PAPR Reduction of OFDM System by Better Performance ICF Technique

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Abstract- In recent years, there is rapid growth in wireless communication technologies that support high speed; efficient, reliable voice & data communication .To achieve this goal, orthogonal frequency division multiplexing (OFDM) is widely used, which is a multicarrier modulation technique. One of the challenging issues in the OFDM system is its high peak to average power ratio (PAPR).This high PAPR causes significant distortions when passed through non-linear amplifier. To reduce PAPR, a number of promising techniques have been proposed and implemented. Clip and filter is a simple method used to reduce PAPR of OFDM signal. In this paper, Iterative Clipping and Filtering (ICF) have been implemented to reduce the distortions and peak power regrowth produced by simple clipping & filtering method. It is found that, Iterative Clipping and Filtering (ICF) gives better performance than simple clipping & filtering technique.

Keywords: **Orthogonal Frequency Division Multiplexing (OFDM) and Peak to-Average Power Ratio (PAPR), Bit Error rate (BER), Clipping Ratio (CR), Clipping Level (CL), Complementary Cumulative Distribution Function (CCDF), Iterative Clipping and Filtering (ICF).**

I.   INTRODUCTION

Demands on wireless communication services increases rapidly, as wireless communication area improving in the very fastest way. Single carrier scheme is easy to use for low data rates because of its simplicity, accuracy. Single carrier scheme saves more power since there is no need to add guard interval while transmitting the signal. Single carrier scheme may have some drawbacks for high data rates including equalizing complexity. OFDM is used to overcome the drawback of single carrier system. Multicarrier (MC) modulation is a widely adopted technique in wireless communications because of its advantages. Here the orthogonal subcarriers uses Fourier transform without addition inter-carrier interference (ICI).

OFDM system have main drawback of high peak-to-average power ratio (PAPR). An inherent property of MC transmission schemes is the high dynamic range of the transmitted signal. The theoretical value of the PAPR is given by the number of subcarriers in use. The probability of having such high peaks is marginal in systems with enough subcarriers, but still in practice the PAPR of MC signals is much higher than in case of single carrier signals [1]. The high dynamic range of the MC signals causes a problem in most communication systems, since the signal has to be amplified by a power amplifier (PA) at the transmitter. Practical PAs do not maintain linearity over the whole dynamic range of the MC signal, thus amplifying different parts of the signal differently. This distorts the MC signal, resulting in a reduced bit error rate (BER) performance and also in a spectral regrowth, basically radiating energy at frequencies adjacent to the signal and at higher values than originally planned [1]. A number of approaches have been proposed and implemented to reduce PAPR which falls under different categories like signal distortion techniques, multiple signaling and probabilistic techniques and coding techniques with further classification in each category [2].

The rest of the paper is organized as follows: section II contains the fundamentals of OFDM and need of PAPR reduction. In section III simple amplitude clipping and filtering method is explained. In section IV proposed Iterative Clipping and Filtering (ICF) technique is discussed. Section V is results and discussion, where simulation and their results of simple clipping and filtering and ICF scheme are discussed. Concluding remarks are given in section VI. References are mentioned in section VII

II. FUNDAMENTALS OF OFDM AND PAPR

In this section, we discuss about the basics concept of OFDM systems and overview of PAPR in OFDM, mathematical formula for PAPR & the motivation of reducing PAPR.

A. Basic OFDM

OFDM is a special class of the multi-carrier modulation (MCM).In OFDM modulation scheme, multiple data bits are modulated simultaneously by multiple carriers. This procedure partitions the transmission frequency band into multiple narrower subbands, where each data symbol's spectrum occupies one of these subbands. As compared to the conventional frequency division multiplexing (FDM), where such subbands are non-overlapping, OFDM increases spectral efficiency by utilizing subbands that overlap (Fig. 1). To avoid interference among subbands, the subbands are made orthogonal to each other, which mean that subbands are mutually independent [2]

B. Mathematical formula of OFDM signal

In OFDM systems, a fixed number of successive input data samples are modulated first (e.g., PSK or QAM), and then jointly correlated together using inverse fast Fourier transform (IFFT) at the transmitter side. IFFT is used to produce orthogonal data subcarriers. Let, data block of length N, is represented by a vector, $X=[X_0, X_1 \ldots XN_{-1}]^T$. Duration of any symbol X_K in the set X is T and represents one of the sub-carriers set. As the N sub-carriers chosen to transmit the signal are orthogonal, so we can have, $f_n = n\Delta f$, where $n\Delta f = 1/NT$ and NT is the duration of the OFDM data block X. The complex data block for the OFDM signal to be transmitted is given by [3],

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \, e^{j2\pi n \Delta ft} \qquad 0 \leq t \leq NT$$

Where, $j = \sqrt{-1}$, Δf is the subcarrier spacing and NT denotes the useful data block period.
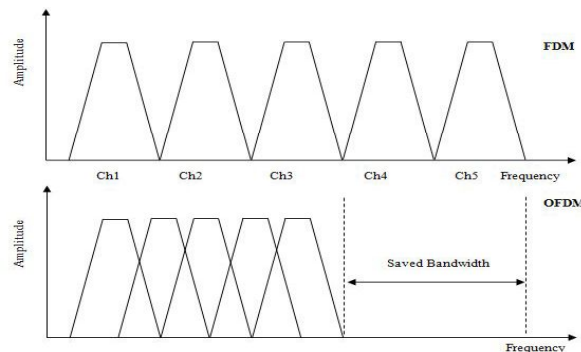

Figure1. Comparison of the spectral utilization efficiency between FDM and

OFDM schemes

C. Overview of PAPR

When the OFDM signal is transformed to the time domain, the resulting signal is the addition of all the subcarriers, and when all the subcarriers add up in phase the result is a peak N times higher than the average power. This high PAPR causes the degradation of performance of OFDM signals by forcing the analog amplifier to work in the nonlinear region. Hence in this way, the signal is distorted and makes the amplifier to consume more power [4].

The PAPR for the continuous-time signal x(t) is the ratio of the maximum instantaneous power to the average power. For the discrete-time version $x[n]$, PAPR is expressed as [2],

$$PAPR(x[n]) = \max_{0 \leq n \leq N-1} \frac{|x[n]|^2}{E|x[n]|^2}$$

where E [.] is the expectation operator.

III.   SIMPLE CLIPPING AND FILTERING METHOD

Clipping and filtering is one of the simplest methods of PAPR reduction in OFDM system. This is the method of clipping the high peaks of the OFDM signal before passing it through the power amplifier (PA). This is done with the help of clipper that limits the signal envelop to the predetermined level known as clipping level(CL),if the signal goes beyond the CL; otherwise clipper passes signal without any change[5]. The clipped signal is given by [2],

$$y[n] = \begin{cases} -CL, & if\ x[n] < -CL \\ x[n], & if\ -CL \le x[n] \le CL \\ CL, & if\ x[n] > CL \end{cases}$$

where $x[n]$ is the OFDM signal, CL is the clipping level. Fig.2 shows OFDM signal transmission block diagram using simple clipping and filtering scheme [9]. Clipping is a nonlinear process that causes the distortion as source of noise, which falls in both in-band and out-of-band distortions [6].In –band distortion can degrade the BER performance and cannot be reduced by filtering. However, oversampling by taking longer IFFT can reduce the in-band distortion effect as portion of the noise is reshaped outside of the signal band that can be removed later by filtering [2].While the out of band distortion causes spectral spreading and can be eliminated by filtering the clipped OFDM signal which can preserve the spectral efficiency and, hence, improving the BER performance but it can results in some peak power regrowth.
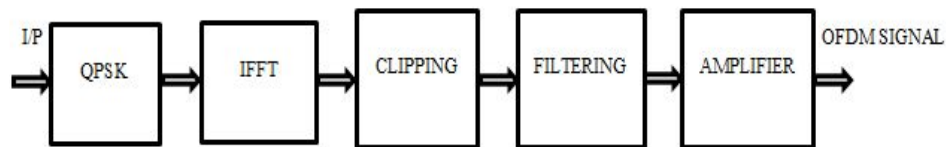

Figure 2. OFDM signal transmission block diagram

A. Limitations of Simple Amplitude Clipping and Filtering
1) As clipping is a nonlinear process, it causes two types of distortions namely, in-band signal distortion and out of band signal distortion. In- band distortion resulting in BER performance degradation.
2) Out-of-band distortion caused by Clipping 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 [8].
3) Filtering the clipped signal can reduce out-of-band radiation at the cost of peak regrowth. Signal after filtering operation may exceed the clipping level specified for the clipping operation [3].
4) Aliasing problem is faced in clipping after filtering which can be reduced by adding zeros in original input called zero padding [9].

IV.   PROPOSED ICF TECHNIQUE

Iterative clipping and filtering (ICF) is a widely used technique to reduce the PAPR of OFDM signals and to overcome the limitations of simple amplitude clipping and filtering method. Fig.3 shows the basic block diagram of the ICF PAPR reduction scheme [10]. However, the ICF technique, when implemented with a fixed rectangular window in the frequency-domain, requires much iteration to approach the specified PAPR threshold in the complementary cumulative distribution function (CCDF) [10].

The proposed clipping is performed by using following formula [10],

$$\hat{x}_m(k) = \begin{cases} C_m e^{j\theta_m k}, & |x_m(k)| > C_m \\ x_m(k), & |x_m(k)| \le C_m \end{cases}$$

Where $1 \leq k \leq lN$, θ_m represents the phase of x_m, and c_m is the clipping level in the m-th iteration. Here clipping level is recalculated in each iteration according to a constant value known as the clipping ratio (CR) using following formula [10],

$$CR = \sqrt{PAPR_{max}} = \frac{C_m}{\frac{1}{\sqrt{N}}\|x_m\|_2}$$

The filtering step is dependent upon a rectangular window with frequency response defined by [10],

$$F_m(i) = \begin{cases} 1, & 1 \leq i \leq N \\ 0, & N+1 \leq i \leq lN \end{cases}$$

The steps for proposed ICF method are described below:

Step 1: Set the value of clipping ratio (CR) and the number of iteration (M)

Step 2: A new OFDM symbol enters to the proposed ICF block loop

Step 3: Calculate the clipping level C_m and clip the signal x_m

Step4: Convert the clipped signal to frequency domain using FFT transform

Step 5: Filter the output of step 4

Step 6: Convert filtered signal into time domain using IFFT

Step7: Let, m = m +1, if m > M, reset m = 1 and go to step 2 and start processing the next OFDM symbol.
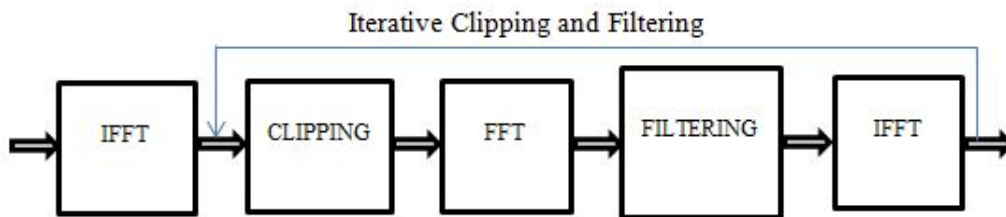

Figure 3. Basic block diagram of the ICF PAPR reduction scheme

V. RESULTS AND DISCUSSION

The simulations are conducted first for simple clipping and filtering method to reduce PAPR value of OFDM signal with QPSK modulation and a clipping ratio(CR) of 1dB, 5dB and 7dB.The CR is related to the clipping level by the expression [2],

$$CR = 20 \log_{10}\left(\frac{cl}{E[x[n]]}\right),$$

Where E[x[n]] is the average of OFDM signal x[n]. The empirical CCDF is the most regularly used for evaluating the PAPR. PAPR reduction capability is measured by the amount of CCDF reduction achieved. CCDF provides an indication of the probability of the OFDM signal's envelope exceeding a specified PAPR threshold within the OFDM symbol and is given by [2],

$$CCDF[PAPR(x^n(t))] = prob[PAPR(x^n(t) > \delta)]$$

Where PAPR $(x^n(t))$ is the PAPR of the nth OFDM symbol and δ is some threshold. Fig. 4 shows the empirical CCDF versus PAPR plot for simple amplitude clipping and filtering method with different values of CR. From fig.4, it is found that as CR goes on decreasing from 7dB to 1 dB, empirical CCDF is decreasing and hence more reduction in PAPR from 7dB to 1 dB. The performance of a modulation technique can often be measured in terms of required signal-to-noise ratio (SNR) to achieve a specific bit error rate (BER). Fig. 5 shows the BER versus SNR plot for simple amplitude clipping and filtering method with different values of CR. Clipping the high peaks of the OFDM signal causes a substantial in-band distortion that leads to degradation in the BER performance. As shown in fig. 5, as CR goes on decreasing from 7dB to 1 dB, the BER is increasing.
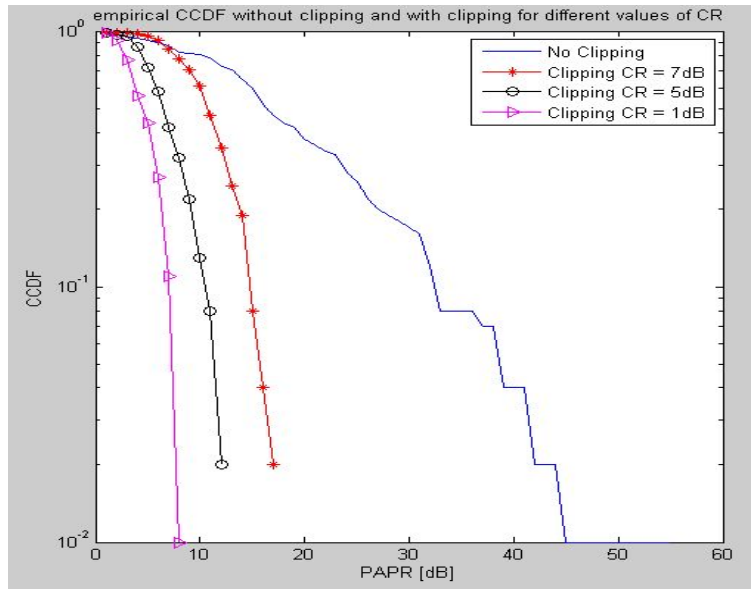
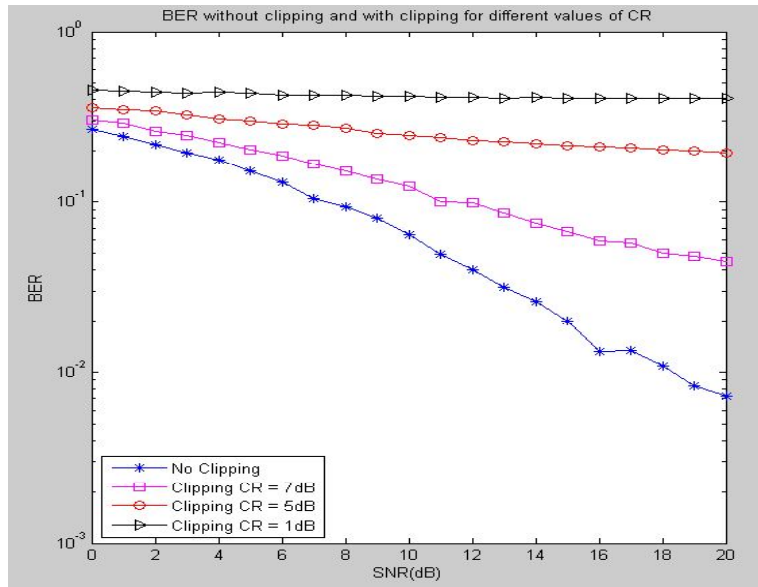Figure 4. Empirical CCDF without clip and with clipping and filtering

Figure 5.BER without clipping and with clipping and filtering

Secondly, we evaluate the performance of our proposed ICF scheme. Fig.6 shows the CCDF versus PAPR plot of the iterative clipping and filtering with FFT/IFFT. The proposed ICF scheme gives better performance compared with simple amplitude clipping and filtering techniques.

Table I. Parameters Used for Simulation of proposed ICF scheme

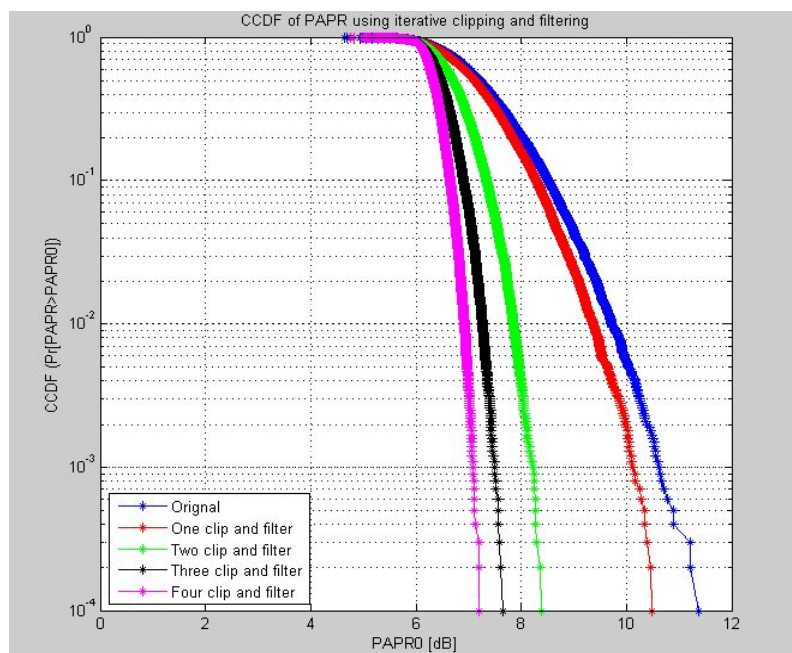| Parameters	Value
Modulation	QPSK
OFDM symbol size	128
Oversampling factor	2
FFT size	256
Clipping ratio(CR)	4

Figure 6. CCDF of PAPR using Iterative Clipping and Filtering

VI.   CONCLUSION

OFDM is an efficient multicarrier modulation technique for both wired and wireless applications due to its high data rates and spectral efficiency. The major drawback in OFDM system is high peak-to-average power ratio. This high PAPR drives the transmitter's power amplifier into saturation, causing nonlinear distortions and spectral spreading. In order to minimize the effects of high PAPR in OFDM systems, clipping & filtering is a simple solution among all other PAPR reduction techniques. Simple amplitude clipping and filtering method causes the in band distortion which cannot be reduced by filtering .Filtering used to reduce out of band distortion results in peak power regrowth. The proposed Iterative Clipping and Filtering reduces both in- band distortion and peak power regrowth. It can be observe that OFDM signal has higher PAPR and after applying this method, PAPR reduces significantly. Also it is observed that as the number of clip and filter is increasing from one to four levels, PAPR value goes on decreasing. One can use ICF with DCT/IDCT transformation in proposed method to improve performance.

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