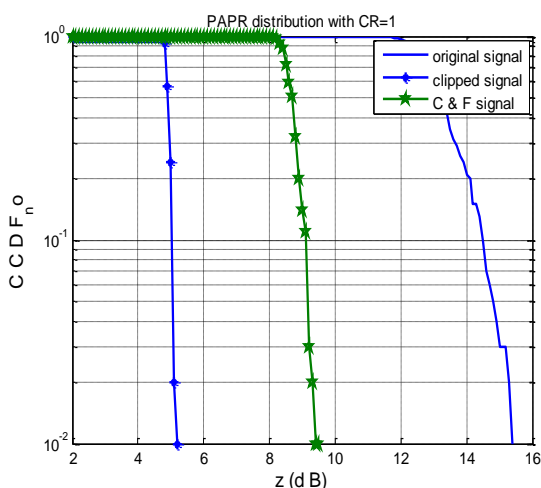
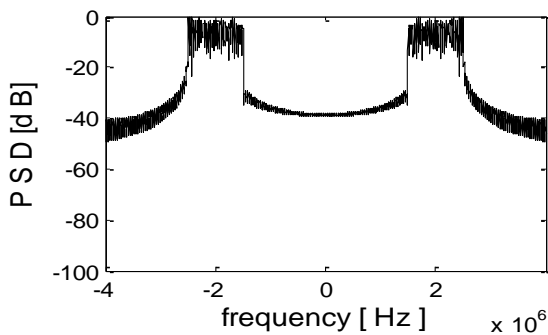
(a) Baseband Unclipped signal  $x'[m]$



(b). PDF of passband Unclipped signal



(c) Power spectrum of baseband Unclipped signal

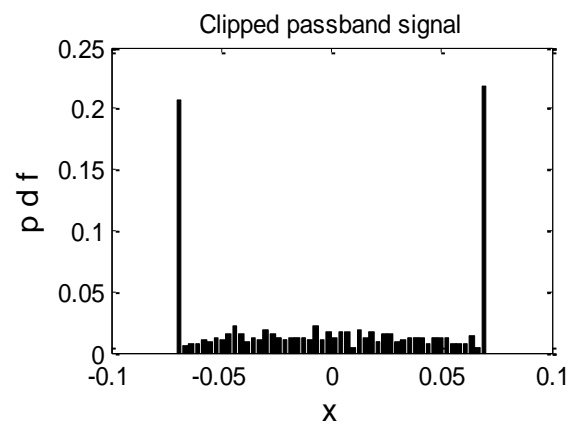


(d). Power spectrum of pass band Unclipped signal

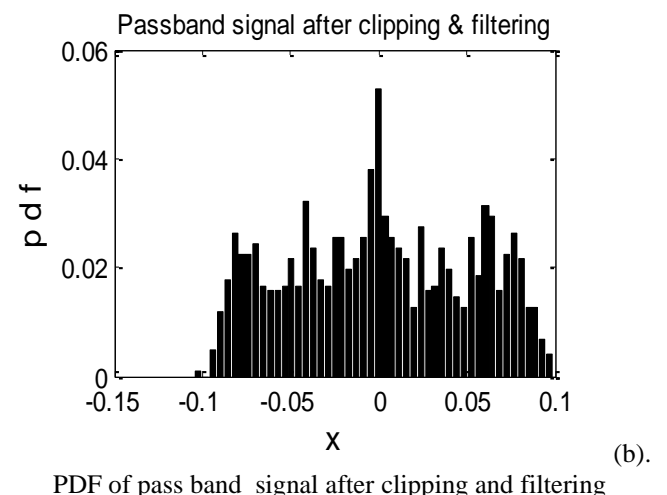
**Figure 4 (a) - (d)** Probability Density Function (PDF) and Power Spectrum Density (PSD) of unclipped signal

Figure 4 (a) shows the Oversampled Baseband OFDM signal  $x^p[m]$  with Cyclic Prefix (CP), these dotted lines indicate the CP portion. Figure 4 (b) shows the histograms of PDF of the unclipped passband signal  $x^p[m]$ . Figure 4 (c) and (d) shows the power spectrum density of the baseband signal and the pass band signal respectively. Figure 4 (b) and (d) shows that the OFDM signal approximately follows a Gaussian distribution.

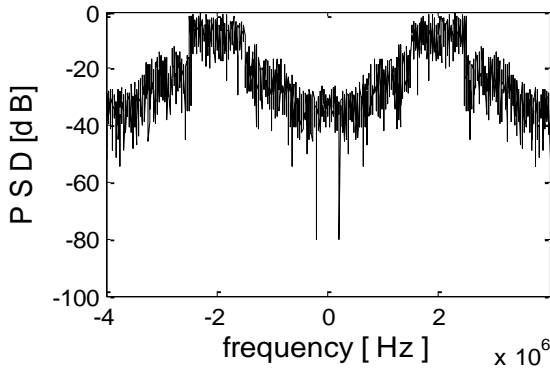
Figure 5 (a) and (c) shows that the amplitude of the clipped signal is distributed below the clipping level. It can be seen from figure 5(b) and (d) that the filtered signal shows its peak value beyond the clipping level. It can be seen from figure 5 (a-d) that out-of-band spectral distortion increases after clipping, but it decreases again after filtering.



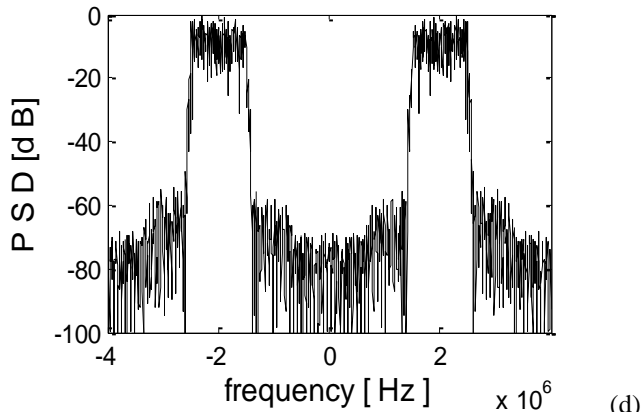
(a) PDF of the clipped pass band signal



(b). PDF of pass band signal after clipping and filtering



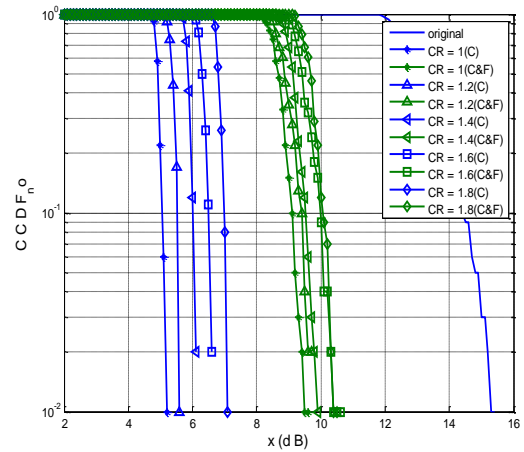
(c) Power spectrum of clipped signal  $x_c^p [m]$



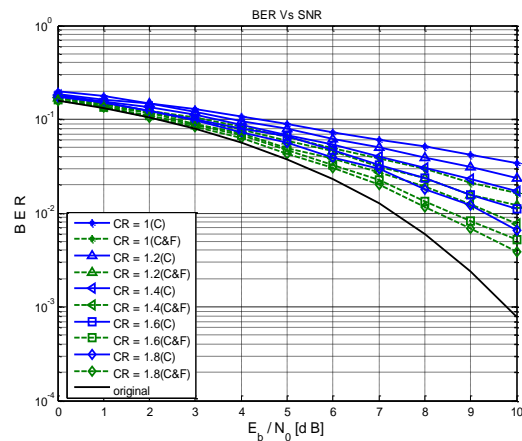
(d) Power spectrum of clipped and filtered signal  $\tilde{x}_c^p [m]$

**Figure 5:** (a) – (d) Power Density Function (PDF) and Power Spectrum Density (PSD) of clipped and filtered signal (CR = 1)

The PAPR reduction and BER using different clipping ratios (CR = 1, 1.2, 1.4, 1.6, 1.8) are shown in figure 6 and figure 7 respectively. The CCDF of the PAPR for the transmitted signal are plotted in figure 6. Figure shows that the PAPR of the OFDM signal decreases significantly after clipping of the high peaks with the different clipping ratios and increases a little after filtering due to peak re-growth. Also note that the smaller the CR is, the greater the PAPR reduction effect. Here the “C” and “C & F” denote the case with the clipping only and the case with both clipping and filtering, respectively. It can be seen from the figure 7 that the BER increases significantly after clipping but it reduce to some level after filtering. The BER performance becomes worse as the clipping ratio (CR) decreases from 1.8 to 1.



**Figure 6:** PAPR performance with clipping and filtering with different clipping ratios (CR = 1, 1.2, 1.4, 1.6, and 1.8)



**Figure 7:** BER performance with clipping and filtering (CR = 1, 1.2, 1.4, 1.6, and 1.8)

## V Conclusion

In this paper, we simulated the effect of Amplitude clipping with filtering on the CCDF of PAPR, BER and PSD of the randomly generated OFDM signal. The PAPR of the OFDM signal decreases significantly after clipping the high peaks with the different clipping ratios and increases a little after filtering due to peak re-growth. Also note that the smaller the CR is, greater the PAPR reduction effect and BER performance become worse as the clipping ratio decreases.

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