Peak to Average Power Ratio Reduction in OFDM Systems Using Clipping and Filtering Technique

Begared Salih Hassen

Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) has been currently under intense research for broadband wireless transmission due to its robustness against multipath fading. However OFDM signals have a problem with high Peak-to-Average power ratio (PAPR) and thus, a power amplifier must be carefully manufactured to have a linear input-output characteristic or to have a large input power back-off. The drawbacks of high peak to average power ratio (PAPR) can outweigh all the potential benefits of Orthogonal Frequency Division Multiplexing (OFDM) signals. In this Paper, a sophisticated PAPR reduction technique, named Iterative Clipping and filtering (ICF) is proposed for OFDM system. By considering the example of OFDM, with Quadrature Phase-Shift Keying (QPSK) mapping, simulation results under Matlab environment show that the proposed method performs well in reducing PAPR..

Index Terms*— OFDM, High Peak to Average Power Ratio, Iterative Clipping and Filtering..

I. INTRODUCTION

Latest Technologies and therefore new applications are emerging not just in wired environment but also in the wireless arena. The next generation mobile systems are expected to provide a substantially high data rate to meet the requirements of future high performance multimedia applications. To provide such a high data rate with high spectral efficiency, new methods must be used to reduction the multipath effects and PAPR. scheme. A promising modulation technique that is increasingly being considered for adoption by 4G community is OFDM [1]. Orthogonal Frequency Division Multiplexing (OFDM) possesses some desirable attributes, such as immunity to the inter-symbol interference, robustness with respect to multi-path fading, and ability for high data rates. Thus, OFDM has been proposed in various wireless communication standards such as IEEE802.11a standard for wireless Local Area Networks (WLAN), IEEE802.16a standard for Wireless Metropolitan Area Networks (WMAN), digital audio/video broadcasting, Terrestrial Digital Video Broadcasting (DVB-T), the ETS1 HIPERLAN/2 standard and high speed cellular data [2]. However, one of the key a disadvantage of OFDM system has been its high Peak-to-Average Power Ratio (PAPR). The high PAPR brings the OFDM signal distortion in the non-linear region of high power amplifier (HPA) and the signal distortion induces the degradation of bit error rate (BER). Moreover, to prevent spectral development of the multicarrier signal in the form of inter-modulation among subcarriers and out-of-band radiation, the transmit power amplifier has to be operated in its linear region [3]. If the HPA is not operated in linear region with large power back-offs, it is not possible to keep the out-of band power below the specified limits. This situation leads to very inefficient amplification and expensive transmitters. Therefore, it has been important and necessary to research on the characteristics of the PAPR, including its distribution and reduction, in OFDM systems, in order to utilize the technical features of the OFDM [4]. In 2005, the Wi-media alliance worked with the European Computer Manufactures Associations (ECMA) and announced the establishment of the Wi Media MB-OFDM (Multiband Orthogonal Frequency Division Multiplexing), Ultra- Wideband (UWB) radio platform as their global UWB standard, ECMA-368 and the latest updated version incorporated spectral nulling. ECMA -368 was also chosen as the physical layer (PHY) for the high data rate wireless specifications, for high-speed wireless USB (W-USB), Bluetooth 3.0 and wireless high-definition Media Interface (HDMI) [5]. To reduce the PAPR several techniques have been proposed such as partial transmit sequences (PTS) [6], selective mapping (SLM) [7], clipping and filtering [8], using unitary matrix [9], tone reservation (TR) and tone injection (TI) [10]. Each of these methods has a different cost for the reduced PAPR. Although some techniques of PAPR reduction have been summarized, it is still necessary to give a comprehensive review of PAPR reductions in terms of transmission power, data rate loss, implementation complexity and BER performance, etc..

Manuscript Received on March, 2014.
Begared Salih Hassen, Electronic Technique Dept. Institute of Technology, Baghdad, Iraq.

II. BENEFITS OF OFDM

The main benefits of OFDM compared to other multi-carrier techniques are [11]:-

1. Spectral efficiency
2. Resiliency to RF interference
3. Lower multi-path distortion
4. High bit rate wireless communications
5. Reducing ISI probability.

III. DISADVANTAGES OF OFDM

OFDM signals have a high peak to average power ratio (PAPR) causing RF devices to operate at a lower efficiency to avoid working in their non-linear region. OFDM systems also require a guard interval that causes a loss in power and bandwidth efficiency. Besides that, OFDM is sensitive to frequency offsets and phase noise. Frequency offsets occur when the voltage-controlled oscillator (VCO) at the receiver is not oscillating at exactly the same carrier frequency as the VCO in the transmitter. For the receiver, this offset between the two VCOs is seen as frequency translation in the signal and can lead to an increase in the error rate. While this is generally true for all

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

modulations, OFDM is particularly sensitive to frequency offsets. In addition to the constant frequency offset discussed above, the frequency generated by a practical VCO tends to jitter, or vary, over time. To the receiver, this frequency variation looks like noise in the phase of the received signal and as a result this impairment is referred to as phase noise [11]

IV. THE PAPR PROBLEM OF OFDM

An OFDM signal consists of a number of independently modulated sub-carriers, which can give a large peak-to-average power ratio (PAPR) when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. Because OFDM signal has a very large PAPR, it is very sensitive to non-linearity of the high power amplifier that is RF power amplifiers should be operated in a very large linear region. Otherwise the signal peaks get into non-linear region of the power amplifier causing signal distortion. This distortion introduces intermediation among the subcarriers and out of band radiation. and the high PAPR increase complexity of the analog to digital (A/D) and digital to analog (D/A) converters.[12] The PAPR of the continue-time OFDM signal is defined as

$$PAPR = \frac{\max_{0 \le t \le T} |X(t)|^2}{E\left[\frac{1}{T}\int_0^T X|(t)|^2 dt\right]} \qquad (1)$$

The PAPR of the discrete-time OFDM signal is defined as

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

Nee and Prasad [12] mention that the amplitude of the OFDM signal has a Rayleigh distribution, while the power distribution becomes a central chi-square distribution with two degrees of freedom and zero mean, with a cumulative distribution given by

$$F(X) = 1 - e^{-x} \qquad (3)$$

Assuming the samples of OFDM symbol are mutually uncorrelated and non-oversampling. The probability of PAPR is below some threshold level can be written as

$$P(PAPR > X) = 1 - (1 - e^{-x})^N \qquad (4)$$

The assumption made in deriving Equation 4 that the samples should be mutually uncorrelated is not true anymore when oversampling is applied. Because it seems quit difficult to come up with an exact solution for the peak power distribution, Nee and Prasad [12] propose an approximated by the distribution for LN sub-carriers without oversampling, with L large than one. Hence, the effect of oversampling is approximated by adding certain number of extra independent samples. The distribution of PAPR is the given by

$$P(PAPR > X) = 1 - (1 - e^{-x})^{LN} \qquad (5)$$

In this paper, we will use Equation 5 to compare the CCDF (Complementary Cumulative Distribution Function) of the proposed method with selective sinusoidal transform method. In order to obtain an exact and reasonable result, we let 20,000 sets of randomly generated data in time domain when the number of subcarriers is 64, 128, 256, 512, 1024, 2048, 4096 and 8192.

The complementary cumulative distribution function (CCDF) is the distribution of PAPR and has stochastic characteristics. The CCDF of PAPR is defined as the probability that the PAPR of the OFDM symbols exceeds a given threshold A such as [12]

$$CCDF = 1 - Pr(PAPR \le A) \qquad (6)$$

V. CLIPPING AND FILTERING TECHNIQUE

Nee and Prasad [12] mention, "The simplest way to reduce the PAPR is to clip the signal, such that all signal values cannot exceed the threshold are limited to the threshold. Although clipping is definitely the simplest solution, there are a few problems associated with it. First, by distorting the OFDM signal amplitude, a kind of self-interference is introduced that degrades the bit error rate (BER). Second, the nonlinear distortion of the OFDM signal significantly increases the level of the out-of-band radiation. The latter effect can be understood easily by viewing the clipping operation as a multiplication of the OFDM signal by a rectangular windows function which amplitude is the clipping threshold. The spectrum of the clipped OFDM signal is found as the input OFDM spectrum convolved with the spectrum of the window function. The out-of-band spectral properties are mainly determined by the wider spectrum of the two, which is the spectrum of the rectangular window function. This spectrum has a very slow roll-off that is inversely proportional to the frequency."The simplest and most widely used technique of PAPR reduction is to basically clip the parts of the signals that are outside the allowed region [8]. For example, using HPA with saturation level below the signal span will automatically cause the signal to be clipped. Generally, clipping is performed at the transmitter. However, the receiver need to estimate the clipping that has occurred and to compensate the received OFDM symbol accordingly. Iterative clipping and filtering (ICF) is a widely used technique to reduce the PAPR of OFDM signals. However, the ICF technique, when implemented with a fixed rectangular window in the frequency-domain, requires many iterations to approach the specified PAPR threshold in the complementary cumulative distribution function (CCDF). Figure 1 shows the basic block diagram of the classic ICF PAPR reduction scheme.

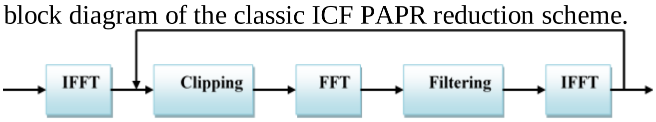

Figure 1. Block Diagram of the Classic ICF Using FFT/IFFT

In the first iteration (i=1), the new OFDM symbol enters the ICF block. Then clipping and filtering is iteratively performed. In the I th (final) iteration, the output x is produced. Typically, at most one clipping occurs per OFDM symbol, and thus the receiver has to estimate two parameters: location and size of the clip. However, it is difficult to get these information. Therefore, clipping method introduces both in band distortion and out of band radiation into OFDM signals, which degrades the system performance including BER and spectral efficiency. Filtering can reduce out of band radiation after clipping although it cannot reduce in-band distortion. However, clipping may cause some peak re-growth so that the signal after clipping and filtering will exceed the clipping level at some points. To reduce peak re-growth, a repeated clipping-and-filtering operation can be used to obtain a desirable PAPR at a cost of computational complexity increase. As improved clipping methods, peak windowing schemes attempt to minimize the out of band radiation by using narrowband windows such as Gaussian window to attenuate peak signals [8].

VI. OFDM SYSTEM MODEL

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required based on the input data, and modulation scheme used. Each carrier to be produced is assigned same data to transmit. The required amplitude and phase of them are calculated based on the modulation scheme. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform (IFT). In most applications, an
Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently and provides a simple way of ensuring the carrier signals produced are orthogonal. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time domain signal. An IFFT converts a number of complex data points, of length that is a power of 2, into the time domain signal of the same number of points. Each data point in frequency spectrum used for an FFT or IFFT is called a bin. The orthogonal carrier required for the OFDM signal can be easily generated by setting the amplitude and phase of each frequency bin, thus performing the IFFT. The signal generated is at base band and so to generate an RF signal, the signal must be filtered and mixed to the desired transmission frequency.

VII. SIMULATION AND RESULTS

In this work, computer simulation is implemented to evaluate the performance of the proposed method. The OFDM system was modeled using MATLAB to allow various parameters of the system to be varied and tested. Table 1 shows the values of parameters were used in the simulation model. A simple AWGN channel is used as channel model. Two set number of subcarrier (N=256) were tested with five, ten and twenty percent of trimming percentage. The simulation results will be presented as the (CCDF) of the PAPR of the OFDM signals.
We use the MATLAB simulations to evaluate the performance of the proposed PAPR reduction techniques over 64 subcarriers with QPSK modulated data. As a performance measure for different techniques, we use the CCDF of the PAPR. Performances of the proposed system are first compared with before using Clip and Filter techniques. Fig (3) shows the comparison between original signal, peak signal and clipped signal from this Figure explain this way have best performance to reduction PAPR. Fig (4) shows the comparison between original signal and one, two, three and four clip and filter signal from this Figure can be conclude when increase the iteration of clip and filter decrease CCDF of the PAPR

Table 1: Simulation Parameters

Parameters	Values
Modulation scheme	**QPSK**
Estimator	**MMSE**
Channel	**AWGN**
Oversampling Factor	**4**
No. of Subcarrier	**256**
Data Block Size	**16**
FFT Size	**256**
$\mathbf{T_{FFT}}$	**3.2µs**

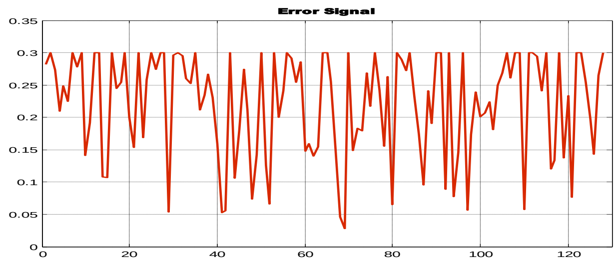

Figure 2. Explain the Error Signal before Clip and Filter techniques

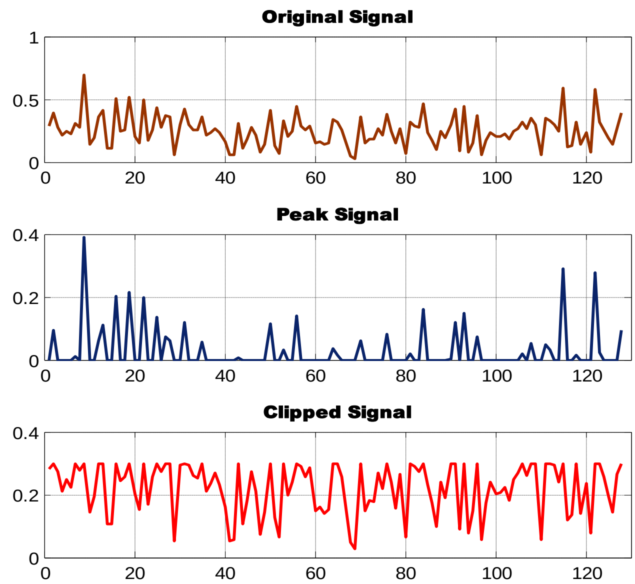

Figure 3. Explain the Original, Peak and Clipped Signal, using Clip and Filter technique

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

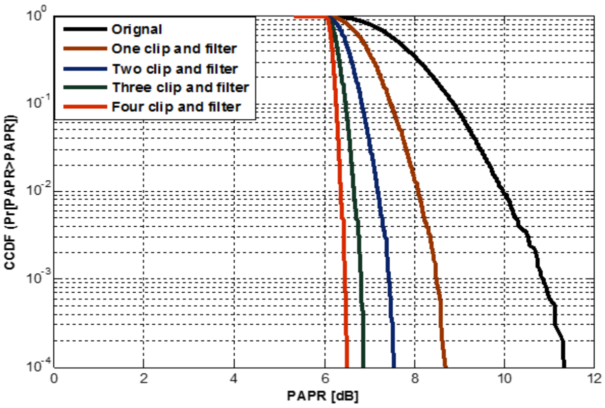

Figure 4. Comparisons of CCDF based on different iteration Clip and Filter techniques

VIII. CONCLUSION

A PAPR reduction method for the OFDM system by clip and filter has been proposed and investigated. This was achieved by replacing the conventional arithmetic mean formula in the PAPR calculation formula. The performance is seen through CCDF curves. Although we demonstrate that significant PAPR reduction is obtained through Iterative clipping and filtering using FFT/IFFT transform .The proposed method is more suitable for OFDM applications that are sensitive to spectral efficiency and noise, since it allows reduction in PAPR value.

REFERENCES

1. Z. Cheng, D. Dahlhaus: Time versus Frequecy Domain Channel Estimation for OFDM Systems with Antenna Arrays, Proc. of the 6th International Conference on Signal Processing, ICSP'02, vol. 2, pp 1340-1343, Aug. 2002
2. Jeffrey G. Andrews, Ph.D., Arunabha Ghosh, Ph.D,Rias Muhamed., ed, Fundamentals of WiMAX Understanding Broadband Wireless Networking. Theodore S. Rappaport, Series Editor, ed. P.H.C.E.a.E.T. Series. 2007
3. Y.-J. Wang, W. Chen. A PAPR Reduction Method Based on Artificial Bee Colony Algorithm for OFDM Signals. IEEE Trans. Wireless Commun.; vol. 9, no. 10, pp. 2994-2999, Oct. 2010.
4. L. J. Cimini Jr. and N. R. Sollenberger. Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences. IEEE Comm. Lett.; vol. 4, no. 3, pp. 86-88, Mar. 2000.
5. Physical Channels and Modulation (Release 9); 3GPP TS 36.211 v9.1.0, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); 2010.
6. T.Jiang, W.Xiang, P.C.Richardson, J.Guo, and G. Zhu, "PAPR Reduction of OFD Signals Using Partial Transmit Sequences with Low Computational Complexity," IEE Transactions on Broadcasting, Vol.53, No.3, September 2007, pp.719-724.
7. C.-P. Li, S.-H. Wang, and C.-L. Wang. Novel Low-Complexity SLM Schemes for PAPR Reduction in OFDM Systems. IEEE Trans. Signal Processing; vol. 58, no. 5, pp. 2916-0921, May. 2010.
8. Y.-C. Wang and Z.-Q. Luo. Optimized Iterative Clipping and Filtering for PAPR Reduction of OFDM Signals. IEEE Trans. Commun.; vol. 59, no. 1, pp. 33-37, Jan. 2011.
9. X. Zhu, G. Zhu, and T. Jiang. Reducing the peak-to-average powerra-dio using unitary matrix. IET Commun.; vol. 2, no. 2, pp. 161-171, 2009.
10. D.Guel and J.Palicot, "FFT/IFFT Pair based Digital Filtering for the Transformation of Adding Signal PAPR Reduction Techniques in Tone Reservation Techniques," Fifth International Conference on Wireless and Mobile communications, (ICWMC 2009), August 2009.
11. Y.Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: A multi-carrier modulation scheme," IEEE Trans. Consumer Electronics, vol. 41, no. 3, pp. 392–399, Aug. 1995.
12. J. Tellado, "Peak to Average Power Ratio Reduction for Multicarrier Modulation," PhD thesis, University of Stanford, Stanford, 1999.

AUTHOR PROFILE

Begared Salih Hassen Received her B.Sc. in Electrical and Electronics from the Faculty of Electrical Engineering, College Of Electrical and Electronic Techniques Baghdad, Iraq in 2005, received the M.Sc. degree in Electrical engineering from Faculty of Electrical Engineering, College Of Electrical and Electronic Techniques Baghdad, Iraq in 2010. Currently she is Assist Lecturer, Researcher and training supervisor, Dep. of Electronic in Institute of Technology Baghdad