Modern Education
and Computer Science
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PAPR Reduction in OFDM System Using Clipping and Filtering Methods Based on CCDF

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Abstract—Wireless communication systems are becoming so promising day-by-day due to the mobility and the dynamicity of communication pattern. But, to fulfill the wide range of user's demand it has become much important to use some techniques which would be most efficient in terms of bandwidth and speed. The multicarrier strategy, called as orthogonal frequency division multiplexing (OFDM) has outstanding features to fulfill these demands. Multipath fading, delay spread, frequency selective fading and inter channel interference all of these limitations of wireless communication compound it with the scarcity of bandwidth gave rise to OFDM. However, the high peak-to-average power ratio is a great problem or a barrier in OFDM which causes the signal being distorted with the insufficient power at the receiver. There are some specified techniques to minimize it. In this paper, we have used clipping and filtering methods to minimize the effect of peak-to-average power ratio.

Index Terms—OFDM, PAPR, Fourier transform, Clipping, and Filtering.

I. INTRODUCTION

In recent years, wireless communications are getting more improvements in a very speedy way due to the growing demand of wireless services [1]. Since wireless channels cannot be perfectly predictable, it is slightly difficult to find the noise and the propagation of signal. While, in wired channels, the propagation of signal follows a predefined path, and so the noise is easily calculated in the channel. Using AWGN as a channel in the communication system tends to reduce the signal strength which makes the signal being distorted for the sources which may be industrial or natural [2]. Fading channels can be of different types like multipath, and frequency selective. Transmission of signal can be possible through a single path and multipath. Signal can be transmitted through a single carrier called single carrier transmission technique which is much easier to use for its simplicity. The main problem of using it is to take the high transmission time with a chance of complete loss of full transmission. But, using multicarrier transmission, the possibility of appearing multipath fading is high which causes the inter symbol interference due to the interference of symbols. As a multicarrier technique we use orthogonal frequency division multiplexing (OFDM) to defeat the problem of single carrier so that high date rate is achievable [3, 4]. The remaining part of this paper is arranged in the following way: In section 2, we discuss the principle of OFDM system with its benefits, and problems. Section 3 includes the discussion of peak-to-average power ratio with its characteristics and complementary CDF. In section 4, we see the classification of strategies used to minimize the PAPR and discuss the considered methods used in this paper. In section 5, we discuss the step by step experimental results with proper arguments. Finally, section 6 includes the research summary with upcoming works.

II. PRINCIPLE OF OFDM WITH MERITS AND DEMERITS

The background behind OFDM is that it divides the frequency spectrum into subcarriers which are mutually independent to each other, i.e., orthogonal so that interference between symbols is minimized. The data in each subcarrier are transformed from serial to parallel channel for simultaneous transmission in different channel. The inverse fast fourier transform, i.e., IFFT, can be utilized to generate the orthogonal features where either QAM or BPSK are used to modulate the sample data and then the modulated results are correlated jointly [5]. The function of FFT is to transform the time representation into frequency. OFDM has significant challenge due to the symbol time less than the delay spread leading to ISI which can be minimized by using cyclic prefix or guard band concept [6, 7]. The basic structure of OFDM is shown in Figure 1.

From the above figure we see that at first the modulating signal s(t) is passed through a serial to parallel converter to transform the serial stream into a parallel form. The parallel streams are then passed through an IFFT block which is then passed through a cyclic prefix to add each part with a cyclic block. Then, the output of cyclic prefix block is converted into serial stream by passing through a parallel to serial converter block which is then passed through the transmitter. After that the serial stream are passed through the channel. The received signal streams are then passed through Receiver filter. After that, it is passed through S/P, cyclic prefix

removal, FFT, P/S block. Finally, the received signal which is sent from the sender end is received by the receiver.
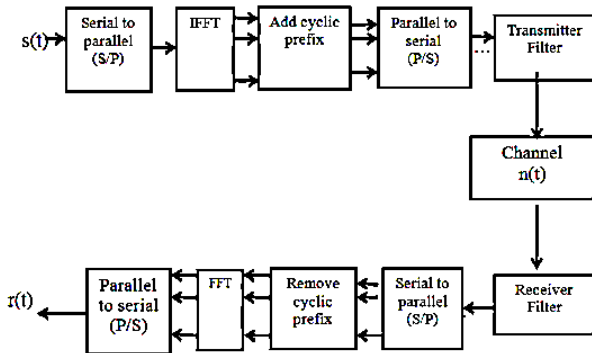

Fig.1. Basic Structure of OFDM system.

In the communication system, to solve the problem of single carrier, OFDM multicarrier is used which provides very high data rates by reducing the effects of multipath and ensuring the proper use of frequency spectrum [8]. The problem with OFDM is to rise the high PAPR due to the use of nonlinear amplifier which degrades the results of output amplifier. An OFDM signal is basically generated by the combination of many independent subcarriers after modulation which makes high peak and thereby resulting high PAPR [9]. This finally introduces the distortion and high bit error. Many techniques have been discovered to recover the PAPR effect [10, 11, 12].

OFDM system offers the following merits [13]:

1. High spectral efficiency
2. Lower multi-path distortion
3. Spectrum can be used perfectly by supporting the overlapping symbols
4. Reduction of ISI has been possible by the inclusion of cyclic prefix
5. Computationally efficient implementation of the demodulation and modulation processes.

It has some limitations. These are:

1. Sensitive to frequency offset
2. Large peak to average ratio
3. IFFT/FFT complexity
4. Inter-symbol interference (ISI) due to multipath

III. PAPR AND CCDF

The most challenging problem in the communication system is very high PAPR [15]. The main reason of having it is the presence of irregular power spectrum that means we need to keep the symbol stream of IFFT uniform [5, 16, 17]. Another reason of having high PAPR is to use the huge amount of subcarriers which causes some difficulties at the end of transmission [18, 19, 20]. We can define PAPR as the ratio of the peak or maximum power during the transmission of OFDM symbol with respect to its mean power. Mathematically, it is as

follows:

$$PAPR = \frac{max\,[|x(n)|]^2}{E[|x(n)^2|]} \qquad (1)$$

where $|x(n)|$ is the value x(n) and the expected value of it is $E[\ ]$.

A peak is generated by the combination of N signals with equal phase [21]. With N subcarriers, we can get a peak value of utmost 10logN (dB).

Now, we will discuss the effects of PAPR as shown in Figure 2. Let us consider the amplifier characteristics. The linear amplifier range of a device exists only a certain range. If the input is larger than the voltage range, the output is no longer linear. It becomes linear that means saturated [22, 23].
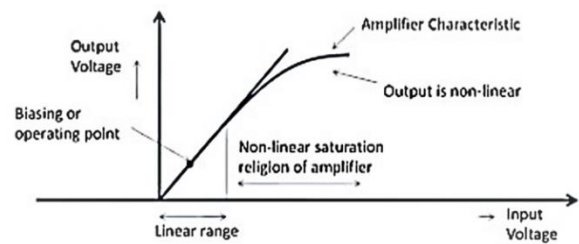

Fig.2. Amplifier characteristics.

The problem in the OFDM [28] system is to have non-ideal amplifier in practice. It has a limited linear amplification range and the swing of the peak power can be greater than the expected power. Here, the amplifier crosses over the saturation region. The output is no longer linearly related to the input, means that OFDM properties are sized. So, orthogonality is lost, and inter carrier interference (ICI) is introduced [6]. We can use complementary CDF to determine the performance of each PAPR strategy. The main reason of using CCDF rather than CDF is to get that possibility of a data block which is greater than a fixed value [24, 25]. Using a greater amount of subscribers for such a system, we consider that the real and imaginary components contain a mean of 0 with a variance of ½ which introduces the distribution of Gaussian. The equation of a CDF of such a signal amplitude is given by

$$f(x) = 1 - \exp(x) \qquad (2)$$

After calculating CDF, we can determine the CCDF of each block of PAPR as follows-

$$\begin{aligned} P(PAPR > x) &= 1 - P(PAPR \le x) \\ &= 1 - f(x)^N \\ &= 1 - (1 - \exp(-x))^N \qquad (3) \end{aligned}$$

IV. CLIPPING AND FILTERING

In recent years, a number of strategies have been proposed to minimize the PAPR [26, 14]. Some components before implementing the filtering and clipping strategies are essential to maintain the system

requirements which are greater efficiency of spectrum, to prevent the degradation of data rate and signal strength, lower bit error, etc. These reduction strategies are classified into two broad categories, namely, signal distortion and scrambling which are shown in Figure 3.

The simplest strategy is clipping where a high signal voltage exists before traveling it across the specified amplifier. Using this, we can minimize the power by

adjusting an utmost point of the signal being sent [27]. However, it faces few problems as follows:

1. High amount of in-band distortion can change BER reversely.
2. Adjacent interference can be found due to the out-of-band distortion.
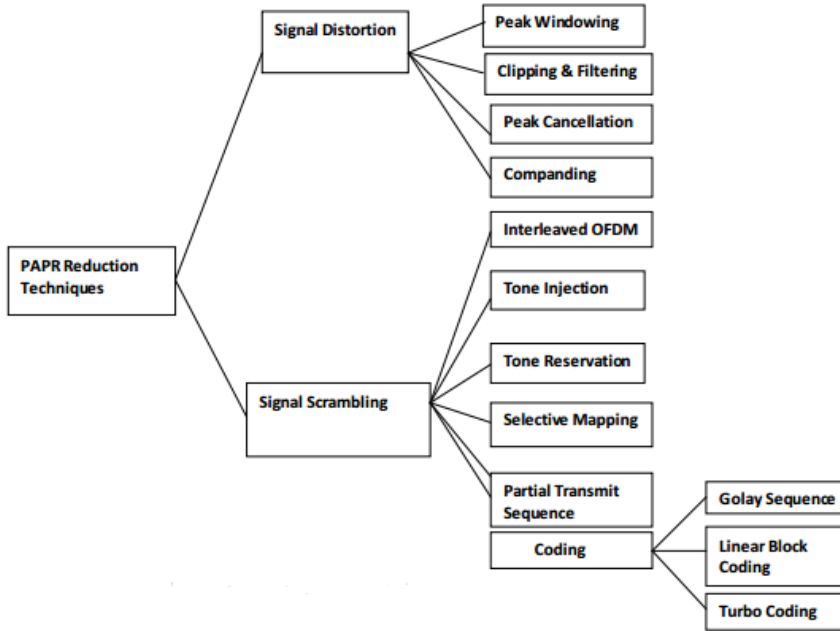
Fig.3. PAPR Minimization Strategies.

The distortion mentioned in (ii) can be reduced by using filtering techniques where there will be a high possibility of passing the utmost point of the clipping strategy. The basic structure of the considered strategies in this paper is shown in Figure 4. Here, at first the signal are passed through a L-N point IFFT block where total subcarrier and oversample components are indicated by respective symbols N and L. This block produces L-times output which is passed through digital up conversion (adding carrier frequency here) block whose output is then clipped. The resulting output is then passed through L-N point FFT, BPF, again L-N point IFFT and finally LPF. Less BER and distortion is achieved at the output of filtering. The signal before BPF (clipping level indicated by B) is expressed as follows:

$$x_c^p[m] = \begin{cases} -B & x^p[m] \le B \\ x^p[m] & \left| x^p[m] \right| < B \\ B & x^p[m] \ge B \end{cases} \qquad (4)$$
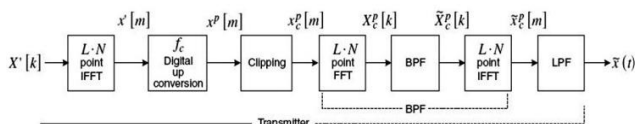

Fig.4. PAPR reduction scheme using clipping and filtering.

V. RESULT AND DISCUSSION

We use Matlab as the simulation tool. In the experimental figures, we show the original signal of OFDM and also the signal which is clipped and filtered. We also plot CCDF comparison between original, clipped and filtered OFDM signals.

Table 1. Arguments for clipping and filtering

Arguments	Value
Sub-carriers (N)	64, 128, 256, 512, 1024
Modulation	16-QAM
Oversampling Factor (L)	4
Clipping level	0.70
Channel Model	AWGN

Using N=64, Figure 5 (b) indicates that without clipping, PAPR is 11.5 dB at CCDF of 10^{-4}. PAPR is reduced to 8.9 dB after clipping but 6.5 dB after applying clipping and filtering techniques. The CF procedure achieves PAPR reduction by 43.47 % when compared to the original OFDM signal but by clipping, it achieves only 22.60%.
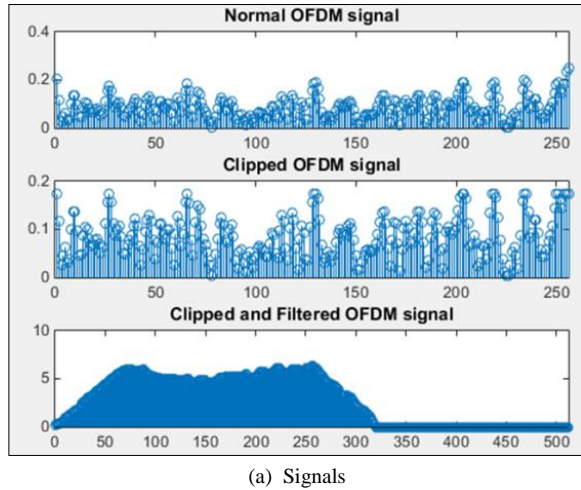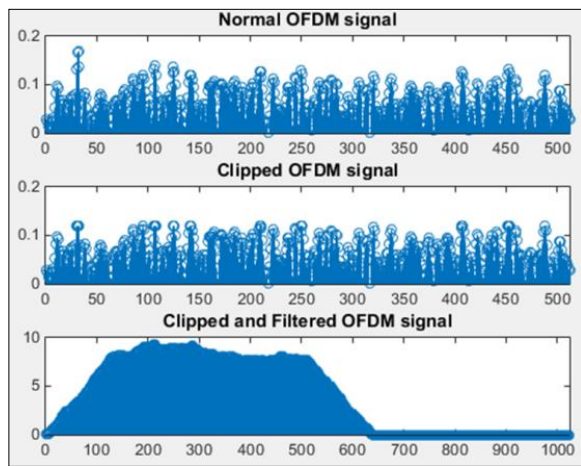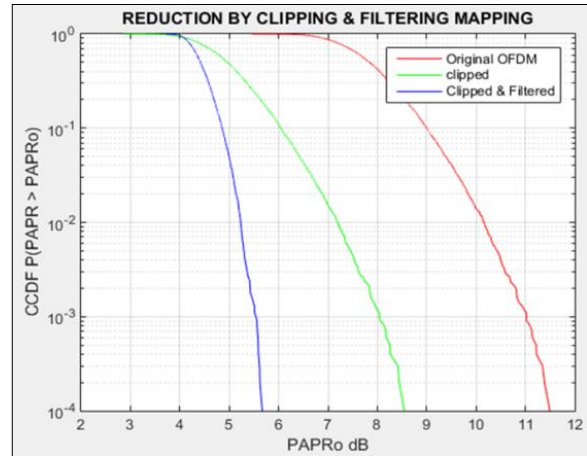
(a) Signals
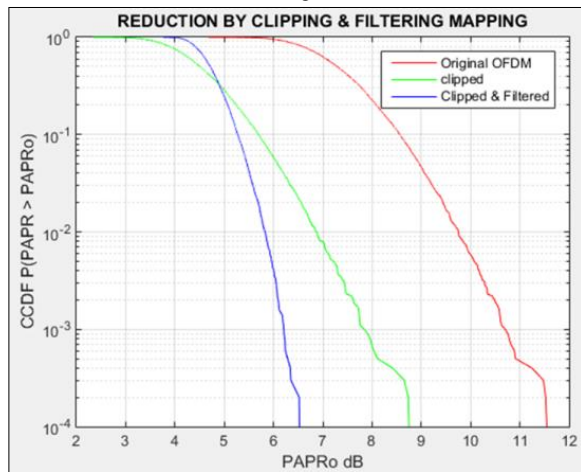
(b) CCDF

Fig.5. Representation of (a) signals and (b) CCDF comparison for N=64.

Figure 6 (a) shows the OFDM signal using N = 128. Figure 6 (b) indicates without clipping, PAPR is 11.4 dB at CCDF of 10^{-4}. PAPR is reduced to 8.6 dB after clipping but 5.7dB after applying clipping and filtering technique. The CF procedure achieves PAPR reduction by 50% when compared to the original OFDM signal but by clipping, it achieves only 24.13%.
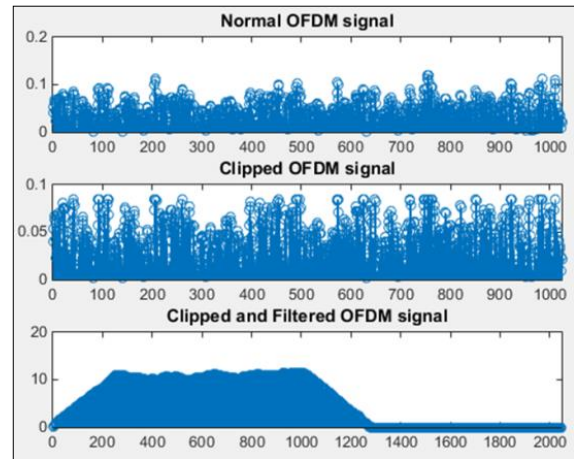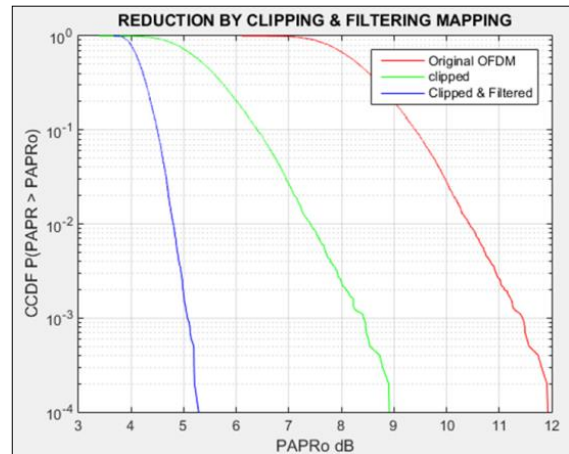

(a) OFDM signal

(b) CCDF

Fig.6. Representation of (a) signals and (b) CCDF comparison for N=128.

Figure 7 (b) indicates that without clipping, PAPR is 11.98 dB at CCDF of 10^{-4}. PAPR is reduced to 8.9 dB after clipping but 5.3 dB after applying clipping and filtering techniques. The CF procedure achieves PAPR reduction by 55.75% compared to the original OFDM signal but by clipping it achieves only 25.70%.
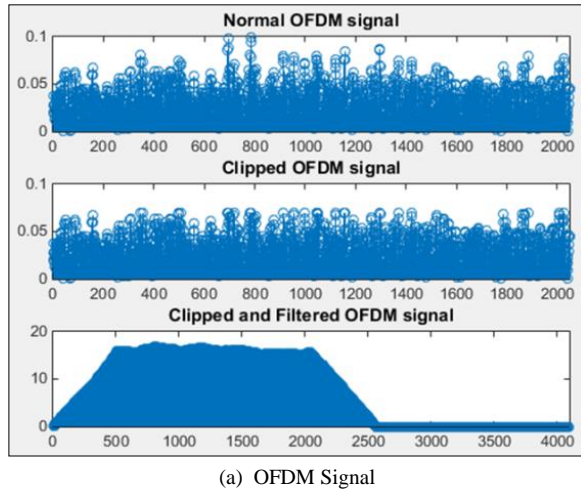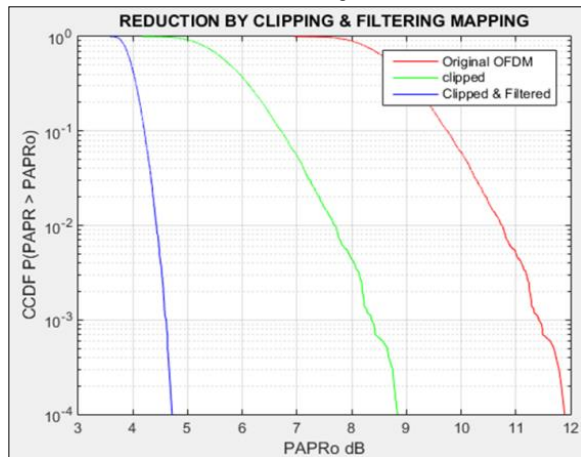

(a) OFDM Signal

(b) CCDF

Fig.7. Representation of (a) signals and (b) CCDF comparison for N=256.

Figure 8 (b) indicates that without clipping, PAPR is 11.99 dB at CCDF of 10^{-4}. PAPR is reduced to 8.8 dB after clipping but 4.6 dB after applying clipping and filtering technique. The CF procedure achieves PAPR reduction by 61.63% when compared to the original OFDM signal but by clipping, it achieves only 26.60%.
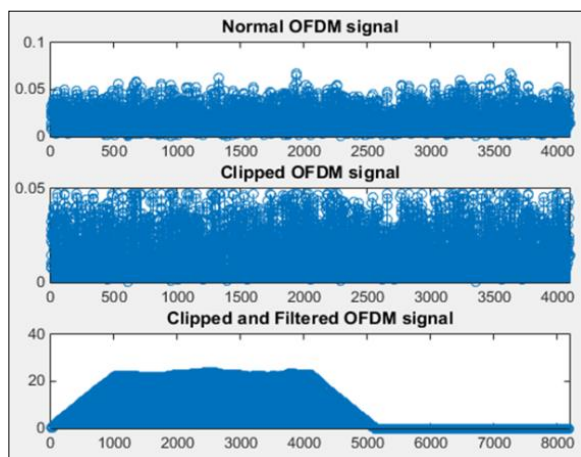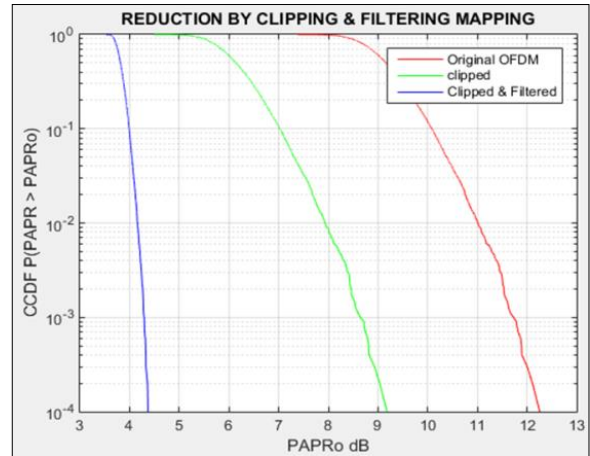

(a) OFDM Signal

(b) CCDF

Fig.8. Representation of (a) signals and (b) CCDF comparison for N=512.

(a) OFDM Signal

(b) CCDF

Fig.9. Representation of (a) signals and (b) CCDF comparison for N=1024.

Figure 9 (b) indicates that without clipping, PAPR is 12.2 dB at CCDF of 10^{-4}. PAPR is reduced to 9.1 dB after clipping but 4.3 dB after applying clipping and filtering technique. The CF procedure achieves PAPR reduction by 64.47% when compared to the original OFDM signal but by clipping, it achieves only 25.54%.

VI. Conclusion and Future Works

Orthogonal frequency division multiplexing (OFDM) is a multicarrier strategy where a broadband channel is divided into multiple narrowband sub-channels, i.e., a high speed data rate stream is divided into many parallel low data rate stream which uses the respective sub-channels instead of using a single broadband channel. The major problem in OFDM system is high peak-to-average power ratio (PAPR). In this paper, we have attempted to minimize the PAPR using clipping and filtering strategy on CCDF. Our investigation indicate how these strategies improve upon the PAPR of OFDM signal where clipping level contributes to clip a signal while distortion is reduced with the use of filtering. With the increase of subcarriers, the investigated results of CCDF vary also. Using clipping and filtering strategies, we observe lower CCDF for N=1024 compared to using other subcarriers, N.

In near future, we would like to improve the performance by minimizing lower PAPR with a hybrid technology which is the combination of clipping and SLM technique.

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