



PAPR Reduction in OFDM System Using Clipping and Filtering Method

¹Shilpa Bavi, ²Sudhirkumar Dhotre

¹P.G. Student, Department of Electronics & Telecommunication Engineering, Solapur, India

¹Associate Professor, Department of Electronics & Telecommunication Engineering, Solapur, India

Abstract: *In recent years, there is rapid growth in multimedia based applications, which require technologies that support high speed data transmission. To achieve this goal, orthogonal frequency division multiplexing (OFDM) is widely used. OFDM uses orthogonal subcarriers and also uses available bandwidth efficiently. However as number of subcarriers in OFDM increases, the Peak to average power ratio (PAPR) increases. This high PAPR causes significant distortions when passed through non-linear amplifier. To reduce PAPR, a number of promising techniques have been proposed & implemented. In this paper, clipping & filtering method of PAPR reduction is evaluated. It is found that clipping & filtering technique gives significant improvement in PAPR reduction with slight increase in BER.*

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)*

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]

II. FUNDAMENTALS OF OFDM SYSTEM 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, $X=[X_0, X_1 \dots X_{N-1}]^T$. 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],

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

Where,

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

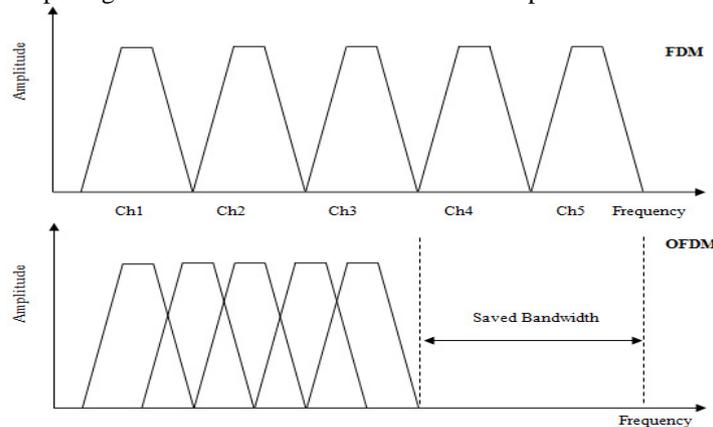


Fig.1. Comparison of the spectral utilization efficiency between FDM and OFDM schemes

C. Overview of PAPR

When the OFDM signal is transformed to time domain, the resulting signal is the sum 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. High PAPR degrades performance of OFDM signals by forcing the analog amplifier to work in the nonlinear region, distorting this way the signal and making 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],

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

III. 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],

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

where $x[n]$ is the OFDM signal, CL is the clipping level.

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 result in some peak power regrowth. Fig.2 shows OFDM signal transmission block diagram using simple clipping and filtering scheme [8].



Fig.2. OFDM signal transmission block diagram

IV. SIMULATION PARAMETERS AND RESULTS

The simulations are conducted for the OFDM signal without clipping and when clipping and filtering is used with a clipping ratio (CR) of 1dB, 5dB and 7dB. For the simulation, parameters used are given in the table 1. 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 $x[n]$.

Table I. Parameters used for simulation of clipping and filtering

Parameters	Value
Modulation	QPSK
Channel model	Rayleigh, AWGN
FFT size	64
Sub-carrier Number	52
Clipping Ratio (CR)	1dB, 5dB, 7dB
Clipping level (CL)	0.5, 0.79, 1

The OFDM signal before applying clipping and filtering as PAPR reduction method shown in fig. 3 and clipped and filtered signal after applying clipping and filtering method at three different clipping ratios 1dB, 5dB and 7dB are shown in fig.4, fig. 5, and fig. 6 respectively.

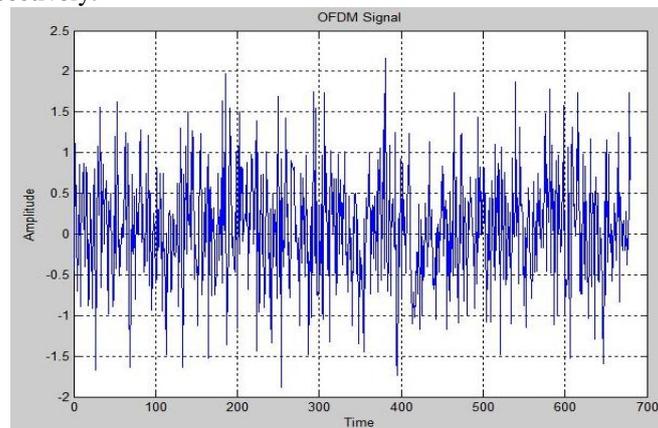


Fig. 3 OFDM signal without clipping and filtering

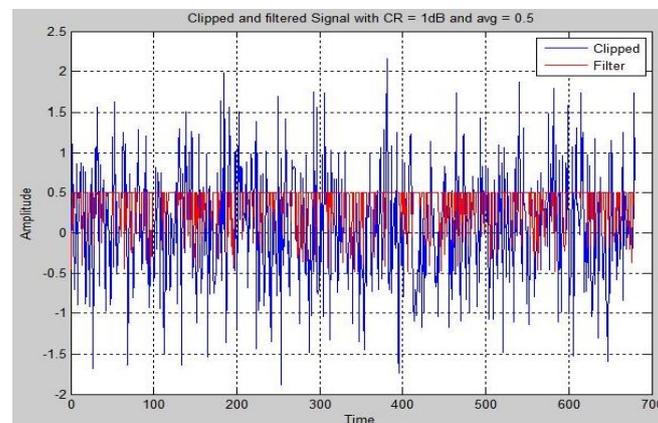


Fig. 4 clipped and filtered signal with CR=1dB and CL=0.5

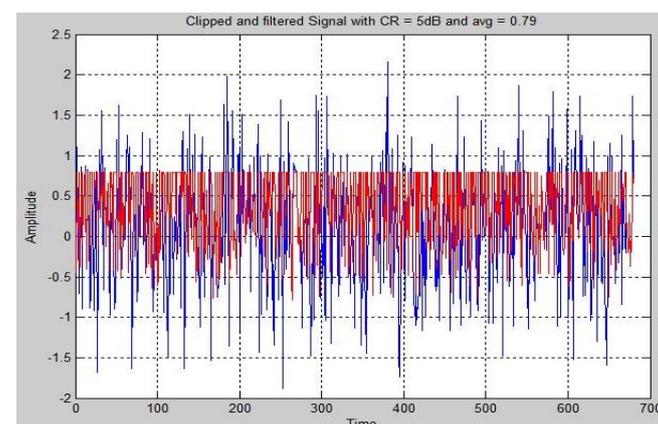


Fig. 5 clipped and filtered signal with CR=5dB and CL=0.79

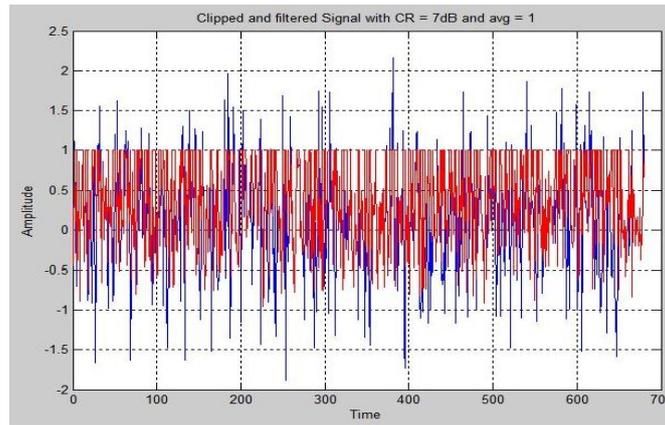


Fig. 6 clipped and filtered signal with CR=7dB and CL=1

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],

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

Where $PAPR(x^n(t))$ is the PAPR of the n^{th} OFDM symbol and δ is some threshold.

In Fig. 7, we show the empirical CCDF without clipping and with clipping & filtering method for different CR. As shown in fig. 2, 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 the required signal-to-noise ratio(SNR) to achieve a specific bit error rate(BER). Clipping the high peaks of the OFDM signal causes a substantial in-band distortion that leads to degradation in the BER performance. In Fig. 8, we show the BER performance as a function of the received signal-to-noise ratio (SNR), without clipping and with clipping & filtering method for different CR. As shown in fig. 8, as CR goes on decreasing from 7dB to 1 dB, the BER is increasing.

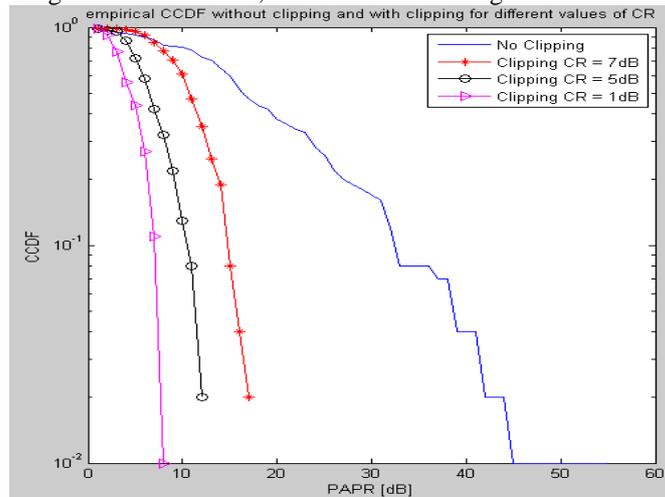


Fig. 7 Empirical CCDF without clipping and with clipping and filtering for different value of CR

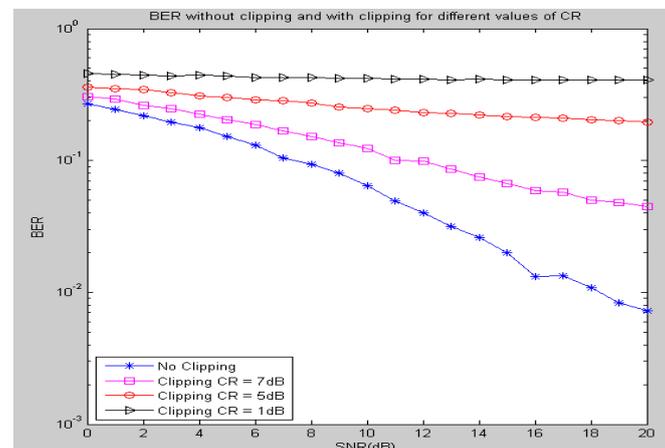


Fig. 8. BER without clipping and with clipping and filtering for different values of CR

V. 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. After implementing clipping and filtering method, the results presented in this paper show that as the clipping level decreases, the value of clipping ratio also decreases. Due to reduced clipping level, more parts of the OFDM signal are clipped. Hence the bit error rate is increasing and the empirical CCDF is decreasing which results in decreasing peak-to-average power ratio. It is observed that OFDM signal has higher PAPR without clipping and filtering and after applying clipping and filtering method; PAPR reduces significantly but at the expense of increasing the BER. By modifying and repeating clipping and filtering method, one can achieve both low PAPR and low BER.

REFERENCES

- [1] R. van Nee and R. Prasad, "*OFDM Wireless Multimedia communications*," Artech House, Boston, MA, 2000
- [2] Yasir Rahmatallah, Seshadri Mohan, Member, "Peak-To-Average Power Ratio Reduction in OFDM Systems: A Survey and Taxonomy", IEEE Communications surveys & tutorials, vol. 15, no. 4, fourth quarter 2013.
- [3] S. H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission", *IEEE Wireless Comm*, vol. 12, no.2, pp.56-65, Apr. 2005.
- [4] Sandeep Bhada, Pankaj Gulhane, A.S. Hiwalec, "PAPR Reduction scheme For OFDM", 2212-0173 © 2012 Published by Elsevier Ltd, *Procedia Technology* 4 (2012) 109 – 113.
- [5] J. Heiskala and J. Terry, *OFDM Wireless LANs: A Theoretical and Practical Guide*. Sams Publishing, 2002
- [6] H. Ochiai and H. Imai, "On the clipping for peak power reduction of OFDM signals," in *Proc. IEEE Global Communications Conference (GLOBECOM)*, San Francisco, USA, 2000, pp. 731–735.
- [7] Md. Munjure Mowla, Md. Yeakub Alib and Abdulla Al Suman, "Better Performance ACF Operation for PAPR Reduction of OFDM Signal", *American Academic & Scholarly Research Journal* Vol. 6, No. 1, Jan 2014.
- [8] Sanjeev Saini and Dr. O.P. Sahu, "Peak to Average Power Ratio Reduction in OFDM System by Clipping and Filtering", *International Journal of Electronics Communication and Computer Technology (IJECCCT)* Volume 2 Issue 3, May 2012.