Peak-to-Average Power Reduction using Repeated Frequency Domain Filtering and Clipping in OFDM

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ABSTRACT

The Orthogonal Frequency Division Multiplexing is one of the widely used modulation techniques in the broadband wireless technology. One of the main problems of the OFDM is the high peak-to-average power ratio of transmitting signal due to the superposition of many subcarriers. This paper presents a new proposed peak-to-average power ratio reduction technique, which Repeated frequency domain filtering and clipping over LET channel and compare with Repeated clipping and frequency domain filtering (RCF) technique. The paper highlights the performance and advantages of the proposed technique. The simulations show that the proposed technique realizes an improved PAPR and BER.

Keywords
OFDM, PAPR, RFC

1. INTRODUCTION

During the last two decades, the demand for multimedia wireless communication services have grown tremendously and this trend are expected to continue in the near future. Orthogonal frequency division multiplexing (OFDM) is one of such multi-carrier techniques which have attracted vast research attention from academics, researchers and industries since last two decades. It has become part of new emerging standards for broadband wireless access [1].

Energy efficiency, particularly matters in future mobile communications networks. A key driving factor is the growing energy cost of network operation which can make up as much as 50% of the total operational cost nowadays [2]

The transmitted signal of OFDM exhibits a high Peak-To-Average Power Ratio (PAPR). This high PAPR reduces the efficiency of high power amplifier and degrades the performance of the system.[3]

PAPR has a deleterious effect on battery lifetime in mobile applications. As handy devices have a finite battery life, it is significant to find ways of reducing the PAPR allowing for a smaller, more efficient HPA, which in turn will mean a longer lasting battery life.

In many low-cost applications, the problem of high PAPR may outweigh all the potential benefits of multicarrier transmission systems.[4]

2. DEFINITIONS OF PAPR

For a continuous time baseband OFDM signal, the PAPR of any signal is defined as the proportion of the maximum instantaneous power of the signal and its average power. If x (t) is a transmitted baseband OFDM signal, then PAPR is defined as:

$$PAPR\,[x(t)] = \frac{\overset{MAX}{_{0 \le t \le T_s}}[\,|x(t)\,|^2]}{p_{av}} \qquad (1)$$

Where, p_{av} is the average power of x (t) and can be computed in frequency domain because IFFT is a unitary transformation T_s is useful duration of an OFDM symbol [5].

3. DISTRIBUTION OF PAPR

To design and develop an effective PAPR reduction technique, it is very important to accurately identify the distribution of PAPR in OFDM systems. The distribution of PAPR plays an important role in the design of the whole OFDM system. The distribution of PAPR can be used in determining the proper output back-off of the HPA to minimize the total degradation. It can be used directly to calculate the BER and to estimate the achievable information rates [6].

The power of OFDM signal has chi-square distribution. The distribution of PAPR is often expressed on the one hand Complementary Cumulative Distribution Function (CCDF). In probability theory and statistics, the CCDF describes the probability that a real-valued random variable X with a given probability distribution will be found at a value greater than or equal to x [6].

The Cumulative Distribution Function (CDF) of the PAPR of the amplitude of a signal sample is given by

$$F(z) = 1 - exp(z) \qquad (2)$$

The CCDF of the PAPR of the data block is desired in our case is to compare outputs of different reduction techniques. This is given by:

$$Pr(PAPR > z) = 1 - Pr(PAPR \le z) \qquad (3)$$

$$= 1 - F(z)^N \qquad (4)$$

$$= 1 - (1 - exp(-z)^N \qquad (5)$$

Where, z is the given reference level.

4. REPEATED CLIPPING AND FREQUENCY DOMAIN FILTERING (RCF)

In the clipping technique hard limiting is applied to the amplitude of the complex values of the IFFT output. The filtering technique is designed to alleviate or cancel OOB distortion dependent on oversampling value but cannot correct in-band distortion. [7] .

The input vector $a_0, \ldots, a_{N-1}$ is first converted from the frequency to the time domain wing an oversize IFFT. N is the number of subcarriers in each OFDM symbol. For an oversampling factor of, the input vector is extended by adding

$N(I - 1)$ zeros; in the middle of the vector. This results in the trigonometric interpolation of the time domain signal [9].

Trigonometric interpolation gives perfect interpolation when the original signal consists of integral frequencies over the FFT window. This is the case for OFDM. The input of the Nyquist frequency, $N/2$ has been omitted, as the interpolation technique does not work for this value [9]. This is not a practical limitation as all applications of OFDM null this input

and most do not use a number of adjacent subcarriers. The interpolated signal is then clipped.

In this Technique hard-limiting is applied to the amplitude of the complex values of the IFFT output [10]

After an IFFT, the original signal is clipped in the time domain. The clipping can be described as shown below:
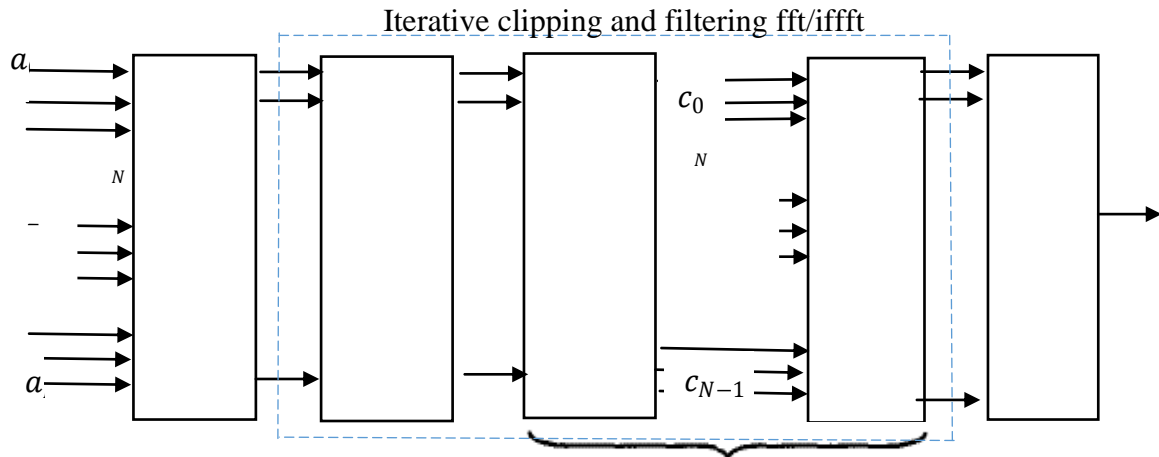

Figure 1 shows the block diagram of the new PAPR reduction scheme [8].

$$C = \begin{Bmatrix} \frac{\sqrt{c_R * E[|x|^2]} * \frac{x}{|x|}} & |x|^2 > c_m \\ x & |x|^2 \le c_m \end{Bmatrix} \qquad (6)$$

Where C represents the output of the time domain signal,

$$c_m = c_R * E[|x|^2] \qquad (7)$$

, c_m Is the threshold clipping level, $signal\ power = |x|^2$; $E[|x|^2]$ Is the mean power. c_R The clipping ratio is defined as the ratio of the clipping level to the mean power of the unclipped baseband signal.

As shown in the equation (6), the discrete time domain signal is clipped in the amplitude. At every point where the complex time domain signal exceeded the clipping level, the amplitude was reduced to the clipping level while the phase of the complex signal was unchanged [11].

The clipping is followed by frequency domain filtering to reduce OOB power caused by clipping. The filter consists of two FFT operations [10].

The clipped time domain signal c is then converted back into the discrete frequency domain using an FFT ,The inband discrete frequency components of the clipped signal $c_0, c_{\frac{N}{2}-1}, c_{NI_1-\frac{N}{2}+1}, \dots, c_{NI_1-1}$ are passed unchanged to the inputs of the second IFFT while the OOB components, $c_{\frac{N}{2}+1}, \dots, c_{NI_1-\frac{N}{2}}$ are nulled [12 and 13] this technique is repeated, depending on iteration number, usually choose between one and four. In this work has been selected four.

Although frequency domain filtering is a common signal processing technique the form shown in figure 1 is unusual. In most filtering applications the filter is designed to meet particular specifications in the continuous frequency domain. In this application, the wanted signal is an OFDM signal,

which is the sum of discrete frequency components in each symbol period. The filter must therefore have as little effect as possible on the in-band discrete frequency domain while attenuating as much as possible any OOB components. This is precisely what is achieved by the simple filter structure in Fig 1 because the filter operates on a symbol by symbol basis; there is no filtering across symbol boundaries and so no resultant ISI. The filtering does cause some peak regrowth. However, this is much less than for clipping before interpolation [10, and 14]

The clipping noise is added at the transmitter rather than the receiver. In fading channels this means that in general the clipping noise will cause less degradation in bit error rate than noise added in the channel since the clipping noise fades along with the signal.

5. REPEATED FREQUENCY DOMAIN FILTERING AND CLIPPING RFC

The proposed method is the same as previous method RCF, but with almost a simple change. The location of the filter becomes before the clipping as shown in figure 2, the frequency domain filtering that depends on the interpolation as noted by previous results that improve the BER but increases the PAPR

The basic idea of this method is that this filter will improve the performance of the OFDM to improve the BER and then the clipping will improves PAPR method is almost the same as RCF, the system have the same receiver But there is a difference in One block in the transmitter. This block is RFC as shown in figure 3. Interpolated baseband signal followed by frequency domain filtering, the same filter which are explained in the case of RCF. The filtering signal is clipped in the time domain. The clipping block is described previously in the case of RCF.
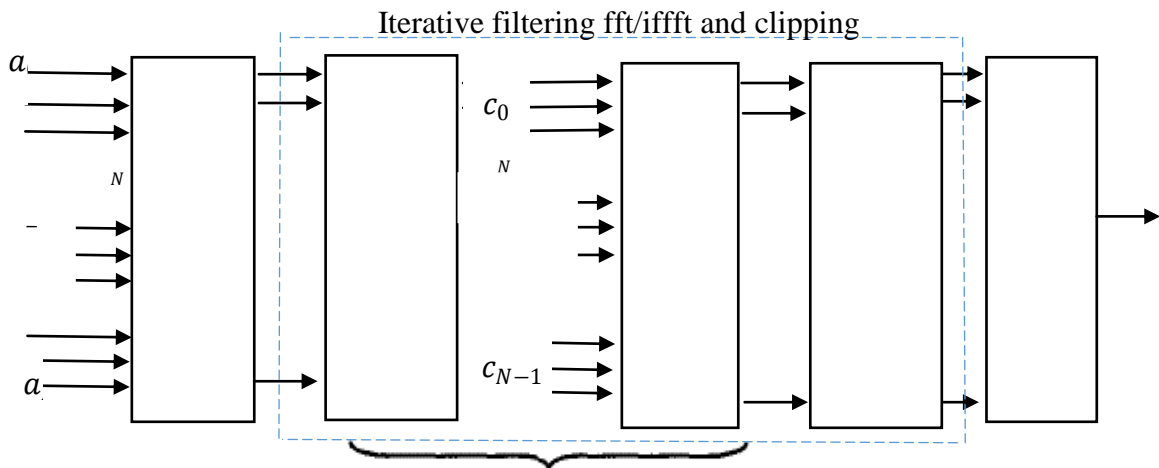
Iterative filtering fft/iffft and clipping

c_0

N

c_{N-1}

Figure 2 shows the block diagram of the new PAPR reduction scheme

Figure 3 the OFDM system model with RFC.

I/P → Signal Mapper → S/P → +pilot symbol → IDFT OR IFFT → RFC → P/S → Add CP → D/A → Multipath Fading Ch. & noise

Multipath Fading Ch. & noise → A/D → Remove CP → S/P → DFT OR FFT → remove +pilot symbol → Equalizer And P/S → Signal demapper → O/P

6. SIMULATION RESULTS AND ANALYSIS

The system model used in the work is shown in figure 4.1. The OFDM parameter used in the test is the LTE parameters as shown in table 4.1

Table 4.1 LTE parameter

FFT size =no. of frame	128
frequency Spacing	15 KHz
BW	1.25MHz
CP	32
No of symbol	1000
Sampling frequency	192MHz
Modulated type	QPSK

one can conclude From figure 4 and 5 the following:

There is an obvious improvement in the CCDF of PAPR and the BER of the RFC In comparison with the RCF.

The CCDF of PAPR of the RFC at CR=2 is better than the CCDF of PAPR of the RCF at CR=1.5, in addition to that the BER of the RFC at CR=2 is better than the BER of the RCF at CR=1.5.
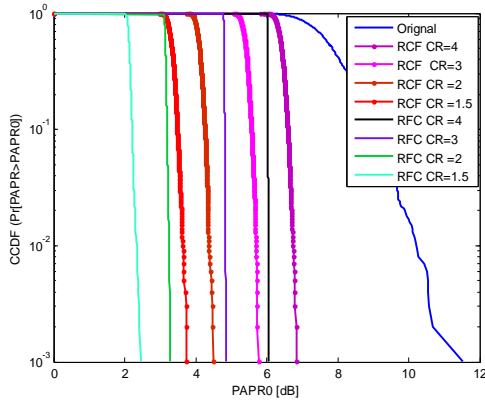

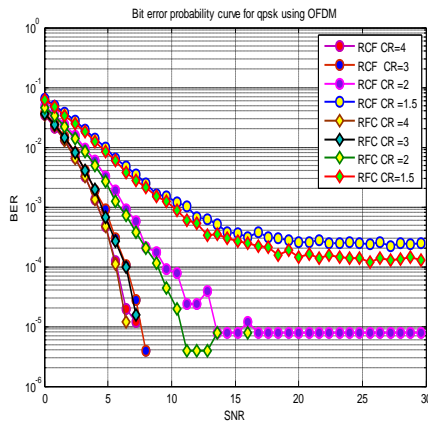**Figure 4 Comparison in CCDF of PAPR between RCF and RFC, where I=4**

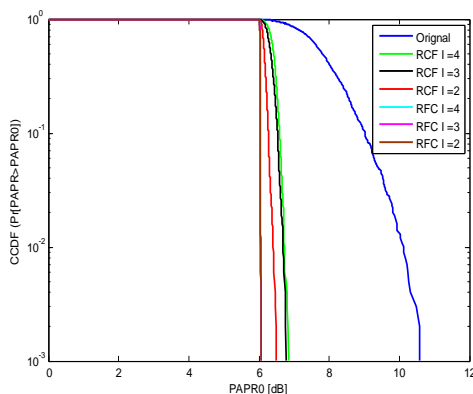**Figure 5 Comparison in BER between RCF and RFC, where I=4.**

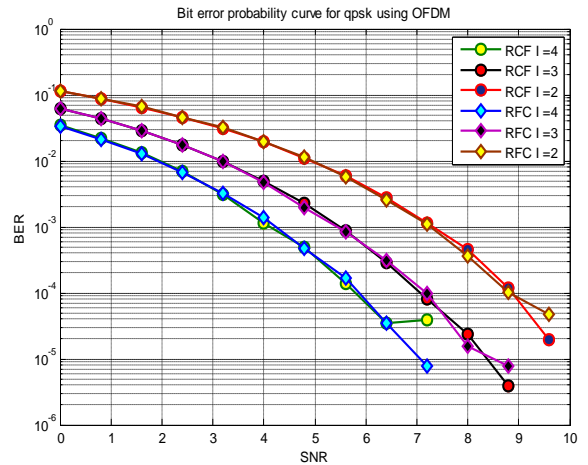**Figure 6 Comparison in CCDF of PAPR between RCF and RFC where CR =4**

Figure 7 Comparison in CCDF of PAPR between RCF and RFC where CR =4

As shown in figure 6 and 7 The CCDF of PAPR and The PAPR for I (N) was increased only Avery small amount could be neglected in comparison with I1.The BER decreases whenever I increased

The improvement in the PAPR at RFC can be seen when comparing figure

CCDF of PAPR was improved in all cases. The improvement ratio was increased with the decrease of CR and the increase of *I*. The biggest improvement is in the case (I = 3 and CR =4).

BER was improved for (I =3 and I =4 in all cases of CR) and for I =2 except when (CR=2) as for the rest I,BER sometimes better, sometimes worse, but by asmall ratio.

RFC is better than RCF because when I increase the BER improve and

PAPR almost preserves its value.

7. CONCLUSIONS
The RFC and RCF can improve the PAPR and BER at the same time.

RFC is better than RCF in performance especially when I ≥ 2 while maintaining the complexity and price of RCF.

RFC have the same complexity and cost RCF because RFC has not added a new function for RCF but the only change filter location.

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