PAPR reduction in OFDM using Iterative Clipping and Filtering Technique

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Abstract:

The disadvantages of high peak to average power ratio (PAPR) can overcome all the potential benefits of Orthogonal Frequency Division Multiplexing (OFDM) signals. High PAPR also leads to saturation in power amplifiers, that generate inter modulation among the sub carriers. Therefore reducing PAPR can be regarded as an important issue to realize efficient & affordable mobile communication. In this Paper, an advanced PAPR reduction technique, named Iterative Clipping and filtering (ICF) is used to abate the disadvantage of high (PAPR). Iterative processing is performed to limit the PAPR in time domain but the subtraction process of the peak that over PAPR threshold with the original signal is done in frequency domain, not in time like usual clipping technique. In the whole paper we see that ICF technique is the simplest way to achieve reduced PAPR.

Keywords: OFDM, High Peak to Average Power Ratio, Iterative Clipping and Filtering, Power Amplifier and Efficiency.

Introduction

High Peak-to-Average-Power-Ratio (PAPR) has been a major hazard of multicarrier signals. PAPR when passed through a non-linear High-Power-Amplifier (HPA), 'peaky' multicarrier signals which leads to develop in-band distortion and degenerate useful signal, and the other problem i.e. out-of-band leakage interferes adjacent channels. Amplifier needs power back-off, however may lead to ineffective amplification (i.e. more input power is required). PAPR is acceptably made up of so many subcarriers. These subcarriers are added constructively to form large peaks. High peak power needs High Power Amplifiers (HPA), A/D and D/A converters. Peaks are distorted nonlinearly due to amplifier inadequacy in HPA.

If HPA works in nonlinear region, out of band and in-band spectrum radiations are developed which appears as the adjacent channel interference and if it is not worked in linear region with large power backs-offs, it may not been achievable to keep the out-of-band power below the certain limitations. These further points to inefficient amplification. To abstain all these problems, power amplifiers has to be operated in its linear region. [1].

Clipping amplitude is defined as the simplest technique for reducing PAPR. As the existence of very high peaks is few, the method of clipping can reduce peaks at small cost of performance degradation. Clipping provides acceptable system performance and the conventional error correction codes can offset any such small degradation [2].

The main purpose of PAPR reduction is to improve the amplifier efficiency with minimal trade-offs.

A. OFDM

Orthogonal frequency-division multiplexing (OFDM), in some cases known as multicarrier modulation (MCM) or discrete multi tone (DMT) is a well known modulation technique that is tolerant to channel disturbances and impulse noise. Multi carrier modulation have been developed 1950's by introducing two modems, the Collins Kineplex system and the one so called Kathryn modem. OFDM has remarkable properties such as bandwidth efficiently, highly flexible in terms of its adaptability to channels and robustness to multipath. To achieve higher spectral efficiency in multicarrier system, the sub-carriers must have overlapping transmit spectra but at the same time they need to be orthogonal to avoid complex separation and processing at the receiving end [1]. As it is stated in, the orthogonal set can be represented as such

$$\left\{\frac{1}{\sqrt{T_s}}\exp^{jw_k t}\ \text{for}\ t\in[0,T_s]\right\} \qquad (1)$$

With $w_k = w_0 + kw_s; \quad k = 0,1,\ldots,N_c - 1$

w_0 Is the lowest frequency used and w_k is the subcarrier frequency.

As a substitute of bank of matched filters & baseband modulator, Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) is active method of OFDM system implementation.

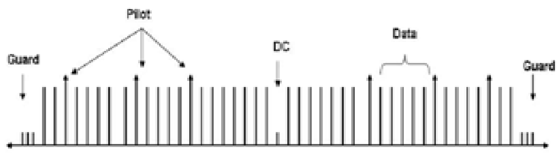

Fig.1 OFDM sub carrier

B. Peak to Average Power Ratio

High Peak-to-Average Power Ratio has been recognized as one of the major practical problem involving OFDM modulation. Generally, the PAPR of OFDM signals *x*(*t*) is defined as the ratio period between the maximum instantaneous power and its average power during an OFDM symbol [3].

The PAPR can be defined as

$$\text{PAPR}=10\log_{10}\frac{P_{peak}}{P_{av}} \qquad (2)$$

Where P_{peak} and P_{av} can be compute as:

$$P_{peak}=\max|x(t)|^2 \qquad (3)$$

$$P_{av}=\frac{1}{T}\int_0^T |x(t)|^2 dt$$

Hence, the PAPR is expressed as:

$$\text{PAPR}=10\log_{10}\frac{\max|x(t)|^2}{\frac{1}{T}\int_0^T |x(t)|^2 dt} \qquad (4)$$

When N sinusoids add, the peak magnitude would have a value of N, where the average may be quite low because of the destructive interference between the sinusoids. High PAPR signals are usually outcast for it and usually force the analog circuitry. For e.g. power amplifier has High PAPR, signals may require a large range of dynamic linearity from the analog circuits which commonly results in expensive devices and high power consumption with lower efficiency (operate with larger back-off to maintain linearity) [3].

In OFDM system, some input sequences would be resulted in higher PAPR than others that mean, input sequence that need all such carriers to transmit their maximum amplitudes would surely result in a high output PAPR. Thus by assigning the possible input sequences to a smallest sub set, it may be possible to obtain output signals with a assured low output PAPR.

High PAPR may create problems when the signal is enforced to transmitter that contains non-linear components such as High Power amplifier (HPA) in the Transmitter chain. The PAPR has the least case value that depends on the no of subscribers N. The non-linear effects on the transmitted OFDM symbols are changing the signal constellation, inter-modulation, spectral spreading. In other way, the nonlinear distortion generates both in-band and out-of-band interference to signals [3].

In [3] the complementary cumulative distribution function (CCDF) assessment of PAPR and has stochastic characteristics. The CCDF of PAPR is defined as the expectation that the PAPR of the OFDM symbols surmount a given threshold A such as

$$\text{CCDF}=1-\Pr(\text{PAPR}\geq A) \qquad (5)$$

CLIPPING AND FILTERING METHOD

In practice, the oversampling technique is widely used for the OFDM. Consider an OFDM system with *N0* sub-carriers. With oversampling, only a subset of *N* sub-carriers is used to carry information. The rest *N0* ¡ *N* sub-carriers are not used. These sub-carriers are usually located in the high frequency end. Such arrangement eases the requirement on the analog filter after the digital-to-analog conversion since the unused sub-carriers can be used for the transition band of the analog filter [4].

The oversampling factor is defined as

$$L = N_0 = N. \qquad (6)$$

In [3] the method of Clipping and Filtering can be seen with modulation technique, QAM. The OFDM signal contains high peaks so it is conveyed from the clipping. In this when amplitude is above the threshold value, the amplitude is clipped off shown in fig 2, while compensating the phase. The clipped sample is given by

$$X_c(n)=\begin{cases}|x(n)| & if \quad |x(n)| \le A(thershold) \\ A & if \quad |x(n)| > A(threshold)\end{cases} \quad (7)$$

The out-of-band radiations appear without filtering due to non linearity. To abate the interference to neighboring channels, out-of-band components must be broken with a band limiting filter. The peak growth becomes less after filtering the oversampled signal. The remade clipping and filtering can reduce the peak re-growth and access the system cost. So there has been a composition between PAPR and system cost also [6].

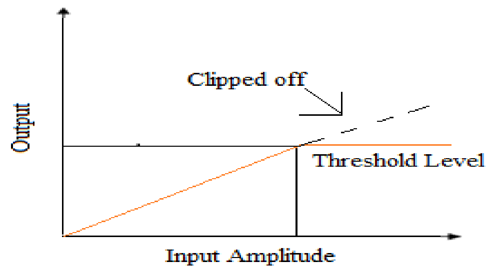

Fig.2 Clipping Method

C. Power Amplifier and Efficiency

Amplifier model is very important for power analysis. We assume a linear power amplifier (PA) model (equivalent to ideally pre-distorted non-linear amplifier)

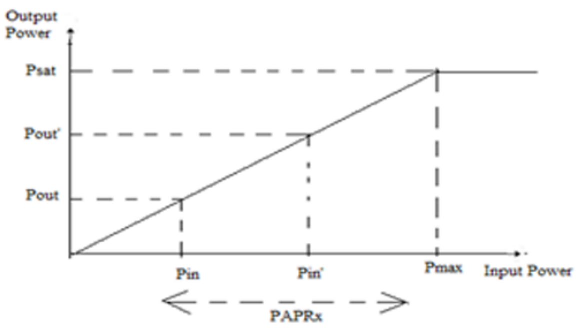

Fig.3 A linear amplifier

as shown in the Fig (3). Input signal is amplified linearly until a certain level and thereafter is clipped to the output saturation level Psat. To optimize the amplifier operation, the input power is biased such that the maximum output power always remains around Psat. Appropriate amplifier back-offs need to be maintained to avoid excessive in-band distortion and spectral leakage. Back-offs are specified in terms of output back-off (OBO) or input back-off (IBO). OBO is the ratio of Psat and average output power Pout, whereas IBO refers to the ratio of input power corresponding to output saturation level, Pmax and average input power Pin. In a linear amplifier, IBO=OBO with the maximum input power satisfying [5].

$$\max_{0\le n\le N-1}|x_n|^2 = P_{max} \quad (8)$$

We can write IBO=OBO=PAPR.

The efficiency of a PA is defined as,

$$\eta=\frac{P_{out}}{P_{dc}} \quad (9)$$

P_{dc} being a constant amount of power consumed by the amplifier regardless of the input power. Class A PAs are the most linear amplifiers with maximum efficiency of 50% and its efficiency is given by η = 0.5/OBO. Therefore, we can write the efficiency in terms of input signal PAPR as,

$$\eta=\frac{0.5}{PAPR_x} \quad (10)$$

In [8] to get an idea how inefficient would be the PA in the case of original OFDM signals, we take an example of N = 256 and p = 10−5. From Fig. 3, considering that the input signal PAPR is 12.7dB (=18.62) at which the amplifier has efficiency of only 0.5/18.62 = 2.68%. Such a low efficiency, for instance, would drain the battery power very quickly. To prolong the battery life and save the system power, we need to seek to lower PAPR. Every 3dB PAPR reduction doubles the amplifier efficiency.

Combining equations (7) and (8), we get

$$P_{dc}=2P_{out}.PAPR_x \quad (11)$$

or equivalently

$$\eta=\frac{0.5P_{dc}}{PAPR_x} \quad (12)$$

The impact of the PAPR reduction on the power analysis can be seen in two ways.

1) When the average output power Pout is fixed, and
2) When the supply power Pdc is fixed.

Taking expectation of both sides in Equations (9) & (10), average power trade-offs can be written as,

$$E[P_{dc}]=22P_{out}.EPAPR_x] \quad (13)$$

And

$$E\,[P_{out}]=\frac{0.5\,P_{dc}}{E[PAPR_x]} \qquad (14)$$

The PAPR reduction, thus, translates into either power savings when P_{out} is fixed or increased transmitted output power when P_{dc} is fixed [8].

SIMULATION AND RESULT

The software has been developed to simulate the OFDM transmission and PAPR reduction technique are evaluated on same test bench .The following parameter are taken during simulation

S. No.	Parameter	Specification value
1	FFT size	64
2	Modulation technique	BPSK
3	PAPR reduction technique	ICF
4	SNR range	0-18 Db
5	CP length	16

The simulation result of above is evaluated. CCDF result with and without ICF technique are given in the figure 4.

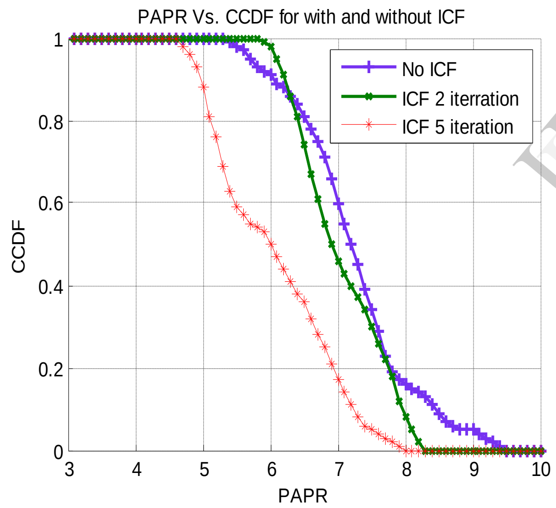

Fig.4 PAPR vs CCDF curve

CONCLUSION

High PAPR leads to saturation in power amplifiers, that generate inter modulation products among the sub carriers and disturbing out of band energy. Therefore, it is covetable to reduce the PAPR. In this paper, the use of iterative clipping and filtering (ICF) technique covers most of the basic needs of practical PAPR reduction techniques include the agreement with the family of existing modulation schemes, high spectral efficiency and low complexity. Thus we use ICF technique to reduce the PAPR in multicarrier system by applying BPSK with N=64 subcarriers. In the whole paper we see that ICF technique is the simplest way to achieve reduced PAPR & based on the performance of CCDF curve we see that after 5 iterations the PAPR value will decrease, but at same time the BER performance is degraded. Thus for sorting the BER performance we may apply various coding techniques like FEC codes, Huffman coding, convolution coding etc.

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