World Applied Sciences Journal 18 (11): 1495-1500, 2012
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2012.18.11.1799

PAPR Reduction in OFDM using Clipping and Filtering

W. Aziz, E. Ahmed, G. Abbas, S. Saleem and Q. Islam

Department of Electrical Engineering, Institute of Space Technology, Islamabad, Pakistan

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is an emerging field of research in the field of wireless communication and finds its application where high data rate is required at low latency and better spectral efficiency. Peak to Average Power Ratio (PAPR) is the limiting factor for an OFDM system as it degrades the system performance by reducing SQNR of ADC/DAC as well as affects transmitter amplifier. There are many techniques to overcome the problem of PAPR like Clipping and Filtering, Coding Technique, Scrambling Technique and many more. In this paper we discussed clipping and filtering technique which is easy to implement and reduces the amount of PAPR by clipping the peak of the maximum power signal. Moreover, analysis of PAPR is given by varying different parameters.

Key word: OFDM . wireless communication . PAPR . SQNR . clipping and filtering

INTRODUCTION

OFDM has its major benefits of higher data rates and better performance. High data rates are achieved by the use of multiple carriers and performance improvement is caused by the use of guard interval thus mitigating ISI. Apart from these basic benefits, it also increases spectral efficiency, minimizes multipath distortion and many more. Keeping in view these benefits, it has a really nice market penetration and one of the most useful technologies is WLAN and OFDM is used in IEEE 802.11a/g/n architectures quite successfully [1].

Although the use of multiple carriers is quite handy, it is accompanied by a lot of implementation problems like major one being the high Peak to Average Power Ratio (PAPR) of OFDM systems. It is given as:

$$PAPR[\tilde{x}] = \frac{\max|x(t)|^2}{E\left[|x(t)|^2\right]} \qquad (1)$$

Where x(t) denotes the pass band signal whose PAPR is to be calculated.

The subsystems used in communication are linear over a limited range. The more frequently used is HPA at the transmitter end to increase the transmitted power. However, the OFDM receiver detection is degraded severely by the use of non-linear so HPA should not be used at full capacity but should be backed off to the limited linear range [4].

PAPR limits DAC and ADC at transmitter and receiver end respectively. It increases Signal to Quantization Noise Error; this has to be increased to tackle the quite high peak powers. One way to minimize is the use of logarithmic quantizer which reduces it to some extent by smaller step sizes for higher amplitudes [5]. This is good as the probability of getting higher power decreases as the power is increased. This probabilistic behavior is discussed in detail in the work to follow. However for the best performance, more advanced ways are used.

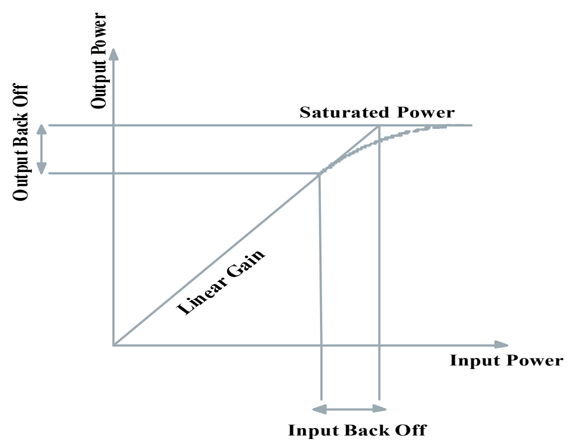

Fig. 1: Power characteristics of high power amplifier

One technique depicts the chopping of excessive power pattern but this increases interference a lot. So ultimately, we have to use the amplifier with a high dynamic range [6]. The basic problem with the amplifiers is the decrease in efficiency with the increase in dynamic range. The amplifier efficiency η is directly given in the term of PAPR as:

Corresponding Author: W. Aziz, Department of Electrical Engineering, Institute of Space Technology, Islamabad Pakistan

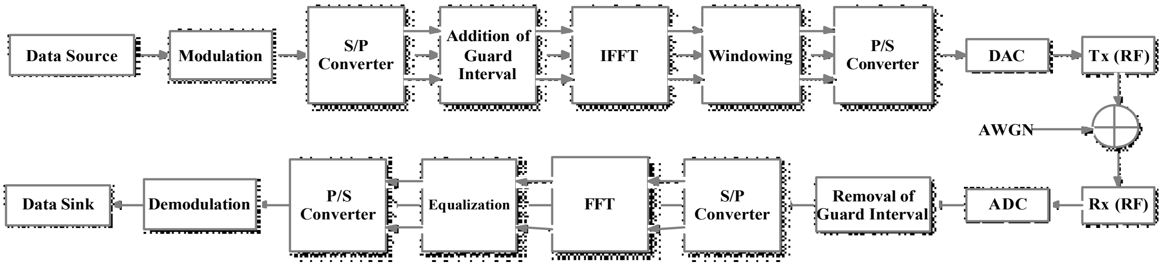

Fig. 2: OFDM system model

$$\eta = \frac{0.5}{PAPR} \quad (2)$$

So this also compels the OFDM system designer to decrease PAPR effectively thus saving power. This paper is distributed as; first the system model of OFDM system with PAPR will be discussed, then simulation results and analysis will be given and at the end the whole work will be concluded.

SYSTEM MODEL

Let an OFDM symbol consists of L subcarriers with time duration of T. We have stream of data $D_{b,n}$ on the nth subcarrier in the bth OFDM symbol then transmitted symbol can be written as:

$$I(t) = \sum_{b=-\infty}^{\infty} \sum_{n=0}^{L-1} D_{b,n} W_{b,n}(t) \quad (3)$$

Where $W_{b,n}(t)$ can be explained by this expression:

$$W_{b,n}(t) = e^{\frac{2\pi jn}{T}}(t - T_g - bT_c) \quad (4)$$

In the above expression T_g is the guard interval inserted among the symbols to avoid collisions and T_c is the total duration of the symbol [7].

Transmitted symbol is passed through Rayleigh Fading channel when medium is wireless. We can approximate the impulse response of Rayleigh Fading channel as:

$$h(t,\tau) = \sum_{b=0}^{L-1} \gamma_b \delta(t - \tau_b) \quad (5)$$

L denotes the total number of multipath through which signal passes and γ_b shows the time varying gain.

The received signal after passing through the channel can be approximated as:

$$Y(t) = \sum_{b=0}^{L-1} \gamma_k \delta(t - \tau_k) + n(t) \quad (6)$$

n(t) shows the Additive White Gaussian Noise (AWGN), an inherited property of the wireless channel.

The received signal can be written in frequency domain as:

$$Y_{b,n} = I_{b\,n} * H_{b\,n} + N_{b,n} \quad (7)$$

$I_{b,n}$ denotes frequency response of the transmitted signal, $H_{b,n}$ shows the frequency response of the Rayleigh Fading channel and in the same way $N_{b,n}$ shows the AWGN noise [8].

PAPR defines a relationship between the maximum signal power to the average signal power in the pass band. It can be described by the expression (1). Let's suppose we have an OFDM system with M subcarriers in it. The maximum power signal will occur when all the M subcarriers are added with the same phases giving rise to total signal power [2]. In a case, when the expected value of the desired signal is equal to unity then PAPR can simply be demonstrated by number of subcarriers. It has been shown by [3] that the occurrence probability of maximum power signal has an inverse relation with the no. of subcarriers. Like when the value of M increases it is very less likelihood that the high power signal will occur.

If the OFDM signal x(t) has amplitude which behaves like Rayleigh Distribution then we can say that complex OFDM signal x(t) having large number of subcarriers obeys Gaussian distribution supported by the central limit theorem. Let's suppose Y_n denotes magnitudes of that complex OFDM samples then it can be approximated as:

$$Y_n = \left[\left| x\left(n\frac{T_s}{M}\right)\right|\right]_{n=0}^{M-1} \quad (8)$$

If the expected value of the desired signal is equal to unity then we can write Probability Density Function of the Y_n as:

$$PDF_{Y_n}[z] = \left\{\frac{z}{\sigma^2} e^{\frac{-z^2}{2\sigma^2}}\right\}_{n=0}^{M-1} \quad (9)$$

The maximum value of Y_n is similar to the Crest Factor (CF), which describes PAPR in the magnitude

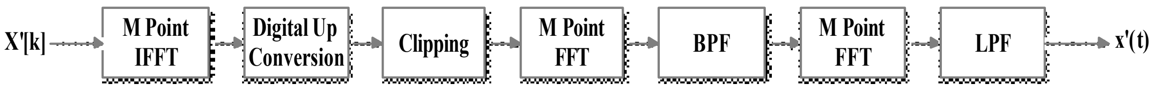

Fig. 3: Block diagram of clipping and filtering

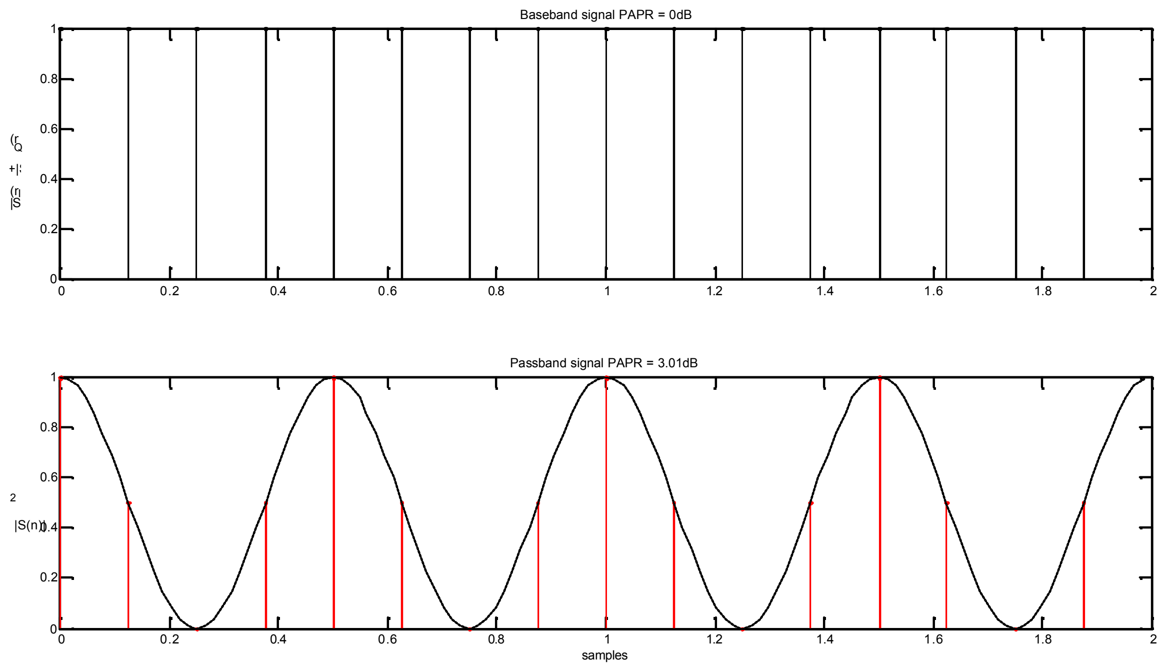

Fig. 4: PAPR difference of baseband and pass band single carrier signal

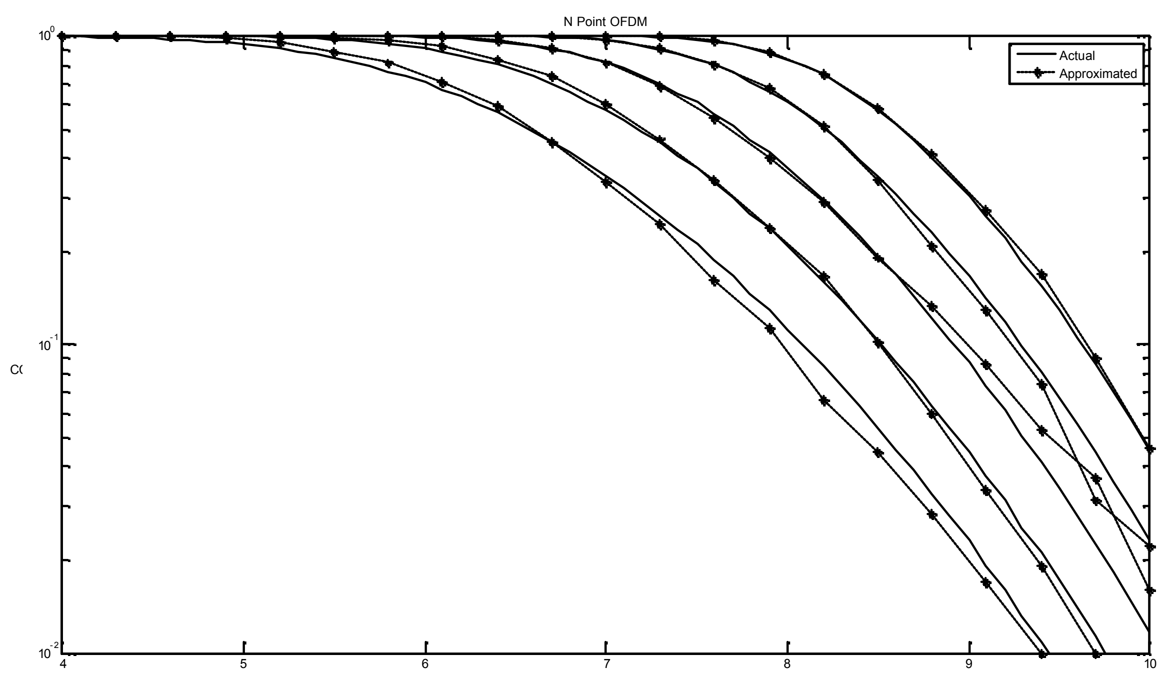

Fig. 5: Approximation of PAPR for different values of N

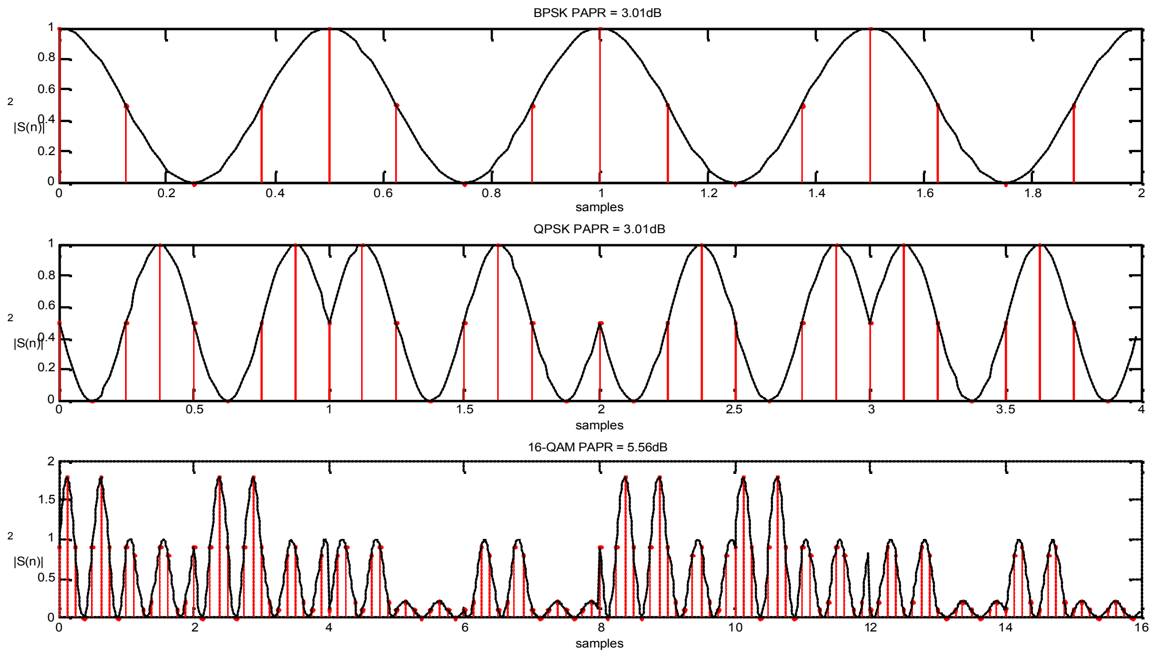

Fig. 6: PAPR of different modulation schemes

form rather than in power. Then Y_{MAX} = CF and its Cumulative Distribution Function (CDF) can be written as:

$$CDF_{Y_{max}}[z] = \Pr obability(Y_{MAX} < z) \tag{10}$$

This CDF can be approximated as:

$$CDF_{Y_{max}}[z] = \left[1 - e^{z^{-2}}\right]^{M} \tag{11}$$

Complementary Cumulative Distribution Function (CCDF) can be used to estimate that CF will have a greater value than z. CCDF estimation can be shown as:

$$CDF_{Y_{max}}[z] = \Pr obability(Y_{MAX} > z) \tag{12}$$

The equation (12) on simplification gives:

$$CCDF_{Y_{max}}[z] = 1 - [1 - e^{z^{-2}}]^{M} \tag{13}$$

The equations (11) and (13) are only valid when M is very large and signals are not oversampled. To cater for the effect of oversampling we can generalize the CDF which can be described as:

$$CDF_{Y}[z] = [1 - e^{z^{-2}}]^{\beta M} \tag{14}$$

β denotes difference between the actual and the theoretical curves.

RESULTS AND ANALYSIS

To compare the multi-carrier OFDM system, first we check the PAPR of a single carrier system in base band as well as the pass band. A sinusoid is considered as a message signal and its corresponding PAPR is calculated as shown in the Fig. 4. It is seen from the figure that PAPR of baseband signal is 0dB and pass band signal is 3dB.

As per equation (14), the CCDF is approximated. This approximation approaches actual value as the number of multiple carriers "N" increase. The actual and its approximation for different values of "N" are plotted in Fig. 5.

PAPR is very sensitive to the choice of modulation in a particular OFDM system. PAPR increases if we deal with the modulations in which amplitude of basis functions changes as in QAM. But same amplitude basis functions correspond to low PAPR. This effect is shown in Fig. 6.

The simplest of its kind, we reduce PAPR by just clipping the excessive peaks. The pass band signal has a PAPR in OFDM, so after clipping considerable PAPR reduction is seen in Fig. 6.

But this clipping expands the signal and thus ISI occurs. Here the trade off is made then by passing the clipped signal through the filter. Now the PAPR is a bit increased but on the brighter side interference is minimized.

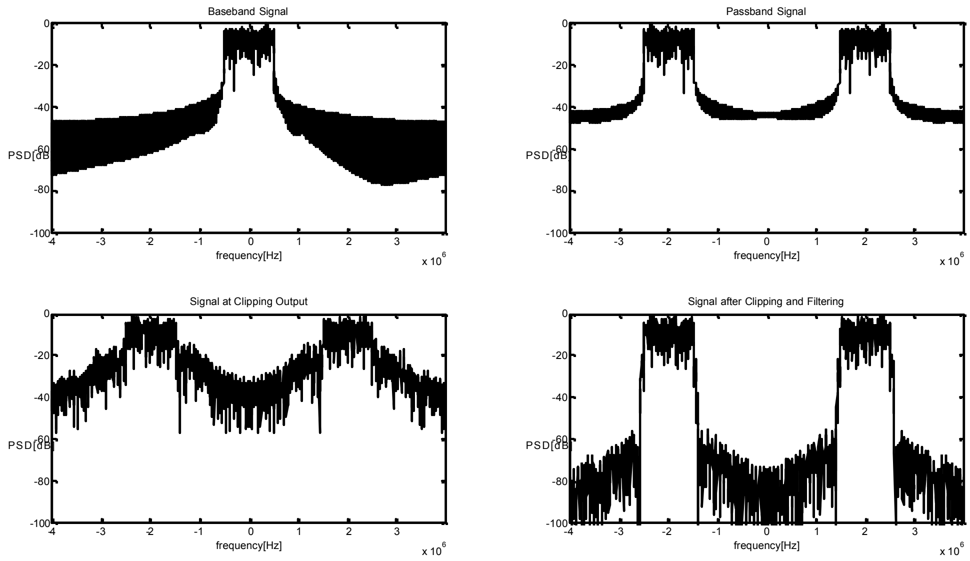

Fig. 7: Clipping and filtering technique for PAPR reduction

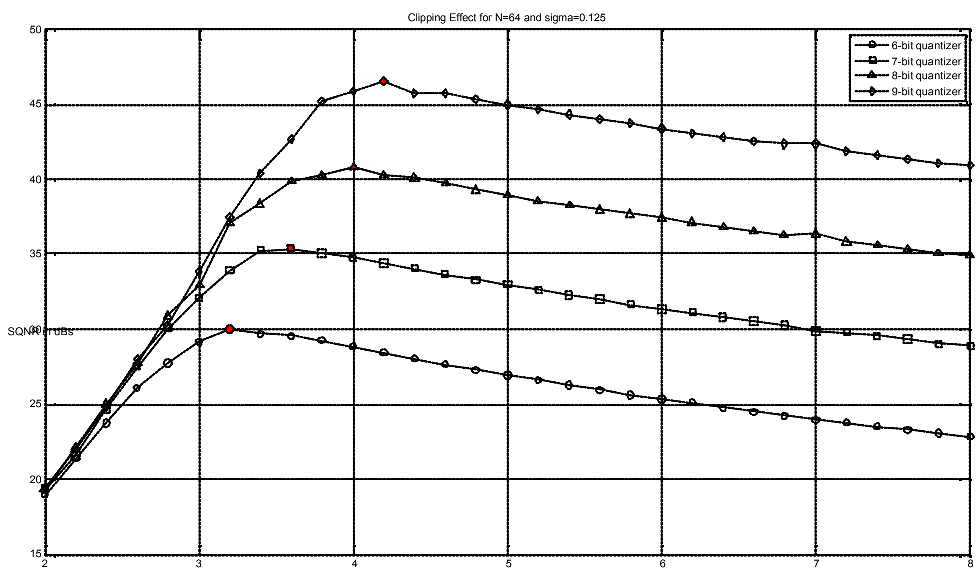

Fig. 8: SQNR for different quantization values

As mentioned earlier, the SQNR is an important parameter of OFDM system affected by PAPR problem. It changes as the number of bits for quantization changes as shown in Fig. 8.

REFERENCES

1. Ahmed, E., W. Aziz, S. Saleem and Q. Islam, 2012. Performance Analysis of OFDM System for Different Channel Lengths and Multipath Channel Taps. Advances in Electrical Engineering Systems, 1 (2): 124-128
2. Ochiai, H. and K. Imai, 1997. Block Coding Scheme Based on Complementary Sequences for Multicarrier Signals. IEICE Transactions Fundamentals, E80-A (11): 2136-2143.
3. Ochiai, H. and K. Imai, 2001. On the Distribution of the Peak-to-Average Power Ratio in OFDM Signals. IEEE Transactions on Communications, 49 (2): 282-289.
4. Shang-Kang Deng and Mao-Chao Lin, 2005. OFDM PAPR reduction using clipping with distortion control. IEEE International Conference of Communications, Taipei, Taiwan, 4: 2563-2567.

5. Liu, C., E. Skafidas, T. Walsh and R.J. Evans, 2007. A survey on OFDM PAPR reduction techniques for 60 GHz wireless CMOS radio. Australasian Telecommunication Networks and Applications Conference, Melbourne, VIC, pp: 317-321.
6. Samer, S. AI-Samahi, Stephane Y. Le Goff, Bayan S. Sharif and Charalampos C. Tsimenidis, 2008. A novel OFDM PAPR reduction scheme using selected mapping without explicit side information, Personal, Indoor and Mobile Radio Communications, pp: 1-5.
7. Saleem, S. and Q. Islam, 2011. Performance and Complexity Comparison of Channel Estimation Algorithms for OFDM System. International Journal of Electrical & Computer Sciences IJECS-IJENS, 11 (2): 6-12.
8. Saleem, S., Q. Islam, W. Aziz and A. Basit, 2011. Performance Evaluation of Linear Channel Estimation Algorithms for MIMO-OFDM in LTE-Advanced. International Journal of Electrical & Computer Sciences IJECS-IJENS, 11 (3): 64-69.
9. Aziz, W., G. Abbas, E. Ahmed, S. Saleem and Q. Islam, 2012. Design Analysis of Analog Data Reception using GNU Radio Companion (GRC). World Applied Science Journal, 17 (1): 29-35.